The Goddard Earth Sciences and Technology Center
Annual Report

May 11, 2006 – May 10, 2007

University of Maryland, Baltimore County
Howard University
Hampton University
Caelum Research Corporation
Northrop-Grumman Corporation

UMBC
AN HONORS UNIVERSITY IN MARYLAND

GEST
GODDARD EARTH SCIENCES AND TECHNOLOGY CENTER

Goddard Earth Sciences and Technology Center (GEST)

Seventh Annual Report

10 May 2007

This page intentionally left blank

INTRODUCTION

This page intentionally left blank

INTRODUCTION

How can it get better than this?

This, the seventh in the Goddard Earth Sciences and Technology Center's series of annual reports, continues to demonstrate the outstanding progress that UMBC's research centers have made for this once small campus. A mere 40 years ago, a short career to some who were here at the beginning, UMBC rose from muddy farm fields to become a new, aggressive and academically excellent University rivaling many schools that have over a century of history. The growth of the University has not been without some soul searching, however, since the founders of this school believed that the small size of UMBC allowed strong faculty student contact and a distinctive undergraduate experience.

UMBC has recognized that a Research Extensive university thrives on its partnerships with the public and private sectors and lives off the growth of its graduate experience. With nearly 2500 graduate students, UMBC has begun to model historically distinctive graduate programs across the nation. But this growth cannot occur in a State-sponsored university without significant external support for its faculty and graduate students. There simply are not enough resources in State university systems to provide the facilities, salary, teaching assistantships, graduate assistantships, etc. for a strong graduate program to survive without partnerships with those who gain from such educational strengths.

NASA and its Goddard Space Flight Center has recognized this synergistic relationship between major research centers and university research. Over the last year, UMBC received another large research center, the Center for Space Science and Technology, CSST, formed by a partnership of the two leading University of Maryland campuses, College Park and Baltimore County. This growth for UMBC is really astounding. We have over $25M per year in NASA funding and have just been recognized for the 2005 Federal Fiscal Year as the 3rd largest recipient of NASA funding in the nation behind only a large consortium of universities and Baylor's Medical School. UMBC's ranking surpasses major universities such as Berkeley, Stanford, CalTech, MIT, and our own College Park. This metric is clearly recognition that UMBC has arrived as a major force in Environment and Earth Science in the U.S.

But it is not just funding. The Institute for Scientific Information (a Phillips Company) published the 2006 Rankings for impacts in scientific fields. UMBC has also ranked third in the nation amongst all universities in the number of scientific journal articles in the Geosciences. Clearly, these accolades are strongly linked. And it is clear that the activities of GEST, JCET, and CUERE, and the faculty on the campus who have benefited from these centers are the cause of this success.

How can it get better than this? These significant achievements will be underutilized unless our relationships with NASA grows with other agencies and corporate partners. The Deans of our Graduate School, Science and Engineering Colleges have recognized that it is time for UMBC to build the bridges to sectors employing our graduates, bridges out of bricks and mortar instead of wood and paper. We need help at UMBC in infrastructure. We are busting out of all our seams. We look forward to our Centers being able to consolidate around a major research facility on this campus that is owned by UMBC rather than in rented space. Are you out there, our benefactor? In the Age of Enlightenment, scholars were supported by patrons. Unfortunately with the limitations on what we can expect from taxpayer support, UMBC needs other assistance to keep on its remarkable trajectory. In my view, this is UMBC's research goal and challenge for the next five years.

Raymond M. Hoff
Director

This page intentionally left blank

TABLE OF CONTENTS

INTRODUCTION ..... **iii**

TABLE OF CONTENTS ..... **vii**

EXECUTIVE SUMMARY **1**

Data Assimilation Research Group **5**

Parameterized Physics Development for GEOS-5 the Global Modeling and Assimilation Office (GMAO) Atmospheric General Circulation Model 9

Julio T. Bacmeister

GEOS-4 Simulations of Polar Stratospheric Clouds 10

Craig Benson

Advancing Best Estimates of the Tails of Probability Density Functions (Extreme Weather Events): Assessing the Role of Tropical Forcing 12

Yehui Chang

Aerosol Data Assimilation 13

Amelia M. Colarco

Goddard Earth Observing System Data Assimilation System 15

Ronald Errico

Determination of the Effects of Non-Modality on the Data Assimilation and Numerical Weather Prediction Problems 16

Francesco Fedele

Aquarius Sea Surface Salinity 17

S. Daniel Jacob

Land Information System (LIS) Development and Applications 19

Sujay Kumar

Moist Physics Parameterization Studies for NASA's Atmospheric General Circulation Models 20

Myong-In Lee

Global Precipitation Measurement Mission 22

Xin Lin

Global Land Data Assimilation System (GLDAS) 23

Jesse Meng

Land Information System (LIS) Precipitation Enhancements 25

Yudong Tian

Coupled Climate Modeling 26

Yury Vikhliaev

Global Modeling, Data Impact and Data Simulation Research Group 29

Application of Satellite Surface Wind Data to Ocean Surface Analysis and Numerical Weather Prediction 33

Observing System Simulation Experiments (OSE and OSSE) to Evaluate and Enhance the Impact of Current and Future Satellite Observations

Juan Carlos Jusem

Land Surface Modeling in Support of the Development of a GMAO Coupled Climate Model 34

Sarith P.P. Mahanama

Sounder Research Team Activity Support 36

Gyula Molnar

Development of an Ocean Biogeochemical EOS Assimilation Model 37

Lars Nerger

Cloud Data Assimilation 39

Peter M. Norris

Synoptic-Dynamic Evaluation and Improvement of the NASA Finite Volume General Circulation Model 40

Observing System Simulation Experiments (OSE and OSSE) to Evaluate and Enhance the Impact of Current and Future Satellite Observations

Oreste Reale

Leadership of the GMAO Satellite Data Group 42

Lars Peter Riishojgaard

GMAO Ocean Data Assimilation System 44

Chaojiao Sun

NASA Modeling, Analysis and Prediction (MAP) Project: Understanding and Quantifying the 1970s Climate Transition in the Presence of a Rapidly Changing Observing System 45

Hailan Wang

Development of a Next-Generation Finite-Volume Dynamical Core on Geodesic Grids 47

Kao-San Yeh

Cloud Modeling and Analysis Research Group 49

Processing and Analysis of Radar and Ancillary Data in Support of NASA's High-Altitude ER-2 Doppler Radar (EDOP) and Cloud Radar System (CRS) 53

Processing and Analysis of Lidar Data in Support of NASA's Micro-pulse Lidar Network (MPLNET)

Larry R. Belcher

The Micro-Pulse Lidar World-wide Observational Network (MPLNET) 54

Timothy Berkoff

Development and Applications of the Goddard Multi-Scale Modeling Framework 56

Jiun-Dar Chern

Precipitation Estimation from Satellite Active and Passive Microwave Observations 58

Mircea Grecu

TRMM Project Science 60

Guojun Gu

Numerical Simulations of Extratropical Cyclones with Applications to TRMM and GPM 61

Mei Han

Flood and Landslide Early Warning for Disaster Management 62

Yang Hong

Global Precipitation Mission Physical Radiative Transfer Model 63

Kwo-Sen Kuo

Radar Development, Field Observation and Dada Analysis for Atmospheric Research 65

Lihua Li

Aerosol-Cloud-Precipitation Interactions Through Modeling Studies 67

Xiaowen Li

Application of Air/Space-Borne Radar to Atmospheric Remote Sensing 68

Liang Liao

Physics of Cirrus Clouds and Their Role in Global Climate 70

Ruei-Fong Lin

Modeling of Interactive Cloud Processes and Precipitation Systems 71

Toshihisa Matsui

Development for dual frequency precipitation radar(DPR) algorithm of the Global Precipitation Measurement Mission (GPM) 72

Katsuhiro Nakagawa

Various Numerical Applications on Tropical Convective Systems 74

Chung-Lin Shie

Improved Understanding of Cloud and Precipitations Properties Using Airborne Doppler Radar Measurements 75

Lin Tian

The Evaluation of NPOL Radar in NAMMA and the Adjustment of TRMM PR Rainfall Data for the Post-Boost Period 76

Jian-Jian Wang

Atmospheric Solar Radiative Transfer 78

Guoyong Wen

Study of Tropical Cyclone Activities 79

Liguang Wu

Evaluating Long-Term Cloud-Resolving Model Simulations with Observations 81

Xiping Zeng

Cloud-Radiation-Precipitation Modeling and Assimilation for Improving Weather Prediction and Climate Modeling 82

Yaping Zhou

FPGA-Implementation of Oriented Cloud Mask Algorithm 82

Yaping Zhou

Atmospheric Chemistry and Dynamics Research Group 85

Improvement and Application of Multiple Chemical Transport Models (CTMs) in Atmospheric Chemistry Study and Mission Support 91

Huisheng Bian

Acquisition and Disbursement of Aura Validation Through the Aura Validation Data Center 93

Bojan Bojkov

Climate and Trace Species 94

Eric Bucsela

Climate Change Science Program through a NASA Supported Intergovernmental Personnel Act Appointment 96

Robert J. Curran

Three-Dimensional Modeling of Atmospheric Chemistry and Aerosol Processes 97

Thomas L. Diehl

Study of the budget, emissions, and long-range transport of carbon monoxide 99

Bryan N. Duncan

Closure in Model Prediction, In-Situ Measurements and Remote Sensing of Aerosol Mass Concentration 100

Analysis of the Performance of the VIRSS Aerosol Land and Ocean Algorithm

Santiago Gassó

UV Remote Sensing 102

Nickolay Krotkov

Stratospheric Dynamics and Chemistry 105

Leslie R. Lait

Chemical Data Assimilation 107

David Lary

Ozonesonde Launches from Houston, Texas and Valparaiso, Indiana for INTEX-B and Aura Validation 108

Gary A. Morris

Stratosphere-Troposphere Exchange 109

Mark A. Olsen

The NASA Global Modeling Initiative (GMI) and Process-oriented Model Evaluation 110

Susan Strahan

Assimilation Studies 112

Clark Weaver

Nitrogen Dioxide from OMI Spectral Data 112

Mark O. Wenig

Measuring Sulfur Dioxide Emissions Using Spectral Data from Ozone Monitoring Instrument (OMI) 113

Kai Yang

A Global Modeling Initiative (GMI) Study of the Long-Range Transport of Pollution Using Fused Carbon Monoxide Measurements from EOS 115

Yasuko Yoshida

The Validation of Aura Ozone Measurements Using Cloud Slicing; The Development of Tropospheric Ozone Data Products from AURA OMI/MLS and Their Scientific Evaluation 116

Sushil Chandra and Jerry Ziemke

Terrestrial Physics Research Group 119

Studies of Earth's Surface Interannual Variability Using data from Satellites and Distributed Ground Stations 123

Assaf Anyamba

Forecast and Analysis of Aerosol Distribution and Transport Using MODIS Near Real Time and Geostationary Satellite Measurements and Trajectory Model for INTEX-B..... 125

Analyze and Evaluate the Model Results Using Satellite and Remote Sensing Observations (ICAP-Phase 3)

D. Allen Chu

AERONET Ground Based Remote Sensing of Aerosol Optical Properties 126

Thomas F. Eck

Characterization of Aerosols and Bidirectional Reflectance Distribution Function from Airborne Radiation Measurements 128

Charles K. Gatebe

Development of Active and Passive Sensors for Remote Sensing Applications 130

Elena Georgieva

NPOESS Preparatory Project (NPP) System Calibration / Product Validation Studies 132

Bruce Guenther

Mission Related Research in Support of the Mars Science Laboratory and the Sample Analysis at Mars Instrument Suite 133

Jeffrey C. Joseph

Antarctic Comprehensive Model from Airborne, Shipborne, Ground, Satellite Magnetometer Data 134

Hyung Rae Kim

Aerosol-Water Cycle Interaction 136

Kyu-Myong Kim

Development of Atmospheric Correction algorithm for MODIS, and Algorithm Analysis for Land Surface and Atmospheric Products for VIIRS 137

Alexei Lyapustin

AERONET - Ground Based Remote Sensing of Aerosol Optical Properties 139

Alexander Smirnov

Laboratory Investigations on Electrical Discharge and Methane Destruction in the Martian Atmosphere 141

Inge L. ten Kate

Multi-Angle Implementation of Atmospheric Correction for MODIS (MAIAC) and AERONET-based Surface Reflectance Validation Network (A-SRVN) 142

Yujie Wang

Measurement-based Assessments of Aerosol Direct Radiative Forcing and Intercontinental Transport 144

Hongbin Yu

Heliophysics Research Group 147

IFM-Modeled Response of the High-Latitude Ionosphere to Auroral Dynamics Based on Auroral Observations Acquired with the Visible Imaging System (VIS) on the Polar Spacecraft 151

Hamed Bekerat

Numerical Modeling to Improve the Performances and the Scientific Return of Space-borne Mass-spectrometers 152

Mehdi Benna

Coupling Between Mercury's Exosphere and Magnetosphere and the Study of Planetary Magnetospheres 153

Scott Boardsen

Solar wind and Magnetospheric Environment 155

Jan Merka

Development of Virtual Observatories for Heliophysics 157

Thomas Narock

Solar Irradiance Variability and Its Origin 158

Judit Pap

Ionospheric Modeling 160

Antti Pulkkinen

Modeling of the Lunar Dust-Plasma Environment 161

Survey of Cusp Electrodynamics Using FAST Data; Cluster Cusp Studies

Timothy Stubbs

ST5 Data Calibration and Field Aligned Current Dependence on Solar Wind and Geomagnetic Conditions..... 163

Yongli Wang

Studies of the Mesosphere, Ionosphere and Plasmasphere 165

Substorms in the Magnetotail

Automating Electron Density Determination from Magnetospheric Dynamic Spectra

Phillip Webb

Kinetic Modeling of Magnetic Reconnection 167

Seiji Zenitani

Information Science and Educational Technology Research Group..... 169

The Analysis and Characterization of Citric Acid and Homologs in Carbonaceous Meteorites 173

Benita Bell

Earth+: Dynamic NASA Earth Science Exploration For Blind Learners 175

Susan Hoban, Daniel Laughlin, Laurie Cook

Science Information Systems 176

Planetary Data Systems..... 176

Susan Hoban

NASA Learning Technologies 177

Daniel Laughlin, Susan Hoban, Marcianna Delaney

NASA Learning Technologies (NASA Exploring Space Challenges and the Digital Learning Network)..... 178

Marcianna Delaney, Susan Hoban

NASA Learning Technologies (Fundamentals of Lunar Exploration)..... 179

Susan Hoban, Anuradha Koratkar, Laurie Cook

Advanced Multi-media/Information Technologies..... 180

Andrew Freeberg, Stefanie Misztal, Silvia Stoyanova

Advanced Multimedia/Information Technologies 181

David B. Stroud

Science (Coordination) Director, Global Water Cycle Program of the U.S. Climate Change Science Program (CCSP) and interfaces with all CCSP science programs, and support to NASA/HQ Earth Sciences (Terrestrial Hydrology, Modeling, Observing Systems, Applications Program, and Decision Support Activities) 182

Sushel Unninayar

Hydrological Sciences Research Group 185

The Use of NASA Land Data Assimilated Products to Improve Flood and Drought Risk Analysis and Forecasting for Water Resources Management in the Columbia River Basin 189

NASA National Applications for Water Management

Kristi R. Arsenault

Superactive-Active-Passive (SAP) Analysis of Phytoplankton Pigment Group and Physiological Variability in Coastal Ocean 191

Alexander M. Chekalyuk

Remote Sensing of Sea Surface Salinity from Space 193

Paolo de Matthaeis

Land Information System (LIS) Data Assimilation on Remote Sensing Snow Product, and Evaluation of the Factors in the Modeling of Water and Energy Fluxes Within the Framework of Land Data Assimilation Systems 195

Jiarui Dong

Coupling High Resolution Earth System Models Using Advanced Computational Technologies 197

Joseph L Eastman

Enhancement and Application of Hydrometeorological Functionalities in the NASA-GSFC Land Information System (LIS) 198

Matthew Garcia

A Double Detector for RFI Mitigation in Microwave Radiometers 200

Priscilla Mohammed

Land Data Assimilation at the NASA Global Modeling and Assimilation Office 202

Assimilation of AMSR-E Data and Application to the Initialization of Soil Moisture Reservoirs in a Seasonal Forecasting System

Global Estimates of Evaporation from Variational Assimilation of Multi-platform Land Surface Temperature into a Dynamic Model of the Surface Energy Balance

Assimilation of GRACE Derived Terrestrial Water Storage Variations

Rolf H Reichle

Dissolved Organic Carbon and Chromophoric Dissolved Organic Matter in Surface Waters in Support of NASA's New Investigators Program (NIP) Project 204

A Comprehensive Plan for the Long-Term Calibration and Validation of Oceanic Biogeochemical Satellite Data (Cal/Val) Project in Support of the Ocean Color Calibration and Validation Office

Mary Elizabeth Russ

NASA Energy and Water Cycle Study (NEWS) Science Integration Team (NSIT) 206

Robert Schiffer

Electromagnetic Models for Microwave Remote Sensing of Snow and Applications 207

Analysis and Correction of Brightness Temperatures for Atmospheric Effects and Forest Cover for Microwave Remote Sensing of Snow

Improved Passive Microwave Snow Retrievals of Snow Depth and Snow Water Equivalent Over Land and Sea Ice Through the Incorporation of Electromagnetic Modeling and Temporal Information

Blending of Existing Snow-Cover Products to Produce a Snow Extent / Snow Depth Product: Estimation of Ripening/Melt Onset from Microwave Observations and Validation

Marco Tedesco

High Resolution Modeling of Land-Atmosphere Ammonia Exchanges 209

Yihua Wu

Analysis of Synthetic Aperture Radar Data of the Antarctic and Greenland for Glaciological Research 210

Boris S. Yurchak

Air-Sea-Ice Interaction 212

Yunhe Zhao

Global Energy and Water Cycle Experiment (GEWEX) 215

International Global Energy and Water Cycle Experiment (GEWEX) Project; International GEWEX Project Office (IGPO) 217

Richard (Rick) Lawford

Goddard Visiting Fellows Program in the Earth Sciences 223

Using Integrated A-Train and In-situ Observations to Study Climate Forcing by Anthropogenic Aerosols 227

Theodore L. (Tad) Anderson

Solar Activity Reconstructions and Investigations of the Solar Influence on Climate 228

Raimund Muscheler

Evaluation of Aerosol Models with Satellite Products 230

Michael Schulz

MODIS Data 2.5km x 2.5km Scale Assimilation to Support NASA's Light Use Efficiency (LUE) Project and Radiative Transfer Model Inversion Project 231

Qingyuan Zhang

Educational Programs 235

Short-Term Visitors 243

APPENDICES 247

References 249

Peer-Reviewed Publications 259

Other Publications 279

Presentations and Conference Publications 283

Grant Proposals and Status 325

Biographies 347

Faculty and Staff 379

Acronyms and Abbreviations 385

Index of Researchers 399

This page intentionally left blank

EXECUTIVE SUMMARY

This page intentionally left blank

Executive Summary

This is seventh year of existence for the Goddard Earth Sciences and Technology (GEST) Center and it has proven to be the most productive of all in terms of journal articles published. New faculty continue to join GEST, attracted by its high standards of scientific excellence. We currently number about 148 in terms of research faculty and staff, divided among 8 research groups organized by their respective affiliations within Goddard and areas of research interest.

All the scientific accomplishments have been through the combined research efforts of UMBC with its other consortium partners, Hampton University, Howard University, and Caelum Research Corporation. Northrop Grumman Corporation continues to provide advice and support through representation on the GEST Executive Board.

This Annual Report predominantly contains brief discussions of the research focus and results for the GEST faculty and staff. There are a total of 115 articles contributed by GEST faculty researchers and visiting fellows. Each report also lists the names of collaborators, accomplishments during the past year, and a plan for work during the forthcoming year. The Appendices consist of cumulative lists of GEST publications in monographs, professional journals, conference proceedings papers, and other presentations/reports. During this year, there were 234 refereed scientific papers that were authored by GEST faculty and published in major journals. Another 40 papers were published in other literature, and a further 553 presentations and posters at numerous conferences and meetings during this same period. The impressive nature of our faculty's research accomplishments are shown in a number of ways. They have received several performance and peer awards from various branches at NASA Goddard for their distinguished work during the past year. The quality of their research is also measurable by the high success rate of proposals (80 funded out of 201, with 73 still pending a funding decision) submitted by our faculty to NASA, NSF, and other agencies in collaboration with their colleagues at GSFC and elsewhere.

This past year, the Goddard Visiting Fellows Program in the Earth-Sun Explorations Division saw four international researchers participating in the program during the reporting period. Five have been selected for this forthcoming year, including a newly created "Yoram Kaufman Visiting Fellowship." The participating fellows, as well as more information about the inaugural Kaufman fellow, are listed along with a summary of their proposed collaboration while at Goddard.

The Summer 2006 Educational Programs continued under GEST management with the following results. Eleven graduates were matched with GSFC-based scientist mentors to work on specific Earth Sciences projects/problems/issues. GEST also hosted six summer interns working with NASA scientist mentors on specific projects in the Earth Sciences. The GEST Graduate Fellowship program awarded one fellowship in the 2006/2007 timeframe.

As part of our cooperative research program with the Earth-Sun Explorations Division, GEST facilitates collaboration between scientists based at GSFC and in organizations outside the Center who must work for short periods at GSFC, at field research locations, or at external conference sites. Over 80 visitors participated in this program from U.S. universities and institutions and international federal laboratories and universities during the reporting time frame. In this report you will find lists of U.S. and international scientists and their collaborating organizations that were assisted by the GEST administrative staff.

GEST continues to have as part of its organization the leadership of the International GEWEX Project Office (IGPO). This office provides management, service and coordination functions for more than 1000 scientists worldwide who are working on the water and energy cycle science and it supports the

information and management needs of the World Climate Research Programme. Its efforts are reported in a separate section of this Annual Report.

This report shows the results of a resurgent growth in GEST. Our scientists are assuming leadership positions in several missions within NASA's exploration programs as the number of Principle and Co-Investigators within GEST continue to increase. All signs are indicating a persistent burgeoning of the stature of GEST in the Earth Sciences community.

Tom B. Low
Associate Director

Data Assimilation Research Group

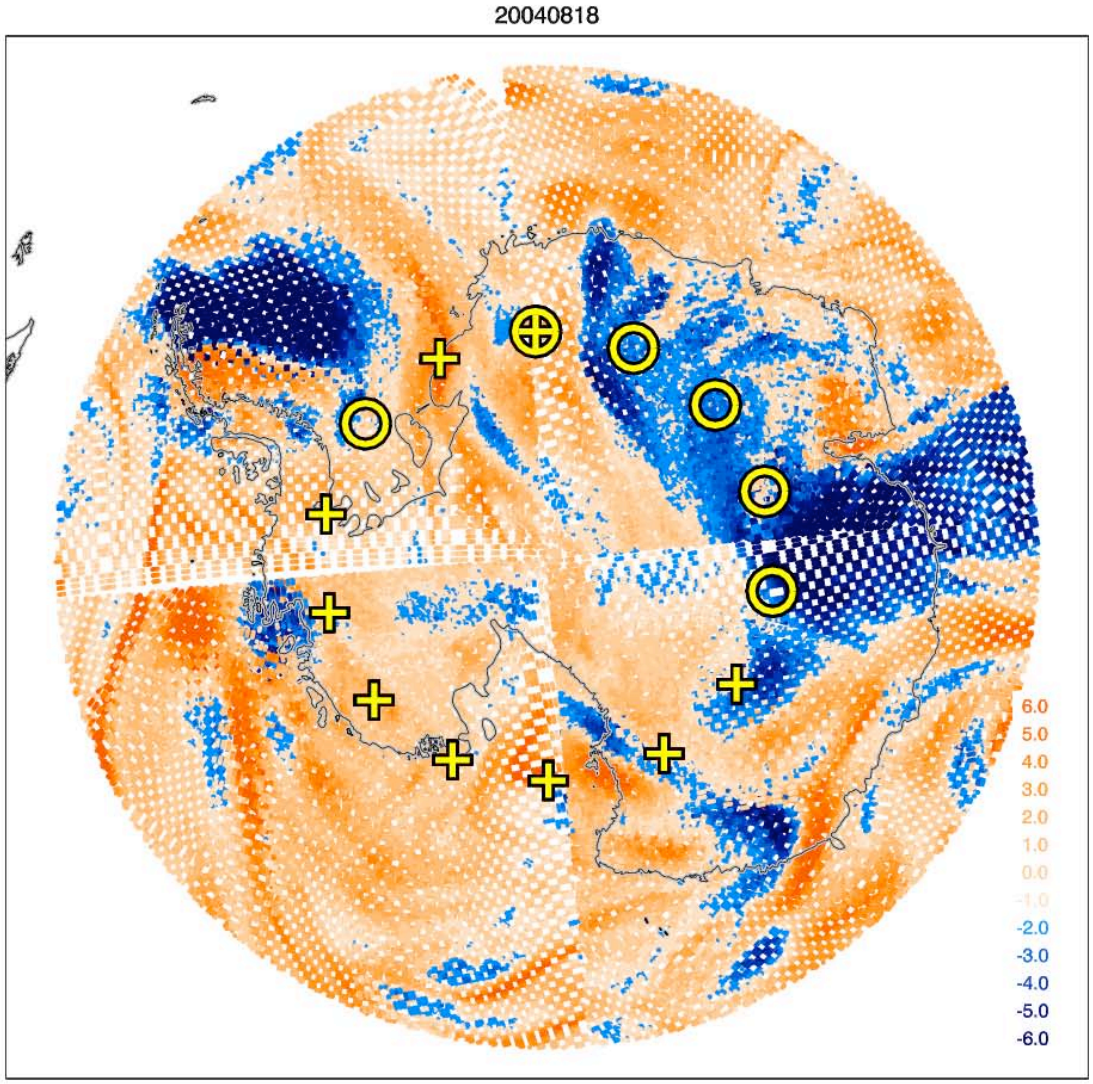
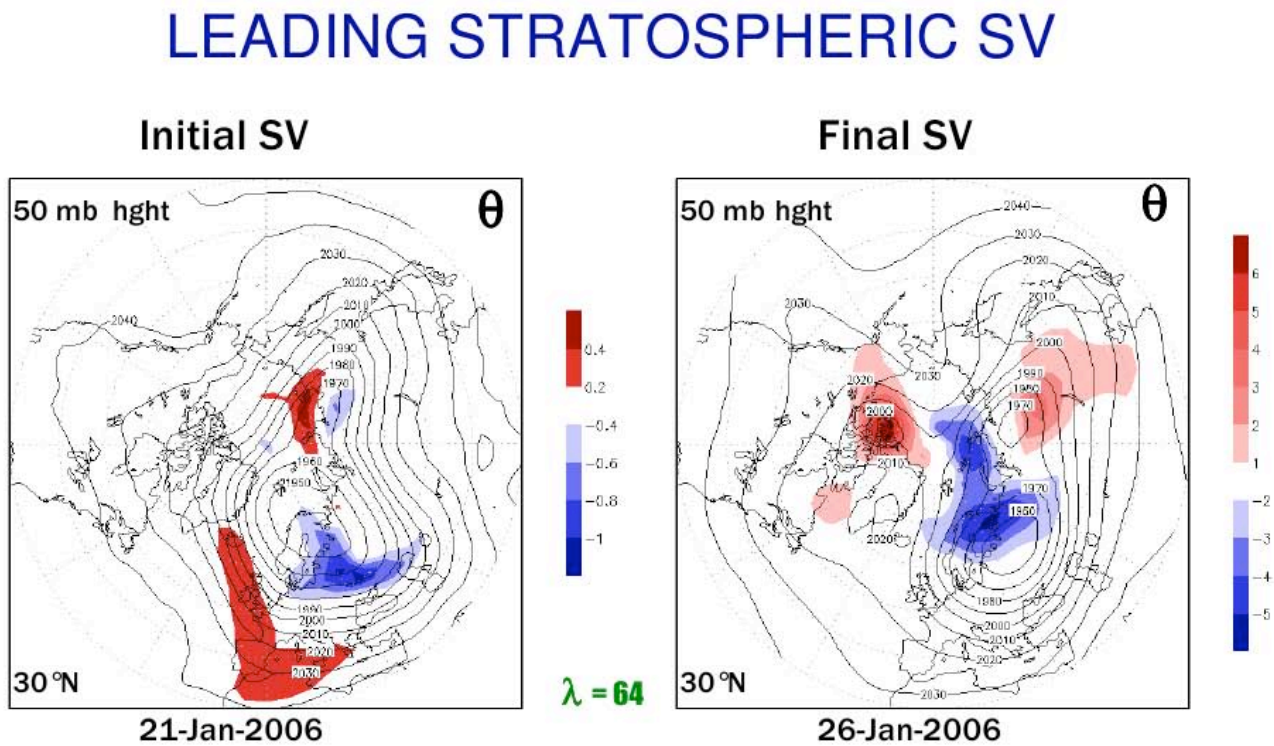


Fig. 1. A composite map of AIRS O-Fs in K (color) for the 6.79-um channel on August 18, 2004. POAM data for that day are marked by the presence of ice PSCs (circle), absence of ice PSCs (plus sign), or presence of a cloud in the immediate vicinity of the tropopause (plus sign inside a circle). In each quadrant AIRS O-Fs for the synoptic time closest to the POAM measurement time are shown for the region south of 60o S. In general, AIRS O-Fs below -2 K coincide with POAM ice cloud detection. Exceptions may be attributable to differences in AIRS and POAM viewing geometries and measurement times. (Figure courtesy of Craig Benson.)



The potential temperature field at 50 hPa for the optimal perturbation, computed as the leading singular vector, for growing perturbations within the stratosphere over the period 21-26 January 2006 as measured by a perturbation energy norm. Fields at both initial and final times are shown, in color, with arbitrary units. They are superimposed on the corresponding analyzed 50 hPa geopotential height field to show their relationship with the breakdown of the polar vortex into three troughs at the end of the forecast period. The fact that the perturbation at the end time is located where the analyzed troughs are suggests that these singular vector perturbations may provide insight into the dynamical mechanism responsible for sudden stratospheric warming events. From the work by R. Errico and colleagues as presented at the 7th International Workshop on Adjoint Model Applications in Dynamic Meteorology. [Figure courtesy of Ron Errico.]

Data Assimilation Research Group

Data assimilation concerns the combining of different types of observations produced by different kinds of instruments with other prior but uncertain information and consideration of possible constraints in order to produce some optimal estimate of the state of some physical system. This state can be the dynamical or chemical state of the atmosphere, ocean, or land. Satellite observations naturally are keys, since only they have the global coverage often required. Models are also keys, because they best extrapolate information from prior observations and estimates to the present time. They can also most accurately quantify physical relationships between what is actually observed (*e.g.*, a band-integrated radiance) and what is to be analyzed (*e.g.*, a temperature at some location). Data assimilation is truly the combining of many useful observations, model described relationships and constraints that yields the least error prone estimates of the states of the earth system.

Even so, the work performed by the GEST Data Assimilation Research Group is very much more diverse than its name suggests. It includes a range of activities: from land, ocean, and atmosphere modeling to examination of current or envisioned observation systems. This reflects a significant span of the broader range of activities performed at NASA by GEST faculty.

A critical step in practical data assimilation is to compare new observations with all previously analyzed information applicable at the same time. The latter always involves various models that interpolate or extrapolate information in space or time and physically, or at least statistically, relate what is measured to what is to be analyzed. Comparing available values measured by instruments with model-produced ones is therefore a critical developmental step. For such purposes, among others, S. Daniel Jacob has been investigating the analysis of sea surface salinity using Aquarius measurements. Amelia Colarco has been developing the infrastructure required for using OMI observations of aerosols and comparing various modeling approaches. In order to improve the detection of polar stratospheric clouds, Craig Benson has compared their formation in models with their observation inferred by various satellite measurements. If such clouds are undetected by a data assimilation system and their radiative effects thus ignored, the analysis of a variety of atmospheric variables will be degraded.

Model development is required for data assimilation, climate analysis, and environmental prediction. Its difficulty is greatly magnified by the necessity of adequately coupling land, sea and atmospheric components and considering broad ranges of space and time scales and a great variety of skill measure, relevant for all these applications simultaneously. The particularly elusive development of precipitation parameterization is being directed by Julio Bacmeister. His work is of direct interest, as the fundamental precipitation prediction technique, but also strongly influences almost all other components of the earth's environment. Myong-In Lee is focusing on modeling of the warm season diurnal cycle of precipitation, comparison of responses to moist physics parameterizations in idealized aqua-planet conditions, and evaluation of simulations of the tropical MJO. Yury Vikhliaev is developing the critical but sensitive coupling between ocean and atmospheric models required for seasonal prediction. Sujay Kumar and Yudong Tian are continuing development and broadening applications of the GSFC Land Information System (LIS). The Air Force Weather Agency (AFWA) has adopted it as their next generation Land Data Assimilation System (LDAS). A Global Land Data Assimilation System (GLDAS) that includes LIS has been developed by Jesse Meng and is being utilized at NCEP for both mid-range and seasonal (weather and climate) prediction systems.

Atmospheric and ocean dynamics play a dominant role in both prediction and assimilation. Yehui Chang estimated the attributable causes for seasonal climate anomalies and an upper limit of U.S. seasonal climate predictability. He also characterized some properties of the MJO. Ronald Errico determined characteristics of the dominant structures of dynamic instability within the stratosphere and their interaction with the troposphere. Consequences of the non-modal nature of the evolutions of structures of

dominant dynamic instability within the troposphere on the atmospheric data assimilation and subsequent weather prediction problems were explored by Francesco Fedele.

In order to make the best use of generally costly observations, a variety of techniques, including simulations, require deployment to tune and validate their information. Xin Lin has conducted extensive simulations to estimate sampling accuracies for precipitation to be measured using the multiple satellite constellations of the future Global Precipitation Measuring (GPM) mission, to help guide the final mission planning. Ronald Errico has examined simulations of a full atmospheric data assimilation system to estimate characteristics of analysis error. He has also validated a technique to efficiently estimate the impacts of arbitrary sets of observations on short-term weather predictions.

Many investigators within and outside NASA and GEST rely on the expertise of scientists within this group to develop the capabilities required to conduct their own research. Most of these tasks have a strong developmental component that is not yet reflected in the peer-reviewed literature. Several of the scientific investigations performed in the summarized tasks are rather fundamental in nature, expanding our understanding of how the earth system and its models work. They will retain their applicability long after the specific tasks are completed.

Ronald Errico

Task 971-00-002: **Parameterized Physics Development for GEOS-5 the Global Modeling and Assimilation Office (GMAO) Atmospheric General Circulation Model**

GEST Investigator: Julio T. Bacmeister

Collaborators: Max J. Suarez (GSFC, Code 610.1), Siegfried Schubert (GSFC, Code 610.1), F. Robertson (NASA/MSFC), Atanas Trayanov (SAIC), Baode Chen (SAIC), Lawrence Takacs (SAIC), Caterina Tassone (SAIC), Sarith Mahanama, Adam Sobel (Columbia Univ.), Gilles Bellon (Columbia Univ.), Jadwiga Beres-Richter (NCAR), Stephen Eckermann (NRL/Washington), Jia-Lin Lin (NOAA)

Abstract

Work on parameterized physics for the GMAO atmospheric general circulation model (AGCM), the GEOS-5 AGCM, continued. This year's development effort focused on obtaining improved representations of precipitation and the vertical structure of humidity in data assimilation experiments. These fields represent special challenges to atmospheric data assimilation because they are poorly constrained by observations. Their final appearance in an assimilation experiment is highly dependent on model moist physics parameterizations, which may in turn be sensitive to details in the input profiles of temperature and humidity. Examination of errors and biases in assimilation and climate experiments systems was conducted. An in-depth study of the connections between precipitation, surface fluxes, and dynamical convergence in the GEOS-5 AGCM was undertaken with F. Robertson of NASA/MSFC.

Description of Research

The GMAO was established in 2003 to take over many of the tasks performed by the Data Assimilation Office (DAO) and NASA's Seasonal-to-Interannual Prediction Project (NSIPP). NSIPP's principal mission was to develop a fully-coupled atmosphere/land/ocean climate prediction system to study the impacts of satellite-based ocean and land-surface observations on climate predictability. The DAO's principal mission was to investigate and implement techniques for assimilating a variety of satellite atmospheric data, and to identify potential scientific and societal uses for these data. An important goal for the GMAO is to develop a single atmospheric model capable of supporting all of these missions with minimal, or no, empirical "retuning" for different applications. Improved parameterization of atmospheric moist processes will be critical to the success of this modeling effort.

Accomplishments during the Reporting Period

During the reporting period the GMAO modeling group focused on delivering a model suitable for use in NASA's Modern Era Reanalysis for Research and Applications (MERRA) project. In May 2006, a version of the GEOS-5 data assimilation system (DAS) was released and tested. This initial version of the GEOS-5 DAS performed well in many respects, but suffered from a dry bias in tropical, lower-tropospheric humidity and excessive tropical precipitation. These biases were thought to be primarily consequences of problems in model physics. Sensitivity tests were performed, varying a number of model physics parameters considered to be poorly constrained by theory or observation, yet also capable of large impacts on the simulated atmospheric water cycle. Parameters controlling the rate of thermodynamic adjustment by parameterized convection (convective relaxation time), and the re-evaporation of falling rain were found to produce noticeable improvements in both tropical precipitation and humidity structure. Encouraging (and largely unexpected) secondary results of this effort were improved simulations of tropical precipitation and subseasonal variability in climate mode, as well as improved simulation of hurricane intensification in high-resolution forecasts. This experience with GEOS-5 is consistent with that at other modeling centers (*e.g.*, NCAR and ECMWF), who have also found improved model performance associated with drastic lengthening of convective relaxation time.

Analysis of high-frequency (periods of one to several days) variability in GEOS-5 climate simulations revealed interesting connections with seasonal mean precipitation, similar to those observed in the NSIPP-2 AGCM [Bacmeister *et al.*, 2006]. Highly-skewed probability density functions (pdfs) of high-frequency fluctuations in low-level convergence were found to be associated with a number of common AGCM precipitation biases. Comparisons with pdfs of observed surface convergence showed that models with good simulations of seasonal precipitation also had well simulated pdfs of low-level convergence. J. L. Lin (NOAA) analyzed subseasonal variability in GEOS-5 climate runs.

During the reporting period, active collaboration was established with NCAR (J. Beres-Richter) and NRL/Washington (S. Eckermann) with the aim of improving gravity wave parameterization in the GEOS-5 AGCM. A framework for exchanging parameterizations has been implemented, and NCAR codes for parameterizing non-stationary gravity wave effects have been used in experimental climate runs in GEOS-5.

An active collaboration with Gilles Bellon and Adam Sobel at Columbia University has also taken shape. Bellon and Sobel are using the Single Column Model (SCM) version of the GEOS-5 model to explore novel techniques for parameterizing large-scale advective tendencies in SCM simulations. Currently SCM simulations can only be run with a restricted number of observed tendency datasets, which do not react to conditions within the simulated column, or in highly-idealized configurations such as radiative convective equilibrium. If successful, Sobel and Bellon's parameterized dynamics approach should lead to more flexible application of SCMs in physics development.

Sarith Mahanama also adapted the GEOS-5 SCM to explore specific aspects of surface/atmosphere interactions. His work identified a number of key parameters that determine the sensitivity of precipitation to land surface processes.

Objectives for the Coming Year

In the coming year the performance of the GEOS-5 AGCM in both climate mode and forecast/assimilation mode will continue to be analyzed. Model performance at high resolution (0.25° x 0.333°) will be a particular focus of study. The performance of "climate-style" parameterization approaches at this resolution, in particular that of the gravity wave drag and convection schemes, needs to be systematically evaluated. In addition, a novel approach to parameterizing gravity wave effects using time-dependent ray tracing techniques will be explored in collaboration with In-Sun Song, who began work at GEST in February 2007.

Task 610-67-232: **GEOS-4 Simulations of Polar Stratospheric Clouds**

GEST Investigator: Craig Benson

Collaborators: Steven Pawson (PI, GSFC, Code 610.0), J. Eric Nielsen (SSAI), Randy Kawa (GSFC, Code 613.3), Ivanka Stajner (SAIC), Hui-Chun Liu (SAIC), Nicole Brubaker (SAIC), Lars Peter Riishojgaard

Abstract

Polar stratospheric clouds (PSCs) are clouds that form at extremely low temperatures in the lower polar stratosphere during winter. PSCs can be composed of supercooled ternary solution (STS, composed of H_2O, HNO_3, and H_2SO_4), nitric acid trihydrate (NAT), or water ice. Ice PSCs in particular are environmentally relevant, as they provide catalytic surfaces for heterogeneous chemical reactions leading ultimately to ozone loss and radiative cooling. Despite their importance, significant questions exist pertaining to their formation mechanisms and abundance. The formation of PSCs is investigated through a series of GEOS-4 simulations, and comparisons of the results to Microwave Limb Sounder (MLS) data. The abundance of PSCs is also investigated through

a novel approach using the Atmospheric Infrared Sounder (AIRS) to construct maps showing the spatial distribution of PSCs, a large improvement over current PSC mapping techniques.

Description of Research

The need for further information regarding the formation and presence of polar stratospheric clouds is clear. GEOS-4 simulations are performed and compared with available denitrification and dehydration observations in order to quantify any deficiencies in model PSC processing and ultimately improve PSC characteristics in the model. Any improvements in the handling of PSCs by the GEOS-4 and GEOS-5 models will lead to enhanced understanding of the global impacts of PSCs. Further, a technique of identifying and mapping PSCs using the AIRS instrument is being developed. Knowledge of the total coverage of PSCs is crucial in improving model PSC processing, and may ultimately lead to the assimilation, rather than calculation, of PSC locations.

Accomplishments during the Reporting Period

Factors involved in the nucleation and growth of polar stratospheric clouds were assessed using several GEOS-4 chemistry-climate model (CCM) simulations spanning seven years. The model runs were constrained by GEOS-4 meteorological analyses; specifically, six-hour average temperatures, winds, surface pressure, and moisture. The “Douglass-Kawa” middle atmospheric chemistry code was included in the circulation model. Model runs performed for the Polar Aura Validation Experiment (PAVE) winter were compared to data obtained by the MLS instrument aboard the Aura spacecraft. In some instances, model results indicated NAT cloud formation where MLS data indicated no denitrification. While there were some constituent biases relative to MLS data, early denitrification observed in the model were likely due to either a 2-3 K low temperature bias at PSC formation altitudes, or the model assumption of PSC formation at saturation temperatures. Further analysis of the model simulations is ongoing, currently focusing on transport characteristics of the model. Tracer-tracer correlations have been generated and are compared to previous simulations and MLS data to ensure accurate model transport.

Additionally, a novel technique was developed for the detection and mapping of ice polar stratospheric clouds using brightness temperatures from the AIRS moisture channel near 6.79 μm. Brightness temperatures are computed from six-hour GEOS-5 forecasts for several hundred AIRS channels using a radiation transfer module. The differences between collocated AIRS observations and these computed values are the observed-minus-forecast (O-F) residuals in the assimilation system, and are expected to contain qualitative information about PSCs due to the clear-sky condition required by the radiation transfer module. Evaluation of the brightness temperatures was performed using data obtained from the Polar Ozone and Aerosol Measurement (POAM) III instrument. At coincident locations, ice cloud detection by the POAM instrument is concurrent with AIRS O-F residuals lower than -2 K. Similarly, clear-sky POAM observations are met by O-F residuals higher than -2 K. Given this relationship, the high spatial density of AIRS data has been used to construct maps of regions in which O-F residuals are lower than -2 K, which can act as a proxy for ice PSCs. This approach is an improvement over most PSC detection techniques, which use occultation or limb sounding instruments with sparse horizontal coverage. The climatology of the 2004 Antarctic winter was a particular focus of the investigation, yielding some interesting results. For example, the region of most intense PSC formation is typically downwind of the Antarctic Peninsula, possibly due to the action of gravity waves, which is in agreement with PSC climatologies using POAM and other instruments. However, during the month of August 2004, a bimodal distribution of intense PSC formation was observed, with a region of PSC formation over high terrain near 100° E exceeding that downwind of the peninsula. Further investigation revealed an upwelling of moist air in the 90° E region during that timeframe, leading to rehydration of the air and subsequent PSC formation.

Objectives for the Coming Year

The first objective is to complete transport studies of the GEOS-4 model runs constrained by meteorology. Some anomalous conditions have been observed in these simulations, including higher than expected water vapor mixing ratios at low pressure levels. After the transport studies have been resolved, similar studies will be performed using the GEOS-5 model, and will include further research into denitrification and PSC formation. Additionally, the AIRS O-F PSC observation technique will be further refined through trajectory analysis to obtain better POAM-AIRS temporal coincidences, as well as comparison with additional satellite instruments. MODTRAN simulations will also be performed to enhance understanding of the expected detection threshold of the technique.

Task 910-14-123: **Advancing Best Estimates of the Tails of Probability Density Functions (Extreme Weather Events): Assessing the Role of Tropical Forcing**

GEST Investigator: Yehui Chang

Collaborators: Siegfried Schubert (PI, GSFC, Code 610.1)

Abstract

El Nino/Southern Oscillation (ENSO) associated global-scale climate variations are ultimately manifest in phenomena and processes that control regional-scale climates. For example, shifts in the wintertime planetary scale waves forced by tropical sea surface temperature (SST) anomalies or tropical heating due to the Madden Julian Oscillation (MJO) can result in changes in the normal storm tracks and frequencies of extreme weather events. The specific aims of this collaborative task are to estimate the attributable causes for seasonal climate anomalies and assess their predictability on determining the upper limit of U.S. seasonal climate predictability for the recent climate record using SST-forced and tropical constrained AGCM simulations.

Description of Research

Analysis has been completed from the comparison of AGCM simulations with observed SSTs and the model constraining (effectively nudging) to the NCEP II reanalysis in the various tropical regions. Since the climate prediction problem is probabilistic in nature, as such, large ensembles of simulations are thus necessary to provide estimates of uncertainty and information about how the tails of the probability density functions (the extreme events) change as a response to large-scale climate forcing. An increase in the occurrence of extreme events (*e.g.*, major storms, floods and droughts) is of particular concern since these tend to have substantial economic and social consequences. The combined requirements of high model resolution, large ensembles and the state of the art global assimilation system make regional climate prediction a computationally and scientifically challenging problem. Currently, climate related predictions are necessarily carried out at relatively coarse resolution and with a very modest number of ensemble members, only grossly evaluating the changes in the mean and variance of the largest scales. But it is inadequate for accessing climate related regional extreme events.

Accomplishments during the Reporting Period

The NCEP GODAS analyses data is used to study the interannual variability of the subsurface thermal structure in the equatorial Pacific Ocean with particular reference to its relationship with ENSO events. The 1st EOF is characterized by a large equatorial Pacific water mass that propagates eastward and upward. The time series of associated data (PC1) shows a strong connection with the variations of the tropical Pacific warm water volume, and leads the Nino3 SST index by two seasons (*i.e.*, six months). The 2nd EOF represents upwelling and near surface reflection of warm (cold) water at the equatorial Pacific east coast. These two leading EOFs clearly demonstrate important asymmetries in the development of warm and cold ENSO events. The development of an El Nino (surface warm) event is preceded by both eastward and upward propagation of the eastern

and central Pacific warm water and the subsequent reflection/upwelling and westward propagation of the near surface warm water in the eastern equatorial Pacific. SST changes in these areas provide a positive feedback via enhanced deep atmospheric convection. This creates anomalous easterly winds in the eastern Pacific, which amplify the SST gradient and accelerate the entire process. In the La Nina (surface cold) phase, however, the eastward and upward propagating cold water in the central Pacific, creates a negative feedback as a result of weakened deep atmospheric convection. An anomalous westward wind slows the eastward propagation of the cold water. As such the large cold water volume rarely reaches the east coast of the equatorial Pacific, and the upwelling and westward propagation of the cold mass volume is weak or nonexistent. This negative feedback prohibits long-lived large magnitude La Nina events despite the existence of large long-lived subsurface cold water volume.

It is now well established that the MJO plays a key role in the variability of the tropical atmosphere on subseasonal time scales. MJO is a key source of untapped predictability in the tropics and subtropics. While the GEOS-5 AGCM simulates a very realistic MJO in upper level winds it is still deficient in the MJO-related precipitation variability. A number of idealized simulations have been done to try to develop a better understanding of the type of impacts that one might expect to see on the extratropics from an improved simulation of the MJO. One idealized approach is to utilize the data assimilation technology developed at the GMAO. The technique (termed “replay”) allows the researchers to assess, for example, the impact of the tropics on the extra-tropics in a very well controlled environment. By running the model in replay mode, the model can, in fact, be constrained in any region of the world using any existing reanalysis data set. The investigative team have re-run the model constraining (nudging) it to the NCEP II reanalysis in various tropical regions during 2004/05. The fields u,v,T,q,ps are adjusted towards the 6-hourly analyzed fields in these regions. The ensemble model simulations, when constrained by the tropical regions, show a great reduction of variance and a southward shift of the upper level zonal wind during the major MJO events in the west coast of the U.S., which is not simulated by the free running model. The time evolution of particular rain events in winter of 2004/05 show the eastward propagation in the extra-tropics associated MJO that is captured by the tropically constrained simulations but not by the free running model. The event in particular had resulted in a major rain event over California.

Objectives for the Coming Year

A continuation of the study is to simulate several recent climate extremes with a high resolution AGCM. The GEST investigator proposes to use the GEOS-5 AGCM to carry out large ensembles of high resolution simulations of the 1997/99 El Nino/La Nina events, the 2004/05 winter that was characterized by a period of enhanced storminess associated with an active “Pineapple Express” and an active MJO. Chang will also assess the impact of NASA’s new MERRA products and Japanese reanalysis data set in various tropical regions for predicting the impact of the MJO. The combination of high resolution, large ensembles, and improved tropical constraint should provide much-improved estimates of how El Nino and La Nina and the MJO affect extreme weather events, especially winter storms over the United States.

Task 610-73-253: **Aerosol Data Assimilation**

GEST Investigator: Amelia M. Colarco

Collaborators: Arlindo da Silva (PI, GSFC, Code 610.1), Peter Colarco (GSFC, Code 613.3)

Abstract

Since joining GEST in May 2006, the investigator has been pursuing the assimilation of data from OMI, aboard the Aura satellite, and the GMAO GEOS model output with aerosols from several different angles. Processing of OMI

retrievals to make them comparable with model output, including global grid and temporal averaging, has been completed and preliminary comparisons with the corresponding model output have been done, along with some comparisons with other satellite observations. Both look-up tables (tables of precalculated variables under various conditions) and full radiative transfer models—required for assimilation—are being evaluated for suitability. The ability to use the existing look-up tables in a way that is compatible with the model analysis is the current focus of Colarco's research.

Description of Research

Due to the many uncertainties involved in obtaining aerosol properties from remote, passive satellite measurements, the accuracy of such retrievals is very difficult to pin-point. It is the hope that, in using the output from well-understood model analyses can be combined with these retrievals in such a way as to benefit both—improving retrieval process based on the type and vertical location of aerosols from the model, and improving the model by comparing the quantity and horizontal location of observed aerosol plumes. This requires carefully evaluating the processes involved in the initial retrievals, an understanding of what variables are available in the different observational data products, as well as how the model was parameterized for a given set of analyses.

Accomplishments during the Reporting Period

The OMI data has now been processed into the ODS file format, a format developed by GMAO to standardize comparison of model and observation data. These files have also been gridded to the model resolution and further reduced to monthly and seasonal averages. Initial comparisons between the resulting OMI averages and the corresponding model output have been done, along with some qualitative comparisons with other satellites for both UV and visible wavelengths. These initial comparisons have indicated some possible issues with the OMI retrievals at absorbing wavelengths (*i.e.*, the UV) that seems to cover up the expected aerosol signal that is indicated both in the model analysis and other satellite measurements. The cause for this discrepancy is being investigated. The look-up tables used to perform the current OMI retrievals have been obtained through collaboration with Omar Torres (JCET) and the investigative team is currently working on a system to integrate these tables into the analysis. They have also been working on setting up a data server based on the OPeNDAP protocol so that the data can be accessed remotely.

Objectives for the Coming Year

The main objective for 2007 is to come up with comparables between the model and the OMI retrievals—either using the look-up tables or doing a full analysis using a radiative transfer model. The advantage of the look-up table is the speed of the analysis; the disadvantage is that, in gaining speed, the ability to vary the parameters to match predicted conditions is lost. One of the main hurdles to determining the best way to match these two conflicting sets is to determine where and when the mixture of aerosols and/or the vertical profile becomes complex. To do this, Colarco would like to come up with a set of classifications that will allow researchers to determine when the problem can be simplified and thus use the look-up tables and when the problem is too complicated and requires full radiative analysis. This involves extensive statistical analysis of available model analysis and various observational datasets. Once this is complete, the team can start looking more quantitatively at comparisons between OMI and GEOS, and begin assimilation studies.

Task 971-00-002: **Goddard Earth Observing System Data Assimilation System**

GEST Investigator: Ronald Errico

Collaborators: Ronald Gelaro (PI, GSFC 610.1), Ricardo Todling (SAIC), Runhua Yang (SSAI), Michiko Masutani (NCEP), Francesco Fedele (GEST), Martin Ehrendorfer (Univ. Innsbruck), Elena Novakovskaia (ERT)

Abstract

Ronald Errico has been applying his expertise to a number of facets of data assimilation problems encountered at the GMAO. These include development of adjoint-model techniques and software for identifying likely locations of data analysis errors; development of measures for ranking the importance of observation types and monitoring the earth observing system; development of techniques for examining and imposing appropriate atmospheric dynamical balances; examination of OSSE results for estimating the character of analysis error; examination of the many issues peculiar to assimilation of precipitation; and development of an intermediate-complexity dynamical model for evaluation of proposed new data assimilation techniques.

Description of Research

As data assimilation matures, it requires more sensitive measures of success and more informative techniques to ferret out errors. As the subject's popularity has increased, so too has the number of remarkable results requiring independent verification. In support of these demands, Ronald Errico has been developing and applying sophisticated tools for examination and improvement of data assimilation systems. These include tangent linear and adjoint versions of the GEOS-5 AGCM, including their applications to the stratosphere and to estimation of observation impacts, the use of OSSEs for characterizing both analysis and background error statistics, and application of the theory of nonlinear normal-mode initialization for specification of appropriate, multivariate, background error statistics. Errico also was the co-chief organizer of the Seventh International Workshop on Adjoint Applications in Dynamic Meteorology, held in Obergurgl, Austria, October 2006, which has become the preeminent workshop series on variational data assimilation and other adjoint model applications.

Accomplishments during the Reporting Period

Singular vectors (SVs) are the optimal structures for maximizing ratios of quadratic norms applied to perturbations of the atmospheric state at the beginning and end of some short time period. Examination of SVs in the troposphere has profoundly affected the way in which meteorologists consider dynamical stability. SV determination has now been extended to the stratosphere using the tangent linear and adjoint versions of GEOS-5. This required development of a new norm that is less reflective of the model's vertical grid structure. The stratospheric SVs are similar to their tropospheric cousins with regard to their evolution being non-modal, with structures exhibiting an initially strong westward tilt as height increases but becoming equivalent barotropic after several days of evolution. The stratospheric SVs are also notably different in many important aspects, however, such as being much less geographically local and having much smaller growth rates. Their tangent linear evolution also remains highly correlated with corresponding nonlinearly-evolving perturbations for longer times and larger initial amplitudes. These SVs therefore show promise for explaining observed dynamical behaviors in the stratosphere, such as sudden warming events. A manuscript describing all these characteristics has been submitted to a special issue of Meteorologische Zeitschrift being devoted to the Seventh Adjoint Workshop.

An adjoint-model based estimate of the reduction of forecast error due to analysis of an arbitrary set of observations was developed at NRL [Baker and Daley 2000, Langland and Baker 2004]. Its original developers erred in their derivation, however, mistakenly

interpreting their estimate as linear in observation innovation values. The correct derivation, presented in Errico [2007], shows that the estimate is nonlinear, explains the need for dual trajectories for the adjoint calculations, and presents a warning of its possible misinterpretation due to the presence of cross products of innovation values. A numerical evaluation of the estimate is reported in a second manuscript submitted to the special issue of Meteorologische Zeitschrift.

The formulation originally proposed for the initial tendency constraint term in the cost function for the joint NCEP/GMAO analysis system was shown to be inappropriate. It failed to adequately discriminate between small-scale, but geostrophically balanced, analysis increments and unrealistic gravity-wave increments. Since nonlinear normal mode initialization provides all the theoretical guidance for appropriate construction of gravity noise constraints, components from that theory were incrementally incorporated into the tendency constraint. This required many modifications of the analysis software as well as new diagnostic capabilities to scientifically guide them. The latest version of the constraint yields significantly reduced forecast noise and better subsequent forecast scores than when it is absent.

Objectives for the Coming Year

Errico has three primary objectives for next year. The first is to demonstrate the utility of the almost completed adjoint modeling capability at the GMAO for error determination and observation monitoring. The second is to complete development of a dynamical noise suppression algorithm consistent with the FVGSI assimilation scheme. The third is to develop several data assimilation simulators, including a complete Kalman filter, for a dynamical model of intermediate complexity (being developed jointly with M. Ehrendorfer, University of Innsbruck, Austria), and to use these to compare properties of various proposed reduced-rank and ensemble data assimilation schemes.

NSF Grant: ATM-0351938

Determination of the Effects of Non-Modality on the Data Assimilation and Numerical Weather Prediction Problems

GEST Investigator: Francesco Fedele

Collaborators: Ronald Errico (PI), Steven Cohn (GSFC, Code 610.1)

Abstract

Short-term weather forecasts, used for either data assimilation or longer-term prediction, exhibit a variety of errors. Of those that are caused by erroneous data analysis, the errors that amplify most strongly have non-modal structures; *i.e.*, that radically change their general characteristics (vertical tilt, scales, etc.) with time The use of observations to correct such errors that have developed during a data assimilation process therefore will not necessarily the kinds of structures from which subsequent forecast errors will evolve. This effect of non-modality may negatively affect the utility of several recently proposed, next generation, data assimilation techniques that severely restrict their corrections to the evolved rather than initiating sub-space of errors. The degree to which it is important must be estimated numerically.

Description of Research

Franco Fedele attempted to investigate this affect of non-modality by using a model of intermediate complexity developed by Ehrendorfer and Errico [2007]. It applies quasi-geostrophic dynamics to the sphere using a spherical harmonic representation truncated at resolution T47L6. Although simple, the model duplicates several atmospheric statistics of the transient atmosphere during the Northern Hemisphere Winter. Fedele determined an orthogonal set of successively optimal, non-modal perturbation structures (called singular vectors, or SVs) for a single two-day period of the model's integration. Then he determined the shapes of the error structures beginning 12-hours

prior to this two day period that would evolve during that 12 hours to optimally affect the initial errors in some individual SVs selected from the set first determined.

Accomplishments during the Reporting Period

Fedele discovered that the mathematical problem of finding the structures that will optimally excite a single SV defined for a subsequent forecast period in a linearized model does not require mathematical iteration. Unfortunately, he selected SVs that exhibited much less non-modality than observed for the dominant SVs in much more realistic atmospheric models. It is possible that either the Ehrendorfer and Errico [2007] model is generally deficient in producing realistically non-modal SVs, or that it was applied with too low vertical resolution, or that simply the wrong SVs were selected. So, the question of the importance of non-modality remains.

Objectives for the Coming Year

Fedele departed from GEST in December. The PI will now take full charge of the investigation, but using the GEOS-5 forecast model that now includes the necessary software components for determining both SVs and the other optimal perturbations required.

Task 971-20-137: **Aquarius Sea Surface Salinity**

GEST Investigator: S. Daniel Jacob

Collaborators: David Le Vine (Deputy PI, GSFC, Code 614.6), Saji Abraham (RSIS), Emmanuel Dinnat, Paolo de Matthaeis

Abstract

The primary focus of this task during the current reporting period has been on the continuing development of a sea surface salinity forward model in relevance to the Aquarius Sea Surface Salinity (SSS) Mission. The forward model consists of an ocean general circulation model that simulates SSS and temperature and a microwave emissivity model that simulates the brightness temperatures at the Satellite. In addition to simulating the surface contribution, other integrated components of the forward model quantify direct and reflected contributions from the sun, moon, galaxy and the earth's atmosphere. These simulated brightness temperatures will be used with auxiliary data to derive the algorithms for the retrieval of SSS from Aquarius measurements. As part of a synergistic effort, multiple simulations were performed using the global model to investigate SSS variability on different spatial and temporal scales for available atmospheric forcing data sets and ocean mixing parameterizations. The nature and magnitude of bias in the simulated SSS realizations for the different forcing data sets are quantified to examine the viability of using Aquarius measurements to constrain the evaporation to precipitation balance.

Description of Research

The upcoming NASA Earth System Science Pathfinder (ESSP) Aquarius mission will provide excellent spatial and temporal SSS coverage to better estimate the net transfer of water vapor from the ocean surface. At the Aquarius operating frequency of 1.4 GHz, sea surface emissivity depends on the SSS, temperature and roughness induced by the surface wind. Additionally, contribution from the sun, moon and galactic sources also affect Aquarius measurement. Therefore, a full forward model that quantifies these contributions is needed for the retrieval of SSS. While the forward model uses the simulated SSS as input, the SSS itself is also controlled by advection and mixing processes; therefore, as part of the Aquarius science team, numerical simulations are conducted using the global ocean general circulation model to understand and quantify various mechanisms controlling SSS in relation to surface freshwater fluxes over seasonal and inter annual time scales.

Accomplishments during the Reporting Period

The Aquarius salinity forward model has two components. The ocean component of the simulator is a primitive equation ocean general

circulation model. Based on prior effort, a massively parallel version of the fully global hybrid coordinate ocean model coupled with an ice model (HYCOM) was implemented on the GSFC SC45 and the Goddard SGI Altix super cluster at two horizontal resolutions (2° and 0.72°). Based on previous research [Jacob, Koblinsky and Le Vine 2007 to be submitted to Journal of Geophysical Research], the climatological Coupled Ocean-Atmospheric Data Set (COADS) is used during the spin-up phase followed by the National Centers for Environmental Prediction (NCEP) reanalysis fields for actual calendar days. Continuing from the prior reporting period, the NCEP fields from the year 1948 to present are used to simulate the ocean circulation variability globally using the 0.72° resolution ocean model during for multiple boundary conditions. While the free running model provided surface salinity and temperatures over three complete three-year cycles of Aquarius starting in the early 90s to the present, the temporal and spatial scales of SSS variability were investigated from the other simulations. More than 30 numerical experiments were performed at the two different resolutions. The GEST investigator continues to maintain the live access server (LAS) set up at http://aquarius1.gsfc.nasa.gov:8080/las/servlets/dataset to host relevant data sets used in these simulations. For the 10 year period from 1994 to 2004 covering low, high and medium solar activity, SSS and temperature simulated by the global model are interpolated on to a 0.1° horizontal resolution grid consistent with the land-sea mask used in the forward algorithm along with wind speeds, land temperatures and soil moisture from the NCEP reanalysis fields.

In collaboration with the Aquarius simulator team, significant upgrades were carried out to the forward model during the current reporting period. While the surface component of the forward model computes the brightness temperatures over the field of view using the emissivity algorithms for ocean, land and ice using the surface temperature, salinity and soil moisture data in general, a newer version of the model was developed in Earth Centered Inertial (ECI) Coordinate system. Individual components for simulating the contributions from the sun, moon, galaxy, earth's atmosphere and the atmospheric limb were integrated with the surface component during this period. Polarized brightness temperatures from each of the surface or reflected components are then corrected for the rotation induced by the ionosphere. These are then convoluted with the specified antenna pattern along with the direct components. Due to the computational time involved, optimization of the various pieces of the forward model is a continuing process. Simulated brightness temperature data at the satellite are provided to the Aquarius data systems team to develop the formats and verify the magnitude of the data stream from the satellite.

The SSS fields from the multiple simulations were analyzed to examine the spatial and temporal scales of variability. As the Aquarius SSS measurements will be available in 2009 after launch, the model fields allow for the identification of regions of maximum variability. Results indicate that this variability remained large near the convergence zones and in the regions of significant river discharges. Since the main Aquarius product will be monthly SSS fields, results indicated that the contribution from sub-monthly variability may be too large to ignore in a few regions such as the Bay of Bengal and in the Equatorial Atlantic Ocean.

Objectives for the Coming Year

The major focus for the coming year will be on simulating the total brightness temperatures at the satellite for multiple years. Using these fields, SSS retrieval techniques can be further refined. While the SSS variability scales were investigated in the current reporting period, its impact on oceanic thermohaline circulation also will be focused upon. *In-situ* data from profiling floats will be analyzed to confirm earlier model findings. Regional circulation features and associated budgets in the Eastern Equatorial and North Pacific will be investigated using a combination of *in situ*, remotely sensed and numerical model analyses.

Task 971-00-002: **Land Information System (LIS) Development and Applications**

GEST Investigator: Sujay Kumar

Collaborators: Christa Peters-Lidard (GSFC, Code 614.3)

Abstract

The Land Information System (LIS) is a high-resolution, high-performance, land surface modeling and data assimilation system used in the support of a wide range of land surface research activities and applications. The system has been demonstrated at high spatial resolutions (such as 1km) globally, with the use of scalable computing technologies. The flexible and interoperable design of LIS enables it to be used in a number of cross-cutting applications. Using advanced computational technologies and software tools, an interoperable data assimilation extension that encapsulates many different algorithms has been implemented. Many operational and functional extensions for LIS have been proposed, ranging from flood forecasting to use in operational numerical weather prediction.

Description of Research

The land surface and atmosphere are coupled to each other over a variety of time scales through the exchanges of water, energy, and carbon. An accurate representation of land surface processes is critical for improving models of the boundary layer and land-atmosphere coupling at all spatial and temporal scales and over heterogeneous domains. Long term descriptions of land use and fluxes also enable an accurate assessment of climate characteristics. In addition to the impact on climate modeling, land surface processes also affect the environment for growth of natural vegetation and provision of water resources. The goal of LIS is to provide a system capable of modeling at high resolutions, enabling the ingestion of the vast array of high resolution observations from satellites and other environmental monitoring systems. The ability to operate at the same fine spatial scales of the atmospheric boundary layer and cloud models also helps in improving characterizations of the energy and water cycle. The accurate assessment of the spatial and temporal variation of the global land surface water can be used to improve the understanding and more efficient management of natural processes. LIS can also be used in countless “what-if” studies, to assess the impact of land surface parameters on climate change and resource utilizations.

Accomplishments during the Reporting Period

In this year, a sequential data assimilation extension has been implemented in LIS to facilitate the development of a comprehensive interoperable hydrologic data assimilation system. The extensible LIS data assimilation framework allows the incorporation and interplay of multiple observational sources, multiple sequential data assimilation algorithms, and multiple land surface models. These capabilities were demonstrated using a suite of synthetic experiments to assimilate hydrologic data into different land surface models to propagate observational information in space and time. The implemented data assimilation algorithms vary in complexity, ranging from direct insertion to Ensemble Kalman Filtering (EnKF). These experiments demonstrate the use of the flexible and extensible LIS data assimilation framework to effectively apply hydrologic observations and modeling tools to understand and improve the prediction of land surface water and energy cycling.

The Mississippi Research Consortium (MRC) is implementing a computational Rapid Prototyping Capabilities (RPC) infrastructure, based on a systems engineering concept, advocated by the NASA Applied Sciences Program, in order to identify, evaluate, and integrate research results for applications. LIS is being used in RPC experiments to address the decision-making needs of applications of national priority such as the evaluation of USDA Natural Resource Conservation Service (NRCS) Soil Climate Analysis Network (SCAN) decision support tool (DST) for agricultural planning and management.

In a new effort, LIS is being employed in a sensor web framework to allow for optimal 2-way information flow that enhances land surface modeling using sensor web observations, and in turn allows sensor web reconfiguration to minimize overall system uncertainty. Through continuous automatic calibration techniques and data assimilation methods, LIS is being used to enable on-the-fly sensor web reconfiguration to optimize the changing needs of science and solutions.

The coupled modeling system using LIS and WRF/GCE was used to perform simulations over a regional area in Oklahoma and results were evaluated against field observations. LIS is used as the land modeling component in the coupled system, enabling the use of an ensemble of land surface models, high resolution data, and data assimilation techniques. The impact of using realistic, high resolution land surface initial conditions on mesoscale processes such as convective initiation was demonstrated using the coupled system. The coupled system is being used to develop of suite of modeling and observational products to study the strength of local Land-Atmosphere Coupling.

LIS has also been employed to provide distributed modeling support for the Romanian destructive water abatement project. Algorithms for stream channel routing and distributed routing models were implemented in LIS as part of this effort. This work was conducted in collaboration with the National Center for Atmospheric Research (NCAR) and Baron Advanced Meteorological Systems, Inc. The system is currently being deployed on the Romanian basins after the initial, successful calibration efforts over certain watershed basins in the United States.

Objectives for the Coming Year

In the coming year, the researchers plan to use enhanced data assimilation system in exploring the impact of various hydrologic satellite and remote sensing products in hydrologic data assimilation. These products include various sources of soil moisture, snow, and land surface temperature. The continuing work on the use of the coupled LISWRF system will explore the strength of land-atmosphere coupling strength in local coupled action scenarios. Several function extensions to the LIS framework are proposed in the coming year, including the implementation of several new land surface models, such as the Community Land Model (CLM) version 3, and the Colorado State University (CSU) Land Model. These models are expected to provide functionalities such as modeling dynamic vegetation, ground water, etc. which currently does not exist in LIS. Another key extension planned in LIS is the inclusion of optimization/calibration tools that can be used for parameter estimation, calibration activities, tuning physical and data assimilation configurations.

Task 971-00-002: **Moist Physics Parameterization Studies for NASA's Atmospheric General Circulation Models**

GEST Investigator: Myong-In Lee

Collaborators: Siegfried Schubert (PI, GSFC, Code 610.1), Max Suarez (GSFC, Code 610.1), Thomas Bell (GSFC, Code 613.0), Kyu-Myong Kim, Jia-Lin Lin (NOAA), William Lau (GSFC, Code 613.0), In-Sik Kang (SNU)

Abstract

Several studies have been conducted to examine and improve the moist physics parameterizations in the NASA's atmospheric general circulation models (AGCMs). These involve modeling of the diurnal cycle of warm season precipitation, the model intercomparison of the moist physics in an idealized aqua-planet condition, and the simulations of the tropical MJO. To large degree, the capability of the models in representing those pronounced atmospheric variabilities was limited by the deficiencies in the parameterizations of moist process involving cumulus convection and interactions with

clouds, radiation and large-scale dynamics. Several key findings are highlighted from these studies, and these are expected to contribute to the modeling efforts in improving the NASA's current GEOS-5 GCM.

Description of Research

Although the diurnal cycle is a fundamental component of the warm-season climate, the current AGCMs are poorly representing this phenomenon, and consequently do poorly in simulating the mean climate and hydrological cycle. One of the major goals is to evaluate and understand the diurnal cycle of warm season precipitation, by a careful assessment of observations and model simulations in several different AGCMs that developed independently in different organizations. The current models have also common problems in correctly simulating the tropical MJO, which is practically important in sub-seasonal timescale predictions. The second goal is focusing on the evaluation of the current GCMs' forecast skill, and extracting the potential prediction skill associated with tropical diabatic heating. The third goal is to examine and cross-validate the moist physics schemes in various models in highly simplified boundary conditions. This approach is useful in eliminating the complicated feedbacks with the boundary forcing, and it helps isolate the models' moist physics sensitivities.

Accomplishments during the Reporting Period

In the closing year of the three-year project (NOAA's Climate Prediction Program for the Americas (CPPA) Project) on the diurnal cycle study, the key findings were documented in a number of papers that have either been accepted or submitted for publication. These include papers that describe an overall comparison of the summertime mean climate and the diurnal cycles over North America simulated by several AGCMs [Higgins *et al.*, 2006; Lee *et al.*, 2007a], and the models' sensitivity to increases in the horizontal resolution [Lee *et al.*, 2007b]. The key findings are that: 1) The models exhibited significant biases in the maximum phase of the precipitation diurnal cycle; 2) The phase biases were not substantially improved by simply increasing the horizontal resolution of the models; 3) The differences in the moist physics parameterizations, particularly the cumulus convection scheme and its coupling with the boundary layer processes, are the primary causes for the model differences. In the in-depth analysis in Lau *et al.* [2007] and Lee *et al.* [manuscript submitted to JGR, 2006], the research team has identified that the maximum phase of the simulated diurnal precipitation is quite sensitive to the definition of the convection starting level and the increase of the convection adjustment (relaxation) timescale in the convection scheme. Both modifications to the convection scheme led to improvements in the diurnal cycle of precipitation, especially in correcting the phase errors over land, which agree well with the TRMM observations in the global-mean and regional signals. Another study of Lee *et al.* [manuscript submitted to JGR, 2007] further highlighted the importance of the convection trigger functions inside the convection scheme in correctly simulating the nocturnal precipitation maximum over the U.S. Great Plains. In addition, in-depth analysis on the observed diurnal and weekly cycle of precipitation and storm heights over the U.S. has been documented in Bell *et al.* [manuscript submitted to JGR, 2007].

Lee has finalized the design of the simplified framework for benchmarking moist physical parameterizations in AGCMs. In this framework, all the physical parameterizations and dynamical assumptions of the models are retained, but the models are run over a homogeneous saturated ocean surface (aqua-planet) with no mountains. A simple mixed-layer ocean is added to enable air-sea coupling processes and allow climate changes. This simple coupled framework has been applied to four different AGCMs (NASA/NSIPP, NASA/GEOS-5, GFDL, and SNU). In Lee *et al.* [2007, manuscript submitted to JC], it is highlighted that the benchmark test appears useful in identifying the important processes that produce the inter-model differences. One of the key findings is that the simulated, subtropical cloud distributions should be one of the more important aspects in determining the ITCZ strength. It is also shown that the amplitudes of the sub-seasonal variances and the eastward propagation speeds are quite different among the

model simulations, which are quite sensitive to the strength of the convection inhibition in the convection schemes. The sensitivity to the greenhouse forcing was also evaluated, where the models tend to produce different amplitudes of global mean surface temperature and precipitation at doubled CO_2, and net changes in the cloud-radiative forcing. This reflects large uncertainties in the moist physics parameterizations in the current GCMs.

In collaborations with Jia-Lin Lin (NOAA) and In-Sik Kang (SNU), the impacts of the moisture trigger [Lin *et al*., manuscript submitted to JC, 2006] and the cloud-radiation interaction [Lin *et al.*, manuscript submitted to JGR, 2006] on the simulation of the tropical MJO have been studied. In addition, the simulated intraseasonal variability by various coupled GCMs has been analyzed in Lin *et al.* [two manuscripts submitted to JC, 2006]. A website was created to help coordinate the work and support approximately monthly teleconferences with the investigators (http://gmao.gsfc.nasa.gov/ extranet, id: mapsubseasonal, pw: 1234).

Objectives for the Coming Year

The research will be focusing more on the predictability of the GCMs in the sub-seasonal timescale. The sensitivity of the tropical MJO simulation to the moist physics parameterizations will be further investigated using the latest version of the GEOS-5. In addition, as an intermediate step to developing a hybrid empirical/dynamical forecast system, the researchers will conduct a number of idealized simulations to try to understand the role of tropical diabatic heating on the subseasonal variability in the extratropics, using the data assimilation technology developed at the GMAO.

Task 910-14-124: **Global Precipitation Measurement Mission**

GEST Investigator: Xin Lin

Collaborator: Arthur Hou (PI, GSFC, Code 610.1)

Abstract

The Global Precipitation Measuring (GPM) mission, being planned for the beginning of the next decade, is based on the concept of providing frequent global precipitation measurements using a space borne precipitation radar as a calibrator of a constellation of passive microwave radiometers. GPM is designed to extend the successful Tropical Rainfall Measuring Mission (TRMM) in the tropics to higher latitudes, but with better temporal sampling and more accurate precipitation measurements. Extensive pilot studies have been carried out to simulate the multiple satellite constellations in sampling and rain space, thus providing a guide to the mission planning.

Description of Research

The GPM mission is an internationally sponsored partnership on the part of multiple space agencies using a multi-member, rain-measuring satellite constellation to improve precipitation measurements over the Earth. The baseline GPM constellation was originally envisioned to comprise a fleet of dedicated and operational conically-scanning microwave radiometers. The Dual-frequency Precipitation Radar on board the GPM Core Spacecraft will be able to improve the calibration and retrievals of these PMW measurements. In addition, rain estimations made by operational high frequency microwave sounders such as the NOAA AMSU-B heritage are also considered as a likely option to enhance sampling and coverage on the global scale.

In order to achieve better sampling and coverage on the global scale, one of the most important issues is to obtain an improved understanding of satellite rainfall retrieval error statistics of current PMW radiometer and sounder data over land and ocean. The GEST researcher has comprehensively examined rain detection capabilities and retrieval error characteristics of current satellite microwave rainfall estimates including both radiometer and sounder data through coincident comparisons against TRMM Precipitation Radar data between 35ºS and 35ºN.

In addition, the sampling and coverage of the future GPM satellite constellations have also been thoroughly evaluated. Such a feasibility study provides valuable information for the GPM mission planning.

Accomplishments during the Reporting Period

The accomplishments are reflected by two first-author papers that are either published or currently in press, as well as a number of papers that have been submitted. A paper on the physical and dynamical impact of microwave rainfall assimilation on the GEOS analyses is in press at *Monthly Weather Review*, American Meteorological Society. In this study, global microwave rainfall retrievals from a 5-satellite constellation, including TMI from TRMM, SSM/I from DMSP F13, F14 and F15, and AMSR-E from EOS-AQUA, were assimilated into the NASA Goddard Earth Observing System (GEOS) Data Assimilation System (DAS) using a 1-D variational continuous assimilation (VCA) algorithm. The physical and dynamical impact of rainfall assimilation on GEOS analyses and forecasts was examined at various temporal and spatial scales. demonstrating that the 1-D VCA algorithm, which was originally developed and evaluated for rainfall assimilations over tropical oceans, can effectively assimilate satellite microwave rainfall retrievals and improve GEOS analyses over both the Tropics and the extratropics where the atmospheric processes are dominated by different large-scale dynamics and moist physics, and also over the land, where rainfall estimates from passive microwave radiometers are believed to be less accurate.

By collaborating with scientists from NASA GMAO, JPL, ECMWF, and NCEP, Lin has analyzed a tremendous amount of cutting-edge satellite data to document the evolution of one of the most devastating tropical cyclone ever to hit the United States: Hurricane Katrina. The performance of the ECMWF and NASA global quarter-degree forecasts was evaluated against satellite observations, with a focus on precipitation and clouds. A paper has been published in *EOS*, American Geophysical Union.

Lin has also been collaborating with scientists from NCAR, and NASA GMAO, Climate Radiation Branch to examine the diurnal cycle of precipitation in surface and satellite observations over low- and mid-latitudes, as well as statistics of rainfall, clouds and radiative fluxes by comparing observations with long-term 3-D cloud simulations forced by NASA GEOS rainfall-assimilation analyses.

Objectives for the Coming Year

The objectives for FY 07-08 are to simulate the multiple satellite GPM constellations in a global high-resolution model and a global cloud model and conduct observation system simulation experiments in rain and radiance space. Another interesting topic Lin has been working on is to examine the frequency distributions of global rainfall and clouds related to global changes.

Task 974-03-070: **Global Land Data Assimilation System (GLDAS)**

GEST Investigator: Jesse Meng

Collaborators: Ken Mitchell (NOAA), Matt Rodell (GSFC, Code 614.3), Christa Peters-Lidard (GSFC, Code 614.3), Rolf Reichle, Paul Houser (George Mason Univ.)

Abstract

To facilitate the technology transferring from scientific investigation in land surface processes to operational environmental prediction systems, the infrastructure of the Global Land Data Assimilation System (GLDAS) and the Land Information System (LIS) has been implemented on the NOAA/NCEP IBM supercomputers that serve the operational Global Forecast System (GFS, mid-range weather prediction) and Climate Forecast System (CFS, seasonal climate prediction). Two modes of GLDAS experiments are continuing executed following the GFS and CFS configurations, respectively. The Noah land surface model (LSM), same as the land component in GFS and CFS, is executed in

GLDAS to perform offline uncoupled land simulation with control and observed forcing options. The GFS mode of GLDAS extends from June 2005, the time of the most recent GFS upgrades, to near real time for updated global land condition monitoring. The CFS mode of GLDAS offers a 25-year land simulation (1980 - 2005) for global climate assessment.

Description of Research

Accurate assessment of land surface states, namely, soil moisture, soil temperature, vegetation, and snowpack, is critical in numerical environmental prediction systems because of their regulation of surface water and energy fluxes between the surface and atmosphere over a variety of spatial and temporal scales. GLDAS/LIS, developed jointly by NASA/GSFC and NOAA/NCEP, aiming to perform high-quality global land simulation using state-of-art LSMs, enhanced surface and satellite observations, and advanced land data assimilation techniques. GLDAS/LIS can apply to a wide array of studies in the earth system biogeosciences and has the potential to improve the monitoring, assessment, and prediction of weather, climate, and the terrestrial energy, water, and carbon cycles.

Accomplishments during the Reporting Period

After the successful pilot execution of GLDAS/LIS at NOAA/NCEP in 2005, two modes of NCEP GLDAS/LIS are executing in near real time with the CFS and GFS configurations, respectively. The CFS mode of GLDAS (T126 Gaussian grid, ~1.0° resolution) starts from 01 January 1980 thru present, using NCEP Global Reanalysis 2 and optional observed forcing, for global climate assessment, also providing the land state ensembles for the development of the next generation CFS. The GFS mode of GLDAS/LIS (T382 gaussian grid, ~0.3° resolution) starts from 31 May 2005 thru present, using NCEP Global Data Assimilation System (GDAS) and optional observed forcing, for updated global land condition monitoring. The CFS initialization experiment using GLDAS/LIS has been conducted. The preliminary focus is to evaluate the impact on the CFS seasonal forecast skill for summertime monsoon in the southwest U.S. Results have been presented in various conferences.

Another important activity is the assessment of land surface skin temperature from weather forecast system, data assimilation, and satellite estimates. Meng discovered that the operational GFS has a non-trivial cool bias in predicted land surface skin temperature that causes very limited impact in the satellite data assimilation systems for the surface sensitive satellite measurements. The GEST investigator further concluded that the cool bias is not from the Noah land surface model but mostly from the boundary layer turbulent exchange scheme in GFS which promotes too much land atmosphere interaction and resulting not enough land surface heating. Several experiments have been executed to evaluate various turbulent exchange schemes. The conclusion has been widely discussed in NCEP modeling groups, which triggered a series of subsequent activities in NCEP toward investigating an optimal exchange scheme to be unified in the future NCEP forecast systems over the scales of global/regional and midrange/seasonal forecast.

Objectives for the Coming Year

Meng will prepare for the implementation of GLDAS/LIS as the land component within the development the new generation of NCEP Global Reanalysis. He will also investigate the boundary layer turbulent exchange scheme to improve the land surface skin temperature prediction and the impact of assimilating the surface sensitive satellite measurements. The researcher will continuously extend the land initialization experiments of GFS and CFS to evaluate the impact of enhanced land conditions to the prediction, as well as continuously extend the current GLDAS/LIS executions and apply the results in a broad monitoring and assessment of weather, climate, and the terrestrial energy and water cycles. Finally, Meng will prepare for the GMAO the optimal land surface forcing for the ensemble land initialization experiment.

Task 974-44-184: **Land Information System (LIS) Precipitation Enhancements**

GEST Investigator: Yudong Tian

Collaborator: Christa Peters-Lidard (PI, GSFC, Code 614.3), Matthew Garcia, John B. Eylander (AFWA), Jing Zeng (SAIC)

Abstract

The award-winning Land Information System (LIS) developed at GSFC has been adopted by Air Force Weather Agency (AFWA) as their next generation Land Data Assimilation System (LDAS). The quality of precipitation forcing as input to LIS is critical for its operational success at AFWA. In this task, AFWA's current precipitation processing performance has been evaluated, and each component of the precipitation data streams has been studied in detail. A framework has been established to inter-compare precipitation estimates from models, gauges, radars and satellites, to facilitate before-and-after comparisons of precipitation enhancements to be implemented in AFWA.

Description of Research

The GSFC Land Information System (LIS) [Tian, *et al.*, 2006] is the next generation Land Data Assimilation System (LDAS) for the Agricultural Meteorological Model (AGRMET) at the Air Force Weather Agency (AFWA). It will combine real-time precipitation observations, regional and global forecast model products, topographic analyses, and vegetation and soil information with the Noah land surface model (LSM) to generate analysis of soil moisture, soil temperature, and other important land surface characteristics.

Currently, the meteorological input routines within LIS do not benefit from cross-dataset checks for physical consistency and the presence of reliable climatological precipitation and temperature fields, especially in regions of complex topography. LIS provides a framework for the spatiotemporal interpolation and dis-aggregation of meteorological fields observed by *in situ* or remote sensing (radar and satellite) and the application of model-derived meteorological fields, as from numerical weather prediction (NWP) methods. The capability for mixed-source meteorological fields also introduces the need for analyses and diagnoses of consistency between those fields to ensure the application of plausible physical conditions to the LSM. The incorporation of consistency analyses and background climatological surface observations in the LIS will result in improved high-resolution precipitation products as well as improved soil moisture and soil temperature results of LSM simulations. The enhanced model will also ensure that AGRMET customers receive the most accurate and consistent surface analyses possible for precipitation and related (cloud and radiation) fields.

Accomplishments during the Reporting Period

To make LIS work under AFWA's operational environment, the research team first systematically analyzed and documented AGRMET's current precipitation and cloud processing logic and data flow. Each input precipitation component, including infrared and passive microwave-based remote-sensing data, climatology and cloud analysis, was evaluated, and its impact on the merged input and output filed has been assessed. In addition, AGRMET's precipitation output archive has been validated against NCEP gauge data over the continental U.S. and Southeast U.S. and compared with global satellite datasets including TRMM 3B42 and CMORPH over both the U.S. and Africa. Prototyping studies with CMORPH integration were undertaken, and the initial results were encouraging.

To modernize AFWA's precipitation process with the newly available TRMM-based high-resolution datasets, including 3B42 and CMORPH, Tian performed extensive analysis on these products over multiple time scales [Tian *et al.*, 2007]. The two products were evaluated against ground-based rain gauge-only and gauge-corrected Doppler radar measurements. The analyses were performed at multiple time scales, ranging from annual to

diurnal for the period March 2003 through February 2006. The analyses show that at annual or seasonal time scales, TRMM 3B42 has much lower biases and RMS errors than CMORPH. CMORPH shows season-dependent biases, with overestimation in summer and underestimation in winter. This leads to 50% higher RMS errors in CMORPH's area-averaged daily precipitation than TRMM 3B42. At shorter time-scales (5-days or less), CMORPH has slightly less uncertainty, and about 10-20% higher probability of detection of rain events than TRMM 3B42. In addition, the satellite estimates detect more high-intensity events, causing a remarkable shift in precipitation spectrum. Summertime diurnal cycles in the U.S. are well captured by both products, although the 8km CMORPH seems to capture more diurnal features than the 0.25° CMORPH or 3B42 products. CMORPH tends to overestimate the amplitude of the diurnal cycles, particularly in the Central U.S.

Objectives for the Coming Year

Tian will focus on implementation and experimentation of various precipitation enhancement procedures in LIS, evaluating their impact on the quality of precipitation estimates, and consequently on the land surface states and fluxes. In particular, Tian will evaluate the feasibility of incorporating the high-resolution TRMM-based global precipitation estimates, either 3B42 or CMORPH, for operational runs of the AFWA-LIS.

Task 610-67-230: **Coupled Climate Modeling**

GEST Investigator: Yury Vikhliaev

Collaborators: Michele Rienecker (PI, GSFC, Code 610.1), Max J. Suarez (GSFC, Code 610.1), Atanas Trayanov (SAIC), Paul Schopf (COLA/GMU), Julia Manganello (COLA), Jelena Marshak (GSFC, Code 587.0)

Abstract

The goal of this work is to complete the development of the GEOS-5 coupled general circulation model (CGCM) that will further be used by GMAO for data assimilation, climate forecast and climate studies. An interface for coupling of atmospheric components developed by the GMAO with externally developed ocean components was completed by the modeling group. Two different ocean general circulation models (OGCMs) were tested under the GEOS-5 framework. Testing involved a set of multi-year simulations with climatological forcing. Model deficiencies were detected and are being solved. When the testing of each ocean component in the uncoupled mode is completed, century-long coupled simulations with the GEOS-5 CGCM will be performed.

Description of Research

Research in the GMAO involves the use of satellite observations to address questions about climate variability and climate prediction. An important goal for the GMAO is to develop a coupled General Circulation Model (CGCM) that will be used in data assimilation and climate forecast systems as well as for addressing questions of seasonal to decadal climate variability. This project also involves performing and analyzing multi-decadal free-running climate simulations with high-resolution models. The major advantage of the new GEOS-5 coupled model over existing coupled models is its architecture which relies on the Earth System Modeling Framework (ESMF).

Accomplishments during the Reporting Period

The principal accomplishment of the modeling group was to complete the development of the ESMF compatible interface for coupling ocean models with the GEOS-5 atmospheric GCM (AGCM). The ESMF provides a universal interface for coupling ocean, atmosphere and land components of the CGCM together and for incorporation of these components into data assimilation and forecast systems. Such approach provides flexibility in choosing externally developed components for the GEOS-5 CGCM, and allows incorporation of components with the most advanced physics.

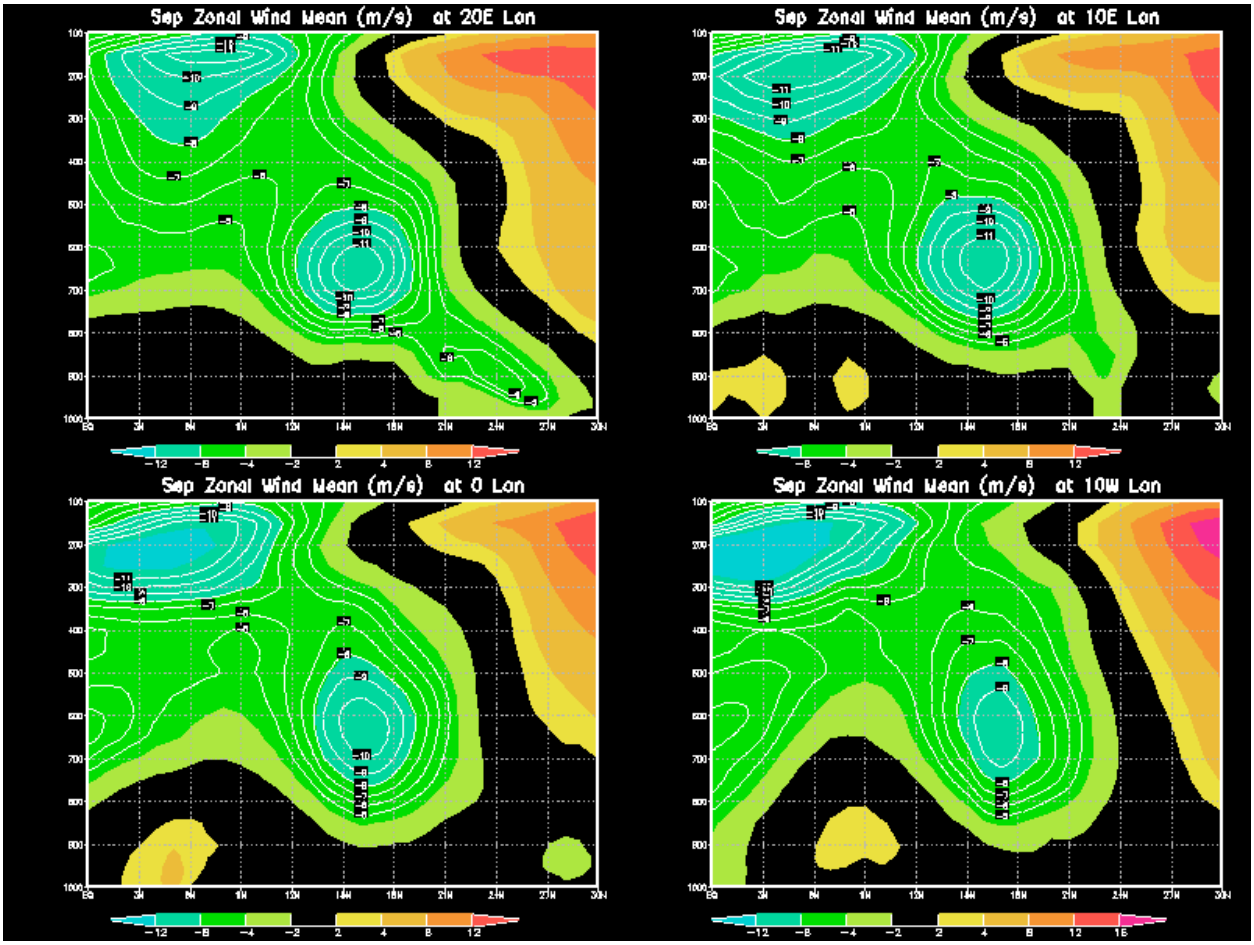
The intent of this project is to perform multi-year inter-comparison experiments using different ocean GCMs (OGCMs) coupled to the GEOS-5 AGCM. This approach allows investigation of the impact of differences in model physics on seasonal to decadal climate simulations. Three different ocean models are planned to be used in the GEOS-5 CGCM, namely: Poseidon Ocean Model version 5, GFDL Modular Ocean Model (MOM) version 4 and MIT Ocean Model. The Poseidon-5 and MOM-4 are already incorporated into the GEOS-5 framework and are running in the test mode. Before coupling the ocean models to the GEOS-5 AGCM, multi-year free-running ocean simulations with climatological forcing were performed and analyzed. Though these test simulations were done in uncoupled mode, the ocean models received climatological forcing through the developed coupling interface, such that model physics and coupling routines were tested. Analysis of the simulation done with the Poseidon-5 indicated an inconsistency in the heat budget. The model exhibits cooling of surface layers and heating of deep layers giving overall persistent increase in the global ocean heat content. One possible reason for such bias in the global heat content is a poor parameterization of the surface mixed layer processes. A set of decade-long experiments with different mixed layer parameters was done to investigate the impact of vertical mixing in the top layer on the ocean circulation. It was found that reducing the vertical mixing by increasing the dissipation in the mixed layer reduces the rate of accumulation of heat in the sub-surface. A set of multi-year free-running simulations with climatological forcing was performed using MOM-4 as well. These simulations allowed the team to tune the parameters of the surface skin layer, which is a part of the coupling interface developed in the scope of this project. Testing the Poseidon-5 and MOM-4 in the uncoupled mode is continuing.

Objectives for the Coming Year

First priority objective for the upcoming year is to complete uncoupled testing of the Poseidon-5 and MOM-4 in the GEOS-5 framework. Vikhliaev plans to finish this within the next several weeks. Simultaneously, the development of the GEOS-5 plug-in for the MIT ocean model will be completed. Once uncoupled testing of all three models is finished, side-by-side, century-long, free running coupled simulations with three ocean models will be performed for diagnostic purposes. The GEOS-5 CGCM will also be incorporated into the GMAO data assimilation and forecast systems.

This page intentionally left blank

Global Modeling, Data Impact and Data Simulation Research Group



One of the current tasks in the MAP Observing System Simulation Experiments (OSSE) funded proposal (PI Oreste Reale, co-I Juan Carlos Jusem) is the evaluation of the European Center for Medium Range Weather Forecast (ECMWF) so-called Nature Run (NR). The Nature Run is an essential OSSE research requirement, for both purposes of extracting the observations to be simulated, and validating the forecasts. The ECMWF has produced the longest high-resolution NR available (one year), and a multi-agency (NOAA, NASA and NCAR) team has been created to assess its realism and its suitability for OSSE work. Individuals in this GEST group working under the MAP OSSE proposal are actively involved. The Figure shows an example of the many analyses performed. Four meridional cross-sections of the zonal wind (m/s) at four different longitudes are shown, to analyze the structure of the African Easterly Jet (AEJ) as represented in the NR. The AEJ appears very well depicted with respect to climatological data sets. The AEJ is one of the most important features in controlling rainfall over Africa, African Easterly Waves (AEWs) and ultimately the development of tropical cyclones in the Atlantic. An unrealistic NR would lead to a very poor representation of the tropics in any model. Reale has been analyzing the evolution of the AEJ in time, its horizontal and vertical shears, the potential for instabilities to develop, the process of kinetic energy extraction from the jet, and the development of waves into close circulations, to assess the overall realism of the ECMWF NR over the African Monsoon region.

Global Modeling, Data Impact and Data Simulation Research Group

The work performed by the members of the Global Modeling, Data Impact and Data Simulation Research Group is focused on atmospheric, land, and oceanic data assimilation and modeling on a global scale, observing system simulation experiments, hurricane studies and development of next generation global atmospheric models. The group, which includes scientists supported by the Global Modeling and Assimilation Office (GMAO), by the Goddard Laboratory for Atmospheres (GLA), and by the Software Integration and Visualization Office (SIVO), increased slightly during 2006: Gyula Molnar joined GEST from JCET and became a member of this group. The scientists of the group, despite its relative small size of only 10 people, have demonstrated outstanding productivity by co-authoring 18 articles in peer-reviewed journals, seven more than the previous reporting period.

There is such a wide variety of expertise in the group that it cannot be summarized any way but individually. Among the GMAO-funded scientists, Sarith Mahanama performs research on land surface modeling in support of the development of the GMAO Climate model, performing Single Column Model (SCM) experiments to assess the strength of the land-atmosphere coupling and exploring the impact of deep soil temperature memory to the seasonal forecast of Atmospheric General Circulation Models (AGCMs). Lars Nerger is working on an ocean biogeochemical (OB) assimilation model and has further extended and improved the NASA OB model he previously implemented. Peter Norris is involved in cloud assimilation studies, continuing the development of a new cloud parametrization scheme to model the higher-order statistics of GCM subgrid-scale moisture variability. Lars Peter Riishojgaard leads the GMAO Satellite Data Group, which serves as a central resource within Goddard and NASA for atmospheric modeling and assimilation of satellite data in particular. He was recently appointed Deputy Director of the NASA/NOAA/DoD Joint Center for Satellite Data Assimilation (JCSDA). Chaojiao Sun has been working primarily in ocean data assimilation, developing a model error covariance estimation with MOM4, and is involved in a funded Modeling, Analysis and Prediction (MAP) proposal as a Co-I, estimating model parameters through data assimilation in a coupled model.

Among the scientists supported by the GLA, Gyula Molnar works on validating Outgong Longwave Radiation (OLR) and cloud parameters in the Sounder Research Team (SRT) and to use the Atmospheric Infrared Sounder (AIRS) retrievals for climate change assessments. Hailan Wang works on investigating the climate shift of the mid-1970s, assessing the relative roles of sea surface temperature (SST) modes associated with global warming and the natural variability. Juan Carlos Jusem is a senior visiting scientist who is working predominantly on the application of satellite surface wind data to improved ocean surface analyses and numerical weather predictions and is Co-I on a funded MAP proposal on Observing System Simulation Experiments (OSSE), led by Oreste Reale. The goal of this proposal is to assess the impact of existing observing systems and to simulate the impact of future ones. Beyond research on OSSE, Oreste Reale is involved in synoptic-dynamic evaluations of the GEOS model and is also Co-I on a funded proposal on NASA African Multidisciplinary Analysis (NAMMA), led by William Lau.

One scientist, Kao-San Yeh, is affiliated to SIVO and is involved in global atmospheric modeling. He has finalized a second-order Streamline Subgrid Integration (SSI) method for numerical transport on a geodesic grid.

All these efforts are meant to provide some practical applications to a large community of users, namely the entire GMAO, the Laboratory for Atmospheres, and the entire NASA community involved with Earth sciences. Several scientists in the group work also on multi-agency projects, and the recognition of Lars Peter Riishojgaard as Deputy Directory of the JCSDA is a particularly relevant achievement in this regard.

All the scientists in the group are part of a complex, multitasking, multidisciplinary team effort that can be evaluated in its entirety only over several years of activity. However, in spite of the group's small size and of the demands of multidisciplinary tasks that sometimes can limit individual productivity in favor of team work, the scientists of the group produced 18 publications that were accepted or published in major peer-reviewed journals during the reporting period. Three scientists are involved in funded MAP proposals either as PI or Co-Is, and a number of other proposals submitted during the year are still pending decisions.

All scientists in this group have been proving their motivation, knowledge, enthusiasm and skill through their steady progress towards carefully planned long-term research goals and their excellent productivity.

Oreste Reale

Task 613-38-236: **Application of Satellite Surface Wind Data to Ocean Surface Analysis and Numerical Weather Prediction**

GEST Investigator: Juan Carlos Jusem

Collaborator: William Lau (PI, GSFC, Code 613.0)

Grant 0000161626: **Observing System Simulation Experiments (OSE and OSSE) to Evaluate and Enhance the Impact of Current and Future Satellite Observations**

GEST Investigator: Juan Carlos Jusem

Collaborators: William Lau (GSFC, Code 613), Oreste Reale

Abstract

High resolution (~25 km) surface wind observations via satellite constitute a precious tool for safety at sea and for the construction of climatological datasets over the World Ocean. Assimilation of these wind observations by numerical prediction (NWP) models filter out the non-balanced part of the data as a requirement to initiate a forecast. By contrast, the Variational Analysis Method (VAM), currently in use at GLA, takes the set of full observations, which it adjusts in a minimum square sense. VAM utilizes NWP only as a background from which it makes the necessary corrections according to the wind observations. The surface wind data analysed in this research is the result of an optimal combination of several sources of wind observations, including the NWP model used as a background from the European Centre for Medium-Range Weather Forecasting (ECMWF) during January 2004.

The increasing success of numerical models in analyzing and simulating tropical cyclones gives origin, in the case of a long simulation, to the possibility of constructing a tropical climatology of the simulation that includes hurricane tracks. Since the construction of each track, point by point, is a time-consuming endeavor, a procedure to simplify that construction could be helpful. Currently a simple procedure exists for extratropical cyclones. That procedure consists in reproducing storm tracks utilizing a variation of the second order moment statistics of the 500 hPa height. The GEST researcher discovered that the normalized third order central moment (*i.e.,* the "skewness") of sea level pressure accurately describes the tropical cyclone tracks.

Description of Research

The role of the GEST investigator in this task was to identify cases in which VAM represents a conspicuous improvement respect to the background. The criterion used to declare "improvement" is the more logical time-sequence and the better correspondence between baric and motion field exhibited by the wind pattern proposed by VAM. The idea of a relationship between skewness and hurricane activity emerged from the observation that, in contrast with its extratropical counterpart, a hurricane is not followed by anticyclonic development inside the tropics. Therefore, a point located at a low latitude that was affected by a hurricane roughly recovers the previous value of sea level pressure. Thus, a time-series at that point exhibits a significant degree of asymmetry in the monthly pressure record, which is reflected in a negative skewness whose magnitude is greater than unity. The idea was tested on the old (FVGCM) and new (ECMWF) nature runs.

Accomplishments during the Reporting Period

It was possible to identify several cases, all in the Southern Hemisphere, where extratropical cyclones analysed by the ECMWF model showed both an awkward discontinuity in their propagation and a lack of correspondence between wind and pressure fields. In those cases, VAM corrected the anomaly. It is remarkable that the corrections to the surface winds by VAM produced a pattern similar to the ECMWF

pressure, when, in fact, VAM does not have any information about pressure.

The monthly skewness of the sea level pressure was applied to every one of the twelve months of the ECMWF nature run. As a result, the community that uses the outputs of this nature run chose August 2005 as the month to perform simulated observations. In that month, a simulated hurricane developed in the North Atlantic, made landfall in Florida and then dissipated over the southeastern United States.

Objectives for the Coming Year

A complex set of experiments is being prepared consisting in forecasts with the WRF model, boundary and initial conditions provided by GEOS-5 analysis and with inputs from different combinations of SSM/I, WSAT and QSCAT surface wind observations. The role of the GEST researcher will continue to be that of a subjective and objective evaluator of the different WRF forecasts.

The main objective is to write a paper explaining the relationship between sea level pressure skewness and hurricane activity. The paper will contain both illustrations and modeling. The modeling of a time series of pressure affected by a hurricane helps elucidate subtle relations between skewness, the length of the recording period (typically a month) and the amplitude of the diurnal pressure wave.

Task 971-00-002: **Land Surface Modeling in Support of the Development of a GMAO Coupled Climate Model**

GEST Investigator: Sarith P.P. Mahanama

Collaborators: Michele Rienecker (PI, GSFC, Code 610.1), Randal Koster (GSFC, Code 610.1), Max Suarez (GSFC, Code 610.1)

Abstract

The land-atmosphere coupling strength was explored using a series of Single Column Model (SCM) experiments. The SCM is an offshoot of the GEOS5 AGCM that uses the same physics and software structure as the AGCM. Since the SCM is run on a single vertical column, using tower observations, the framework provides an ideal setting for a computationally manageable sensitivity experiments at the land-atmosphere boundary. In a separate study, impact of deep soil temperature memory to the seasonal forecast of AGCMs was explored. Three AGCM experiments were performed to help isolate the impact of deep soil temperature variability and SST variability on the surface temperature variability, including: 1) a standard AMIP-type ensemble experiment with an interactive deep soil temperature, 2) an ensemble that used the daily mean climatology of deep soil temperature from the first experiment, and 3) ensemble with prescribed SST climatology. The impact on the hydrological cycle was also studied. The final project was a water energy budget study in Sri Lanka focusing on soil moisture memory and predictability of seasonal streamflow.

Description of Research

Proper understanding on impact of land surface variability on seasonal prediction of precipitation and temperature of AGCMs should in principle increase the skill of an AGCM's forecasting skill. The GEST researcher's major goals for this research, as a member of the land-modeling group of GMAO, is studying land-atmosphere interaction as influenced by land surface processes and a continuous upgrade of land surface parameters using the most recent satellite observations.

Accomplishments during the Reporting Period

The GMAO atmospheric GCM (the GEOS-5 AGCM) has a SCM counterpart, a model that includes all of the vertical physics of the atmospheric model (the radiation physics, the convection scheme, etc.). The GEOS-5 SCM can be used for fast, inexpensive sensitivity experiments. In this study, it was used to determine how details of the imposed

atmospheric turbulence and convection parameterizations affect land-atmosphere coupling strength, *i.e.*, the response of simulated precipitation to variations in soil moisture. The ultimate goal is to improve the simulation of coupling strength in the GEOS-5 AGCM modeling and prediction system. Sixteen parameters associated with the AGCM cloud moisture and turbulence parameterization schemes were identified as candidates for the sensitivity experiments. Observations from the Atmospheric Radiation Measurement/Cloud and Radiation Testbeds (ARM/CART) measurement station in Oklahoma were used for the SCM's lateral boundary conditions. By merging 2 observation episodes, a 63-day long set of lateral forcing for boreal summer was created, and through the repeated random sampling of this dataset, the research team derived forcing for 100-member ensembles of simulations, each lasting two months. (Ensembles are needed for the coupling strength diagnostic examined.) Idealized cycles of latent and sensible heat fluxes were prescribed at the land surface in each simulation; the cycles were given a two-week period, with a tunable amplitude.

The SCM sensitivity analyses identified two parameters with a particularly strong impact on land atmosphere coupling strength: a parameter related to the relative humidity threshhold for cloud water formation, and a parameter associated with the assumed subgrid variability in the atmosphere. The impact of these particular parameters on coupling strength was tested in the full atmospheric GCM.

Anomalous atmospheric conditions can lead to surface temperature anomalies, which in turn can lead to temperature anomalies deep in the soil. The deep soil temperature (and the associated ground heat content) has significant memory—the dissipation of a temperature anomaly may take weeks to months—and thus deep soil temperature may contribute to the low frequency variability of energy and water variables elsewhere in the system. The memory may even provide some skill to subseasonal and seasonal forecasts.

This study uses three long-term AGCM experiments to isolate the contribution of deep soil temperature variability to variability elsewhere in the climate system. The first experiment consists of a standard ensemble of AMIP-type simulations, simulations in which the deep soil temperature variable is allowed to interact with the rest of the system. In the second experiment, the coupling of the deep soil temperature to the rest of the climate system is disabled—at each grid cell, the local climatological seasonal cycle of deep soil temperature (as determined from the first experiment) is prescribed. Finally, a climatological seasonal cycle of sea surface temperature (SST) was prescribed in the third experiment. Together, the three experiments allow the research team to isolate the contributions of variable SSTs, interactive deep soil temperature, and chaotic atmospheric dynamics to meteorological variability.

The results show that allowing an interactive deep soil temperature does indeed significantly increase surface air temperature variability. An interactive deep soil temperature, however, reduces the variability of the hydrological cycle (evaporation and precipitation), largely because it allows for a negative feedback between evaporation and temperature.

Global water and energy budget studies as well as long-term soil moisture observation records have shown that the time scales of soil moisture anomaly dissipation are about 2-3 months. This implies that the baseflow component of streamflow should, in principle, be partly predictable at seasonal time scales. Mahanama investigated the hypothesis of seasonal streamflow predictability for Sri Lanka. Gridded 0.25° monthly precipitation observations for Sri Lanka were merged with 0.5° 6-hourly bias-corrected global reanalysis data for the period 1979-1993 and used to force the NASA Catchment Land Surface Model (CLSM) over Sri Lanka. CLSM simulations of monthly minimum and maximum surface temperatures and streamflow compared well with station observations. One-month lagged autocorrelation of simulated soil moisture was high (spatial average was about 0.75), with anomaly

dissipation time scales of about 3-5 months. The lagged cross-correlation between simulated total runoff efficiency and soil moisture showed predictability of streamflow up to 3 months in advance in the drier seasons (April to June and July to September).

Objectives for the Coming Year

Equipped with preliminary findings of the SCM experiments, the SCM study will continue in two directions. The first is the impact of the identified two parameters on the land-atmosphere coupling strength at the global scale will be tested in a comprehensive fully coupled AGCM simulation. The second direction for this investigator's research will be an attempt to parameterize the spatial variability of surface temperature in a AGCM grid cell using high resolution (5km) MODIS land surface temperature measurements.

Task 610-83-290: **Sounder Research Team Activity Support**

GEST Investigator: Gyula Molnar

Collaborators: Joel Susskind (SAIC), John Blaisdell (SAIC), Lena Iredell (SAIC), Fricky Keita (SAIC)

Abstract

The primary ongoing products (Sept. 2002 being the first full month analyzed) of the Atmospheric Infra-Red Sounder (AIRS) are twice daily global fields of atmospheric temperature-humidity profiles, ozone profiles, sea/land surface skin temperature, as well as basic cloud parameters and outgoing longwave radiation (OLR). The main task of the Sounder Research Team (SRT) at NASA/GSFC is to further improve/develop algorithms to achieve these goals, as well as to improve retrieval schemes for other atmospheric constituents, *e.g.*, ozone, carbon monoxide, carbon dioxide, methane, OLR and cloud parameters. The GEST investigator's main efforts were focused on validating OLR and cloud parameter retrievals, as well as to use AIRS retrievals for climate change assessments in general. He also has started work on creating a decadal scale, sounder-based OLR and cloudiness climatology by (eventually) merging TOVS Path-A (1980 being the first full year analyzed) and AIRS retrievals.

Description of Research

The AIRS/Atmospheric Microwave Sounding Unit (AMSU) is a state of the art infrared/microwave sounding system that was launched on the EOS Aqua platform in a 1:30 AM/PM sun synchronous orbit on May 4, 2002. OLR and basic cloud parameters are also derived from the AIRS/AMSU observations. However, so far the AIRS cloud product has not been rigorously evaluated/validated on a large scale. Fortunately, collocated/coincident radiances measured by MODIS/AQUA (at a much lower spectral resolution but roughly an order of-magnitude higher spatial resolution than that of AIRS) are used to determine analogous cloud products from MODIS. This allows for a rather rare and interesting possibility: the intercomparisons and mutual validation of imager vs. sounder-based cloud products obtained from the same satellite positions. The retrieved cloud field has to be consistent with the OLR, so the validation of the AIRS-retrieved OLR would increase confidence in the AIRS cloud product. This can be accomplished using the collocated, high quality CERES-based OLR retrievals. These studies have led to the creation of a satellite sounder-based climatology of various atmospheric parameters by uniting appropriately (re)processed TOVS Path-A climatologies with AIRS retrievals.

Accomplishments during the Reporting Period

The investigator continued to perform AIRS validation studies, addressing AIRS-MODIS cloud fraction/cloud top height intercomparisons. Since the CERES instrument is also onboard the AQUA satellite, outgoing longwave radiation, or OLR (a basic AIRS product) was the topic of another validation effort. While the MODIS cloud fractions were generally much higher and cloud top heights were considerably lower than that of AIRS,

rather surprisingly, the spatial-, inter-annual and intra-seasonal correlations of cloud parameter variabilities were quite high. This means that both instruments may assess climatic variabilities rather reliably, despite the great discrepancies in absolute values. Continuing CERES-AIRS OLR intercomparisons were even more encouraging, showing very high correlations of spatial-, inter-annual and intra-seasonal variabilities.

The general under-usage of satellite data (in particular for climate change related studies) has led the investigator to initiate efforts to create the longest possible satellite sounder-based climatologies of several, climatically important atmospheric parameters, in terms of GCM-grid-scale (1° x 1° and/or 2.5° x 2.5°) monthly mean products. Thus, the TOVS Path-A data, covering the 1979-2004 period, data were revisited, and corrected for orbital drifts. Up to this point, cloud and OLR climatologies were carefully created by combining the TOVS data from the available NOAA satellite sounders. Cloud parameter retrieval validations with ISCCP (1983 on) were encouraging, including decadal trends of GCM grid-scale cloud fraction. OLR values and variabilities compared well to available CERES OLR analyses (Sept. 2002 on), and in terms of global mean OLR values, were nearly identical [Molnar and Susskind, 2006a, 2006b, 2007].

Subsequently, the investigator addressed interrelationships/correlations among these parameters as well as surface temperature, mid-troposphere temperature, mid-stratosphere temperature, and upper tropospheric humidity values. Most recently, as gridded AIRS analyses became available, the AIRS time series (09/02-12/06 so far) of these climatically important parameters were also subjected to trend as well correlation analyses.

Objectives for the Coming Year

After continuing the AIRS OLR and cloud distribution validation effort, the investigator aims to finalize the construction of the longest possible satellite sounder-based, climatically important atmospheric parameter climatologies. This means to extend the TOVS Path A-based climatologies using continuing AIRS retrievals. Preliminary results are encouraging [Molnar and Susskind, 2007]. Participation in any newly arising AIRS retrieval-development/validation problems is also planned.

Task 900-55-207: **Development of an Ocean Biogeochemical EOS Assimilation Model**

GEST Investigator: Lars Nerger

Collaborator: Watson Gregg (PI, GSFC, Code 610.1)

Abstract

The previously implemented assimilation system based on a simplified version of the Singular Evolutive Interpolated Kalman (SEIK) filter with localized analysis implemented with the NASA Ocean Biogeochemical Model (NOBM) has been further extended. The application of a bias estimation scheme and the use of more representative covariance matrices resulted in improvements of the assimilation process. In the assimilation of the total chlorophyll data from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) estimates of surface chlorophyll are now obtained over the years 1998 to 2004 which are superior to both the free-run model and SeaWiFS data alone. Further studies have been focused on the multivariate assimilation such that nutrient fields like nitrate (for example) are included in the assimilation update. The multivariate assimilation results in improvements of nutrient fields, but instabilities appear locally. The assimilation process is stabilized by the application of bias estimation. However, the bias estimation decreases the overall improvements of the nutrient fields.

Description of Research

Satellite observations of ocean surface color provide nearly global information of the distribution of ocean surface chlorophyll. Due to the measurement of radiances in the visible part of the light spectrum, gaps in the observations

result from clouds or polar nights. In addition the satellite track results in regular data gaps. By assimilating ocean chlorophyll data into the global three-dimensional NOBM, which simulates physical, biogeochemical, and radiative processes, a complete chlorophyll field can be obtained together with other model fields like nutrients. In addition, improved model estimates of different fields can be obtained and derived variables like primary production can be produced. Furthermore, the combination of the observations with the NOBM has the potential to improve the understanding of the fundamental processes governing the distributions of biogeochemically important variables observed from space. In addition, the performance of different assimilation systems can be studied.

Accomplishments during the Reporting Period

This work continued the development of the data assimilation system for ocean chlorophyll data. The simplified variant of the SEIK filter with localized analysis, which is provided by the parallel data assimilation framework (PDAF) [Nerger *et al*., 2005], is applied for the assimilation. The localized analysis [Nerger *et al*., 2006] is obtained by the subsequent update of each single surface grid point of the model taking into account only observations within a specified distance from this grid point. While the PDAF contains the full dynamic SEIK filter, a simplified variant of the algorithm is created by keeping the covariance matrix, which estimates the errors in the model state, constant. This avoids the requirement of an ensemble integration of model states, which strongly reduces the computational requirements of the assimilation process. Experiments have been performed in which either only the surface chlorophyll field of the model or also nitrate related variables (nitrate, ammonium, nitrate/carbon detritus) are changed during the assimilation.

To improve the estimation capabilities of the assimilation system an online bias estimation scheme has been implemented. It aims at the separation of the update of the model fields into the estimation of systematic, slowly changing errors (bias) and random errors. This separation permits to integrate only the model fields without bias, while the bias estimate is kept static during the daily assimilation updates and stabilized the forecast of the model state.

The assimilation system was applied to assimilate daily chlorophyll concentrations from SeaWiFS, which are interpolated to the model grid [Nerger and Gregg, 2007]. The assimilation was performed over a period of seven years (1998-2004). The model error covariance matrix is initialized from a multi-year simulation of the NOBM without assimilation. Here improvements of the assimilation have been obtained by switching from a covariance matrix based on monthly deviations from a long-time mean to more frequent deviations from a 3-month running mean. The error estimates for the observations are assumed to be regionally varying. They are motivated by the varying deviations of SeaWiFS ocean chlorophyll data from independent in-situ observations of total chlorophyll concentrations.

The assimilation provides daily complete estimates of the total ocean surface chlorophyll concentration as well as the fields simulated by NOBM (Phytoplankton groups, nutrients, etc.). Comparing the state estimates to independent in situ data can assess the performance of the assimilation. With the inclusion of the bias estimation, the estimates of surface chlorophyll are superior to both the free-run model and SeaWiFS data alone.

The multivariate assimilation including nitrate, ammonium and the nitrate-related detritus widely improves these fields. However, locally the assimilation results in strong overestimates of, for example, nitrate, which destabilize the assimilation process and lead eventually to a breakdown of it. Here, the bias estimation stabilizes the assimilation process, but at the same time results in smaller improvements of the fields.

Objectives for the Coming Year

The GEST investigator will continue to develop the assimilation system. The focus of this development will be on the multivariate assimilation where it is also planned to explicitly update the single phytoplankton groups. By

now, these have been updated under the constraint that their relative abundances remain constant. To improve the error estimates of the model state, the implementation of the full SEIK filter with ensemble integration is planned. The performance of the full SEIK filter will be compared to that of the simplified filter.

Task 910-01-010: **Cloud Data Assimilation**

GEST Investigator: Peter M. Norris

Collaborator: Arthur Hou (GSFC, Code 610.1)

Abstract

NASA has made a large investment in high-resolution satellite cloud observing systems (*e.g.*, MODIS, AMSR-E and CloudSat). The GEST investigator along with Arthur Hou of GSFC have been conducting theoretical and modeling efforts to assimilate the maximum information content from these systems into weather and climate models with much coarser resolution. This is done by devising new cloud parameterizations which model the higher order statistics of GCM subgrid-scale moisture variability. This variability can then be constrained using high-resolution cloud observations. An exploratory Bayesian assimilation technique using the flexible Markov Chain Monte Carlo method has been tested and is showing promising preliminary results. A novel cloud overlap scheme has also been devised based on statistical theory and cloud-resolving model simulations. New work was begun with Graeme Stephens (CSU), Julio Bacmeister, and Angela Benedetti (ECMWF) on comparison of CloudSat retrieved and GCM modeled cloud and precipitation properties. A report on previous cloud data assimilation work with Arlindo da Silva was accepted by the Journal of the Atmospheric Sciences.

Description of Research

It is widely recognized that clouds play an essential role in moderating the climate. This recognition has prompted the continuing development of new cloud parameterizations for global climate models. What is currently needed is the ability to test these new parameterizations against different sources of observed and retrieved cloud information with global or large-scale coverage. Furthermore, at a time when many forms of ground-based and remotely sensed data are being assimilated into global models—such as the NASA Global Modeling and Assimilation Office (GMAO) GEOS system—there are currently few mature efforts to directly assimilate cloud information into models. This is the background for this task within the GMAO to use retrieved cloud information to validate cloud properties within the GEOS model, to measure the capability of various new trial cloud parameterizations, and to assimilate cloud measurements directly into the data assimilation system. This work is funded by the Cloud-Radiation Modeling and Assimilation IDS, Arthur Hou, PI.

Accomplishments during the Reporting Period

This year saw a transition to a series of theoretical studies on the potential for assimilating high-resolution satellite cloud data within the context of statistical cloud parameterizations. The basic idea is that satellite cloud data is available at very high resolution (1 km for MODIS) compared to the typical GCM grid size. This grid size is too large (due to computational restrictions) to model many cloud processes, so several solutions are currently being explored by the GCM community. One approach is to model not just the mean properties of a model gridbox, but other statistical properties as well. The so-called assumed-PDF cloud schemes fall into this category. These schemes assume a certain parametric form for the PDF of subgrid-scale moisture variability, from which the cloud fraction and condensed water content are diagnosed. To close the system, the PDF parameters must be diagnosed or prognosticated by the GCM. The question addressed by Dr. Norris' research is "How can the available high-resolution satellite cloud data be taken advantage of to constrain the subgrid-scale statistical properties of these assumed-PDF

cloud schemes?" An answer to this question will facilitate the assimilation into climate and weather models of greater information content from the many capable cloud observing systems that NASA has invested in.

Norris's initial line of investigation has involved the constraint of grid-column state by high-resolution cloud mask observations. Assume that each layer of a GCM grid-column has a PDF of total water content with a first-guess mean and variance specified within certain error bounds. Also assume a first-guess layer temperature profile and some specification of interlayer correlations and cloud overlap. Given N pixel observations of the grid-column, of which n are cloudy, what is the most probable updated state of the layer moisture PDFs and temperatures? This simple example with cloud mask observations can easily be expanded by providing brightness temperatures, optical depths, radar reflectivities, etc. The maximization of the probability in multivariate space was made using the "Markov Chain Monte Carlo" (MCMC) method, which is very flexible to the addition of new constraints and to non-linear dependencies and multiple modes in solution space. A paper on this work is in preparation. A faster variational scheme will be devised later to simulate the MCMC scheme behavior for operational use.

The above work has required an improved forward model for cloud overlap. With the help of a new theoretical apparatus for multi-layer moisture variability and with synthetic observations from Goddard Cumulus Ensemble (GCE) cloud scale model simulations, a new cloud overlap scheme is under-development which promises to be a groundbreaking new approach to this classic thorny GCM problem. Preliminary testing of the new method is promising and a paper is about half written up.

Some new work is also being done with Graeme Stephens (CSU), Julio Bacmeister and Angela Benedetti (ECMWF) on comparison of CloudSat retrieved and GCM modeled cloud and precipitation properties. Finally, previous work with Arlindo da Silva to assimilate cloud data (ISCCP, SSM/I) into GMAO's GEOS model culminated in a journal article acceptance [Norris and da Silva, 2006].

Objectives for the Coming Year

The first of a three-part paper on the new cloud overlap scheme is half completed now and will be submitted by summer. The second part including temperature variability will follow later in the year. The work on MCMC cloud fraction assimilation will be continued and a preliminary paper submitted. Norris will work with Julio Bacmeister to include the new PDF cloud parameterization/overlap scheme into GMAO's GEOS-5 model. The method will be expanded to include brightness temperature assimilation. The CloudSat/GCM Intercomparison will be advanced to publication.

Task 910-08-99: **Synoptic-Dynamic Evaluation and Improvement of the NASA Finite Volume General Circulation Model**

Grant 00001994: **Observing System Simulation Experiments (OSE and OSSE) to Evaluate and Enhance the Impact of Current and Future Satellite Observations**

GEST Investigator: Oreste Reale

Collaborator: William Lau (GSFC, Code 613.0)

Abstract

The first task is focused on the synoptic and dynamic evaluation of various aspects of the atmospheric model originally named finite volume General Circulation Model (fvGCM), and currently known as GEOS. Two versions of this model (GEOS-4 and GEOS-5), sharing the same dynamical core but with a different physics, were examined throughout the year with emphasis on tropical cyclones. This effort produced co-authorship on two peer-reviewed articles and one chapter in a book.

The second task was to lead the Data Impact and Modeling Team originally created by Robert Atlas in the Goddard Laboratory for Atmospheres (GLA) at GSFC, and focused on data impact and data simulation. This task is currently funded by a MAP proposal on Observing System Simulation Experiments (OSSE) on which the GEST investigator is the PI.

During the year another proposal (with William Lau as the PI and Reale and other NASA scientists as co-Is), was funded within the NAMMA framework. The research will continue over the next three years and will be focused on tropical cyclogenetic processes in the Atlantic, impact of Saharan air and Saharan dust, and more generally the African Monsoon.

Description of Research

The main goal of the first task is to evaluate the potential of the GEOS system in simulating weather events at spatial and temporal scales near the limits imposed by model resolution, with particular emphasis on tropical cyclones. The increase in resolution imposed on the GEOS system have produced fundamental changes in the way in which the tropical atmosphere is represented and in particular tropical cyclones are reproduced. The PI has investigated changes in structure, intensity, track and large scale forcing of tropical cyclones and easterly waves and the behavior of GEOS-4 and GEOS-5 (two versions of the model sharing the same dynamical core but with different physics) under different situations and for different cases of hurricanes.

The research performed under the OSE-OSSE task explores the impact of different data types (*e.g.*, satellite-derived wind, temperatures, etc.) in the overall GEOS-5 performance and/or in particular synoptic situations. Emphasis was placed on the impact of version 4.7 of AIRS temperature retrievals over the GEOS-5. AIRS data were found very beneficial to the forecast of mid-latitude disturbances originating over the northeastern Pacific and propagating throughout North America and the Atlantic. As a part of the OSSE research, the PI has contributed to a multi-agency effort involving NCAR, NCEP and NASA (GLA, GMAO and SIVO), and lead by Dr. Masutani at NCEP, to define the specifics and start analyzing a new Nature Run produced by the European Center for Medium Range Weather Forecast (ECMWF). The Nature Run is a fundamental tool to perform research in OSSE. Collaboration with Lars Peter Riishojgaard has produced a number of OSSE experiments on Lidar winds.

As a part of the newly funded NAMMA proposal, the PI has started assessing the performance of the GEOS-5 model over the African Monsoon region.

Accomplishments during the Reporting Period

As a part of task 910-08-99, Reale contributed to the analysis of a further experimental increase in resolution in the NASA fvGCM in a set of experiments at the resolution of 1/8° performed by Bo-Wen Shen. This work lead to co-authorship in an article published early in 2006 [Shen *et al.*, 2006a], the first demonstrating the capability of a GCM to resolve mesoscale vortices. During the same year, the GEST researcher contributed to another article investigating the performance of the model in forecasting Hurricane Katrina and on the impact of disabling parametrized convection at ultra-high resolution [Shen *et al.*, 2006b]. The American Geophysical Union (AGU) highlighted this article.

The effort funded under the Proposal Observing System Simulation Experiments produced some interesting results on the impact of AIRS 4.7 data. The AIRS community appreciated the results and an invited talk was given at the Science Team Meeting in September (presented by Bob Rosenberg). Preliminary work on the validation of the ECMWF Nature Run has also been found useful by the NCEP, the ECMWF and by the OSSE community and was posted on an NCEP website.

As a part of an effort somewhat bridging between the MAP and the newly funded NAMMA effort, the PI collaborated with the GMAO and with William Lapenta (NASA MSFC) during the NAMMA field mission to provide mission support. The mission consisted

in flying into African Easterly Waves off the coast of Africa to collect various measurements. Real-time subjective briefings based upon the GEOS-5 operational forecast were sent by the PI daily to the NAMMA team in Africa throughout the entire campaign and found beneficial by the team for the planning and execution of the mission flights. A number of interesting features pertaining to the African Easterly Wave formation and development were identified and analyzed. Issues on the quality of the operational analyses over the African region were unveiled.

Objectives for the Coming Year

The main goal of task 910-08-99 is to continue to evaluate the potential of the GEOS-5 to simulate weather events at spatial and temporal scales near the limits imposed by model resolution. An ongoing collaboration with Man-Li Wu and Sigfried Schubert from GMAO is focused on analysis of the ERA-40 and NSIPP runs over the African and Atlantic regions. Two co-authored articles are in preparation. Another article is being prepared on selected cases of hurricanes and their GEOS forecast.

The emphasis of the OSE/OSSE effort will continue to lead the former Data Impact and Modeling team and perform research of different data types and to simulate new instruments. A complete and exhaustive evaluation of the ECMWF Nature Run will be completed and released during 2007.

Finally, the research performed under the NAMMA proposal on the African Monsoon will become a separate task.

Alongside these three main goals, research will be conducted to investigate any new, fundamental, aspect pertaining to synoptic and dynamic meteorology, which might arise during the evaluation of the GEOS-5, with particular emphasis on hurricanes.

Task 910-01-010: **Leadership of the GMAO Satellite Data Group**

GEST Investigator: Lars Peter Riishojgaard

Collaborator: Michele Rienecker (PI, GSFC, Code 610.1)

Abstract

The primary responsibility of the investigator is to lead the research and development efforts taking place in the satellite data group of the GMAO. The office serves as a central resource within GSFC and the agency for atmospheric modeling and assimilation of satellite data in particular. The satellite data group consists of about ten individuals, and the role of this group within the GMAO is to ensure that current and future satellite data—both from research and operational satellites—be assimilated as efficiently as possible, and when necessary to initiate new experimental activities or develop new methodologies to ensure that this overall goal is met. Another important area of activity is leading the development of rationale for new weather-related space initiatives, *e.g.*, the Molniya Orbit Imager and the Global Winds Observing Sounder. The third major function is to serve as the NASA Deputy Director of the NASA/NOAA/DoD Joint Center for Satellite Data Assimilation.

Accomplishments during the Reporting Period

Work in the satellite data group falls into five main categories: (i) data ingest, including preparation of operational data streams and research data sets, file conversion, and quality control; (ii) supervising the routine assimilation of satellite data and troubleshooting; (iii) conducting data impact experiments to verify and where possible improve the impact of satellite data on GMAO systems; (iv) devise new methodologies appropriate for satellite data; and (v) test candidate new satellite data in GMAO systems.

In the previous reporting period, most of the emphasis had been on areas (i) and (ii), with effort devoted to preparing GEOS-5 for the Modern Era Retrospective-analysis for Research and Applications (MERRA) project, a 25+ year reanalysis of the entire satellite record of

atmospheric observations. Part of the challenge of this project is that for certain historical satellite measurements this will be the first time they are evaluated and analyzed using modern data assimilation tools.

Over the course of the past year an increasing amount of effort was put into area (iii), with three main foci: AIRS, MODIS, and surface pressure observations. Concerning AIRS, both data selection, channel selection and the basic methodology has been evaluated, and the first direct intercomparison of radiance versus retrieval assimilation for a hyperspectral sounder is nearly completed. Concerning the MODIS winds, the main objective is to finalize a set of diagnostics for a joint GSFC/NESDIS study assessing the economic impact of feature tracking satellite winds for the polar areas. Considering the fact that no current plans exist for an operational follow-on to the MODIS winds, the report for this study is expected to be an important tool for decision-makers in NOAA and NASA. And finally, the impact of surface pressure observations on forecast skill is being tested in preparation for a possible request to NASA to make available a real-time surface pressure data product from the upcoming Orbiting Carbon Observatory mission.

In 2004, the investigator proposed to launch a meteorological imager in a Molniya orbit in order to demonstrate the capabilities of this orbit to provide high repeat rate cloud and water vapor images. Work on the mission proposal continued throughout 2006 as the investigator addressed the technical, scientific and programmatic aspects, albeit at a reduced pace. The scientific rationale is solid, and the baseline mission design is largely complete. Most of the effort has therefore been concentrated on exploring some of the alternative scenarios under which NOAA and/or a foreign partner would play more important roles, also financially. Interest in the mission continues to grow, and it appears likely that two separate pre-Phase A studies will be launched within the next year—one by the Canadian Space Agency, one by the European Space Agency—largely parallel to the Goddard MOI study. Russia has already completed a mission concept study based on the MOI mission rationale and is currently looking for implementation partners.

In the fall of 2006, GSFC completed a series of advanced concept mission studies in anticipation of the publication of the report of the Decadal Survey of Earth Science Mission completed by the National Academy of Sciences. The investigator served on the Science Working Group of the Global Winds Observing Sounder, a Doppler Wind Lidar mission aimed at providing vertically resolved wind vector measurements with global coverage for improving weather prediction skill. The contribution consisted of helping to establish the requirements for the new mission, participate in ISAL and IMDC studies, provide the science justification parts of the final report and give the science presentation at the final mission study review.

The role of the NASA Deputy Director of the JCSDA is to—in collaboration with the JCSDA Director—define the strategic goals of the center, to ensure the coordination between the JCSDA and relevant activities in the GMAO, and to manage the resources allocated to the center by NASA Headquarters. The Joint Center for Satellite Data Assimilation (JCSDA) continues to develop, and a substantial amount of time was spent on reviewing and managing the grants awarded by the JCSDA through its Announcement of Opportunity (AO). The investigator is also active in leading the NASA portion of a multi-agency effort toward developing a national Observing System Simulation Experiment (OSSE) capability for satellite observations under the auspices of the Joint Center.

Effective February 28, the investigator was appointed as Acting Director for the Joint Center following the departure of the previous director John Le Marshall. A formal search for a permanent replacement is expected to open shortly.

Objectives for the Coming Year

The key tasks for the satellite data group in the GMAO in 2007 will be to provide continued support for the MERRA project, to continue

improving the use of the current satellite data and to prepare for testing and assimilating the data from the upcoming satellite missions, especially ADM and NPP. Much of this work will be undertaken jointly with partners in the Joint Center for Satellite Data Assimilation. In addition, a major focus area will be to solidify the developing interagency collaboration on Observing System Simulation Experiments, both from a scientific and a funding perspective. Concerning the Molniya Orbit Imager, the goal is to find a way to leverage the broad international support for the support for the mission into a concrete contribution from NASA and NOAA contribution.

Task 971-00-002: **GMAO Ocean Data Assimilation System**

GEST Investigator: Chaojiao Sun

Collaborators: Michele Rienecker (PI, GSFC, Code 610.1), David Behringer (NCEP), Jiande Wang (NCEP & SAIC), Ichiro Fukumori (JPL), Michael Ghil (UCLA/Ecole Normale Supérieure), Dmitri Kondrashove (UCLA)

Abstract

In the first task, the GEST invstigator is researching global ocean data assimilation at GMAO. The second task involves outside collaboration with scientists at JPL, UCLA and Ecole Normale Supérieure in France through a funded NASA MAP project on which Sun is a Co-I. The major achievement for the first task is a model error covariance estimation with MOM4 and the evaluation and validation of GMAO and GFDL ocean data assimilation systems. A paper has been accepted for publication in the journal *Monthly Weather Review* that documents the comparison and sensitivity of GMAO and GFDL ODAS. The second task focuses on the problem of estimating model parameters through data assimilation in an intermediate coupled model. Two important coupling parameters have been successfully estimated using NCEP/DOE Reanalysis 2 SST data.

Description of Research

Model error covariance is often poorly known due to its complexity and a multitude of causes. In ocean models, model uncertainty due to the uncertainty in atmospheric forcing is the most dominant factor. This research focuses on the ocean model uncertainty due to uncertainty in surface forcing. Different model simulations are performed subject to different forcing datasets (for example, NCEP/DOE Reanalysis 2 and ERA40 Reanalysis daily mean fields). The difference in the simulations is due to difference in the forcing products. By studying the patterns of difference ensembles, multivariate model error covariance structure can be derived. EOF analysis is used to effectively reduce the high dimensionality of model states. Another project is to estimate key coupling parameters of an intermediate coupled model using state augmentation technique in the extended Kalman filter by assimilating *in situ* and satellite observations of ocean states.

Accomplishments during the Reporting Period

The GEST investigator performed a model error covariance estimation with MOM4. MOM4 is the state-of-the-art global ocean circulation model that will become the workhorse of GMAO ocean model in its suite of coupled models. This research has been pursued with close collaborations with colleagues in NCEP. The grid configuration of MOM4 is the same as that used in NCEP to facilitate comparison of the two ocean data assimilation systems at GMAO and NCEP. It has a high global resolution of 0.5° with refinement near the equator to ¼°. Model error covariance estimation is a very important issue because the knowledge of model and observation error covariances determines how much weights are given to model and observations to achieve accurate estimates of the state of the ocean. The GEST investigator downloaded the two major atmospheric reanalysis products (NCEP/DOE Reanalysis 2 and ERA40 Reanalysis daily mean fields) from the WWW, and painstakingly reprocessed them so they can be used by MOM4. Reynolds monthly SST product (v.2)

were also downloaded from the web, and used as relaxation fields for model SST. Preliminary results show that the model error covariance structure derived from ensembles of simulations under different forcing compares well with that derived from UOI and EnKF schemes in a different global ocean circulation model (Poseidon V. 4). This indicates the robustness of model uncertainty estimation for MOM4. An EOF analysis demonstrates major characteristics of model uncertainty.

Another achievement is the acceptance of a paper on ocean data assimilation by a major journal, the *Monthly Weather Review* [Sun *et al.*, 2007]. The GMAO and GFDL ocean data assimilation systems (ODAS) are two major systems in the ocean assimilation community. These well-exercised ODAS of optimal interpolation and 3D-VAR, are used in intercomparison experiments as part of the CEDP Consortium for Ocean Data Assimilation Consortium for Seasonal-to-Interannual Prediction (ODASI). In these experiments, same observations (temperature only) and same forcing are used by all assimilation systems. The GMAO ODAS updates salinity either through model T-S relationship or assimilating synthetic salinity profiles derived from Levitus climatology. Extensive and diverse data sets are utilized in evaluating and validating analyses, including TAO mooring data, TAO service cruise data collected over the years, and data from a cruise during the Tropical Instability Wave Experiment in 1991. The results show that both GMAO and GFDL analyses capture the main variability of temperature, current and salinity. The treatment of salinity has significant impact on salinity and current structures. Schemes that adjust salinity based on climatology while assimilating temperature are able to correct model salinity bias successfully, and produce better currents. Newly available Argo temperature and salinity data are now assimilated, and work is under way to investigate the impact of salinity observations on ocean analysis and evaluate model forecast error covariances between temperature and salinity.

A peer-reviewed paper has also been accepted in the journal *Remote Sensing of the Environment* [Dong *et al.*, 2007] in which Sun is a co-author. This paper complements two earlier papers on snow data assimilation and satellite snow observation error estimation [Sun *et al.*, 2004 and Foster *et al.*, 2005], and assimilated satellite observation of snow mass with an improved retrieval algorithm and the observation error model by Foster *et al.* [2005], using the assimilation method developed by Sun *et al.* [2004].

Objectives for the Coming Year

The GEST investigator plans to make a significant contribution to the GMAO ocean data assimilation system and the NASA MAP project on coupled data assimilation. The main objectives are to 1) derive and evaluate model forecast error covariances from MOM4; 2) help to implement multivariate assimilation method in MOM4; 3) develop methods for parameter estimation in a coupled model; and 4) continue to develop diagnostic tools to evaluate ocean data assimilation systems.

Task 610-73-252: **NASA Modeling, Analysis and Prediction (MAP) Project: Understanding and Quantifying the 1970s Climate Transition in the Presence of a Rapidly Changing Observing System**

GEST Investigator: Hailan Wang

Collaborators: Siegfried Schubert (PI, GSFC, Code 610.1), Max Suarez (GSFC, Code 610.1), Arun Kumar (NOAA NCEP), Martin Hoerling (NOAA ERSL), Junye Chen (ESSIC)

Abstract

The climate shift in the mid-1970s marks the beginning of accelerated trends in a number of key climate parameters. The causes of the observed climate trends over Asia and North America during 1950-2000 are being investigated by linking them to concurrent changes in oceanic low boundary conditions.

The relative roles of SST modes associated with global warming and natural variabilities such as the Pacific Decadal Variability are also being assessed. The physical and dynamical processes through which these SST modes affect regional climate changes are revealed through these investigations.

Description of Research

The mid-1970s are characterized by abrupt shifts in a number of physical and biological climate records, such as intensity of the Aleutian low, the Pacific Decadal Oscillation, various North Pacific fisheries time series, and Alaskan glacier mass balances. The goals of this project are to provide substantially improved estimates of the global extent of the climate transition in the 1970s, and to improve understanding of the fundamental cause(s) of the climate shift.

Accomplishments during the Reporting Period

The focus of this work has been on understanding the climate trends over the Northern Hemisphere (NH) continents that occurred during the last 50 years or so. The 1970s climate shift is imbedded in this trend and, in fact, to a large extent marks the beginning of the very strong trends of the last few decades. This work proceeds by linking the climate trends over the NH continents to concurrent changes of SST including those associated with leading SST modes such as global warming and decadal variability. A series of idealized AGCM experiments forced by SST anomalies associated with various combinations of the global warming, decadal variability modes, and the residual SST component over global domain and specific oceanic basins are performed. With the results of the set of AGCM simulations with idealized SST forcing patterns, existing long AMIP-style simulations as well as various observational and reanalyses data sets, the work to date has been on 1) seasonality and regionality of the climate changes over the U.S., and 2) wintertime surface temperature trends over Asia and North America, during 1950-2000.

The observed climate trends over the United States during 1950-2000 exhibit distinct seasonality and regionality. The surface temperature demonstrates a warming trend during winter, spring and early summer and a modest country wide cooling trend in late summer and fall, with the strongest warming occurring over the northern U.S. in spring. Precipitation enhances in all the seasons, peaking over the central and southern U.S. in fall. This study investigate the causes of the seasonality and regionality of the climate trends over the U.S. during 1950-2000, particularly the cooling and wetting trends during summer and fall. Results show that the observed climate trends over the U.S. are mostly explained by changes in SST. Among the leading SST modes, the decadal variability mode plays a prominent role in maintaining the seasonality and regionality of the climate trends over the U.S. The residual SST component in the NH Atlantic makes a comparable contribution during fall. By contrast, the SST changes associated with the global warming mode mainly provide a warming environment. They do not explain the observed climate trends in both seasonality and regionality. The SST changes associated with the decadal variability mode in the Pacific may affect the U.S. climate through atmospheric bridge mechanism and strong local soil-moisture feedback processes, whereas the residual SST component in the NH Atlantic forces a precipitation increase over the U.S. in fall by exciting a strong low-level anticyclone over the Gulf of Mexico. The findings of this study have important implications to the U.S. climate prediction.

The trends of wintertime surface temperature over the NH continents in observations, NCEP/NCAR reanalayse and ERA40 products, and AMIP type simulations with a number of AGCMs are examined and compared to each other. The comparison shows the general consistency of the disagreement between the observations and models over Asia, and general agreement among them over North America. Over Asia, while the observations and the reanalyses show a pronounced surface warming trend, all the model simulations show either a mixed signal of weak warming and cooling or an overall tendency for cooling. Such differences result from the delayed impact of global warming in the AMIP simulations relative to

observations and the reanalyses. The AGCM experiments with the idealized SST forcing show that the warming over Asia is forced primarily by the SST mode associated with the global warming, whereas the strong warming over northwest North America is mostly forced by the decadal variability in the Pacific. An additional experiment with an idealized spatially uniform SST anomaly that is equal to the spatial average of the global warming mode shows similar results, indicating the any spatial inhomogeneities in the global warming mode do not play an important role in the warming over Asia.

Objectives for the Coming Year

In the coming year, the NASA GEOS-5 model and data assimilation system will be used to carry out experiments designed to assess the sensitivities of the reanalysis products to the changing observing system. Adaptive bias correction techniques are tested to evaluate their effectiveness in correcting observational bias during a period of abrupt climate change. AMIP-style simulations will be carried out to isolate the SST contributions to the atmospheric climate shift.

Task 910-14-125: **Development of a Next-Generation Finite-Volume Dynamical Core on Geodesic Grids**

GEST Investigator: Kao-San Yeh

Collaborator: Michael Seablom (SIVO; GSFC, Code 610.3)

Abstract

The GEST investigator finalized a journal article on the second-order Streamline Subgrid Integration (SSI) method for numerical transport on (icosahedral) geodesic grids. He also improved the formulations of the third-order transport schemes and the shallow-water algorithms for geodesic grids and tested some formulations for 3D hydrostatic atmospheric dynamics on geodesic grids.

Description of Research

The goal of this task is to develop a next-generation dynamical core with the finite-volume method on (icosahedral) geodesic grids. This potential dynamical core is intended for future application in the NASA finite-volume General Circulation Model (fvGCM) as a major component for global high-resolution modeling. While the quasi-uniform distribution of isoscahedral geodesic grids provides a solid foundation for achieving great parallel efficiency for the enormous amount of computation required by global high-resolution modeling, the major effort is to overcome the scientific difficulty of developing sufficiently accurate numerical algorithms with desired physical properties, such as local conservation and monotonicity for both weather and climate applications.

Accomplishments during the Reporting Period

In this fiscal year, Yeh has continued to revise the paper on the second-order transport schemes. It is now finalized after three years of harsh review, due to serious debate on some fundamental issues from different aspects of the reviewers.

The generalization of the second-order transport schemes to the third-order ones was found to have appreciable computational noise in its early formulations. This issue was resolved by refining the third-order formulations with stronger diffusion effect. The shallow-water algorithm is modified accordingly to enhance the numerical stability of the dynamics in the horizontal.

A simple hydrostatic formulation for the 3D atmospheric dynamics has been derived and tested. However, the simulation of this early trial was found to not be symmetric with respect to the equator, perhaps due to the asymmetry of the geodesic grids. More sophisticated formulations are expected to resolve this issue.

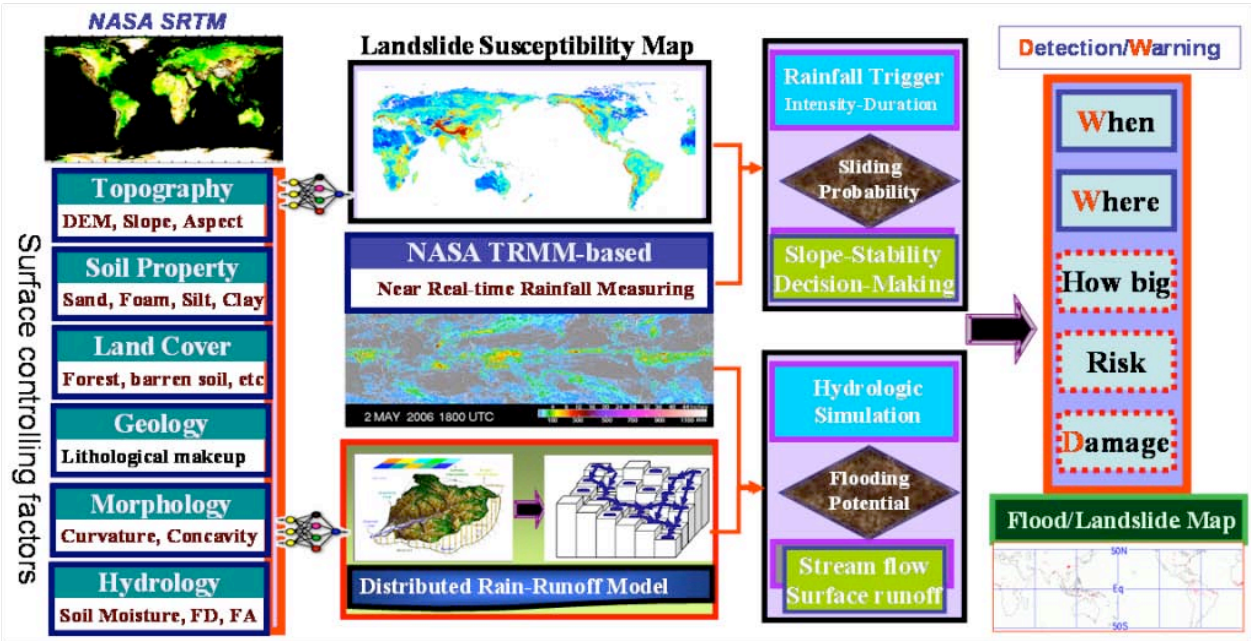
In addition to the primary research stated above, Yeh has also participated in the forecasting of hurricanes with the high-resolution NASA fvGCM, and in the writing of a related paper, as shown in the following section entitled "Refereed Publications".

Objectives for the Coming Year

The GEST investigator plans to write a paper on the third-order SSI transport schemes, and another on the shallow-water model, so as to demonstrate the advantages of using the SSI method to simulate atmospheric dynamics in the horizontal with geodesic grids.

The hydrostatic formulation of the 3D atmospheric dynamics will be the major work for this task in the coming year. Earlier research has shown that simple treatments of the pressure gradient force were not sufficient for the geodesic grids, and much more sophisticated formulations are expected to overcome this issue.

Cloud Modeling and Analysis Research Group



A framework to predict floods and landslides related to heavy rain events in near-real-time is proposed. Key components of the framework are: a fine resolution precipitation acquisition system; a comprehensive land surface database; a hydrological modeling component; and landslide and debris flow model components. The major outcome of this work is to expand regional hazard modeling components into a monitoring/predicting system for flood/landslide disaster preparedness and mitigation around the world. [Figure courtesy of Yang Hong.]

Cloud Modeling and Analysis Research Group

The Cloud Modeling and Analysis Research Group is the largest science group in GEST. The group seeks to understand the physical process of different cloud systems and their interaction with climate changes. This research, conducted mainly through numerical modeling and data analysis, involves various scientific studies aiming to better understand the mechanisms of cloud dynamics, microphysics, atmospheric radiation transfer, and the impact of aerosol on cloud and precipitation, as well as to improve the remote sensing retrieval algorithm of cloud and precipitation.

Using cloud modeling to understand the interaction between a cloud system and its environment continues to be one of the major research elements within the group. Xiping Zeng continues to make progress on the improvement/development of the Goddard Cumulus Ensemble (GCE) model (a cloud-resolving model), as well working with Chung-Lin Shie on the performance of numerical simulations to better understand the physical processes of the tropical and mid-latitude convection. The modeled rainfall results are found consistently corresponding to a properly correlated large-scale temperature and moisture forcing not only temporally but also quantitatively. Jiun-Dar Chern has been developing the Goddard Multi-scale Modeling Framework (MMF) by implementing a 2-D GCE into the finite-volume General Circulation Model (fvGCM). A promising result was found that the MMF outperformed the fvGCM in simulating the geographical distribution of precipitation and cloud amount. Xiaowen Li has implemented a new explicit bin microphysical scheme into GCE to better understand the interaction between aerosol and cloud, and hence the impact of aerosol on precipitation. This improved microphysical scheme produced a more realistic distribution of the cooling due to melting, and thus a more reasonable structure of stratiform rain. Yaping Zhou led another study that utilized a GCE simulation dataset and the collocated satellite observations to identify the similarities and discrepancies between the modeled and satellite retrieved rain and cloud properties, as well as to provide the basic matrix for improvement of model's physics and the satellite retrieval algorithm. Several scientists in the group performed studies using observational or numerical data to understand the interaction between the cloud system (occurring in a hurricane, tropical cyclone, or convective system) and its large-scale environment. Guojun Gu's research examines the seasonal and interannual-to-decadal climate variability using global precipitation data, a first step to answer whether there is a corresponding acceleration of water cycle given a relatively confident belief of global warming in the past decades. There are growing concerns regarding whether the increased tropical cyclone activity is a result of global warming. Liguang Wu's numerical study suggested that the change in cloud dynamics caused by global warming might affect hurricane intensity. Significant progresses have been made by Yang Hong on flood and landslide early warning for disaster management based on global precipitation observations and land surface characteristics. The upcoming Global Precipitation Measurement Mission (GPM) leads to an increased interest in the middle latitude weather system, which led Mei Han to conduct a numerical simulation of extratropical cyclones. Non-precipitating clouds, such as cirrus, have been well known to play an important role in the global energy balance. However, the mechanisms determining its maintenance and dissipation are not well understood. Raman Lidar and millimeter wave cloud radar were used by Ruei-Fong Lin to examine the diffusional growth of observed cirrus. Aerosol amount is an important parameter for studying the effects of aerosol on cloud properties. In a study using a 3-D radiative transfer, Guoyong Wen found that the aerosol optical depth is difficult to retrieve in clear regions of fair-weather cumulus because clouds enhance the reflected sunlight substantially.

Another major research element in the Cloud Modeling and Analysis Research Group is to study clouds, precipitation, and aerosols via remote sensing. Progress continues to be made in developing methods to better estimate precipitation using satellite, airborne, and ground-based radar and radiometers. Mircea Grecu applied an algorithm which combined radar and radiometer to snow estimation using the observations from cloud radar and radiometers. Chung-Lin Shie produced a series of vertical heating

profiles for shallow clouds using cloud models, which will later be added into the “look up” table of current algorithm, attempting to improve the low-level latent heating retrieval from satellite data. NASA’s high-altitude ER-2 Doppler radar (EDOP) and Cloud Radar System (CRS) continue to be used for field experiments and developing new methods for estimating cloud and precipitations. Last year, the radars were deployed in supporting CloudSat/Calipso validation experiment and many other supporting activities such as preparing radar and software, data processing and analysis were provided by Lihua Li and Larry Belcher. Lin Tian used the observations from X-band and W-band radar to estimate drop size distribution, vertical motion and attenuation in stratiform rain. Lihua Li is developing a new X-band radar flying on an Unmanned Aerial Vehicle (UAV) and a dual-wavelength and dual-beam conical scanning radar to be used to observe convective storm and hurricanes. Several efforts are underway to support the ground validation of TRMM/GPM including evaluating the performance of the NASA polarimetric ground-based radar by Jian-Jian Wang and validation of satellite radar measurements with ground radar measurements by Liang Liao. Liao, along with Lin Tian, is also studying various topics associated with microwave radar application for the retrieval of microphysical properties of hydrometeors. Kwo-Sen Kuo is investigating the diurnal variations of rainfall using eight years of TRMM rain rate data products. This has been conducted aiming to further our understanding of the global water cycle. Lidar is used to retrieve aerosol microphysical parameters. Instrument management and technical oversight was provided to the Micro-Pulse Lidar World-wide Network (MPLNET) for long term observations of aerosol and cloud properties around the globe by Timothy Berkoff and Larry Belcher.

This brief summary and the detailed reports that follow demonstrate that the GEST Cloud Modeling and Analysis Research Group is active in a variety of relevant research topics of interest to the global climate change and hydrological science communities. This research has been well advertised through journal publications, conference participation, and seminar presentations.

Lin Tian and Chung-Lin Shie

Task 912-19-131: **Processing and Analysis of Radar and Ancillary Data in Support of NASA's High-Altitude ER-2 Doppler Radar (EDOP) and Cloud Radar System (CRS)**

GEST Investigator: Larry R. Belcher

Collaborators: Gerald Heymsfield (PI, GSFC, Code 613.1), Lihua Li, Lin Tian

Task 912-52-202: **Processing and Analysis of Lidar Data in Support of NASA's Micro-pulse Lidar Network (MPLNET)**

GEST Investigator: Larry R. Belcher

Collaborators: Ellsworth J. Welton (PI, GSFC, Code 613.1), Timothy Berkoff (Instrument Manager), Sebastian Stewart (SSAI)

Abstract

Support of the NASA ER-2 Doppler radar (EDOP), Cloud Radar System (CRS), and Micro-pulse Lidar Network (MPLNET) was conducted this reporting period. EDOP and CRS were deployed to support the CloudSat/Calipso validation Experiment (CCVEX). This deployment required preparation and maintenance of networking and computing equipment, processing, quality control, and archival of the radar data collected during this field experiment. Travel to Cape Verde was required during this period to support the NASA African Multidisciplinary Analysis (NAMMA) field program. Lastly, a complete overhaul of the NASA GSFC Micro-pulse Lidar Network (MPLNET) computing resources has prompted construction and development of new IT resources and software development.

Description of Research

The high-altitude EDOP and CRS are able to observe clouds from a perspective similar to that of weather-observing satellites. This quality has been exploited numerous times in the form of NASA field campaigns designed to validate various satellite platforms. The deployment of EDOP and CRS requires support prior to, during, and following each field campaign. The pre-campaign efforts involve preparing the radars and hardware, including computing equipment. During a field deployment, the focus shifts to collecting data and of course data processing follows each deployment.

MPLNET is a network of Lidar systems that provide long-term observations of aerosols and clouds, comprising a network of instruments located around the globe. The data from these instruments is processed in near real-time utilizing computing and software resources located at NASA GSFC. Development of processing and analysis tools is a continued need for this project as well as ongoing maintenance of existing instruments and IT resources.

Accomplishments during the Reporting Period

The EDOP and CRS radars were deployed to the CloudSat/Calipso Validation Experiment (CCVEX) mission in Georgia in July 2006. This deployment required the development and maintenance of networking and computing equipment for use during the field campaign. Processing, quality control, and archival of the radar data were conducted following the field campaign to enable analysis of cloud systems as viewed by airborne radar. To support planned EDOP and CRS deployments in 2007, a new computer with associated software installation and networking setup has been constructed. Ongoing research investigating statistical results (*e.g.*, radar echo heights, echo intensities, etc.) from EDOP/CRS data collected during the Tropical Cloud Systems and Processes (TCSP) field program was also conducted during the reporting period. Participation in the NAMMA field program in August 2006 in Sal, Cape Verde also occurred during the reporting period. This deployment included numerous flights aboard the NASA DC-8 serving as dropsonde instrument scientist.

The MPLNET project is currently utilizing computing resources that will soon be "out-of-date" and no longer supported (*e.g.*, discontinued support of the SGI computers). To address this issue, new computing resources have been purchased and are currently being built (*e.g.*, operating system install). The scope of this effort includes a complete re-design of the MPLNET web page, data acquisition, and data processing software. While some of the existing software and tools can be employed, development of new processing software is ongoing. Additionally, systems administration tasks are performed regularly for both the EDOP/CRS and MPLNET tasks.

Objectives for the Coming Year

Due to changes in funding and research interests, the GEST investigator has recently become a full-time member of MPLNET group and will no longer be working with the EDOP/CRS platforms. However, support of field deployments, data processing, and IT support will continue as required. Development of new data acquisition and processing software and the re-design of the MPLNET web site will be the primary focus of this task in the upcoming year.

Task 912-52-202: **The Micro-Pulse Lidar World-wide Observational Network (MPLNET)**

GEST Investigator: Timothy Berkoff

Collaborators: Sandra Valencia (SSAI), Ellsworth Welton (PI, GSFC, Code 613.1), James Campbell (SSAI), James Spinhirne (GSFC, Code 613.1), Si-Chee Tsay (GSFC, Code 613.2), Larry Belcher, Sebastian Stewart (SSAI)

Abstract

During this reporting period instrumentation management and technical oversight was provided to ensure the successful deployment and operational performance of Lidar systems in NASA GSFC's Micro-Pulse Lidar Network (MPLNET). This included continued efforts to support commercial activities specifically tailored for MPLNET. In addition to continuing support of existing MPLNET sites, instrument coordination and implementation of Lidar deployments for new sites and field campaigns.

Description of Research

MPLNET is a network of Lidars systems (MPLs) that provide long term observations of aerosol and cloud properties at multiple sites around the globe. Each site in the network uses an elastic-scattering Lidar co-located with a sunphotometer to provide data products of aerosol optical and physical properties. Expansion of the network is based on partnering with research groups interested in joining MPLNET. Reliable and accurate instrumentation performance in the field is essential to assure the generation of high-quality data from remote sites. To promote the success of MPLNET, technology and calibration issues are investigated in relation to network operational activities. Instrumentation oversight is provided for implementation of systems in the field, laboratory calibration/validation facilities and equipment, as well as commercialization efforts.

Accomplishments during the Reporting Period

General management of MPLNET instrumentation matters were carried out throughout the reporting period to enable MPLNET participation in field campaigns and the continued operation of multiple sites around the globe. Sites included in this effort were: NASA Langley's CERES Ocean Validation Experiment (COVE) platform in the Atlantic ocean, Korea Global Atmospheric Watch Observatory's Anmyeon site in Korea, Goddard Space Flight Center's Greenbelt site in Maryland, Seoul National University's Gosan station in Korea, Spain Institute of Aerospace Technology's Tenerife station in Canary Islands, National Central University's site in Taiwan, Naval Research Laboratory's Monterey site in California, National Institute of Polar Research (Japan) operating a Lidar at Syowa station in Antarctica and Ny-Alesund station in Norway,

NOAA's South Pole Atmospheric Research Observatory in the Antarctic and Trinidad Head Observatory in California.

MPLNET instrumentation and calibration support was also provided for two successful field campaigns: the NASA African Monsoon Multidisciplinary Analyses (NAMMA) mission, where an MPL was deployed with the Surface Atmospheric Radiative Transfer (SMART) platform to the Cape Verde islands of the coast of Africa, and the Biomass Aerosol and Smoke Experiment (BASE-Asia). Additionally, technical information and assistance was also provided for several pending new MPLNET partner institutions at five different universities: University of New Hampshire, University of Illinois, University of Miami, Ben-Gurion University(Israel), and University of Alabama. The integration of these new sites into MPLNET is expected in the next reporting period.

Guidance and training on instrumentation and calibration issues were provided to both in-house personnel at NASA GSFC as well as the NASA MPL licensed vendor Sigma Space. This is the second full year that a NASA MPL licensed vendor (Sigma Space) has been selling the new "Type 4B" version of the instrument, that enables research groups to purchase a Lidar fully compatible with MPLNET operational requirements. More than 15 of these systems have been sold to research groups around the globe. Systems purchased by MPLNET network partners were evaluated for alignment quality, performance, and calibration prior to deployment. Technical feedback was provided to correct deficiencies observed in commercial units and improve instrument operational performance. During this time frame, the first MPL utilizing an athermal telescope was deployed and will undergo field testing later in 2007. This improvement is expected to extend the allowed thermal operating range of the instrument. Results from this deployment will help validate the performance of the Lidar, and allow improvement in data quality and reduce operational constraints for future MPLNET sites.

Improvement in the calibration of nighttime data was investigated. MPLNET data product retrievals of aerosol extinction and backscatter are dependent on co-located measurements of columnar aerosol optical depth (AOD), available from NASA's AERONET project. However, AERONET relies on the sun as a radiation source to obtain column atmospheric transmission measurements. Without AERONET information, MPLNET retrievals have to rely on interpolation methods to obtain nighttime Lidar calibrations needed to generate aerosol data products. In order to improve MPLNET calibration and data product capabilities, the use of the moon as a radiation source to obtain columnar aerosol optical depth measurements was investigated. Preliminary AOD measurements were obtained to quantify the potential use of AEROENET sunphotometers for this purpose and its benefit to the nighttime Lidar calibrations. The results are expected to lead to additional measurement capabilities for both the MPLNET and AERONET projects.

Objectives for the Coming Year

The main objectives for the upcoming year is to enable further expansion of MPLNET by continuing to provide management of instrumentation matters for the network, and investigation of key technology and calibration improvements. This would include qualification of instrument thermal improvements for MPLNET operations, ground-base to satellite comparison studies, and investigation of new nighttime aerosol calibration techniques.

Task 912-54-204: **Development and Applications of the Goddard Multi-Scale Modeling Framework**

GEST Investigator: Jiun-Dar Chern

Collaborators: Wei-Kuo Tao (PI, GSFC, Code 613.1), Christa Peters-Lidard (GSFC, Code 614.3), Bo-Wen Shen (ESSIC), Xin Lin

Abstract

The foremost challenge in parameterizing convective clouds and cloud systems in large-scale models is the proper representation of the many coupled, dynamical and physical processes that interact over a wide range of scales, from microphysical to synoptic and planetary. This makes the representation of convective clouds and cloud systems one of the most difficult scientific problems in earth system modeling. To break the cloud parameterization deadlock in global models, a new modeling approach, the Multi-scale Modeling Framework (MMF) or superparameterization, was developed. The ideal is to use cloud-resolving model (CRM) in each column of a global model to explicitly represent small-scale and mesoscale cloud processes and interactions among them. The framework is very promising but also very expensive computationally. The PI has successfully developed a Goddard MMF based on the finite-volume General Circulation Model (fvGCM) and the Goddard Cumulus Ensemble Model (GCE). Many yearly control experiments and monthly sensitivity studies have been carried out to explore the capabilities and limitations of the system. The MMF has a great potential to reduce some of the common systematic biases found in climate models. Recently the PI has improved the cloud microphysics, fully compressible dynamics, and radiative top boundary condition in the embedded 2D GCE. New sensitivity studies have been performing to evaluate the global and long-term impacts of these improvements. The research team successfully integrated the CSU CloudSat radar simulator into Goddard MMF utility and implemented MPI parallelism in the simulator on NASA Columbia supercomputer. The simulator is used to bridge the model-simulated hydrometeors mixing ratios and observed radar reflectivity from CloudSat. The MMF can provide detailed cloud statistics that can be compared against observations from NASA satellite platforms such as the Tropical Rainfall Measuring Mission (TRMM), the Moderate Resolution Imaging Spectroradiometer (MODIS), Microwave Limb Sounder (MLS), and the CloudSat.

Description of Research

Current and future NASA satellite programs can provide cloud, precipitation, aerosol and other data at very fine spatial and temporal scales. Such programs will be benefited by a MMF that couples a global general circulation model (GCM) with a CRM in order to use these satellite data to improve the understanding of physical processes that are responsible for the variation in global and regional climate and hydrological systems. The use of a GCM will enable global coverage, and the use of a CRM will allow for better and more sophisticated representation of physical processes. At Goddard, a MMF based on the two-dimensional GCE and the fvGCM has been developed. The main objective are (1) to use NASA satellite data and field campaign observations for validating and improving the MMF; (2) to compare the MMF results with results from conventional GCMs and other MMFs; (3) to produce and provide multi-dimensional cloud datasets (*i.e.*, a cloud data library) to the global modeling community to help improve the representation of moist processes in climate models and to improve understanding of cloud and radiation processes. The MMF also has a great potential to substantially reduce systematic errors in forecast models and to improve long-range forecasts and climate prediction capabilities.

Accomplishments during the Reporting Period

The Goddard MMF has been developed based on the fvGCM global model and the 2D GCE cloud-resolving model. It includes the fvGCM

running at 2.5° x 2° horizontal resolution with 32 vertical layers from the surface up to 0.4 hPa and a two-dimensional GCE embedded at each fvGCM grid column using 64 x 28 grid points with 4 km horizontal resolution and cyclic lateral boundaries. Globally, there are a total of 13,104 GCEs running at the same time. The MMF has been successfully applied and its performance tested for two different climate scenarios, El Nino (1998) and La Nina (1999), using observed sea surface temperatures (SSTs). Overall the MMF is superior to fvGCM in simulating the geographical distribution of precipitation, high cloud amount, the Madden-Julian oscillation (MJO) signal, and diurnal cycle of precipitation over land and ocean.

Despite some promising preliminary results from the MMF, many yearly control experiments and monthly sensitivity simulations have been carried out to establish the baseline climate and explore possible limitations of the system. In addition, a newly revised bulk 3ICE microphysics scheme with special improvements on the ice/graupel process and saturation technique has been implemented to the MMF. The scheme removes the unrealistic presence of high-density ice (*i.e.*, graupel or hail) and excessive snow amount in the stratiform region. Preliminary results show the new microphysics improves the global mean precipitation amount. However, unbalance was found between global mean surface evaporation and precipitation amount, indicating the needs of further model testing. Recently, the team successfully implemented a fully compressible dynamics and radiative top boundary condition into the embedded 2D GCE in the MMF system. The impacts of these modifications on long-term global circulation are under investigating.

CloudSat was launched on April 28 2006 as a NASA Earth Science Pathfinder satellite mission to fly the first satellite-based millimeter-wavelength cloud radar (94 GHz) to advance our understanding of cloud abundance, distribution, structure and radiative properties. The cloud radar is able to provide profiles of cloud condensates and precipitation with a vertical resolution of 500 m. The Colorado State University (CSU) CloudSat radar simulator (QuickBeam) is used to bridge the model simulated hydrometeors mixing ratios and observed radar reflectivity from CloudSat. It is capable of simulating vertical radar reflectivity profiles at any common microwave frequency, from either the top-down or the bottom-up. The user provides information about the state of the atmosphere and the water/ice species contained therein, and the simulator produces profiles of effective radar reflectivity factor that emulate what a physical radar system would observe. The simulator has been successfully integrated into the Goddard MMF utility and MPI parallelism has been implemented in the simulator on the NASA Columbia supercomputer. The observed and simulated radar profiles are further classified into four different regimes—clear sky, cloud only, drizzle, and storm. The simulated hourly radar reflectivity profiles from one-month MMF simulations in July 2006 have been analyzed with a cumulative frequency by altitude diagrams (CFAD). The CFAD provides a convenient way of displaying the probability distribution of a large sample of reflectivity profiles. For each radar profile in storm regime, the cloud echo top height (ETH) is plotted against the precipitation ETH (*i.e.*, ETH of -30dBZ versus that of 10 dBZ). The CFADs of three cloud regimes and ETH histogram in the tropic from two-month CloudSat observations (July-August, 2006) and one-month MMF simulations are compared against each other. Preliminary comparison indicates some model deficiencies in producing shallow convection and the penetration of precipitation echo (10 dBZ) to upper troposphere (12-14 km) in tropical deep convection. The result suggests that more model testing and improvements of cloud microphysics are needed.

The MMF requires a substantial amount of computing resources, two to three orders more expensive than current climate models. Only supercomputers with thousands of processors, such as the Columbia computer at NASA/AMES, are able to achieve results in a timely fashion. The original MMF inherited the fvGCM's multi-level parallel hybrid MPI/OpenMP design for parallel computing. The fvGCM uses OpenMP in the vertical and

one-dimensional MPI horizontal domain decomposition in the latitude direction. The hybrid parallel computing design has been achieved in computational efficiency, scalability, and portability for fvGCM runs with high resolution such as 1/8°. For the low-resolution (2° x 2.5°) MMF application, however, the maximum number of processors was limited to 30 processors due to only one-dimensional MPI horizontal domain decomposition. To overcome the aforementioned limitation, a multi-scale multi-component modeling framework coupler has been developing based on a multiple programs multiple data (MPMD) parallelism. While the host fvGCM still uses an MPI-OpenMP two-level parallelism, the embedded GCEs are managed on a meta grid with a 2D MPI parallelism. Preliminary result with a prototype coupler shows very promising scalability up to 364 CPUs.

Objectives for the Coming Year

The new version of 3D MPI GCE will be implemented into Goddard MMF to replace the old 2D GCE. The PI will carry out more MMF control experiments to assess the performance of the model and compare the results with NASA satellite observations. The research team will continue the improvement of cloud microphysics and the capability of the MMF system, as well as continuing to develop a coupled fvGCM-3D MPI GCE-LIS modeling system to study the effects of land surface-atmosphere interaction on cloud and precipitation systems. The PI will work with Henry Jin at NASA/AMES and Bo-Wen Shen at UMCP/ESSIC to study the parallelization strategy and improve the performance of this system. The goal is to have MPI in both fvGCM and 3D GCE for using at least 2048 CPUs on the Columbia computer.

Task 912-21-140: **Precipitation Estimation from Satellite Active and Passive Microwave Observations**

GEST Investigator: Mircea Grecu

Collaborator: Robert F. Adler (PI, GSFC, Code 613.1)

Abstract

Precipitation is an important variable in the Earth's hydrologic cycle. In the past decade, precipitation observations with global coverage have become available from space-borne instruments. The progress in satellite precipitation estimation and the advance in precipitation assimilation techniques proved to be beneficial to the quality of global atmospheric analyses and forecasts. Past research showed that precipitation and moisture estimates derived from observations collected by the NASA Tropical Rainfall Measuring Mission (TRMM) and three U.S. Air Force Defense Meteorological Satellite Program (DMSP) satellites can be used to improve both the analyses and the short term forecasts of various atmospheric variables in the Tropics. Similarly, various studies showed positive impact of assimilating passive microwave rain estimates on hurricane forecasting. The forthcoming NASA Global Precipitation Mission (GPM), which will provide precipitation observations of TRMM's quality but at a much higher frequency, is expected to have an even larger positive impact on global analyses and forecasts. However, challenges lie in making optimal use of satellite precipitation observations in numerical weather prediction (NWP) models. The optimal utilization of precipitation observations in analysis and forecasting involves complex forward models and observation operators that need to be rigorously characterized in terms of uncertainties. Significant effort is required to achieve this optimum.

Description of Research

Currently, there are two different but related avenues to incorporate precipitation observations into NWP models. The first consists of assimilation of precipitation estimates independently derived from satellite observations, while the second consists of

assimilation of brightness temperatures. The physical retrieval of precipitation takes advantage of detailed and realistic representation of moist physical processes derived from cloud-resolving models (CRMs) and/or independent high quality observations (such as combined observations of TRMM precipitation radar profiles and radiometer brightness temperatures). The database of hydrometeor profiles and the associated brightness temperatures derived from CRM simulation and/or combined TRMM combined retrievals (Grecu and Olson, 2006) provides background information and physical relationship between the satellite observations and precipitation. In the rain estimation phase, the database can be thoroughly searched for the best match; and an efficient retrieval scheme using multi-channel or multi-instruments can be employed for an optimal retrieval solution. Rain retrievals have been used in global data assimilation to reduce errors in precipitation induced by the parameterization of unresolved scales and subgrid-scale moist processes in NWP models. However, the fact that even in conditions of a perfect model, the precipitation assimilation does not make the best use of satellite information because of errors in the precipitation estimates constitutes a limitation in this approach. This limitation does not currently prevent precipitation assimilation from being a viable alternative to brightness temperature assimilation. This is because NWP models are not perfect and their errors affect the brightness temperature assimilation to the point that it does not present any benefit relative to the precipitation assimilation. But the NWP are constantly improving and in the future the situation may change. Therefore, both direct assimilation of brightness temperatures and precipitation retrievals need to be considered in NWP and atmospheric analyses.

Accomplishments during the Reporting Period

To extend the current precipitation estimation algorithms to snow and light rain retrievals, a combined methodology applicable to cloud radar and millimeter wave radiometer observations has been developed [Grecu and Olson, 2007]. Cloud radar and millimeter wave radiometer observations are synthesized from the cloud model output. The retrieval problem is formulated as a minimization problem and addressed through an iterative Newton method based on the statistical estimation of the objective function gradient. The application of the retrieval algorithm to the synthetic data yields unbiased results provided that the snow density is correctly parameterized. However, even if the assumed snow density is in error by a factor of two, only a 15% bias of estimated snow water contents results. The application of the retrieval algorithm to actual data from the Wakasa Bay Field Experiment yields snow estimates consistent with both the cloud radar and radiometer observations. Moreover, the estimates are very similar to estimates from the same algorithm applied to combined Ku-band and millimeter wave radiometer observations. This is an indication that the attenuation correction, normally provided by radar-derived PIA estimates (but not available at Ku-band), can be effectively performed with the addition of millimeter wave radiometer observations. However, the snow estimates are somewhat sensitive to assumptions made about the snow density, with a 12.5% bias resulting from a factor of two error in the assumed snow density.

Objectives for the Coming Year

During FY 07, the work will focus on the direct assimilation of brightness temperatures into a global atmospheric model. Recently, a new paradigm, referred to as super-parameterization, emerged in climate modeling. The paradigm consists of replacing cloud-related parameterizations in general circulation models by 2D cloud resolving models. This super-parameterization proved to be significantly superior to conventional cloud parameterizations in reproducing complex atmospheric phenomena such as the Maiden-Julian Oscillation and the diurnal cycle of precipitation. From the satellite remote sensing standpoint, the super-parameterization is an exciting concept as it facilitates the direct assimilation of satellite observations into a global circulation model. In super-parameterization-based global circulation models (SPMs), the direct assimilation of satellite brightness temperature is more straightforward because the high resolution of the 2D cloud resolving models upon which the

super-parameterization is based allows for the direct simulation of satellite brightness temperatures from the global model's variables. The coarse resolution of low frequency radiometer observations can be mitigated through the techniques presented in Grecu and Olson [2006].

Task 971-21-145: **TRMM Project Science**

GEST Investigator: Guojun Gu

Collaborator: Robert F. Adler (GSFC, Code 613.1)

Abstract

Interannual-to-decadal precipitation variability is an essential part of the global hydrological (water) cycle. Precipitation and associated variability includes variations are closely related to ENSO, NAO, and volcanic eruption, and possibly longer-term change/trend, for instance, global temperature change. Exploring and correctly estimating these precipitation variations are critical to understand the possible variability/change within the entire climate system.

Description of Research

Global and large regional rainfall variations, and possible long-term changes are examined using the 27-year (1979-2005) Global Precipitation Climatology Project (GPCP) monthly dataset. The emphasis of this task is to quantify various variations resulting from ENSO, volcanic events, and possible long-term climate changes in the tropics. Linear regression methods have been applied to extract the relations between rainfall anomalies and two large-scale environmental anomaly indices in the tropics, *i.e.*, Nino3.4 and volcanic index. Statistical tests are used to examine the results, particularly the estimated long-term rainfall changes/linear trends.

Accomplishments during the Reporting Period

Global and large regional rainfall variations and possible long-term changes are examined using the 27-year (1979-2005) GPCP monthly dataset. Gu's emphasis is to discriminate among variations due to ENSO, volcanic events, and possible long-term climate changes in the tropics. Although the global linear change of precipitation in the data set is near zero during the time period, an increase in tropical rainfall is noted in the data set, with a weaker decrease over northern hemisphere middle latitudes. Focusing on the tropics (25°S-25°N), the data set indicates an upward linear change (0.06 mm day^{-1}/decade) and a downward linear change (-0.01 mm day^{-1}/decade) over tropical ocean and land, respectively. This corresponds to an about 5.5% increase (ocean) and 1% decrease (land) during the entire 27-year time period. The year 2005 has the largest annual tropical total precipitation (land plus ocean) for the GPCP record. The five highest years are (in descending order) 2005, 2004, 1998, 2003, and 2002. For tropical ocean, the five highest years are 1998, 2004, 2005, 2002, and 2003.

Techniques are applied to isolate and quantify variations due to ENSO and two major volcanic eruptions during the time period (El Chichón, March 1982; Pinatubo, June 1991) in order to examine longer time-scale changes. The ENSO events generally do not impact the tropical total rainfall, but rather induce significant anomalies with opposite signs over tropical land and ocean. The impact of the two volcanic eruptions is estimated to be about a 5% reduction in tropical rainfall over both land and ocean. A modified data set (with ENSO and volcano effects removed) retain the same approximate linear change slopes, but with reduced variances, thereby increasing statistical significance levels associated with the long-term rainfall changes in the tropics. However, although care has been taken to ensure that this data set is as homogeneous as possible, firm establishment of the existence of the discussed changes as long-term trends may require continued analysis of the input data sets and a lengthening of the observation period.

Objectives for the Coming Year

The GEST investigator's first objective is to examine regional, long-term precipitation changes and related physical mechanisms, and to further explore their possible association with global surface temperature changes. Secondly, he plans to investigate the coupled processes in the tropical Atlantic basin and West African region on the subseasonal time scales, and assess the possible impact of the MJO on this region, by means of various satellite products.

Task 912-54-203: **Numerical Simulations of Extratropical Cyclones with Applications to TRMM and GPM**

GEST Investigator: Mei Han

Collaborators: Scott Braun (PI, GSFC, Code 613.1), Jian-Wen Bao (NOAA/ETL), William Olson (JCET), P. Ola. G. Persson (CIRES, NOAA/ETL)

Abstract

As the future Global Precipitation Measurement (GPM) mission leads to the increasing interest on precipitation systems in higher latitudes, TRMM data in the middle latitudes were applied to analyze the distribution of precipitation associated with extratropical cyclones. TRMM observed an intense NCFR over the eastern Pacific Ocean offshore of California. The TMI brightness temperature suggests that, compared to the southern end of the rainband, more precipitation ice was present in the northern portion of the NCFR. A high-resolution numerical simulation with MM5 showed that a larger amount of graupel was present in that region. The model diagnosis suggests that the combination of an advancing upper-level front and a surface cold front played the key role in determining the structure. The comparison between the observed and simulated microwave brightness temperature, radar reflectivity, and precipitation hydrometeors has been conducted. The study implies that the ice content is over-predicted in the model simulation. Discrepancies between the observed and simulated rainwater are also revealed.

Description of Research

The GPM mission will lead to an increased focus on midlatitude weather system so that improving rain rate retrievals at higher latitudes will become important. Although designed to monitor and study precipitation throughout the tropics, TRMM has coverage in the higher latitudes (up to ~38°N and ~38°S). TRMM PR and TMI observations are used to examine mid-latitude frontal rainbands associated with extratropical cyclones in the eastern Pacific Ocean. Numerical simulation using MM5 was conducted, and the dynamics and thermodynamics of frontal rainbands have been examined. The relationships between the simulated precipitation and microwave brightness temperature, and its consistency with the observations/retrievals have also been explored. Such comparison will allow for evaluation, validation and improvement of the model cloud microphysical parameterization.

Accomplishments during the Reporting Period

During the reporting year, the research team continued to study the dynamics and microphysics of a Narrow Cold Frontal Rainband (NCFR) occurring in the eastern Pacific Ocean on Feb 19, 2001 during NOAA Pacific Landfalling Jets experiments (PACJET). The NCFR was observed by 3 overpasses of the Topical Rainfall Measuring Mission (TRMM) satellite. TRMM precipitation radar and microwave imager revealed a high concentration of precipitation ice at the middle to northern portion of the NCFR, while the precipitation in the southern portion of the front consisted mainly of rainwater. A simulation with the fifth-generation Pennsylvania State University-National Center for Atmospheric Research (PSU-NCAR) Mesoscale Model (MM5) has been conducted. The high-resolution MM5 simulation replicated the distribution of precipitation that well agrees with TRMM observation. The simulation shows that both low-level front and upper-level front played roles in determining the structure of the precipitation hydrometeors. A high-PV air

intrusion led by the upper-level front contributed quasigeostrophic forcing to the upper levels at the middle to northern portion of the low-level front, where the rising motion was intensified. It therefore enhanced the condensation and produced more ice particles in that region. In contrast, only low-level front was present in the southern portion of NCFR. The updraft was shallower and almost no precipitation ice was produced. These findings will be submitted to a peer-reviewed journal shortly.

The MM5 simulation has been used as input data to a cloud-radiative model to calculate the simulated microwave brightness temperature. The researcher compared the observed and simulated microwave brightness temperature, the polarization corrected temperature (PCT), normalized polarization (NP), and scattering index (SI) at the low and high frequency channels. Han also investigated the observed and simulated radar reflectivity, the retrieved and simulated precipitation hydrometeors, and their relationships with the microwave brightness temperatures. It was found that the model generally produces more precipitation ice content than the TRMM retrievals. Discrepancies between the retrieved and simulated rainwater content has also been found. Preliminary research reveals differences in the relationship of radar reflectivity and brightness temperature for rain in different portions of the frontal rainband, which might be partially attributed to the beam-filling problem of TMI. These findings will be useful in evaluate the performance of the microphysical parameterization schemes and explore the possible improvements.

Objectives for the Coming Year

The comparison between observed and simulated microwave brightness temperature and the precipitation hydrometeors will continue. The precipitation ice categories, graupel and snow, will be considered in determine the relationship between the hydrometeors and brightness temperatures. The 3 overpasses of TMI and PR observations as a whole will be used to compare with the model simulations. The research team will conduct sensitivity simulations with MM5 model to investigate how the different microphysics schemes influence the relationships among the precipitation hydrometeors, the radar reflectivity, and the microwave brightness temperatures. They also plan to use the Weather Research and Forecasting (WRF) model to simulate one or two additional winter cyclones. The simulations will be compared to available satellite remote-sensing data (TRMM, Aqua) in order to identify the model errors and examine the structure of precipitation.

Task 613-65-221: **Flood and Landslide Early Warning for Disaster Management**

GEST Investigator: Yang Hong

Collaborators: Robert F. Adler (PI, GSFC, Code 613.1), George Huffman (SSAI)

Abstract

The purpose of this task is to provide flood and landslide Decision Support Tools (DST) based on NASA-based data sets of precipitation and land surface characteristics, and to rapidly evaluate the potential benefit of the prototype early warning system to support the element of the NASA Applied Sciences Program: Disaster Management, Response, Preparedness and Mitigation Activities around the globe.

Description of Research

Floods and landslides associated with heavy rainfall account for the largest number of natural disasters and affect more people than any other types of natural disasters. Prevention of these disasters is very difficult and expensive since the required data collection and transmission is not yet practical in most developing countries that need it the most but lack the resources and techniques to cope with. Drawing upon recent advances in remote sensing techniques that detect land surface characteristics and monitor the real-time rainfall, this project is to

investigate the potential for data sets future planned GPM NASA science missions, combined with satellite-based land surface information and hydrological models to provide critical information as input to expand the geographical coverage of the DST's from national and regional to global scales and to contribute to meeting operational requirements in the area of disaster management.

Accomplishments during the Reporting Period

Requirements for hydrological hazards (including flood and landslide) DST have been identified and evaluated as part of the efforts in developing an experimental prediction system for flood and landslides. The result indicates that both the precipitation information and the land surface data sets are of value for input into the DST and the improved new NASA (and other) data will allow these DST to be successful. Significant progress has been made in this project preparing for movement into the design and implementation stages. Resulting publications include more than ten journal papers and proceedings.

Objectives for the Coming Year

Verifying and validating the DST will take place and benchmark activities will be initiated by the GEST investigator. The researcher's objective in the coming year is to develop cost-effective solutions to rapidly prototyping effective early warning systems in representative test-beds and then tailoring the transferable technology to the regions that need them most. This will be accomplished as the final design for the modifications to the required software developed and implemented. A global flood and landslide prediction system using NASA data input for improvement appears to be a very realizable goal.

Task 912-24-147: **Global Precipitation Mission Physical Radiative Transfer Model**

GEST Investigator: Kwo-Sen Kuo

Collaborator: Steve Bilanow (SAIC), Hezekiah Carty (Univ. of Maryland), Amita Mehta (JCET), Eric A. Smith (PI, GSFC, Code 613.1), Song Yang (George Mason Univ.)

Abstract

The Global Precipitation Measurement (GPM) mission will consist of a core satellite and several constellation satellites. The core satellite will be equipped with a dual-wavelength rain radar and a microwave radiometer while the constellation satellites will have only radiometers on-board. This is an ambitious mission aimed to further our understanding of the global water cycle.

In this reporting period, in association with his colleagues, Kuo developed a hybrid data product that consists of nearly coincidental CloudSat Cloud Profiling Radar (CPR) and TRMM Precipitation Radar (PR) data at the same geolocations. He has participated in the investigation of the diurnal variations of rainfall using eight (8) years of TRMM rain rate data products. He has also been following up with further investigation into his previous published research on the principal parameters for rainfall retrieval using a space-borne radar.

Description of Research

The role that precipitation (mostly drizzles) plays in the life cycle of marine stratocumulus (Sc) is not yet well understood. This lack of understanding is mainly due to the absence of long-term and extensive observations. Although the Precipitation Radar (PR) onboard TRMM is capable of observing precipitation associated with embedded convection within marine Sc, it is not sensitive enough to accurately detect much of the light rain. In contrast, the W-band Cloud Profiling Radar (CPR) onboard CloudSat in a geosynchronous orbit is sensitive to such light rain but only observes the same geolocation at two constant local times of the day. By combining long-term and concurrent precipitation measurements of both CloudSat CPR and TRMM PR, the GEST investigator and colleagues hope to paint a more complete picture of Sc precipitation, including its diurnal variations.

Kuo participated the detailed investigation of the horizontal variation of precipitation diurnal cycles at various spatiotemporal scales using eight years of TRMM rain rate data products. The investigation is aimed to better understand the assorted mechanisms controlling the global distribution of diurnal rainfall variability. Results not only demonstrated the prominence of the late-evening to early-morning precipitation maxima over oceans and the mid- to late-afternoon maxima over continents, but also revealed a widespread distribution of secondary maxima occurring over both oceans and continents, maxima which generally mirror their counterpart regime's behavior.

Accomplishments during the Reporting Period

The first step to combine CloudSat and TRMM observations is to find CloudSat and TRMM orbit intersects, for which a simplified orbit model is used. This model, although not highly accurate, is fast and performs satisfactorily for this purpose. The orbit model lists the latitude, longitude, and corresponding CloudSat and TRMM orbit numbers for each predicted intersect. Facilitated with this knowledge, the corresponding pairs of orbit granules for CloudSat CPR reflectivity and TRMM PR reflectivity as well as TRMM PR rain rate data products are ftp'ed and read. Their coincidences within a 100-minute (±50 minutes) window are extracted to form a new data product. The confirmed intersect geolocations and times are then used as feedback to improve the accuracy of the simple orbit model. The research team implemented the algorithm for automating the entire process, *i.e.*, predicting the orbit intersects, downloading the relevant CloudSat and TRMM data, and processing and combining the data to produce the intersect data product. This data product, once checked out and approved, will be made available through CloudSat data ordering system.

The analysis of eight (8) years of TRMM rain rate products shows the prominence of the late-evening to early-morning precipitation maxima over oceans and the mid- to late-afternoon maxima over continents. Moreover, it reveals a prevalence of secondary maxima occurring over both oceans and continents. The time-of-day of these maxima generally mirror that of the primary maxima of their counterparts. That is, many ocean regions exhibit clear-cut secondary afternoon precipitation maxima while many continental areas exhibit just as evident secondary morning maxima. This investigation represents the first comprehensive study of these secondary maxima and their widespread nature using a semi-global precipitation dataset. The characteristics of the secondary maxima are thoroughly mapped and described on a grid from latitude of 35°S to 35°N. A Fourier harmonic decomposition scheme was also employed to examine detailed amplitude and phase properties of the primary and secondary maxima—as well as tertiary and quaternary modes. Accordingly, the advantages, ambiguities, and pitfalls resulting from using harmonic analysis are also examined.

Kuo has also been following up with his previous study in identifying principal parameters for radar rainfall retrieval [Kuo *et al.*, 2004]. He is investigating drop size distributions (DSD) derived from disdrometer measurements, unlike the previous study where mathematical formulae are used to describe the DSDs. He found that in more than one way, when combined with liquid water content, effective radius and effective variance demonstrate clear advantage over the customary medium mass diameter and shape parameter as the choice parameters for radar rain rate retrieval.

The results of the pulse averaging study from last year have been drafted into a manuscript which was submitted to the *Journal of Atmospheric and Oceanic Technology* and accepted conditionally. The manuscript is currently under revision.

Objectives for the Coming Year

Kuo plans to complete automation of the CloudSat/TRMM intersect data product production and deliver the datasets to CloudSat Data Ordering System for distribution. CloudSat CPR and TRMM PR intersect data over areas with persistent stratocumulus coverage will be analyzed. Specifically the probability density functions of retrieved rain rates below 3 mm-hr^{-1}

will be inter-compared between the two instruments.

He will also continue the investigation into principal parameters for radar rainfall retrieval and publish the findings. The usefulness of environment atmospheric state variables in constraining this classical under-determined remote sensing problem will be looked into. These state variables include, but not limited to, parameters such as temperature, wind components, vorticity, etc., which may be obtained from forecast model analysis.

Task 912-19-131: **Radar Development, Field Observation and Dada Analysis for Atmospheric Research**

GEST Investigator: Lihua Li

Collaborators: Gerald Heymsfield (PI, GSFC, Code 613.1), Larry Belcher, Lin Tian

Abstract

Research efforts by the GEST investigator have contributed to the following areas: 1) new instrument development including the NASA GSFC funded X-band UAV Radar (URAD) and the NASA Instrument Incubator Program (IIP) funded High-altitude Imaging Wind and Rain Airborne Profiler (HIWRAP); 2) NASA GSFC Cloud Radar System (CRS) field deployment in Warner Robins air force base , Georgia during the summer of 2006 in support of the NASA CALIPSO and CloudSat Validation Experiment (CCVEX) mission; 3) Radar data analysis for cloud and precipitation property retrieval; 4) Supervising summer students, engineers (GSFC Code 555), and a technician to fulfill instrument development or scientific research tasks.

Description of Research

Microwave and millimeter Doppler radars have proven their effectivness in measuring the structure of cloud and tropical storm systems, as well as tracking the position and intensity of these weather related events. The development of new technologies enables the production of more sophisticated instruments to better serve the demands of research. One such area is the study of tropospheric wind, which is critical to understanding the genesis and processes of tropical storms. The goals of the development of URAD and HIWRAP are to obtain fine resolution reflectivity and wind field measurements from tropical weather systems and gain experience for spaceborne sensor development. In 2006, NASA successfully launched CloudSat and CALIPSO satellites. CloudSat carries a 94 GHz Cloud Profiling Radar (CPR), which enables scientists to assess cloud coverage and cloud microphysics properties in global scale. Post launch validation is essential to ensure the spaceborne radar calibration and data quality.

Accomplishments during the Reporting Period

In new radar development, this task effort has contributed to the development of the UAV radar (URAD), which is a low-cost, miniaturized, light-weight, X-band (9.3 GHz) for flying on a UAV. During the Atlantic hurricane season, frequent waves are generated off the African continent of which approximately 10% develop into hurricanes that eventually may threaten the coastal U.S. Key measurements as to whether or not a wave develops into a tropical storm are the ocean surface winds and sea surface temperatures. Current satellite precipitation and wind sensors (TRMM, QuickScat, AMSR, etc.) have resolutions that are too large and revisit times that are too infrequent to study this problem. Aircraft sensors with higher spatial resolutions and frequent sampling are desired. Unfortunately, tropical storm genesis frequently occurs in the 5000 km region between the outer Caribbean Islands and Africa. The Global Hawk is the only current UAV and aircraft that is capable of flying in this region for an extended period (24-48 hours) and with a large payload (2000 pounds). Instruments for this promising UAV are required and it will be necessary to miniaturize and reduce costs of current aircraft radars and radiometers. Currently, the radar

antenna drive has been fabricated and the radar transceiver is near completion. A pressure sealed enclosure is under development for the radar RF front end. Electronic boards, such as timing control and house keeping units, have been built.

The NASA IIP project HIWRAP is also designed for tropical storm research, but HIWRAP is a more sophisticated conical scanning Doppler radar system. The scientific goal of HIWRAP is to obtain the 3D wind field from tropical storms and 2D surface wind by measuring the Doppler velocity, as well as storm intensity by measuring radar reflectivity. It will take advantage of a cutting edge solid state power transmitter, using advanced pulse compression technique and low power consumption Field Programmable Gate Array (FPGA) digital receiver to reduce the size, weight and power consumption to boost up the Technique Readiness Level (TRL) in the subsystem and system level and serve as prototype instrument for possible future space operation. HIWRAP operates at Ku- and Ka-band frequencies (near NASA GPM radar band) and transmits and receives four beams at two different incident angles simultaneously. The development of HIWRAP poses a number of technique challenges including design and fabrication of a compact, dual-band, dual looking angle scanning antenna; a compact, low power consumption multi-frequency radar transceiver for high altitude operation; a high altitude, power efficient real time digital receiver and processor. To this end, the radar transceiver design and intensive simulation using RF design software have been completed. Component selection and procurement are under the way. Dual frequency and dual beam antenna design has been finished. The antenna feed and reflector are under fabrication.

The successful launch of CloudSat Cloud Profiling Radar (CPR) enables scientists to assess cloud coverage and cloud microphysics properties on a global scale. The CALIPSO & CloudSat Validation EXperiment (CCVEX) provides the first opportunity for thorough validation of NASA A-train satellite sensors including CloudSat and CALIPSO. There are two goals for CCVEX: establish sensitivity and calibration for the CloudSat radar and CALIPSO Lidar, and the initial microphysical validation of the A-train algorithm simulation. The NASA GSFC CRS is a 94 GHz Doppler radar, which operates at the same frequency as the CloudSat CPR. Flying CRS on a high altitude aircraft enables the researchers to simulate the CloudSat radar of field and provide independent validation for the spaceborne radar. During CCVEX, CRS was deployed on a NASA ER-2 along with NASA GSFC Cloud Physics Lidar (CPL) and NASA Ames MODIS Airborne Simulator (MAS). A total of 12 flights were conducted under CloudSat/CALIPSO satellite overpasses between July 24 and August 14, 2006, observing a variety of thin and thick cirrus, mid-level clouds, precipitating clouds as well as ocean surface returns. Post CCVEX analysis on CRS measurement from clouds and ocean surface is under the way. The ocean surface has been used as a calibration reference for both CRS and CPR. Preliminary results from inter-comparison show good agreement between CRS and CloudSat CPR.

On a final note, Lihua Li received an Outstanding Scientific Support Award from the Mesoscale Atmospheric Processes Branch, NASA GSFC, in January, 2007.

Objectives for the Coming Year

The objectives of the coming year include: 1) finish the development of the URAD radar transceiver and digital receiver/processor board, carry out URAD system test on the rooftop; 2) Development of HIWRAP transceiver, including components procurement, test and integration; development radar mechanical structure and aircraft interface; 3) CRS and EDOP future field deployment in support DOE ARM CLASIC and NASA field observation program, Tropical Composition, Cloud and Climate Coupling (TC4); and 4) CRS data analysis in support of the CloudSat validation and inter-comparison using CCVEX data.

Task 912-29-152: **Aerosol-Cloud-Precipitation Interactions Through Modeling Studies**

GEST Investigator: Xiaowen Li

Collaborator: Wei-Kuo Tao (PI, GSFC, Code 613.1)

Abstract

The researcher is using a cloud-resolving model, the Goddard Cumulus Ensemble (GCE) model with an explicit bin micophysical scheme, and applying it in two fields: 1) to study the impact of increasing aerosol concentrations on cloud structures, their radiative properties and surface precipitation (aerosol indirect effects); 2) to study the microphysics in snow systems in support of the snowfall retrieval in GPM. For the first study field, continuing analyses and simulations have revealed the complexity and different mechanisms that produced different model sensitivities, sometimes in opposite directions, at such diverse locations as tropical western pacific, Japan Sea, the great plain in the US, Arctic coast, and in large polluted cities such as Houston. Simulations of snowfall events were new tasks that have been undertaken during the past year. Preliminary simulations have successfully reproduced these cold systems. Microwave radiative transfer simulations using GCE model output reveal the role of supercooled water on high frequency channels proposed in GPM mission. These simulations are potentially useful in snow retrievals from the space.

Description of Research

Aerosols pose the biggest uncertainty to the future climate according to ICCP reports, due to the complexity of both their chemical components and physical characteristics, and their short life spans in the atmosphere. Quantification of the direct effect of anthropogenic aerosols, *i.e.*, the radiative forcing of the aerosol itself, has achieved much progress using global circulation models. However, the indirect effect of aerosols, *i.e.*, changes of cloud life span and precipitation strength by increasing anthropogenic aerosols, is much harder to quantify, both by observation and by simulation. The investigator's approach to this problem is to use a cloud-resolving model with bin spectral microphysical scheme to understand the physics of the indirect effects. In the meantime, the detailed particle size distribution information simulated in such a model is valuable for space-based remote sensing because all cloud, ice and surface precipitation retrieval algorithms require some levels of assumptions on the particle size distributions that are based mainly on sporadic in situ observations. The well-calibrated GCE model could provide size distribution information over large spatial and temporal span and is much cheaper than in situ measurements.

Accomplishments during the Reporting Period

The investigator has been continuing the testing and improving of GCE bin spectral microphysical model during the 06-07 academic year. A new cloud drop mapping method which adds the conservation of the 6th moment of the distribution in addition to the previous 1st and 2nd moment conservation, is implemented in the spectral bin scheme. This new method reduces the artificial diffusion of drop growth in the previous method. It also reduces the simulated radar reflectivity factor in the convective region. As part of the effort of building a unified cloud-resolving model with various physical packages, the 2D bin spectral code is streamlined and restructured to accommodate different microphysical packages. In collaboration with Colorado State University, the RAMS microphysical package has also been added to the 2D GCE model. The unified codes are currently being tested using SCSMEX case and will be incorporated into the 3D MPI version of the GCE code.

Two new cases have been successfully simulated during the past year. One is a snow system during the 2001 WMO-01 Experiment in Japan Sea. The other one is an Arctic snow case during the ARM M-PACE period in 2004. In the Japan Sea case, the GCE data are used as input to a microwave radiative transfer model to simulate the brightness temperature at proposed GMI frequencies. The model synthesized

brightness temperature reveals that water drops mixed in the snow can reduce the snow signal near the water vapor channel significantly. At 166 GHz, it may totally block the snow signal. Simulated brightness temperature enhancements agree well with the airplane measurement conducted in Wakasa Bay Experiment for a similar snow system. Further quantitative model and observation comparison is currently underway and will be presented at the next PMM conference. The bin spectral model is also modified to use the observed aerosol size spectrum and composition during the M-PACE period. Preliminary results show good agreement in cloud structure and surface snowfall amount between the 3D bulk, 2D bin simulation and observations. This case is presented in the 17th ARM Science Team Meeting.

Continuing studies of the aerosol-cloud-precipitation interactions through two case simulations reveal different mechanisms for different precipitation systems. In a continental case, smaller cloud drops in the dirty environment resulted in a wider stratiform rain region and suppression of the surface rainfall. For a tropical maritime case, enhanced cloud condensation in the dirty environment actually increases the surface rainfall. A research paper is in preparation for this study.

Objectives for the Coming Year

The spectral bin microphysical scheme, as well as RAMS schemes, will be implemented into 3D MPI version of the GCE model to allow for faster and more realistic cloud system studies. On the study of aerosol indirect effect, major effort will be on using observed aerosol spectra, compositions, and vertical profiles for future case studies. The investigator is also planning on adding aerosol source terms and chemistry in the cloud model to simulate the two-way interactions of the aerosol and clouds. Searching of observational evidences that support/contrast the simulated aerosol-cloud-rain interaction mechanisms will also be carried out. On the cloud retrieval study, the particle size distribution simulated by the GCE model will be compared with in situ observations for validations. This is the first step toward the model contribution to the space-based cloud retrievals.

Task 975-32-159: **Application of Air/Space-Borne Radar to Atmospheric Remote Sensing**

GEST Investigator: Liang Liao

Collaborator: Robert Meneghini (GSFC, Code 614.6)

Abstract

The investigator conducts research on a variety of topics associated with microwave radar applications for the retrieval of microphysical properties of hydrometeors. These include the simulations of air/space-borne radar signatures in snow, mixed-phased hydrometeors and rain and development of radar algorithms in deriving the characteristic parameters of particle size distribution. An assessment of uncertainties or errors of the radar algorithms is carried out by use of the radar measurements during field campaigns in which a more complete set of data are available. While the focus is on the dual-wavelength radar techniques for the TRMM and GPM radar in estimating snow and rainfall rates, the researchers also exploit the methods that combine with the measurements of polarimetric and dual-Doppler radars. To validate the estimates from radar and other satellite sensors, a technique is developed for an accurate registration of multi-sensor data taken at different platforms (air/space- and ground-based measurements).

Description of Research

Simulations of dual-wavelength radar profiles in precipitating hydrometeors are essential to improve accuracy of space-borne radar in inferring microphysical properties of hydrometeors. Validation of radar measurements and its algorithms for estimates of rain rate is also important to ensure the success of radar in mapping precipitation globally, such as TRMM PR and GPM DPR. This is usually achieved by employing the data taken from the instruments

mounted on different platforms and comparing their common products. In addition, some of fundamental studies are useful to understand radar scattering and propagation effects, which include computations of scattering fields from non-spherical and non-homogeneous particles, and effective dielectric constant of mixed-phase particles.

Accomplishments during the Reporting Period

The TRMM Precipitation Radar (PR), space-borne radar operating at a frequency of 13.8 GHz, is attenuated by cloud water, rain and partially melted hydrometeors. The correction for attenuation is therefore one of the most important procedures in the estimation of rain rate. Validating the TRMM PR estimates and examining some of TRMM standard algorithms require comparisons with well-calibrated non-attenuated ground-based radar measurements. One of the critical steps of validation is to accurately resample data from space-borne and ground-based instruments to a common grid. Because of differences in the scattering geometries of space-borne and ground-based observations, accurate registration of data is a challenging problem. This problem is further complicated if there are offsets in time among the measurements. As a result, one or more of the data sets may require translation, rotation, or scaling to ensure reliable comparisons among them. A technique for transforming data acquired from different platforms to a common coordinate is developed and applied to the measurements of PR and ground-based radar. In this study the ground-based measurements are taken from the S-band WSR-88D radar for the period from 1998-2007 for the overpasses of TRMM satellite over the Melbourne, Florida site during times when significant precipitation was present in the overlap region of the PR and WSR-88D. Instantaneous and statistical features of the PR products such as radar reflectivity factor and rain rate are compared to the same products obtained from the ground-based observations. Comparisons of PR to WSR-88D provide a means to examine the radar calibrations and attenuation correction procedures adopted in the satellite radar algorithms. Because the spatial (sample) resolution of the ground-based weather surveillance radar varies as a function of radar range (while the satellite radar yields nearly uniformly spatial sampling), uniform gridding over the overlap area of satellite and ground radar observations leads to biases or ambiguities particularly because of variability of precipitation in space. These uncertainties are checked through the results of comparisons that are broken into several radar ranges relative to the WSR. The analysis of results indicates that the reflectivity fields derived from the PR data after attenuation correction agree well with those obtained from the WSR-88D. Comparisons of rain rates also yield good agreement with the conditional mean rain rate from the PR and WSR-88D. This agreement improves when area-averaged rain rates, rather than high resolution rain rates, are compared.

One of the most difficult problems in the study of the radar signature of the melting layer is the determination of the effective dielectric constants of melting hydrometeors. In this study, the primary focus is on the derivation of the effective dielectric constants of non-spherical particles that are mixtures of ice and water. The computational model for the ice-water particle is described by a collection of 128x128x128 cubic cells of identical size. Because of the use of such a high-resolution model, the particles can be described accurately not only with regard to shape but with respect to structure as well. The Cartesian components of the mean internal electric field of particles, which are used to infer the effective dielectric constants, are calculated at each cell by the use of the Conjugate Gradient-Fast Fourier Transform (CG-FFT) numerical method. The validity of the effective dielectric constant for non-spherical mixing particle is investigated by comparing the scattering and polarimetric parameters of an ice-water oblate spheroid obtained from the CGFFT to those computed from the T-matrix for a homogeneous particle with the same geometry as that of the mixed phase particle (such as size, shape and orientation) with an effective dielectric constant derived from the internal field of the mixed-phase particle. The accuracy of the effective dielectric constant can be judged by whether the scattering parameters of interest can accurately reproduce those of the exact solution,

i.e., the T-matrix results; its utility can be judged by the class of particles for which the effective dielectric constant is valid. Although the effective dielectric constant can be defined for a particle with an arbitrary shape, size, and orientation, its utility may be marginal if it cannot be used to characterize a class of particle types. On the other hand, in many cases, the use of the effective dielectric constant may greatly reduce the complexity of the scattering calculations. Once obtained, the effective dielectric constant may be applicable to a range of particle sizes, shapes and orientations if the fractional ice-water contents remain the same. In addition, the effective dielectric constants of the ice-water spheroids are computed for cases in which the particles can assume different sizes, shapes and orientations.

Objectives for the Coming Year

The GEST investigator plans to continue research on a variety of topics associated with airborne and spaceborne weather radar analysis generally and the TRMM Precipitation Radar (PR) and GPM Dual-Wavelength Precipitation Radar specifically. The work includes single- and dual-wavelength radar analysis of hydrometeor profiles, simulation of polarimetric radar signatures in rain and snow, retrieval of the microphysical properties and characteristic parameters of drop size distribution using data from a dual-wavelength Doppler airborne weather radar, and the validation of the TRMM standard products using ground-based measurements.

Task 912-02-036: **Physics of Cirrus Clouds and Their Role in Global Climate**

GEST Investigator: Ruei-Fong Lin

Collaborator: David O'C. Starr (PI, GSFC, Code 613.1)

Abstract

The Raman Lidar and millimeter wave cloud radar (MMCR) deployed in the ARM SGP site continuously monitors tropospheric water vapor and clouds that pass through the site. The Raman Lidar measures profiles of water vapor, the extinction coefficient, the depolarization ratio, and the backscatter-to-extinction ratio. MMCR renders the profiles of radar reflectivity and Doppler velocity. The research team developed a scheme to estimate the water vapor uptake rate in cirrus clouds using the Raman Lidar and MMCR data. The water vapor uptake is a key term in the water vapor budget. From the derived rate, the researchers could examine whether the diffusional growth is effective in the observed cirrus.

Description of Research

Modified gamma distributions are frequently used to describe particle size distributions (PSDs) in cirrus clouds. The modified gamma distributions have a very nice feature: their moments are known. Thus, the combination of modified gamma distributions and power-law relationships renders nice and fast analytical solutions. There are three parameters in a modified gamma distribution. Thus, basically, three equations (*e.g.*, three moments) are needed to solve the three unknown parameters in a modified gamma distribution. If only two moments are known, can the reasonable range of a third moment be estimated?

The power-law relationship between the maximum dimension of a particle and the backscatter cross-section in the MMCR wavelength is given in Aydin and Walsh (1999). The power-law relationship between the maximum dimension of a particle and its projected area is reported in Heymsfield and Miloshevich (2003). Therefore, the MMCR reflectivity and Lidar extinction coefficient may serve as the two known moments. Is the water vapor uptake rate also a moment of a given PSD? If yes, is the uncertainty of the estimated water vapor uptake rate small enough for practical use?

Accomplishments during the Reporting Period

A scheme to estimate to water vapor uptake rate by Raman Lidar and MMCR data was developed

and its uncertainty addressed. The scheme includes the following procedures.

First, the GEST investigator examined the full equation of the diffusional growth function; that is, the ventilation effects and kinetic effects are both included. A power-law relationship fairly approximates (within 20% accuracy) the relationship between the particle maximum dimension and its growth rate, especially for a large or a very small deposition coefficient. The coefficients of the power-law relationship for ice supersaturation ratio equal to 1 were estimated. Secondly, the general form was derived for the third moments (moment z), given two moments (moments p and q). The general form is a product of two terms. The first term is a function of z, p, q and the parameter which controls the width of the modified gamma distribution. The second term is a function of z, p, q, and the two known moments. The first term does not vary very much (within ~20%) within reasonably ranges of z, p, q, and the spectrum width.

Finally, the research team checked the Raman Lidar and MMCR data. Data smoothing is required because of random error in the measurements.

The derived water uptake rate was compared with the other terms in the governing equation for the local water vapor. It as also compared with the horizontal advection term in the large-scale forcing rata [Zhang and Lin, 1997]. The sub-grid water vapor forcing (relative to the forcing data) was derived.

Objectives for the Coming Year

The first objective is to drive a one-dimensional cirrus model, which has been developed in-house in GSFC, by the sub-grid water vapor forcing together with the SGP forcing data. The second objective is to run the WRF model for a selected NAMMA case. The research team is particularly interested in the mineral dust loading on the evolution of precipitation systems.

Task 613-65-222: **Modeling of Interactive Cloud Processes and Precipitation Systems**

GEST Investigator: Toshihisa Matsui

Collaborators: Wei-Kuo Tao (PI, GSFC, Code 613.1), Roger Shi (GSFC, Code 613.1), Xiaowen Li, William Lau (PI, GSFC, Code 613.0), Mian Chin (PI, GSFC, Code 613.3), Chris Kummerow (CSU)

Abstract

This research contributes to precipitation mission (PM) and interdisciplinary science (IDS) project. Both projects are related to the interactive cloud processes and precipitation systems by utilizing satellite observations, radiative transfer models, and numerical atmosphere-aerosol-land surface simulations. This report is weighted on the description of research and objective for the coming year.

Description of Research

First, PM science focuses on an improvement of understanding of precipitation process by application of multi-scale modeling systems and radiative transfer models, in order to support TRMM and upcoming GPM projects. GCE and WRF models are run for various environmental cases. Based on the simulated three-dimensional hydrometeors, TRMM- or GPM-consistent brightness temperature will be computed from a microwave radiative transfer (forward) model. Computed brightness temperature will be compared with the satellite-derived brightness temperature in a statistical sense for model validation. Sensitivity of computed brightness temperature to surface emissivity, humidity profiles, and hydrometeor size distribution will be examined in emphasis of continental cold-rain processes and pollution (high CCN) cases, since it is involved in large uncertainties in the precipitation retrieval algorithm in the TRMM and upcoming GPM project.

Second, IDS science examines a role of absorbing aerosols and land cover on the Indian Monsoon and precipitations. Succeeding from the previous global experiments, this project

focuses on regional scale interactions using a coupled WRF-LIS model. Furthermore, WRF-LIS will be coupled with GOCART model to examine the explicit interactions between Indian monsoon and aerosols. Several sensitivity experiments are planned to understand how the absorbing aerosols over India and the Tibetan Plateau affect onset of Indian Monsoon. Existing satellite-based cloud-precipitation datasets, including TRMM and CloudSat A-Train, are also compiled and examined in conjunction with ambient aerosols and thermodynamic environments for investigating aerosol 1st and 2nd kind indirect effects in this region.

Accomplishment during the Reporting Period

The investigator joined GEST at the end of the reporting period. In that short time, he constructed the module that bridges the GOCART aerosol mass concentrations and the Goddard shortwave radiative transfer scheme. This allows the team to examine the aerosol direct effects in the WRF-LIS and GCE models, using the off-line (uncoupled) GOCART model.

Objective for the Coming Year

Matsui plans to accomplish three tasks in the coming year. The first is to couple a microwave radiative transfer to GCE and WRF-LIS models. Sensitivity of high-frequency brightness temperature to surface emissivity, humidity profiles, and size distribution of snow hydrometeor will be examined for better understanding of GPM's snowfall retrievals over land. The second task is to examine the sensitivity of aerosol direct radiative forcing to the Indian Monsoon, using the WRF-LIS model. In this stage, WRF-LIS and GOCART are coupled in an off-line mode; *i.e.*, GOCART aerosol mass concentrations are slightly varied in the WRF-LIS model. The model output will be assessed in terms of i) a performance of dynamic downscaling for Indian Monsoon using the WRF-LIS model, and ii) a sensitivity of aerosol direct effects on the onset of India Monsoon. Finally, the third task is to compile high-resolution three-dimensional satellite-based cloud-precipitation datasets for i) validating the global/regional CRM and MMF, and ii) examining cloud-precipitation processes in conjunction with ambient aerosols and thermodynamics. As an initial step, Matsui will specify what sensors and statistical composites are needed from the TRMM satellite and A-Train satellites.

Task 614-79-269: **Development for dual frequency precipitation radar(DPR) algorithm of the Global Precipitation Measurement Mission (GPM)**

GEST Investigator: Katsuhiro Nakagawa

Collaborators: Robert Meneghini (PI, GSFC, Code 614.6), Yukari Shusse (NICT, Japan), Toshio Iguchi (NICT, Japan)

Abstract

To improve the accuracy of space-borne and ground-based radar estimated rainfall intensity and rain retrieval algorithms for space-borne microwave radiometers, the vertical profile of rainfall parameters, especially raindrop size distribution, are very important. In addition, an appropriate rainfall-type classification method to select the DSD and melting layer models is very important for practical use. Intensive field observations for subtropical precipitation using COBRA (CRL Okinawa Bistatic polarimetric Radar), 400MHz Wind Profiler (WPR), and two types of ground-based disdrometers were carried out in rainy season in 2004 and 2006 at Okinawa Island, Japan. The data were then used to classify the rainfall type by polarimetric radar and to analyze the vertical profile of rainfall parameters.

Description of Research

One of the core instruments for the Global Precipitation Measurement (GPM) mission is Dual frequency Precipitation Radar (DPR). The DPR consists of two radars; *i.e.*, the Ku-band (14 GHz) Precipitation Radar (KuPR) and the Ka-band (35 GHz) Precipitation Radar (KaPR). The high-frequency microwaves used by the DPR are affected by the rain attenuation in general. The amount of the attenuation depends

on the frequency and the size of rain drops. Therefore, the drop size distribution (DSD) of rain can be estimated using the difference of attenuation between the two frequencies in the KuPR and KaPR. In this research, the vertical DSD profile model is to be developed using the data observed by ground-based multi-frequency sensors.

Accomplishments during the Reporting Period

Polarimetric radar observation is one of the useful methods to characterize the cloud microphysical information including the precipitation processes. In the present study, observational data of the COBRA during the Okinawa Baiu Campaign Experiment (Okn-Baiu-04) were mainly used. As a first step of the development of rain-type classification by the COBRA, characteristics of polarimetric radar variables in (1) stratiform type (ST), (2) isolated convective type (ICT), and (3) embedded convective type (ECT), which are common rain types during rainy season over the East China Sea, were studied and compared. The ST was accompanied with an obvious bright band. The ICT and ECT were in their mature stage. They were relatively shallow convections, whose echo-top heights of 30 dBZ were about equal. One important result is that the values of hv(0) significantly decreased around the 0°C level in the ST and the ECT, but did not decreased in the ICT. These features indicate that the melting heavily aggregated snow existed around the 0°C level in the ST and the ECT, but did not exist in the ICT. It follows from this that conventional convective-stratiform classification methods based on radar reflectivity data are not always effective to characterize the microphysical information in the precipitation. On the bases of these facts, the rainfall-type classification method was developed, which gives a judgment of the presence of the melting layer in addition to a conventional convective-stratiform classification.

To characterize the vertical variations in the rainfall parameters that include raindrop size distribution (DSD), mass weighted drop diameter (Dm), normalized number concentration (N0*), radar reflectivity (Z), differential reflectivity (ZDR), and correlation coefficient (HV) for the various rainfall types during the Baiu front event of 2 June 2006 (Okn-Obs-06), the data were separated into the following categories: (a) convective rainfall (CV), (b) stratiform rainfall before the CV (Before-CV), and (c) stratiform rainfall after the CV (After-CV). The research team focused on the differences in rainfall parameters between the ‘Before-CV’ and the ‘After-CV’ rain events. From an examination of the ground-based measurements of the DSD, the size distributions of the ‘Before- CV’ rain are generally broader and less peaked than the ‘After-CV’ rain events. These differences in the DSD during the two stratiform periods of rain are reflected in changes in the Z-ZDR and Z-R relationships for the COBRA radar data where the values of ZDR were typically larger during the ‘Before-CV’ rain than in the ‘After-CV’ rain. This result was confirmed from the radar ZDR estimated from the 400MHz WPR data. Using the COBRA data, the location of the bright band (BB) in the ‘Before-CV’ period was found to be lower than the BB location during ‘After-CV’ period. This result was confirmed by the Doppler spectrum observed by the 400MHz Wind Profiler.

Objective for the Coming Year

An algorithm for DSD above the melting layer will be developed using by 400MHz-band wind profiler. In addition, an analysis for vertical variations of rainfall depending on the rainfall type (stratiform and convective rainfall, etc.) will be performed. This will enable the production of a database of various storm parameters such as rain rate, DSD, and hydrometeor type for development and validate of the DPR algorithm.

Task 912-10-109: **Various Numerical Applications on Tropical Convective Systems**

GEST Investigator: Chung-Lin Shie

Collaborators: Wei-Kuo Tao (GSFC, Code 613.1), Arthur Hou (GSFC, Code 610.1), Scott Braun (GSFC, Code 613.1), William Olson (JCET)), D. Allen Chu

Abstract

Research tasks performed during this past Fiscal Year consist of three major studies. The first study involved extensive 3-D cloud system simulations using a 3-D Goddard Cumulus Ensemble (GCE) model, while the second focused on improving the latent heating retrieval of satellite data through aids from the GCE modeled results. The third study involved hurricane simulations using the Weather Research and Forecasting (WRF) model. The first study was aimed at simulating various marine cloud systems using the GCE model driven by either observed or GEOS-3 large-scale forcing fields. In the second study, numerous cloud model simulations were performed with various prescribed parameter conditions (*i.e.*, with or without random temperature perturbation, wind shear, and divergence). The WRF model was used in the third study for hurricane Emily simulation during a 6-day period of 12-18 July, 2005. Features such as hurricane track and intensity are to be examined.

Description of Research

The primary objectives of this research, which involves numerical simulations using the GCE and WRF model, are (1) to better understand the role cloud systems have played on the water and energy cycle in climate systems by examining interactions between clouds and the large-scale temperature and moisture forcing, (2) to improve the satellite latent heating retrieval, particularly for low-level altitudes, and (3) to better understand the vertical structure of intense storm surrounding hurricane Emily's eye, as well as the evolution of its track and intensity. As the chosen CRM (cloud resolving model) for a NASA Interdisciplinary Science (IDS) project, the 3-D GCE model was used to simulate various marine cloud systems to understand and elaborate on the physical processes associated with the tropical and extra-tropical energy and hydrological cycle. In a funded NASA Energy and Water cycle Study (NEWS) project, a 2-D GCE was used to produce a series of shallow cloud simulations with various idealized parameter setups. The modeled "realistic" vertical heating profiles will be added into the current look-up tables aiming to improve the satellite latent heating profile retrieval. The hurricane Emily study was involved in a project under the Tropical Cloud Systems and Processes (TCSP) mission.

Accomplishments during the Reporting Period

For research Subject 1, the GCE simulated results using the respective field campaign observations and GEOS-3 data generally showed good qualitative agreement, yet with some quantitative discrepancy. For example, in one simulated episode, the modeled water vapor with the GEOS-3 forcing was found to carry a drier bias than that with the sounding forcing, which is consistent to the relatively drier GEOS3 moisture forcing. The modeled rainfall results are also found consistently to correspond to a properly correlated large-scale temperature and moisture forcing not only temporally but also quantitatively [Shie *et al.*, 2006b, c, d]. This research subject also involved a handful of collaborative works, *i.e.*, Lin *et al.* [2006], Zeng *et al.* [2006, 2007], and Zhou *et al.* [2006, 2007]. Based on Olson *et al.* [2006] and Grecu *et al.* [2006], accurate estimates of latent heating rate were found difficult at 1 km, due to the limited information in the satellite data on the relatively weak low-level heating/cooling. In research Subject 2, a series of "realistic" samples of vertical heating profiles were produced for shallow cloud conditions through cloud model simulations. These newly modeled vertical heating profiles will later be added into the current "look up" table hoping to help improving the low-level heating retrieval from satellite data. Hurricane Emily has recently become an interesting case for research study due to an evident finding of its intense (overshooting)

eyewall thunderstorm structure. Based on results from a pair of 6-day simulations performed for hurricane Emily using the Kain-Fritch (KF) and Betts-Miller-Janjic (BMJ) cumulus physics scheme, respectively, the one using BM scheme was found seemingly to produce a stronger system with more rainfall and higher winds, and moving quicker/slower toward north/west than that using the KF scheme. The vertical structure (*e.g.*, the overshooting clouds) of simulated hurricane Emily will be further examined.

Objectives for the Coming Year

One of a few research tasks for next year is to carry on the ongoing projects (Subjects 2 and 3) that were detailed above. Two new projects involving the Saharan Air Layer will also be conducted. For the first one, the impact of Saharan dust on tropical cyclone development and evolution, not only in terms of individual storms, but also for interannual activity will be explored by combining MODIS aerosol optical depth and TRMM rainfall data. Global analyses from NASA's GEOS-5 analysis system will be used to distinguish variations in the synoptic environment on monthly to seasonal time scales to examine factors influencing interannual variability. The same analyses will also be used to examine the evolution of individual storms and their relationship to the Saharan Air Layer. The second new project will investigate the impact of Saharan dust on the development and evolution of local cloud convection by using numerical modeling, *i.e.*, WRF and GCE. A likely third new project for reproducing the Goddard Satellite-based Surface Turbulent Fluxes (GSSTF) dataset may start in 2008 should a proposed project be funded [Shie *et al.*, 2007, Chiu *et al.*, 2007, Xie *et al.*, 2007].

Task 912-02-027: **Improved Understanding of Cloud and Precipitations Properties Using Airborne Doppler Radar Measurements**

GEST Investigator: Lin Tian

Collaborators: Gerald Heymsfield (GSFC, Code 613.1), Lihua Li, Larry R. Belcher, R.C. Srivastava (Univ. of Chicago)

Abstract

During this reporting period, research has been conducted in the following area: 1) continued study of retrieval of light rain using airborne Doppler radar observations at 94 and 10 GHz; 2) application of surface reference technique to 94 GHz radar in support of CloudSat mission; 3) developing methods for three dimensional wind retrieval for upcoming UAV and HIWRAP airborne conical scanning Doppler radars; 4) continued efforts in supporting field campaign, including data processing and analysis.

Description of Research

Measuring global cloud and precipitation by satellite such as the Tropical Rain Measuring Mission (TRMM) and CloudSat mission is important for understanding weather and climate changes and to improve weather prediction. Rain has been very difficult to measure accurately over a wide range of intensities because there is generally insufficient information about the rain properties. A dual-wavelength radar, such as the one proposed for the Global Precipitation Measurement (GPM) can improve the accuracy of rainfall estimation. However, the 14 and 35 GHZ frequencies proposed for the GPM radar may not resolve the raindrop size distribution in light rain due to the small difference of the reflectivity at the two frequencies. By using combination of 94 GHz and 10 GHz reflectivity, and Doppler information that is not available on GPM, it has been found in this work that light rain can be estimated more accurately.

Accomplishments during the Reporting Period

A case of light stratiform rain over southern Florida is examined in detail. The profiles of a Gamma raindrop size distribution (RSD), vertical air velocity, and attenuation by precipitation and water vapor are retrieved using the difference of the Doppler velocity at 10 and 94 GHz. The approach is primarily applicable to

rain rates less than 5 mm hr^{-1}. The magnitudes of the retrieved RSD are similar to those found in ground-based observations of light stratiform rain. The retrieved vertical winds with downdrafts below about 3 km and weak updraft above are similar to what has been observed in wide spread stratiform rain with a melting band. The sensitivities of the retrieval to Gamma shape parameter are discussed. The results were published in JGR. This method has also been applied to ice region of the stratiform rain. It has been found the difference Doppler velocity at the two frequencies in ice region is much smaller than that in rain region, which could result a large uncertainty in the estimation of ice particle size.

The light rain has also been observed by the cloud profiling radar on CloudSat. In principle, single-wavelength surface reference technique used by TRMM PR can be applied to CloudSat to retrieve light rain. However, the accuracy is limited by uncertainty in the raindrop size distribution (RSD), surface return, and water vapor distribution that vary both inside and outside of the rain region. The investigator has used airborne 94-GHz radar and 10-GHz radar to evaluate the performance of SRT on cloud radar data.

Two new conical scanning radars are under development for the study of hurricanes and convective storm. These new radars will provide an opportunity for mapping the three dimensional wind field inside the hurricane and convective storms. The GEST investigator is evaluating the different methods for retrieving 3D wind field.

Objectives for the Coming Year

The GEST investor will continue 1) to explore the different applications of using airborne Doppler radar measurements to study the cloud and precipitations; 2) to support field campaigns CLASSI and TC-4; and 3) to evaluate the methods of estimating 3D wind fields from airborne conical scanning radars.

Task 912-42-178: **The Evaluation of NPOL Radar in NAMMA and the Adjustment of TRMM PR Rainfall Data for the Post-Boost Period**

GEST Investigator: Jian-Jian Wang

Collaborators: Robert Adler (GSFC, Code 613.1) , Guojun Gu, Ali Tokay (JCET) , Lawrence Carey (Texas A&M Univ.) , John Gerlach (GSFC, Code 614.6)

Abstract

The NASA Polarimetric Radar (NPOL) is NASA's only portable polarimetric precipitation research radar. Polarimetric radar inferred microphysical (*e.g.*, hydrometeor type, amount, and size) and rainfall properties are crucial for an accurate estimation of rainfall amount and can play an important role in the ground validation program of TRMM and future GPM when comparing the satellite measurements to the NPOL observations. One of the efforts under this task is to assess the performance of NPOL radar during the NAMMA field campaign, including the evaluation of both reflectivity and polarimetric data.

When examining the differences between the TRMM PR monthly rainfall (3A25) data, it was found that there is an apparent drop of PR rainfall data at the lower levels since August 2001, when the TRMM raised its orbit from 350 to 402 km to extend the mission's life. Wang developed a simple and robust technique for adjusting the PR monthly rainfall data in the Tropics during the post-boost period to make PR rainfall data a homogenous dataset. As the TRMM PR rainfall dataset is available as an independent and homogenous measurement, the team will further explore the relationship between the space-borne radar measured rainfall and SST.

Description of Research

The GEST investigator's central research efforts are: a) to test the NPOL polarimetric performance relative to that of established polarimetric radars (*e.g.*, CSU-CHILL, NCAR SPOL, and BMRC CPOL) with different

hardware installed to improve the operation, b) to evaluate the improvement of "wet antenna" issues on the NPOL measurements, c) to compare the correlation between rainfall and ENSO events in the whole tropical ocean and land for both the pre-boost and post-boost periods of TRMM satellite, d) to make the necessary adjustment for the post-boost period rainfall to make PR rainfall data a homogenous dataset, and e) to examine the relationship between the variation of tropical rainfall and SST.

Accomplishments during the Reporting Period

The case of 2 September 2006 was selected as the primary case to analyze the NPOL radar performance. In order to evaluate the "wet antenna" issue throughout the NAMMA, the case of 26 September 2006 occurring at the late stage of the field experiment was also studied. The results show that the NPOL polarimetric data are noisy comparing to the standards of other established research polarimetric radars (*e.g.*, CSU-CHILL, NCAR SPOL, and BMRC CPOL). For example, the random measurement error in the measured differential phase is 2 times larger for NPOL than for the other established research radars. More specifically, the measurement error in the NPOL differential phase (Ψ_{dp}) is about 5° compared to more typical values of 1.4° to 2.5° for the other radars. Because of the increased phase noise, the estimated specific differential phase (Kdp) is more noisy. In drizzle, Kdp should be zero. Any deviation from zero is associated with measurement error. The NPOL Kdp distribution in drizzle is relatively flat with a significant fraction of |Kdp| even beyond 1° km^{-1}. The distributions of Kdp for the other radars are more peaked around zero. Similarly, the random measurement error in the differential reflectivity (Zdr) is 2 to 3 times larger for NPOL. In particular, an upper-end empirical estimate of the standard error in Zdr is 0.8 dB compared to about 0.3-0.4 dB for the other radars.

NPOL radar is known for its "wet antenna" problem from previous field experiments. The problem is that the NPOL radar suffered a serious reflectivity attenuation problem (8-10 dBZ off) when the antenna was wet due to the rain at the radar site. Recently, a series of efforts were made to improve the problem including adding a mesh screen and a new coating to the antenna. For the case selected during the NAMMA, Wang compared the histogram of radar reflectivity from two volumes each before and after the antenna became wet. Apparently, the histogram of the radar reflectivity shows limited changes. The maximum value and median value of radar reflectivity after the rain remained about the same. It is a significant improvement from the much more serious "wet antenna" issue documented in the previous report.

The TRMM PR monthly rainfall anomalies over the tropical ocean/land versus Nino3.4 index anomalies for the pre-boost and post-boost periods were compared. Based on the gap between the linear regression lines of rainfall anomalies against the Nino3.4 index for pre-boost and post-boost periods, the team decided to add 6.6%, 6.0%, and 1.1% to the PR rainfall data over the ocean, and to add 5.0%, 4.2%, and 3.0% to the PR rainfall data over the land, at estimated surface, near surface, and 2km level, respectively. No adjustment was made for data above 4 km level.

The variations of monthly rainfall measurements from TRMM (including TMI and PR at different levels) and GPCP against the variation of SST in the tropical region (25°S—25°N) were also studied. In general, the monthly rainfall anomalies except PR rainfall at 6 km over the total tropical region including both ocean and land vary very little along with the change of SST anomalie. However, when examining the tropical ocean and land separately, it is found that both the TRMM and GPCP monthly rainfall show positive (negative) anomalies over the ocean along with positive (negative) SST anomaly, while the monthly rainfall over the land exhibit negative (positive) anomaly associated with positive (negative) SST anomaly.

Objectives for the Coming Year

Although the TRMM and GPCP monthly rainfall anomalies show the same tendency along with SST anomalies over the ocean, the

slopes of each regression line are quite different. Over the ocean, GPCP and TRMM TMI (2A12) rainfall data have larger and similar slopes against SST anomalies. However, the monthly rainfall anomalies derived from the TRMM PR (3A25) exhibit very different slopes against SST anomalies at the different levels over the ocean. At lower levels including estimated surface, near surface, and 2km level, the linear regression line of monthly rainfall anomalies are relatively flat. At 4km and 6km, the monthly rainfall anomalies are more sensitive to SST, showing linear regression lines with larger slopes. The focus of future work is to explore the reason causing the different relationships of SST anomalies and the rainfall anomalies derived from microwave imager and precipitation radar.

Task 913-00-000: **Atmospheric Solar Radiative Transfer**

GEST Investigator: Guoyong Wen

Collaborators: Robert F. Cahalan (GSFC, Code 613.2), Alexander Marshak (GSFC, Code 613.2) , Lazaros Oreopoulos (JCET), Tamas Varnai (JCET), Juan Fontenla (LASP, Univ. of Colorado), Thomas Woods (LASP, Univ. of Colorado), Hiroko Miyahara (Nagoya Univ.)

Abstract

This task focuses on studying the 3D radiative effects of clouds on the aerosol retrieval. The research addresses fundamental questions in aerosol indirect effect study using satellite observations. They are (1) quantifying 3D cloud effects on reflectance in clear region nearby and associated errors in aerosol retrieval from satellite; (2) identifying key parameters and characterization of the primary physical processes in 3D aerosol-cloud interactions; (3) improving aerosol retrieval in cloudy atmosphere, hence isolating aerosol indirect effect on climate. The second research focus area is to study the impact of solar variation on terrestrial climate. In particular, this research focuses on wavelength and time dependence of solar forcing of Earth's atmosphere-ocean system. In this research the spectral solar irradiance (SSI) from the Spectral Irradiance Monitor (SIM) on the Solar Radiation and Climate Experiment (SORCE) satellite were used to extract the spectral and temporal variations of solar output. A convective model is used to study the response of Earth's atmosphere-ocean system to variations of spectral solar irradiance.

Description of Research

The aerosol amount in the clear region of a cloudy atmosphere is an important parameter in studying the effects of aerosol on cloud properties and Earth's climate. To study how aerosol can affect the reflectance of clouds on a global scale, satellite observation is obviously a good choice since one can have both cloud properties and aerosol amount in a nearby clear region. However, satellites do not directly observe aerosols. Aerosol amounts are retrieved from satellite observed reflected sunlight with an operational 1-dimensional algorithm. In the operational aerosol retrieval process, clouds near clear regions are ignored. This may lead to a wrong interpretation of satellite observations. A simple example would be the shadowed pixels in a satellite image. Since aerosols reflect sunlight, a lager reflected amount of sunlight observed from the satellite will be interpreted as more aerosols. For the same amount of aerosols, the shadowed pixels look darker than non-shadowed. Since the amount of reflected sunlight is used to infer aerosols, darker pixels would be interpreted as less aerosol amount if nearby clouds are ignored. Similarly, nearby clouds can scatter sunlight into nearby non-shadowed pixels making those pixels look brighter. Hence aerosol in those clear pixels would be misinterpreted as having more aerosols. This research focuses on quantifying 3D cloud effects on reflectance in clear region nearby, to improve understanding of the underlying physical process, and to make corrections in aerosol retrieval from satellite observations.

Solar radiation is the major driving energy source for atmospheric and oceanic circulations, and climate. Understanding this input energy is crucial for understanding the physical, chemical, and biological processes of the Earth-atmosphere system. There is increasingly strong evidence to link the solar variations to Earth's climate. The objective of this part of the research is to study the characteristics of solar irradiance variations. The spectral and temporal variations of solar output energy observed from satellite will be used as input for modeling study of the response of Earth's atmosphere-ocean system to solar variations.

Accomplishments during the Reporting Period

The 3D cloud effects on reflected sunlight and retrieval of aerosols embedded in cumulus cloud fields are further investigated. Wen extended the 3D aerosol-cloud interaction to include realistic surface reflectance, wavelength dependence, for different aerosol amount, with different spatial resolution. 3D cloud-induced enhancement depends on the optical properties of nearby clouds as well as on wavelength. The enhancement is too large to be ignored. Associated bias error in 1D aerosol optical thickness retrieval ranges from 50% to 140% depending on wavelength and the optical depth of nearby clouds, as well as aerosol optical thickness. A paper about the new findings is in press in a refereed journal [Wen *et al.*, 2007].

The 3-dimensional structure also has significant impacts on cloud droplet retrieval. The investigator worked with colleagues to quantify this effect. A paper describing the results was published [Marshak *et al.*, 2006].

Collaborating with a Japanese scientist and a NASA scientist at Goddard, the investigator carried out a study of the feasibility of deriving total solar irradiance from lunar borehole temperature profiles. Without atmosphere, ocean, biosphere, and human activities, the Moon is an ideal place to reconstruct the total solar irradiance. Since thermal diffusivity of lunar regolith is very low, the historical variations in TSI is recorded as temperature anomalies in the upper layer of lunar regolith. The results were reported in the SORCE science meeting. A paper to summarize the results of this study was submitted to a refereed journal [Miyahara, Wen, and Cahalan, 2007]

Objectives for the Coming Year

The major objective for the coming year is to extend the current Goddard radiative convective model for an equilibrium atmosphere to account for wavelength and time dependence of solar variation. In this study, the solar variations (both time and wavelength) will be estimated from SIM data observed from the SORCE satellite. The ocean storage will be accounted for. Secondly, 3D aerosol-cloud interactions will be further investigated. The research will focus on identifying major physical mechanisms. The research will be extended to clouds over ocean. This work is expected to provide guidelines for aerosol retrieval in cloudy atmospheric conditions.

Task 912-18-129: **Study of Tropical Cyclone Activities**

GEST Investigator: Liguang Wu

Collaborator: Scott Braun (PI, GSFC, Code 613.1)

Abstract

The investigator has been working at the Mesoscale Atmospheric Processes Branch of GSFC since 2002, where he is working mainly on advancing understanding of tropical cyclone activities. During the past year, he researched: (1) tropical cyclogenesis through numerical simulation; (2) potential impacts of global warming on the tropical cyclone activity; and (3) assessing the climatic impact of the Three Gorges Dam through analysis of NASA satellite data and numerical simulation. Preliminary findings include the destructive effect of Saharan dust air on tropical cyclone formation and intensification and the potential effect of the Three Gorges Dam on regional climate.

Description of Research

Hurricanes, as a key component of the global climate system, can be significantly affected by the global climate change, and in turn introduce feedbacks on the global climate system. Therefore, it is necessary to understand the mechanisms involved in the formation and intensity change of tropical cyclones and their interaction with large-scale circulation. During the past year, the research focus has been placed on investigating the physical mechanisms involved in tropical cyclogenesis including the effect of Saharan Air Layer (SAL) through analysis of Aqua/AIRS data products, numerical simulation and identifying the possible impact of global warming on tropical cyclone activities in the western North Pacific, eastern North Pacific, and North Atlantic basins.

Accomplishments during the Reporting Period

The Saharan Air layer (SAL), which is associated with African dust outbreaks, forms as air moves across the Sahara Desert, containing substantial amounts of mineral dust. While the relationships of Sahel rainfall with African dust outbreaks and Atlantic hurricane activity have been documented in previous studies, analyses of various independent datasets show that the Sahel rainfall, SAL activity and hurricane peak intensity in the Atlantic basin are highly correlated. The long-term trend in hurricane peak intensity generally follows the Sahel rainfall and SAL activity. The decreasing trend in hurricane intensity by the mid-1980s was associated with the enhancing SAL activity (drying relative humidity and enhancing vertical shear) and the severe drought in the Sahel, while the recent moderate increasing trend in hurricane intensity is consistent with the weakening SAL activity (wetting relative humidity, weakening vertical shear and decreasing dust load) and the ameliorating Sahel drought. This study suggests that the SAL may act as a link between the summer African monsoon and Atlantic hurricane activity.

Using the retrieved temperature and humidity profiles from the AIRS instrument suite on the NASA Aqua satellite, the Saharan Air Layer (SAL) and its influence on the formation of Hurricane Isabel (2003) and the tropical cyclones that formed during the NAMMA period are simulated numerically with the MM5 and WRF models. The warmth and dryness of the SAL (the thermodynamic effect) is assimilated by use of the nudging technique, which enables the model thermodynamic state to be relaxed to the profiles of the AIRS retrieved data for the regions without cloud contamination. By incorporating the AIRS data, MM5 better simulates the large-scale flow patterns and the activity of Hurricane Isabel in terms of the timing and location of formation and the subsequent track. The temperature and humidity profiles of the AIRS retrieved data products are useful for investigating the influence of the SAL on tropical cyclones. By comparing with an experiment without nudging of the AIRS data, it is shown that the SAL may have delayed the formation of Hurricane Isabel and inhibited the development of another tropical disturbance to the east and significantly regulated the activity of tropical cyclones during the NAMMA period.

Analyses of the National Aeronautics and Space Administration (NASA) TRMM rainfall rate and MODIS land surface temperature indicate that the precipitation in the mountainous area north of the Yangtze River increased after the water level rose to 135 m due to the induced anomalous downward motion in the vicinity of the waterway coupled with the upward motion in the mountainous area during the daytime. This study suggests that the TGD construction altered the regional climate pattern (~ 100 km) rather than the local scale (~10 km) as projected in previous assessments. In addition, very high-resolution simulation has been conducted and shows that the TGD might contribute a little to the extremely hot summer.

Objectives for the Coming Year

The investigator will continue his efforts on understanding of tropical cyclone activities. Most of his research work will focus on the formation of tropical cyclones and the environmental controls on tropical cyclone activity.

Task 912-29-152: **Evaluating Long-Term Cloud-Resolving Model Simulations with Observations**

GEST Investigator: Xiping Zeng

Collaborator: Wei-Kuo Tao (PI, GSFC, Code 613.1), Joanne Simpson (GSFC, Code 610.0)

Abstract

Cloud-resolving models, in contrast to numerical weather prediction models, choose fine spatial resolution so that they represent clouds explicitly, avoiding cumulus parameterization. A question is whether current cloud-resolving models can work well as expected in long-term simulations. Thus, it is imperative to evaluate long-term cloud-resolving model simulations with observational data. Now, several field observations are used to evaluate a three-dimensional (3D) cloud-resolving model (CRM) in long-term simulations. Model biases are analyzed and their origins are explored.

Description of Research

Clouds play a central role in weather and climate change. They are associated with cloud microphysics, radiation and circulations, and connect the processes together. Due to the scale difference of cloud microphysics, cloud and large-scale circulation, numerical simulation plays an important role in studying the nonlinear relations of clouds to other processes. Thus, it is interesting to represent clouds in numerical models properly. Numerical weather prediction models use large spatial grid size, representing clouds implicitly with cumulus parameterization. However, the cumulus parameterization is far from satisfactory, especially in the Tropics.

Cloud-resolving models use fine spatial resolution. They can simulate clouds explicitly and represent the microphysical physics of clouds with parameterization properly. Therefore, the cloud-resolving models provide a framework to study the interaction between clouds and other processes (e. g. aerosol, radiation and large-scale circulations). To evaluate long-term cloud-resolving model simulations, a cloud-resolving model or Goddard Cumulus Ensemble (GCE) model is run and its results are compared with field observations.

Accomplishments during the Reporting Period

Many factors effect the simulations of precipitation and clouds in cloud-resolving models, such as dimensionality and land surface. The research team used the Atmospheric Radiation Measurement (ARM) observational data to evaluate the GCE model in 20-day simulations. All numerical experiments, as compared with observations, give reasonable simulations of surface rainfall but over prediction of cloud residues in the upper troposphere. The sensitivity of cloud properties to dimensionality is studied to isolate the origin of the over prediction of cloud residues. Owing to different buoyancy damping in two- and three-dimensional models, surface precipitation fluctuates rapidly with time and the air near the tropopause is dehumidified spuriously in the two-dimensional model.

Surface fluxes from a land surface model are compared to those from observations. Using the two kinds of surface flux data, the sensitivity of clouds to surface fluxes is studied, showing that the surface fluxes from the land surface model play an interesting role in the proper simulation of cloud fraction in the lower troposphere, which is understandable. Since the land surface model was driven with 1 km-resolution data, their fine resolution may lead to better area-averaged fluxes than that from “sparse” observational stations, although the fluxes from the land surface model is not accurate as the ARM fluxes at a point. However, the topic is still open on the comparison of the two kinds of surface flux data.

Objectives for the Coming Year

In the coming year, the model is going to be evaluated with the observational data from the fields campaigns in the Tropics such as the Kwajalein Experiment (KWAJEX), Southern China Sea Monsoon experiment (SCSMEX), and Tropical Oceanic-Global Atmospheric Program –Coupled Ocean-Atmosphere

Response Experiment (TOGA-COARE). Numerical schemes will be developed or modified to improve long-term CRM simulations.

Task 913-12-117: **Cloud-Radiation-Precipitation Modeling and Assimilation for Improving Weather Prediction and Climate Modeling**

GEST Investigator: Yaping Zhou

Collaborators: Arthur Hou (PI, GSFC, Code 610.1), Leo J. Donner (GFDL), William Lau (GSFC, Code 613.0), Philip Rasch (NCAR), Yogesh Sud (GSFC, Code 613.2), Wei-Kuo Tao (GSFC, Code 613.1)

Grant 4400125438: **FPGA-Implementation of Oriented Cloud Mask Algorithm**

GEST Investigator: Yaping Zhou (PI)

Collaborator: Yongxiang Hu (LARC)

Abstract

High resolution, multi-satellite, multi-senor observations of cloud and precipitation from TRMM, CERES instruments are used to evaluate the cloud, radiation and precipitation simulations from 3D Goddard Cumulus Ensemble (GCE) model for different geographical locations. Part I of the study, which focuses on comparison over South China Sea Monsoon Experiment (SCSMEX), found that that the GCE model is quite robust in reproducing the total surface rain, rain variation with time, and the convective/stratiform rain partition. Large differences between model and observations exist in the rain spectrum and the vertical hydrometeor profiles that contribute to the associated cloud field. The GCE model seems to yield slightly lower overall precipitation efficiency than that derived from TRMM observations. It tends to produce more intense convection and less anvil cloud. These results provide basis for the model improvement. In a separate study, the local and remote SST influences on precipitation are analyzed using multi-variable partial derivative technique and two sets of General Circulation Model (GCM) simulations.

For project 00002236, a previously developed simplified cloud mask algorithm was modified and delivered to collaborators at NASA Langley Research Center for implementation on FPGA platform.

Description of Research

The treatment of cloud-radiation and convective processes represents a major source of uncertainty in global models. Systematic errors in cloud and precipitation parameterization can prevent data assimilation systems from making effective use of observations. They also introduce fundamental uncertainties in modeling the global water and energy cycle, thus limiting the ability to predict climate change. This study aims to use observations of cloud, radiation and precipitation processes and cloud resolving model simulations to evaluate and improve physical parameterizations of global system performance. Cloud resolving model (CRM) will serve as a bridge between observations and physical parameterizations due to its capability of explicitly simulating the cloud and precipitation in great detail. To reach the goal, cloud resolving model itself has to be vigorously tested against observations for various dynamical environments and cloud/rain types.

Monthly to seasonal precipitation anomalies over the ocean are caused by local Sea Surface Temperature (SST) anomalies and large-scale atmospheric circulation anomalies that can often be related to large-scale SST anomalies. In collaboration with Goddard scientist Yogesh Sud, Zhou made a quantitative assessment of the local and remote SST-influences on the local precipitation based on two sets of global circulation model simulations.

Accomplishments during the Reporting Period

Cloud and precipitation simulated using the three-dimensional (3D) Goddard Cumulus Ensemble (GCE) model are compared to Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI) and Precipitation Radar (PR) rainfall measurements and Clouds and the Earth's Radiant Energy System (CERES) single scanner footprint (SSF) radiation and cloud retrievals. Both the model simulation and retrieved parameters are based upon observations made during the South China Sea Monsoon Experiment (SCSMEX) field campaign. The model simulated cloud and rain systems are evaluated by systematically examining important parameters such as the surface rain rate, convective/stratiform percentage, rain profiles, cloud properties, and precipitation efficiency. It is found that GCE is capable of simulating major convective system development and reproducing the total surface rainfall amount as compared with rainfall estimated from sounding. Further examination of the rainfall spectrum finds that GCE produces more heavy rains and many dripping light rain than PR or TMI observations. GCE also appears to produce heavier vertical hydrometer profiles of rain and graupel when compared to TMI retrievals and PR radar reflectivity. The intense rain cells are also consistent with the CERES cloud and radiation measurements. The model produces similar amount of high cloud but less total cloud amount so that domain averaged OLR from the model is higher than the observation. Sensitivity tests are performed to evaluate the impact of model set up (*i.e.*, model resolution, domain size, etc.) and various microphysics schemes on the rain spectrum and vertical hydrometeor profiles.

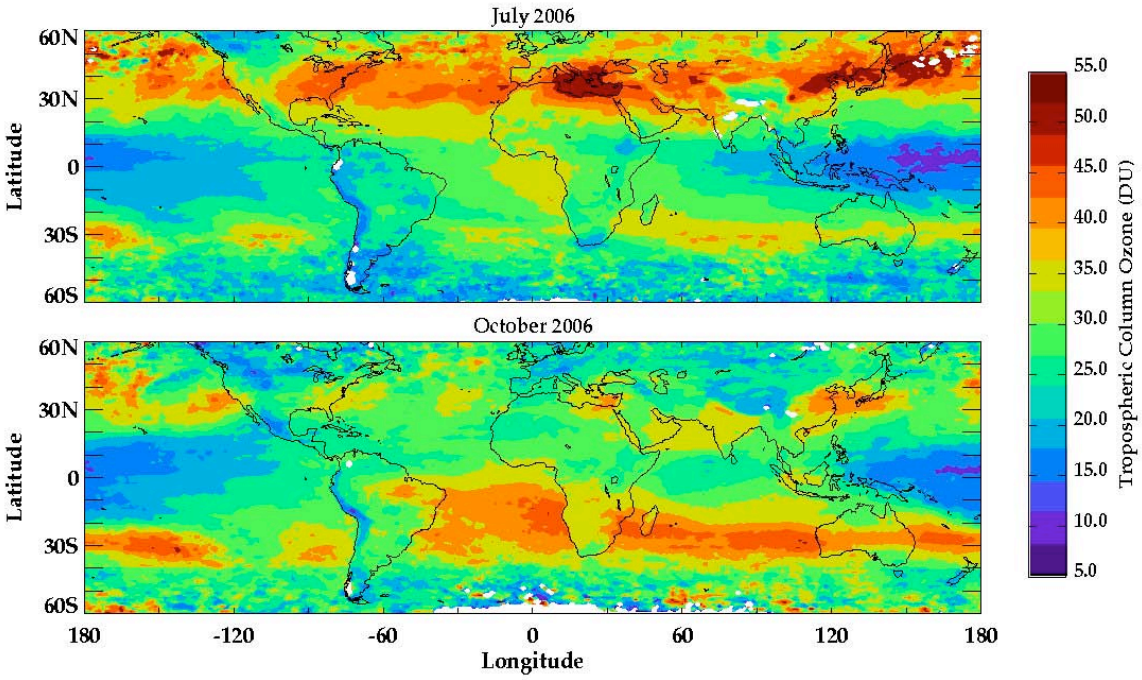
A quantitative assessment of the local SST-influences on the local precipitation is inferred from two integrations of the finite volume General Circulation Model (fvGCM), spanning from January 1, 1982 to December 31, 1991 using two prescribed sea-surface temperature (SST) datasets. Monthly precipitation was doubly binned with respect to SSTs and PBL moisture convergence; this provided partial derivatives of precipitation as a function of SST and PBL moisture convergence. Together with the rate of change of PBL moisture convergence as a function of local SST, the influence of SST change on precipitation was computed for different mass convergence scenarios. These were then used to obtain effects of local SSTs on precipitation at every grid point and for each month. The most dominant local SST-influences emerged in the tropics with significant contribution from dynamic effects. Some features of the double ITCZ were of local SST origin. The study quantifies the relative contributions of local and remote SST anomalies on rainfall anomalies globally on seasonal time scale.

Objectives for the Coming Year

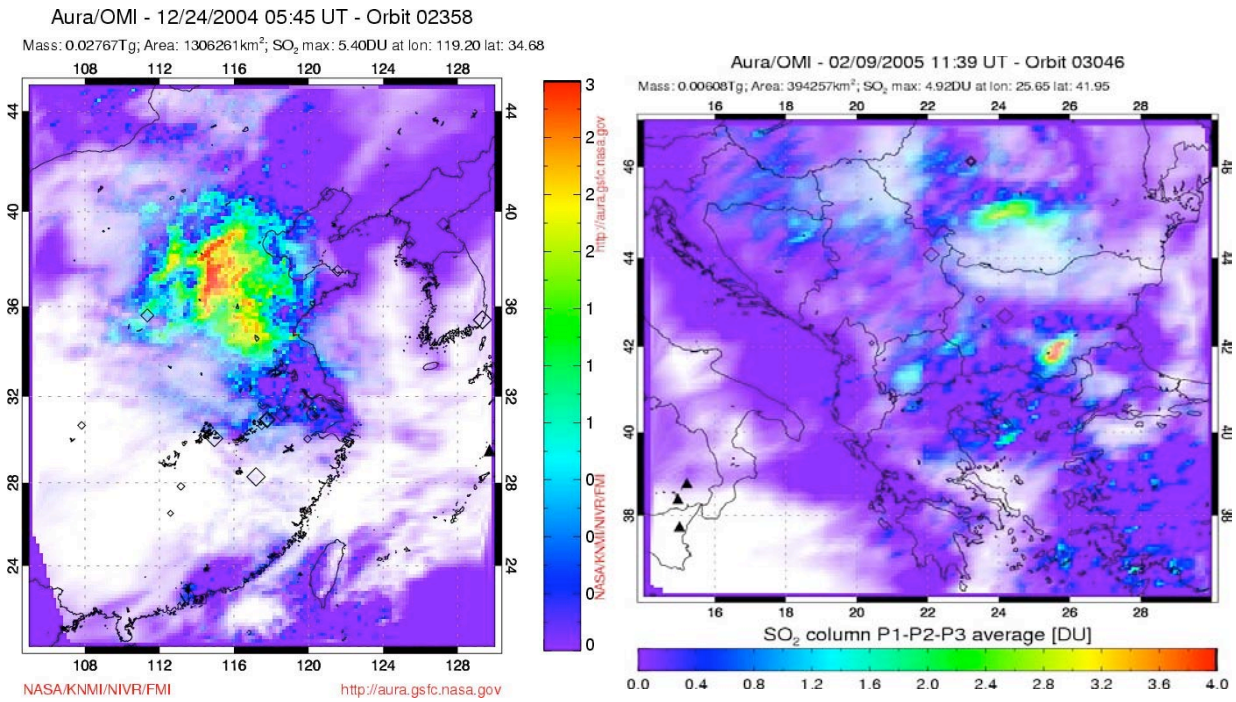
Zhou will expand current analysis to other geographical locations and different cloud systems and investigate aerosol and cloud microphysics effect on cloud and rain simulations. The other important task will be to develop methodology for using a cloud resolving model as a tool to improve GCM parameterization.

This page intentionally left blank

Atmospheric Chemistry and Dynamics Research Group



Tropospheric ozone (in Dobson Units) for July 2006 (top) and October 2006 (bottom) from combined Aura OMI and MLS ozone measurements. July 2006 (top) shows summertime pollution ozone from the U.S. streaming toward Europe, pollution ozone from Asia streaming toward North America, and a characteristic "accumulation region" of high ozone in the Mediterranean caused in part by pollution ozone from Europe transported southward into the region. October 2006 (bottom) shows high ozone throughout the Southern Hemisphere which is generated largely from the effects of cloud lightning and biomass burning over South America and southern Africa.[Figure provided by Jerry Ziemke.]



First EOS Aura Ozone Monitoring Instrument (OMI) measurements of anthropogenic SO_2 emissions in the PBL. Left panel: Air pollution in a region of eastern China on December 24, 2004. Clouds are shown in white. Right panel: SO_2 emissions from sources in S.E. Europe (chiefly in Romania and Bulgaria) on February 9, 2005 from [Krotkov et al.*, 2006]. [Figure provided by Nickolay Krotkov.]*

Atmospheric Chemistry and Dynamics Research Group

The composition of the atmosphere—its gases and particles—plays a critical role in connecting human welfare with global and regional environmental changes since the atmosphere links all of the principal components of the Earth system. The Atmospheric Composition chapter of the Strategic Plan for the U. S. Climate Change Science Program identifies the following questions for research:

Question 3.1: What are the climate-relevant chemical, microphysical, and optical properties, and spatial and temporal distributions, of human-caused and naturally occurring aerosols?

Question 3.2: What are the atmospheric sources and sinks of the greenhouse gases other than CO_2 and the implications for the Earth's energy balance?

Question 3.3: What are the effects of regional pollution on the global atmosphere and the effects of global climate and chemical change on regional air quality and atmospheric chemical inputs to ecosystems?

Question 3.4: What are the characteristics of the recovery of the stratospheric ozone layer in response to declining abundances of ozone-depleting gases and increasing abundances of greenhouse gases?

Question 3.5: What are the couplings and feedback mechanisms among climate change, air pollution, and ozone layer depletion, and their relationship to the health of humans and ecosystems?

[http://www.climatescience.gov/Library/stratplan2003/final/default.htm]

Research by members of the Atmospheric Chemistry and Dynamics Research Group directly contributes to answering these questions.

Robert Curran continues as a member of the staff of the U. S. Climate Change Science Program Office, while maintaining his relationship as research faculty with UMBC. In this capacity he is editor of the annual publication, “Our Changing Planet” and serves as liaison to the interagency working group on Atmospheric Composition. This working group is composed of the federal agency program managers responsible for implementing research programs related to Atmospheric Composition. The working group also oversees the development of integrated science and implementation plans relevant to Atmospheric Composition and Climate Change. The Atmospheric Composition working group serves as a forum in which the relevant federal agencies sponsoring research in atmospheric composition (gaseous and particulate) and its interaction with climate change meet to coordinate joint projects, report highlights of program research and develop future research plans.

Modeling studies and comparisons with measurements

Different Chemistry and Transport Models (CTMs) are being developed and/or improved in Goddard’s Atmospheric Chemistry and Dynamics Branch (Code 613.3) for a range of scientific objectives. The Global Modeling Initiative (GMI) is designed to maintain a state-of-the-art modular 3-D chemistry and transport model and serves as a comprehensive test bed, which can be used for assessment of the impact of various natural and anthropogenic perturbations on atmospheric composition and chemistry. The GMI team (GEST investigators: Susan Strahan, Bryan Duncan and Yasuko Yoshida) continued the

development of a new CTM that has a combined chemical mechanism for both the troposphere and stratosphere.

Susan Strahan has developed new diagnostics of transport processes in the upper troposphere and lower stratosphere (UT/LS) from satellite and aircraft trace gas data sets. They have been used to evaluate two simulations of the GMI Combo CTM, one using meteorological fields from a general circulation model (GCM) and the other using fields from a data assimilation system (DAS). The diagnostics identified many realistic features in the Combo-GCM simulation and support the use of this model in the study of UT/LS phenomena. Evaluation of the Combo-DAS showed surprising realism in the UT/LS, making this model very useful for the interpretation of Aura satellite data. Several multi-decadal GMI simulations were used to assess model uncertainties involved in predicting future ozone recovery.

Bryan Duncan and Mark Schoeberl (NASA GSFC) used the GMI model to interpret the characteristics of the stratospheric 'tape recorder' in carbon monoxide (CO) (a seasonal oscillation in tropical lower stratospheric CO), in the Microwave Limb Sounder (MLS) data on AURA satellite, which are linked to seasonal biomass burning. The CO tape recorder was well reproduced by the GMI COMBO CTM. Duncan, with Jerry Ziemke and Sushil Chandra, compared the seasonal and zonal characteristics of the model's tropospheric column ozone (TCO) with ozone measurements from the Ozone Monitoring Instrument (OMI) and MLS instruments. He has collaborated with Jennifer Logan to study the uncertainties in the emissions and chemistry of CO.

Yasuko Yoshida has compared the GMI CO with aircraft data measured by Measurement of Ozone and water vapour by Airbus in-service aircraft (MOZAIC) and Japan Air Line (JAL). She also has evaluated GMI ozone (O_3) using surface measurement data provided by U.S. Environmental Protection Agency (EPA) and the Cooperative Programme for Monitoring and Evaluation of Long-range Transmission of Air Pollutants in Europe (EMEP).

Thomas L. Diehl continued improving the Goddard Chemistry Aerosol Radiation and Transport model (GOCART), to investigate the influence of aerosols on air quality and climate radiative forcing. GOCART is a global scale model and is driven by assimilated meteorological data from the GEOS-4 DAS. It can simulate the major atmospheric aerosols, including sulfate, dust, black carbon, organic carbon and sea-salt, from both natural and anthropogenic sources. A major accomplishment was the compilation of a global emission inventory for the period 1980-2000 (extending to 2005 for some emissions) for both anthropogenic and natural emissions of black carbon, organic carbon, and SO_2. This inventory was used in a preliminary GOCART simulation for 2000-2005. Other research foci included the investigation of various satellite fire data based methods for calculating biomass burning emissions. He participated in the AeroCom project, contributing to a study of the effects of unified aerosol sources on the global aerosol fields simulated by different models. He has also participated in a number of multi-model studies coordinated by the Task Force on Hemispheric Transport of Air Pollution.

Huisheng Bian continued development, improvement and intercomparisons of different CTMs. She has improved GMI aerosol simulations based on the inter-model comparisons between GMI and GOCART models. She has used the on-line CTM coupled with Goddard Global Modeling and Assimilation Office (GMAO) GEOS-4 Data Assimilation System (DAS) to forecast aerosol and CO/CO_2 fields for mission planning support. She has used Unified CTM (UCTM) to characterize the impact on CO_2 atmospheric distribution due to convective cloud transport and also examined the influence of biomass burning emission on CO simulations by comparing simulated CO using different biomass burning inventories.

Stratosphere-troposphere exchange (STE) and the influence of climate change on the stratospheric circulation were primary topics of Mark Olsen's research. Science issues addressed include ozone trends in the upper-troposphere/lower-stratosphere; seasonal and interannual trends in STE of total mass and ozone mass; the importance of STE to climate change; and the transport of water vapor from the

troposphere to the stratosphere. His initial results show that there is a global moist bias in the upper-troposphere/lower-stratosphere of the operational Global Forecast System and North American Mesoscale analyses compared with new MLS satellite observations.

New satellite data sets

The NASA EOS-Aura satellite was launched in July 2004 in a sun-synchronous afternoon polar orbit. The four atmospheric instruments onboard Aura instruments are: the High Resolution Dynamics Limb Sounder (HIRDLS), measuring infrared emission profiles from high resolution atmospheric limb scans behind Aura; the Microwave Limb Sounder (MLS), obtaining limb emission profiles ahead of the satellite; the Ozone Monitoring Instrument (OMI), a nadir-viewing UV/VIS imaging spectrometer with high spatial resolution; and the Tropospheric Emission Spectrometer (TES), a Fourier Transform infrared spectrometer measuring in both the nadir and the limb mode behind Aura. Members of ACD group have been analyzing data primarily from OMI and MLS instruments.

Jerry Ziemke and Sushil Chandra continued to maintain and refine the NASA satellite-derived data sets of tropospheric column ozone (TCO) and stratospheric column ozone (SCO). With Bryan Duncan they have compared OMI/MLS ozone fields with derived from the GMI COMBO CTM (see figure). Ozone data in conjunction with water vapor data from the Aura MLS are used to study the effects of intra-seasonal and El Nino related changes in the troposphere.

An algorithm to infer troposheric and stratospheric column nitrogen dioxide distribution from the AURA OMI instrument has been developed by Eric Bucsela. OMI NO_2 data were released to the public in Fall 2006. He continued improving the algorithm and analyzed OMI data to detect NO_2 produced by lightning.

Mark Wenig continued developing the OMI NO_2 level 2 to level 3 data processing algorithm. Two gridded NO_2 data products were created, global maps of the total vertical column densities and global maps of the tropospheric vertical column densities, both on a 0.25º x 0.25º grid. He has developed an advanced gridding process, based on the measurement errors, viewing geometry and the OMI ground pixel size, as well as the fractional cloud cover. A detailed analysis of the OMI NO_2 data had been performed. The data sets that consists of daily and monthly maps, are now available on a website which also features the possibility of viewing the data using Google Earth.

Nickolay Krotkov and Kai Yang have developed algorithms and released the first public SO_2 data from OMI. The Aura-OMI Level-2 Sulfur Dioxide Product, 'OMSO2,' is now publicly available from the NASA's GSFC Earth Sciences Data and Information Services Center. The public OMI SO_2 data have been greatly improved compared to the provisional data generated just a year ago. This new data set is suitable for measuring anthropogenic SO_2 emissions and quantification of SO_2 tonnage from volcanic degassing and eruptions. A new SO_2 measurement oriented web site has been created in collaboration with JCET scientists.

Satellite Data Analysis and Validation

The successful validation of geophysical data products from Aura require sufficient planning for comparisons and validation, and the realization that this task should involve a significant group of scientists and support personnel both before and after launch. Bojan Bojkov manages the Aura Validation Data Center (AVDC), a centralized, long-term, archive for validation data hosted by the Atmospheric Chemistry and Dynamics Branch at GSFC. The AVDC mission is to support the Earth Observing System (EOS)-Aura validation and science activities, and the future “A-Train” Earth Science satellites validation activities. He has also organized the Sodankyla total ozone column intercomparisons campaign in Northern Finland and the ozonesonde balloon component of Summer 2006 Water Vapor Validation Experiments (WAVES) in Beltsville, MD.

For the SAUNA campaigns, the organization, logistics and data support for the campaign were coordinated through GEST on behalf of NASA/GSFC and the European Space Agency (ESA). Observations made by space-based instruments aboard several satellites were tightly integrated into the intercomparison strategy of the SAUNA mission. The effect of ozone and temperature profile on total column measurements was explored using LIDAR and ozonesonde observations. The scientific findings from the SAUNA will improve the absolute accuracy of future total ozone observations made under the extreme conditions of high ozone and large solar zenith angles.

The second part of the Intercontinental Chemical Transport Experiment was conducted in the Spring 2006 to make ground-based and *in situ* measurements of atmospheric trace gases that are also measured by Aura satellite instruments like OMI. Eric Bucsela has compared high-quality profiles of NO_2, measured during INTEX-B with model profiles. His analysis has shown good agreement between the measured profile shapes and those of the model. However, some discrepancies were found in column amounts.

Leslie Lait analyzed satellite, ground and airborne measurements taken during the 2006 Costa Rica Aura Validation Experiment and previous missions. He focused on investigating the dynamical context of atmospheric measurements, using both the quasi-conservative coordinate analysis and trajectory modeling techniques. He is also working with the Goddard Software Integration and Visualization Office (SIVO) to develop a new modular trajectory code that can run on a massively parallel computer to simulate the paths of billions of air parcels simultaneously as they are transported by wind.

Gary Morris also participated in NASA's INTEX-B campaign as well as in the Texas Air Quality Study, Part 2 He launched 90 ozonesondes from Houston and several other sites in Southeast Texas as well as from Valparaiso, Indiana in support of Aura ozone measurements. He has also studied the impact of Alaskan and Canadian fires on Houston ozone pollution levels during the summer of 2004.

Santiago Gassó used a combination of surface visibility and satellite data with a trajectory model to characterize a dust event originating in Patagonia and tracked it across the South Atlantic. The observations indicate that dust from Patagonia can reach the free troposphere over the Sub-Antarctic Ocean. Modeling this event suggests that dust reaches the Antarctic Peninsula. This discovery provides evidence in support of long range transport in Patagonian dust to Antarctica during glacial times.

Satellite Data Assimilation

Data assimilation provides an objective metrics of agreement between satellite observations and numerical models. This is particularly useful when the assimilation system has already been used to study data from existing validated platforms with which one can compare the metrics from the new as yet unvalidated platforms. David Lary is using probability distribution functions and multi-constituent chemical data assimilation, with particular emphasis on EOS Aura validation. He has produced the first multi-year multi-constituent analyses using data assimilation. This covers more than a decade from the launch of UARS to the present, and was performed using the AutoChem software. Lary is also using neural networks to parameterize and accelerate various aspects of atmospheric chemical simulation.

Clark Weaver continued development of an assimilation system for atmospheric aerosols and ocean chlorophyll concentrations. The assimilation system directly utilizes radiances in the visible and near infrared as measured by MODIS on the Earth Observing System (EOS) satellite platforms. He has developed a concept CO_2 profiling algorithm for a future satellite Lidar.

Nickolay A. Krotkov

Task 916-39-176: **Improvement and Application of Multiple Chemical Transport Models (CTMs) in Atmospheric Chemistry Study and Mission Support**

GEST Investigator: Huisheng Bian

Collaborators: Mian Chin (GSFC, Code 613.3), Randy Kawa (GSFC, Code 613.3)

Abstract

Three Chemistry and Transport Models (CTMs) are being developed and/or improved in Goddard's Atmospheric Chemistry and Dynamics Branch (code 613.3) for a range of scientific objectives. Global Modeling Initiative (GMI) serves as a comprehensive test bed which can be used for assessment of the impact of various natural and anthropogenic perturbations on atmospheric composition and chemistry. GMI aerosol simulations have been improved based on the inter-model comparisons between GMI and GOCART. The CTM coupled with Goddard Global Modeling and Assimilation Office (GMAO) GEOS-4 system forecasts aerosol and CO/CO_2 fields for mission planning support. CO and CO_2 simulated by GEOS-4 have been evaluated against surface, aircraft, and satellite measurements. Unified CTM (UCTM) can be used easily to explore new and innovative ideas to fill identified scientific gaps. It has been used to characterize the impact on CO_2 atmospheric distribution due to convective cloud transport. It has also been used to examine the influence of biomass burning emission on CO simulations by comparing simulated CO using different biomass burning inventories and evaluated these CO distributions with measurements.

Description of Research

All three models share common features to provide global chemical and aerosol perspective to aid in interpreting surface, aircraft and satellite observations and comparisons. However, each model is specifically designed to pursue its particular purpose. GMI is designed to maintain a state-of-the-art modular 3-D chemistry and transport model that can be used for the assessment of various complex atmospheric chemical processes. Compared with UCTM, GMI is more comprehensive and sophisticated, but it requires more expensive calculation and technical support. GEOS-4 calculates tracer distribution on-line in a global circulation model. This feature enables it to provide real time interaction between meteorological fields and tracer's dynamical and chemical processes. Therefore, GEOS-4 is a powerful tool to support field campaign. UCTM is designed in such a way that each physical and chemistry module can be easily upgraded through an interface. UCTM focuses on studying tracers which are not involved in complex chemical processes. Its concise and flexible features make it a good test bed for exploring new and innovative algorithms. The researcher's efforts in these models' development and improvement are expected to provide powerful and suitable tools for scientific research which focuses on chemical/dynamical processes in the Earth's atmosphere while emphasizing the support of mission (AURA) and mission planning activities (CR-AVE and TC4).

Accomplishments during the Reporting Period

The GEST investigator has been engaged in the development, improvement and application of all three models in the reporting period. First, she implemented a GOCART-like aerosol module into GMI so that she could compare it with existing GMI aerosol modules (GMI-UMich) within a single GMI model framework. The strengths and shortcomings of the two aerosol modules within GMI were investigated by evaluating the simulated aerosol mass and AOT with various measurements from ground stations (*e.g.* IMPROVE network and AERONET), aircrafts (*e.g.*, ACE-Asia and TRACE-P), to satellites (*e.g.*, MODIS and MISR). This work demonstrates that the GMI-UMich aerosol module gives a better simulation for aerosol components that involves a chemistry process such as sulfate, while GOCART-like aerosol module does a better job for aerosol components that are controlled mainly by meteorological fields. The goal is to improve the aerosol simulation by exploring

these multiple choices and then integrating them into an optimized science and technical solution.

Second, CO and CO_2 simulated by GEOS-4 are evaluated using satellite and surface station measurements. Unlike offline models of GMI and UCTM, GEOS-4 can provide various meteorological fields by using different constrains of assimilation data. The research team used GEOS-4 to investigate the influence on CO and CO_2 simulation under three meteorological modes: 1. free GCM field; 2. assimilated meteorological field but water vapor is still come from free GCM; 3. assimilated meteorological field including water vapor. This work is an initial step for a funded 5-year NASA project which is going to assimilate CO_2 into the GEOS-5 system. In addition, the forecast provided by GEOS-4 for CO, CO_2, and aerosol has been used in learning proposed flight conditions in CR-AVE field campaign and will be used to support an upcoming campaign of TC4. In the UT/LS, CO and aerosol are key validation objectives. The post-campaign analyses by comparison of model simulations with Aura and aircraft measurements will help the researchers understand mission data in terms of constituent gradients and temporal changes caused by chemical and transport processes in the troposphere and stratosphere.

Third, Bian continued previous work on using UCTM to understand various scientific questions. She explored the impact on calculated atmospheric CO_2 distributions by using three convective transport approximations ranging from simple to complex forms [Bian *et al.*, 2006]. This work indicates the crucial importance of quantifying the transport error in CO_2 simulations. It also indicates that differences between the convective transport forms have similar magnitudes of uncertainty as the emissions, in the context of agreement between CO_2 simulations and observations. This result highlights the intricate nature of simulating the Earth system, where balances between different processes (in this case uncertainties in convective transports and emissions) can obscure the physical nature of relationships within the system. In addition, Bian investigated the sensitivity of CO simulation to several biomass burning emission inventories, including four bottom-up and two top-down inventories [Bian *et al.*, 2007], because one of the largest uncertainties for global CO simulation is the biomass burning source. This work indicates that the variation is within 30% for the global annual emissions of these six biomass burning inventories. However, their regional variations are generally 2-5 times between highest and lowest emissions during the biomass burning seasons. These uncertainties translate to about 6% variations in the global simulated CO.

Objectives for the Coming Year

In the coming year, GMI aerosol simulations will be further improved by conducting sensitivity experiments to address following issues: 1) How does sedimentation influence the coarse mode aerosol simulation? and 2) What is the optimal time step for AOT calculation in terms of RH variation over high RH regions and where and when is AOT most sensitive to the change of RH? The improved GMI aerosol simulations will be provided to the internationally coordinated multi-model studies of the Hemispheric Transport of Atmospheric Pollutants (HTAP). The researcher will start to implement the coupling of GMI gas and aerosol simulations to study how interactions between the two phases effect atmospheric chemistry and climate.

Task 610-75-262: **Acquisition and Disbursement of Aura Validation Through the Aura Validation Data Center**

GEST Investigator: Bojan Bojkov

Collaborators: Mark Schoeberl (GSFC, Code 610.0), P. K. Bhartia (GSFC, Code 613.3), R. D. McPeters (GSFC, Code 613.3), T. J. McGee (GSFC, Code 613.3), Jay Herman (GSFC, Code 613.3), David Whiteman (GSFC, Code 613.1), Belay Demoz (GSFC, Code 613.1)

Abstract

The NASA EOS-Aura satellite was launched in July 2004 in a sun-synchronous polar orbit (~13:45 equatorial crossing time). The four atmospheric instruments onboard Aura instruments are: the High Resolution Dynamics Limb Sounder (HIRDLS), measuring infrared emission profiles from high resolution atmospheric limb scans behind Aura; the Microwave Limb Sounder (MLS), obtaining limb emission profiles ahead of the satellite; the Ozone Monitoring Instrument (OMI), a nadir-viewing UV/VIS imaging spectrometer with high spatial resolution; and the Tropospheric Emission Spectrometer (TES), a Fourier Transform infrared spectrometer measuring in both the nadir and the limb mode behind Aura. The successful validation of geophysical data products from Aura require either that uncertainty estimates for the geophysical products have been shown to hold, or based on independent comparisons with similar high quality data products that have already been validated themselves. As a result of the coordinated validation efforts, a data user should have enough information to understand the data quality, in terms of precision and accuracy, as well as spatial/temporal variations in these quality attributes. This requires sufficient planning for comparisons and validation, and the realization that this task should involve a significant group of scientists and support personnel both before and after launch.

Description of Research

The purpose of this task is to support the validation efforts of the data products from the four atmospheric chemistry instruments on the EOS-Aura satellite. The work consists of two activities: 1) The operation of the Aura Validation Data Center (AVDC, http://avdc.gsfc.nasa.gov) - providing the central data archive, and supporting the validation efforts of the Aura instrument teams, NRA investigators, and national and international ground-truth and satellite data providers; and 2) The support and/or coordination of NASA aircraft, field and validation campaigns – by providing organizational, logistical and data support.

Accomplishments during the Reporting Period

Many of the activities under this task focused on logistical and data support for the three NASA lead field campaigns: the Sodankyla total ozone column intercomparisons campaigns in Northern Finland (SAUNA, SAUNA2 – http://fmiarc.fmi.fi/SAUNA/) and the ozonsonde balloon component of Summer 2006 Water Vapor Validation Experiments (WAVES) in Beltsville, MD. For the SAUNA campaigns, the organization, logistics and data support for the campaign were coordinated through GEST on behalf of NASA/GSFC and the European Space Agency (ESA).

The AVDC routine activities have continued through this reporting period. Most actions involved direct support of the four Aura instrument teams by providing instrument data subsetting capabilities and field of view (FOV) prediction capabilities for campaigns and ground stations. In addition, the collection and hosting of ground-truth data, a collaborative effort with the Network for the Detection of Atmospheric Composition Change (NDACC), the ESA Envisat Cal/Val activities and national measurement networks, is ongoing. This time-consuming activity allows for rigorous intercomparison and validation of the Aura products.

Objectives for the Coming Year

The GEST investigator will maintain and expand the AVDC. Bojkov will also be publishing results from the SAUNA and WAVES campaigns.

Task 916-13-121: **Climate and Trace Species**

GEST Investigator: Eric Bucsela

Collaborators: James Gleason (GSFC, Code 613.3), Edward Celarier (GSFC, Code 613.3), Mark Wenig (GSFC, Code 613.3), P. K. Bhartia (GSFC, Code 613.3), Kenneth Pickering (GSFC, Code 613.3), Anne Perring (UC Berkeley), Tim Bertram (UC Berkeley), Ron Cohen (UC Berkeley), Paul Wooldridge (UC Berkeley), Pepjin Veefkind (KNMI), Ellen Brinksma (KNMI), Folkert Boersma (Harvard Univ.)

Abstract

Fiscal year 2006-7 saw completion of major projects involving the development and validation of the OMI NO_2 standard data product. The second part of the Intercontinental Chemical Transport Experiment (INTEX-B) was conducted in the Spring of 2006 to make ground-based and *in situ* measurements of atmospheric trace gases that are also measured by Aura satellite instruments like OMI. The data included high-quality profiles of NO_2, which were compared with model profiles. Analysis showed good agreement between the measured profile shapes and those of the model. However some discrepancies were seen in the overall column amounts. A paper describing the development of the OMI NO_2 algorithm was also accepted and published in the journal *IEEE/TGARS* this year. Algorithm improvements continued, and the OMI NO_2 data were released to the public in the Fall of 2006. OMI measurements were also analyzed to detect NO_2 produced by lightning. A paper to *Geophysical Research Letters* describing an analysis of sprite spectra was reviewed.

Description of Research

The principal objective of the past year's research was to support trace-gas-retrieval for the EOS AURA mission. Work focused on NO_2 retrievals from OMI, and on ground- and especially aircraft-based validation programs. The goal was to better understand results from the instrument, deployed on the EOS AURA satellite in July 2004, and to prepare the data for its public release. Measurements made during validation experiments were intended both to verify NO_2 amounts from OMI and to use profile data to improve the retrieval algorithm. Additional goals included improved understanding of the instrument calibration and characterization of retrieval uncertainties.

Accomplishments during the Reporting Period

During 2006, the OMI NO_2 data were publicly released, and a paper describing the algorithm was published. The paper presents results of a study using model output from GEOS-CHEM to optimize retrieval parameters in the algorithm. Results show that optimal accuracy is obtained by masking regions of the initial VCD field having estimated *a priori* tropospheric NO_2 amounts greater than 0.5e15 cm^{-2} and then smoothing the remaining field with a wave-2 function around latitude bands. Differences between the initial and smoothed VCD fields are adjusted with a tropospheric AMF only where the difference is positive. The result is the combined lower and middle tropospheric NO_2 amount. A small upper-tropospheric component (equal to ~5% of the smooth field) is then added to that to give the total tropospheric column. In cases where the difference is negative, the total tropospheric amount is equal to the small upper tropospheric VCD.

In preparation for the data release, several improvements on the algorithm were made. These included the addition of an estimate of the NO_2 amount hidden by any clouds within the OMI field of view, as well as better error estimates. The error estimates were based on a model study of GEOS-CHEM output. Examining statistics of the model output

revealed how daily variations in NO_2 amounts and profile shapes could be used to estimate the uncertainty in the tropospheric air mass factor. Standard Gaussian error propagation techniques were used to combine profile uncertainties with albedo and cloud uncertainties to determine AMF errors for clear and cloudy scenes. Under clear skies, the AMF uncertainty was found to depend mainly on albedo. In typical cases the uncertainty is on the order of 35%. Under cloudy skies, the AMF uncertainty is dependent on the a priori profile shape and is approximately equal to the fraction of NO_2 in the profile below the cloud top.

Uncertainties in the NO_2 column amounts are found by combining the AMF uncertainties with the slant column uncertainty. Due to large slant column errors in the current algorithm, typical tropospheric NO_2 uncertainties are near 100%. It is hoped that improvements in the Level-1b data will reduce the slant column errors and hence the tropospheric column errors.

During the past year, a number of validation campaigns were conducted. One of the largest of these was the Intercontinental Chemical Transport Experiment (INTEX-B). Bucsela joined the first phase of this campaign, which was based in Houston, TX during March. The Houston phase focused on measurements in and around the Gulf of Mexico, with several flights to look at outflow from Mexico City. The latter part of INTEX-B covered areas of the Pacific Ocean. From these flights, approximately 100 *in situ* NO_2 profiles were obtained. Analysis showed them to be similar to the GEOS-CHEM model profiles that are used in the current OMI NO_2 algorithm, but with more apparent vertical structure. However, AMFs calculated with both the modeled and measured profiles differed by about 15% or less. The vertical columns computed by integrating the INTEX-B profiles were compared with the OMI tropospheric NO_2 column retrievals. Initial analysis showed them to be nearly twice as large as the OMI columns. This work was presented at the Fall meeting of the AGU in San Francisco. Analysis of the flight data continues, and recent re-examination of the data shows reduced disagreement between the *in situ* and satellite measurements.

Other projects in the past year included studies of NO_2 from lightning. Initial comparisons between OMI measurements and aircraft campaigns over South America and Australia yielded ambiguous results, due to noise in the OMI data. Further work, focusing on other days or using averages of several days is planned for the upcoming year. Another study involving red sprites, which are produced in the vicinity of thunderstorms, was reviewed.

Objectives for the Coming Year

Future work during fiscal year 2007-8 will involve continued characterization of the OMI instrument, refinement of the algorithm, and analysis of the data. Based on information gleaned from validation campaigns and from improved understanding of the OMI detector, the data product will be improved. Findings from the past year will be implemented in the next public release, expected during the summer or fall of 2007. Further research will continue in understanding discrepancies between the OMI measurements and ground-based NO_2 columns, including the direct-sun measurements made at GSFC. Improved characterization of the NO_2 amounts detected from satellites can be used to help determine anthropogenic source strengths. An in-depth study of lightning-produced NO_2 using OMI satellite and aircraft measurements is also planned. Better understanding of NO_2 seen in and around clouds is needed to interpret the data, and it is hoped that progress will be made in this area. Additional studies will be undertaken as funding permits.

Task 00001762: **Climate Change Science Program through a NASA Supported Intergovernmental Personnel Act Appointment**

GEST Investigator: Robert J. Curran

Collaborators: Jack Kaye (NASA HQ), Peter Schultz (Acting Director, CCSPO)

Abstract

Support of the Climate Change Science Program at NASA by providing reporting and tracking of science initiatives and policy plans across Governmental agencies.

Description of Work

Curran continues his affiliation with UMBC – GEST through a NASA provided, Intergovernmental Personnel Act position in the U. S. Climate Change Science Program Office. The U.S. Climate Change Science Program (CCSP) is a collaborative interagency program designed to improve the government wide management of climate science, integrating the U.S. Global Change Research Program (USGCRP) with the U. S. Climate Change Research Initiative. The USGCRP was established by congress in 1990 to enhance understanding of natural and human-induced changes in the Earth's global environmental system; to monitor, understand, and predict global change; and to provide a scientific basis for decision-making. The congressional act that established the USGCRP mandated an annual report to congress that summarizes recent achievements by the 13 federal agencies involved in climate research, their near term plans, and their progress in implementing long term goals. In addition it provides an overview of recent and near-term expenditures and of requested funding. The annual report, entitled *Our Changing Planet*, is also widely used by the scientific community and others who are interested in global environmental change research as a means of tracking the program's progress and plans. Curran serves as lead editor for *Our Changing Planet*, responsible for document's development, relevant budgetary information and distribution.

In addition to his editorship responsibilities, Curran serves as liaison to the interagency working group on Atmospheric Composition. This working group is composed of the federal agency program managers having the responsibility to implement research programs related to Atmospheric Composition. The working group also oversees the development of integrated science and implementation plans relevant to Atmospheric Composition and Climate Change. Simply put, the Atmospheric Composition working group is a forum in which the relevant federal agencies sponsoring research in atmospheric composition (gaseous and particulate) and its interaction with climate change meet to plan their reporting of results and plans.

Accomplishments during the Reporting Period

The fiscal year 2007 edition of *Our Changing Planet* was developed, published and distributed during the reporting period. Development of the financial appendices that accompany *Our Changing Planet* was a new requirement for this position starting in the past year. This requirement necessitated significant collaboration with the agencies and departments of the federal government supporting Climate Change research. The final version of this document, including the financial appendices was published in December 2006 and is currently available on the web at: http://www.usgcrp.gov/usgcrp/Library/ocp2007/default.htm.

Plans for the Coming Year

In the fall of 2006, it was decided that to provide timely support for release of the President's FY2008 budget, a brief "Our Changing Planet FY2008 - Preview" would be published in March 2007. This Preview will be followed by the publication of a more substantial *Our Changing Planet FY2008 - Annual Report* in late summer 2007. The development of both documents is well underway and expected to meet schedule.

The CCSP atmospheric composition interagency working group is responsible for two of the 21 – CCSP Synthesis and Assessment Products, which are scheduled for completion in the coming year. The synthesis and assessment products integrate climate related research results focused on key issues and related questions frequently raised by decision makers. The two products are (1) Aerosol properties and their impacts on climate, and (2) Trends in emissions of ozone-depleting substances, ozone layer recovery, and implications for ultraviolet radiation exposure

Coordination will be provided to the atmospheric composition working group for the development of these products.

Task 916-62-216: **Three-Dimensional Modeling of Atmospheric Chemistry and Aerosol Processes**

GEST Investigator: Thomas L. Diehl

Collaborators: Mian Chin (PI, GSFC, Code 613.3), Peter Colarco (GSFC, Code 613.3), Bryan Duncan, Huisheng Bian, Tom Kucsera, Alexander Smirnov, Brent Holben (GSFC, Code 614.4), David Giles (SSAI), Charles Ichoku (ESSIC), Mariya Petrenko (Purdue Univ.)

Abstract

A major accomplishment during the reporting period was the compilation of a global emission inventory for the period 1980-2000 (extending to 2005 for some emissions) for both anthropogenic and natural emissions of black carbon, organic carbon, and SO_2. This inventory was used in a preliminary GOCART simulation for 2000-2005. Other research foci included the investigation of various satellite fire data based methods for calculating biomass burning emissions, where the team found an 8-day averaged MODIS fire count product to be a useful compromise. Diehl continued his participation in the AeroCom project, contributing to a study of the effects of unified aerosol sources on aerosol fields simulated by different models. Recently, he also participated in a number of multi-model studies coordinated by the Task Force on Hemispheric Transport of Air Pollution.

Description of Research

The goal of this task is to develop and extend the Goddard Chemistry Aerosol Radiation and Transport model (GOCART), use it to investigate the influence of aerosols on air quality and climate radiative forcing, quantify the intercontinental transport of natural and anthropogenic aerosols, understand the chemical, optical and microphysical properties of aerosols and the processes that control these properties, and improve the sources and processes in the model based on datasets from satellites, networks of ground stations like Aeronet and in-situ measurements. GOCART can simulate the major atmospheric aerosols, including sulfate, dust, black carbon, organic carbon and sea-salt, from both natural and anthropogenic sources. It is a global scale model and is driven by assimilated meteorological data from the GEOS DAS.

Accomplishments during the Reporting Period

A time-dependent global emission inventory for the period 1980-2000 (extending to 2005 for some emissions) was compiled for black carbon, organic carbon, and SO_2 in a horizontal resolution of 1.0°x1.0° and regridded to 1.25°x1.0° and 2.5°x2.0° [Diehl *et al.*, 2006]. This inventory is a prerequisite to analyze multi-decadal aerosol trends and effects on surface radiation and air quality using the GOCART model and estimate the relative contributions of local emissions and long-range transport to the regional surface solar radiation and air quality trends. The inventory includes emissions over land due to biofuel, fuel combustion and other anthropogenic sources; emissions due to biomass burning; emissions from international ship traffic; 3-dimensional emissions from air traffic; and volcanic emissions from both eruptive events and continuous degassing. Oxidant fields required by GOCART (OH, NO_3,

H_2O_2) were obtained from the RETRO project. A preliminary GOCART run for the period 2000-2005 using this inventory was completed and the results are currently being analyzed.

The researcher investigated several satellite fire data based methods for calculating biomass burning emissions. In one study [Petrenko *et al.*, 2007], Diehl estimated daily variations of black and organic carbon emissions from boreal forest fires during July 2004 in North America. The study estimated carbon consumption based on 10 different ecozones and 3 degrees of fire severity. This method yields about 2x1011 kg for the dry mass burnt, which is about 3 times larger than the value provided by the GFEDv2 inventory. The corresponding aerosol optical depth is generally in better agreement with MODIS than the GFEDv2 based values. In a related study [Chin *et al.*, 2006], Diehl compared the biomass burning emissions from several sources: the monthly GFEDv2 dataset, daily MODIS fire counts, 8-day averages of MODIS fire counts, and a method based on the daily MODIS fire radiative power. It was found that monthly averaged emissions are not adequate for capturing large variations of aerosols near the source region, but are not problematic for places where emissions are always present during the burning season (*e.g.*, South America and Africa), and for places located far away from sources. Daily values on the other hand contain many gaps, and 8-day averaged datasets were found to be a good compromise.

Diehl continued his participation in the AeroCom initiative, contributing to a study of the effects of unified aerosol sources on global aerosol fields simulated by different models [Textor *et al.*, 2007]. In this study, results from two AeroCom experiments are compared, where one experiment (ExpA) has different and the other one (ExpB) has unified emissions, injection heights, and particle sizes at the source. Surprisingly, harmonization of aerosol sources has only a small impact on the simulated diversity for aerosol burden, and consequently optical properties, as the results are largely controlled by model-specific transport, removal, chemistry and parameterizations of aerosol microphysics and to a lesser extent by the spatial and temporal distributions of the emissions.

Recently, Diehl participated in multi-model studies coordinated by the Task Force on Hemispheric Transport of Air Pollution (HTAP). This task force has been set up to develop a better understanding of the intercontinental transport of air pollutants in the Northern Hemisphere and to produce estimates of the intercontinental flows of air pollutants for consideration in the review of protocols under the Convention on Long–Range Transboundary Air Pollution (CLRTAP). A number of source-receptor studies were conducted. These simulations consisted of a GOCART reference simulation for the year 2001 (to establish a reference against which the perturbation experiments can be compared) and 4 simulations where the anthropogenic emissions were reduced in 4 specified regions by 20% (to evaluate the non-linearities involved in changing various emissions simultaneously). Additionally, a passive CO tracer run was conducted to evaluate the transport characteristics of individual models. The results are currently being evaluated for the first interim report.

Objectives for the Coming Year

A key goal will be to conduct a 26 year simulation of tropospheric aerosols from 1980 to 2005 in a 1.25°x1.0° resolution to investigate the atmospheric response to changes caused by human activities and natural events. The researchers plan to enhance the quality of aerosol retrieval products from the OMI instrument using a combination of GOCART data and observational data. An alternative numerical scheme with less diffusive properties for the treatment of the gravitational settling will be investigated. Diehl also plans to estimate the fire severity based on the environmental conditions using the Lower Atmosphere Stability Index (Haines index) and to investigate different approaches to determine the injection height for emissions from biomass burning.

Task 00001213: **Study of the budget, emissions, and long-range transport of carbon monoxide**

GEST Investigator: Bryan N. Duncan

Collaborators: Susan Strahan, Jose Rodriguez (GSFC, Code 613.3)

Abstract

The budget, emissions, and long-range transport of carbon monoxide (CO) were studied with the intent to better understand this important tropospheric trace gas. Duncan used a chemical tracer model (CTM) to constrain the sources and sinks of CO and to understand the causes of observed trends from 1988-1997. The researchers conducted a modeling study of the cross-tropopause transport of biomass burning pollution, including from the 1997 Indonesian wildfires, using CO as a tracer of transport.

Description of Research

For this research, the team used the Global Modeling Initiative (GMI) combined stratosphere-troposphere CTM and the GEOS-Chem CTM to study CO, which plays important roles in atmospheric chemistry. Reaction with CO provides the dominant sink for the hydroxyl radical (OH), the main tropospheric oxidant, and oxidation of CO provides a source or a sink for ozone, depending on levels of nitrogen oxides. Changes in emissions of CO have the potential to influence climate by affecting methane and other radiatively important gases that are removed by OH, and by affecting tropospheric ozone itself. Duncan focused on the period 1988-1997 for analysis as there were major changes in the distributions of anthropogenic emissions (*e.g.*, the economic contraction of the former Soviet Union and the rapid industrialization of East Asia) and several large tropical biomass burning events, including major fires in Indonesia in 1997.

Accomplishments during the Reporting Period

The researchers used the COMBO CTM to study the troposphere-to-stratosphere transport (TST) of pollution from major biomass burning regions to the tropical tropopause layer (TTL) and lower stratosphere (LS) [Duncan *et al.*, 2007a, submitted to *Atmos. Chem. Phys. Disc.*]. Duncan found that biomass burning pollution regularly and significantly impacts the composition of the TTL/LS. TST occurs through 1) slow ascent in the TTL and 2) quasi-horizontal exchange in the regions of the subtropical jets. The seasonal oscillation in CO in the TTL/LS (*i.e.*, the CO "tape recorder") is caused largely by seasonal changes in biomass burning. Another contributing factor is the long-range transport of northern hemispheric pollution (*e.g.*, biofuels and fossil fuels) to the northern tropics in boreal winter. Other tropical sources of CO (*e.g.*, methane oxidation) have insignificant seasonal variation, contributing little to the tape recorder. Interannual variation of CO in the TTL/LS is caused by year-to-year variations in biomass burning and the strength, frequency, and locations of deep convection, which lofts pollution to the upper troposphere. During the study period, 1994-1998, the team found that the highest concentrations of CO in the TTL/LS occur during the strong 1997/98 El Niño event for two reasons: tropical deep convection was stronger and emissions were higher. This extreme event can be seen as an upper bound on the impact of biomass burning pollution on the TTL/LS. Duncan's team estimated that the 1997 Indonesian Wildfires increased CO in the entire TTL and tropical LS (<60 mb) by more than 40% and 10%, respectively, for several months. Zonal mean ozone increased and the hydroxyl radical decreased by as much as 20%, increasing the lifetimes and, subsequently TST, of trace gases. Their results indicate that the impact of biomass burning pollution on the TTL/LS is likely greatest during an El Niño event due to favorable dynamics and historically higher burning rates.

Duncan collaborated with Jennifer Logan on a study to look at the uncertainties in the emissions and chemistry of CO [Duncan *et al.*, 2007b, submitted to *J. Geohys. Res.*]. They presented a model study of CO for 1988 – 1997 using the GEOS-Chem CTM driven by assimilated meteorological data, with time-varying emissions from biomass burning and

from fossil fuel and industry, overhead ozone columns, and methane. The hydroxyl radical was calculated interactively using a chemical parameterization to capture chemical feedbacks. They documented the inventory for fossil fuels/industry, and discussed major uncertainties and the causes of differences with other inventories that give significantly lower emissions. They found that emissions hardly changed from 1988 to 1997, as increases in Asia were offset by decreases elsewhere. The model reproduces the 20% decrease in CO at high northern latitudes and the 10% decrease in the North Pacific, caused primarily by the decrease in European emissions. The model compares well with observations at sites impacted by fossil fuel emissions from North America, Europe, and East Asia suggesting that the emissions from this source are reliable to 25%, and the researchers argued that bottom-up emission estimates are likely to be too low rather than too high. The model is too low at the seasonal maximum in spring in the southern tropics, except for locations in the Atlantic Ocean. This problem may be caused by an overestimate of the frequency of tropical deep convection, a common problem in models that use assimilated meteorological data. Duncan and Logan argued that the yield of CO from methane oxidation is near unity, contrary to some other studies, based on removal rates of intermediate species and on model simulations.

Objectives for the Coming Year

Yasuko Yoshida and Duncan will perform COMBO CTM simulations using GEOS-4-DAS and GEOS-4-Forecast fields as applied to the impact of boreal forest fires in 2004 on United States air quality. To evaluate the fidelity of transport in the two simulations, they will compare CTM output with *in situ* observations, such as ground-level ozone from the AIRNow database, and remotely sensed data (*e.g.*, CO from the AIRS instrument). They will concentrate on the summer of 2004, a time with a large number of Canadian forest fires that impacted United States air quality. A plume rise model will be used to account for the lofting of pollution into the free troposphere. The GEST research team will investigate the fire's effect on summertime surface ozone and CO, including the number of violations of the National Ambient Air Quality Standard (NAAQS) for ozone, and the radiative budget by black and organic carbon aerosol.

Duncan will work with Jason West (Princeton University) to simulate the transport of European pollution to northern Africa and the Near East using the COMBO CTM. They will estimate the impact of the ozone perturbation in these regions on human health using the OMI/MLS tropospheric column ozone (TCO) product [Ziemke *et al.*, 2006] to track plume transport.

Task 622-44-16: **Closure in Model Prediction, In-Situ Measurements and Remote Sensing of Aerosol Mass Concentration**

GEST Investigator: Santiago Gassó

Collaborators: Ariel Stein (NOAA), Si-Chee Tsay (GSFC, Code 613.2)

Task 00000706: **Analysis of the Performance of the VIRSS Aerosol Land and Ocean Algorithm**

GEST Investigator: Santiago Gassó

Collaborator: Omar Torres (PI, JCET)

Abstract

Two separate research activities were performed during the year 2006. One project consisted in the characterization of a dust event from the Patagonia desert and the tracking of the dust transport across the South Atlantic. The observations indicate that dust from Patagonia can reach the free troposphere over into the Sub-

Antarctic Ocean and the modeling of the same event suggests that dust reaches the Antarctic Peninsula. This find provides evidence in support of long range of transport in Patagonian dust to Antarctica during glacial times. The second project consisted on an analysis of the VIIRS aerosol retrieval algorithm in different computer platforms and the derivation of research version of the code. The preliminary tests indicate that the code is stable (*i.e.*, it achieves the same results in different platforms) and the retrieval accuracy of AOTs over ocean are well within design specifications.

Description of Research

The role of the Southern Ocean (SO) as a regulator and storage of atmospheric CO_2 has been emphasized in several studies (Sarmiento and Toggweiler, 1984; Marinov *et al.*, 2006). Ice-cores studies in Antarctica show that fluctuations in atmospheric CO_2 correlate with dust deposited in the Antarctic ice sheet [Gaspari *et al.*, 2006]. Because dust layers were deposited right before an observed decrease in atmospheric CO_2, one current theory hypothesizes that iron-rich dust blown from Patagonia during the drier glacial times deposited over the SO and promoted removal of atmospheric CO_2 due to the iron-fertilization effect in primary productivity [Martin, 1990; Wolf *et al.*, 2006]. Although controversial, this theory has received a boost in recent years due to the results of dedicated field experiments which showed an increase in phytoplankton mass due to an artificial increase of iron (*e.g.*, Coale *et al.* [2004]). The extent of the iron-fertilization effect and the possibility that it may be occurring in present times downwind of important dust sources has been the object of many modeling studies (*e.g.*, Jickells *et al.* [2006]). In particular, Erickson *et al.* (2003) showed a strong correlation between modeled dust deposition from Patagonia and observed chlorophyll anomalies in the Sub-Antarctic region of the South Atlantic Ocean. However, there is conflicting observational evidence of recent dust activity in Patagonia. Although some surface studies indicate that dust emission in Patagonia follows a seasonal pattern [Gaiero *et al.*, 2003], satellite observations offer a mixed picture. For example, studies with the TOMS detector indicates that Patagonia is an active source of dust [Prospero *et al.*, 2002] but observations with the MODIS detector does not show important dust activity [Kaufman *et al.*, 2002]. Thus, knowledge of dust activity in the area is limited to modeling studies and it is uncertain whether Patagonian dust can reach the high-nutrient low-chlorophyll waters of the Sub-Antarctic Ocean or even Antarctica.

Accomplishments during the Reporting Period

The GEST investigator found for the first time observational evidence of dust emitted in the Patagonia region and its long range transport to the Sub-Antarctic Ocean in the vicinity of the South Georgia Island (54-55°S, 36-38°W). This case study demonstrates the main features of a Patagonian Dust event and it tracks the dust plume through the South Atlantic with the use of two satellite detectors (MODIS and OMI) and an aerosol transport model (HYSPLIT). The researchers used a combination of surface visibility, satellite measurements (MODIS and OMI) and transport model (HYSPLIT) to track and report for the first time a dust event originating in Patagonia. The research team showed that the dust reached the free troposphere in the Sub-Antarctic Atlantic Ocean. Although the dust emission was significant, cloudiness and dilution of the plume resulted in difficult conditions to track dust in the SW Atlantic. They also showed that the use of any single tool (*i.e.*, MODIS or OMI) is not enough to track the dust and only an integrated approach of satellite and modeling tools can achieve a consistent description. As a result, current platforms used for dust detection are probably underestimating aerosol loading in the area.

The analysis of the NPP aerosol algorithm was restricted only to the last months of performance period. For most of the first six months, a number of bureaucratic steps were required to have proper access to computer accounts, software installation issues and computer setups. Most of the actual activities occurred during the second half of 2006. They centered on tests of the VIIRS aerosol retrieval algorithm in different computer platforms, derivation of research version of the code and a MODIS-to-VIIRS translator code. The researchers carried

out preliminary tests of the VIIRS aerosol algorithm and the test indicate that the code is stable (*i.e.*, it achieves the same results in different platforms) and the retrieval accuracy of AOTs over ocean are well within design specifications.

Objectives for the Coming Year

The GEST investigator plans to expand the case-by-case study of dust events in Patagonia with the following goals: determine the possible pathways of dust transport of dust from Patagonia to the Antarctic continent with the use of multiple satellite platforms (MODIS, OMI, CALIPSO) for selected case studies; examine ocean color maps downwind of Patagonia; and determine if there is any ocean color response. A significant amount of time will be dedicated to the preparation of workshop on Patagonian dust to be held in the city of Puerto Madryn, Argentina on October 4-6, 2007.

The plans for next year concentrate in the development of tools and the testing the NPP Aerosol algorithm. Specifically the research team plans the following activities: 1) Implementation of the new version of the VIIRS algorithm. A new version of the code was delivered by Northrop Grumman, the private contractor developing the algorithm, at the end of August and the research stand alone version will be developed. 2) Study algorithm sensitivity. The objective of this task is to understand and quantify the inherent sources of errors within the retrieval algorithm. For example, it is not clear what uncertainties are introduced in the angle interpolation process. The sensitivity of the code to interpolations is not being addressed by the Northrop Grumman team. 3) Characterization of algorithm performance over the ocean. Northrop Grumman current VALOA tests and studies are focused over land and very little resources are dedicated to ocean retrievals. The team intends to complement Northrop Grumman work by comparing retrievals with AERONET data in ocean sites.

Task 916-04-074: **UV Remote Sensing**

GEST Investigator: Nickolay Krotkov

Collaborators: Jay Herman (GFSC, Code 613.3), P. K. Bhartia (GSFC, Code 613.3), Arlin Krueger (JCET), Simon Carn (JCET), Kai Yang

Abstract

Research was focused on the development of applications of satellite UV remote sensing data, such as SO_2 and ultraviolet (UV) surface irradiance from EOS/AURA Ozone Monitoring Instrument (OMI). The focus was on 1) developing operational SO_2 algorithm for OMI instrument; 2) validating OMI SO_2 pollution data with aircraft *in-situ* data; 3) quantifying satellite UV data bias due to pollution aerosol absorption using ground-based remote sensing techniques. The OMI improved sensitivity permits daily global measurement of passive volcanic degassing of SO_2 and of heavy anthropogenic SO_2 pollution to provide new information on the relative importance of these sources for climate studies.

Description of Research

Satellite Remote sensing in near ultraviolet (UV) spectral region (300nm to 400nm) provides unique information on the atmospheric composition: from global ozone depletion to air quality to volcanic emissions to the effects of UV radiation on biosphere and photochemistry. The NASA TOMS data record (http://toms.gsfc.nasa.gov), which now spans more than 28 years, has played a key role in monitoring long-term changes in the ozone layer and has been used to study the progression and inter-annual variability of the polar ozone depletion, popularly known as the “ozone hole.” By combining measurements of total ozone, clouds, aerosols and UV surface albedo from TOMS, an accurate long-term record of surface UV irradiance on a global scale has also been produced. In addition, the TOMS SO_2 and ash volcanic emission data http://toms.umbc.edu

have led to significant advances in several disciplines, from derivations of eruptive sulfur budgets and emission rates, to tracking of individual clouds and assessing global volcanism and atmospheric impacts. The SO_2 detection sensitivity was limited to large volcanic clouds by the discrete TOMS wavelengths that were designed for total ozone measurements. The Dutch-Finnish OMI, launched in July 2004 on the polar-orbiting EOS/Aura satellite, offers unprecedented spatial and spectral resolution, coupled with global contiguous coverage, for space-based UV measurements of SO_2. The OMI SO_2 data set is continuing the TOMS record but the improved sensitivity and smaller footprint of OMI have extended the range of detection to smaller eruptions, degassing volcanoes, and older clouds, and to anthropogenic pollution. Heavy anthropogenic emissions and volcanic degassing in LT/BL were detected on a daily basis (*e.g.*, http://aura.gsfc.nasa.gov; http://www.knmi.nl/omi/research/product/SO2/introduction.html. Using weekly, monthly or annual average SO_2 maps, the team evaluated longer-term trends, and detect weaker degassing and pollution (*e.g.*, http://aura.gsfc.nasa.gov/science/top10_smelters.html). This research focuses on the development of advanced SO_2 and UV algorithms for OMI as well as validation with concurrent satellite and ground-based measurements.

Accomplishments during the Reporting Period

The OMI volcanic algorithm has been improved to provide quantitative estimates of SO_2 loadings in large volcanic clouds (see the report in this volume by Kai Yang). The Aura-OMI Level-2 Sulfur Dioxide Product, 'OMSO2,' is now publicly available from the NASA's GSFC Earth Sciences (GES) Data and Information Services Center (DISC) at http://disc.gsfc.nasa.gov/Aura/OMI/omso2.shtml). The public data set is suitable for measuring anthropogenic SO_2 emissions and quantification of SO_2 tonnage from volcanic degassing and eruptions. Visualization of daily OMI SO_2 data allows rapid appraisal of the most significant volcanic SO_2 emitters, which in 2006 included Merapi (Indonesia), Tungurahua (Ecuador), Soufriere Hills (Montserrat), Aoba (Vanuatu), Nyiragongo (DR Congo) and Ubinas (Peru). These measurements highlight the deficiencies of previous compilations of volcanic SO_2 emissions, which were biased towards accessible, frequently monitored volcanoes. The eruption of the Soufriere Hills volcano (Montserrat) on May 20, 2006 resulted in a stratospheric injection of ~0.2 Tg of SO_2. Despite the modest size of the SO_2 cloud (2 orders of magnitude lower in mass than Pinatubo), OMI was able to track it for over 3 weeks and ~16,000 miles as it traveled westwards from the volcano. Near-coincident CALIPSO Lidar measurements of the stratospheric sulfate aerosol derived from the SO_2 demonstrate the value of joint A-Train observations of volcanic clouds [Carn *et al.*, 2007a]. The Soufriere Hills eruption and one of similar magnitude at Rabaul (Papua New Guinea) in October 2006 were the largest volcanic SO_2 injections of 2006.

Anthropogenic SO_2 emissions have been measured by OMI over known sources of air pollution, such as the Ohio valley in the U.S., eastern China, and Eastern Europe. For example, emissions from two Peruvian smelters (La Oroya and Ilo) were detected in up to 80% of OMI overpasses between September 2004 and June 2005. SO_2 production by each smelter in this period was quantified and compared with contemporaneous emissions from active volcanoes in Ecuador and southern Colombia [Carn *et al.* 2007b]. These results show that OMI can observe SO_2 emissions in the PBL on a daily basis, thereby improving on GOME on ERS-2 and SCIAMACHY on ENVISAT, which need several days to acquire a contiguous global map and hence could miss short-lived pollution events.

An OMI SO_2 validation study was conducted using aircraft *in-situ* SO_2 data collected over Shenyang in northeast China as part of EAST-AIRE field campaign in April 2005. SO_2 observations from instrumented aircraft flights were compared with OMI SO_2 maps on clear and polluted days under favorable observational conditions (no clouds, near nadir viewing directions). The OMI-derived measurements of SO_2 confirm the *in situ* observations of high

concentrations of SO_2 (ca ~2 DU) ahead of the front and lower concentrations behind it. This comparison demonstrates that OMI can distinguish between background SO_2 conditions and heavy pollutions on a daily basis.

The regional plume of SO_2, detected on 5 April over the Shenyang area, was tracked for 4 days by OMI providing evidence for pollution lofting from the PBL and a large-scale impact of Chinese pollutant emissions. The lofting and plume position were confirmed with trajectory modeling and a plume mass was corrected for estimated altitude and underlying cloud reflectivity.

TOMS surface UV irradiance algorithm has been applied to new AURA OMI instrument in collaboration with the Finnish Meteorological Institute (FMI) [Tanskanen *et al.*, 2006]. The noontime Erythemal surface irradiances derived from the OMI measurements were compared with ground based measurements by Brewer spectrometers at several sites. Positive bias was found in regions where the effect of absorbing aerosols was expected. Past TOMS surface UV estimates were also compared with ground-based spectral UV irradiances measurements from 4 European stations [Kazantzidis *et al.*, 2006]. The comparisons showed clear sky positive TOMS bias 5%-20% depending on location. It was found that the bias was increasing with the increasing of both aerosol extinction (AOT) [Kazantzidis *et al*., 2006] and absorption optical thicknesses (AAOT) [Krotkov *et al.*, 2005b; Arola *et al.*, 2005]. To explain the bias, ground-based measurements were continued to quantify absorbing aerosol properties in UV as well as on clear sky direct aerosol forcing of surface UV irradiance. Radiative transfer modeling was extensively used for combining and cross validating different methods of measuring column aerosol absorption and to ensure consistent aerosol retrievals between UV and visible wavelengths [Krotkov *et al.*, 2005].

Objectives for the Coming Year

Operational OMI SO_2 algorithm sensitivity does not represent the maximum sensitivity theoretically achievable with OMI, hence future algorithm improvements (*i.e.*, spectral fitting) should allow even weaker SO_2 sources to be monitored routinely. Krotkov plans to implement an SF SO_2 algorithm operationally in FY07-08. These measurements are expected to produce the best estimates to date of the volcanic and anthropogenic contribution to global atmospheric SO_2 abundances.

The researchers will continue ground-based passive remote sensing of column aerosol and gaseous (SO_2, NO_2, O_3) absorption across UV-visible spectral range at NASA/GSFC site using a combination of instruments and techniques. The team has modified an existing double-grating Brewer spectrometer so that it is very suitable for simultaneously measuring tropospheric ozone profiles, aerosol properties, and trace gas amounts with the goal to determine daytime variability in tropospheric ozone, NO_2, SO_2 and aerosols. For the lower troposphere, this is important since ozone and NO_2 photochemistry is directly involved in determining the amount of pollution in the boundary layer. Based on this research, it is clear that OMI-provided estimates of aerosol absorption have the potential of improving the quality of OMI UV data over polluted areas, by properly including the spectral attenuation effects of carbonaceous, urban/industrial and mineral aerosols. This work is currently undergoing, given its importance in monitoring changes in the surface radiation, particularly the UVA and photo-synthetically-active radiation (PAR).

Task 613-71-244: **Stratospheric Dynamics and Chemistry**

GEST Investigator: Leslie R. Lait

Collaborators: Paul Newman (GSFC, Code 613.3), Mark Schoeberl (GSFC, Code 610.0), Tom Clune (GSFC, Code 610.3), Shanhu Lee (Kent State Univ.)

Abstract

Research activities under this task center around investigating the dynamical context of atmospheric measurements to aid in their interpretation. Using modeled diabatic trajectories, an investigation was begun into the question of how various commonly-used forms of potential vorticity are conserved; this information helps in determining when and how to apply quasi-conservative coordinate analysis. Statistics compiled from multi-decade meteorological analyses were used to identify an eastern extension of the Walker circulation as the cause of differences in measurements taken during the 2006 Costa Rica Aura Validation Experiment (CR-AVE) and a previous mission. Participation was proposed for the Tropical Composition, Cloud, and Climate Coupling (TC4) Experiment, scheduled to take place in summer 2007, and planning activities began to enable near-real-time meteorological data and forecasts; these will aid in directing mission aircraft towards scientifically more interesting air masses. A collaborative effort was continued with the Software Integration and Visualization Office (SIVO) to develop a new modular trajectory code that will be able to run on a massively parallel computer to simulate the paths of billions of air parcels simultaneously as they are transported by the winds.

Description of Research

One goal of this research task is to achieve a synthesis of data from satellite missions, ground sites, and airborne field experiments to obtain a global picture of trace gas distributions. The quasi-conservative coordinate analysis technique [Schoeberl and Lait, 1992] has proven useful in aggregating data from diverse sources and evaluating them quantitatively in terms of their meteorological context. Yet, questions remain about the circumstances under which the method is applicable---for example, the degree to which parcels in fact retain the values of their quasi-conserved quantities.

Another useful tool in interpreting diverse measurements is trajectory modeling, from which one can gain insight into any number of questions, such as how the history of physical conditions that a parcel has recently experienced aids in interpreting measurements from that parcel. A collaborative effort is underway with colleagues in SIVO at GSFC to develop a major new model, “gtraj”, which should permit large simulations not hitherto considered practical.

Another major activity in this task is the support of field experiments. As preparations began for the TC4 mission scheduled to take place in the summer of 2007, it was important to begin characterizing statistically the kinds of dynamical situations the mission is likely to encounter, as well as implementing visualization tools to aid in planning flights of research aircraft.

Accomplishments during the Reporting Period

Work began on an examination of how well various forms of potential vorticity are conserved: regular “Ertel's potential vorticity,” the vertically-scaled “modified potential vorticity” [Lait, 1994] and equivalent latitude. For two sample periods, diabatic parcel trajectories were calculated over a ten-day interval. Population distributions of the potential vorticity at the parcel locations were examined to determine their rates of change over the parcel histories.

A collaboration continued with the GSFC SIVO computational group, whose programmers are writing a high-performance massively-parallel trajectory model. Research staff under this task worked with SIVO to test, evaluate, and improve the model. Test cases were run on the current trajectory model in GSFC Code 613.3, and the results were compared with the new models' output. These comparisons were instrumental in

detecting and fixing flaws in the new code. Once those flaws were corrected, timing experiments were performed by varying the number of parcels and the number of processors used in the trajectory calculations. An effort was also begun to inspect each module of computer code and write documentation for it.

Assistance was provided in fitting annual cycle and quasibiennial oscillation (QBO) signals on data from the HALOE instrument on board the UARS satellite, and the MLS instrument on board Aura. Statistical tests of significance were devised and applied to tropical measurements of H_2O, HCl, O_3, N_2O, CO, HF, and CH_4. The analysis explains fluctuations in these gases in terms of the Brewer-Dobson circulation and the QBO. Results have been written up into a paper to be submitted soon.

Extracts from multi-decade meteorological analyses were obtained for the CR-AVE operational area, and statistical analyses were applied to determine how typical was the dynamical context of the measurements taken. It was found that an eastward jet, part of the Walker circulation, extended further east than usual during CR-AVE, and the consequent difference in the origin of sampled air explains why measurements differed from those taken during a similar mission in 2004. An oral presentation on this analysis was made before the CR-AVE science team meeting in November 2006.

With the task sponsor as PI, members of this research team helped write a proposal for participation in the TC4 field experiment to take place in Costa Rica in July-August 2007. Planning and other preparation work then began for this mission. To identify desirable sampling situations with flow regimes, an empirical orthogonal fit (EOF) analysis was applied to meteorological fields, and hourly GOES satellite imagery was acquired for July-August of 2006. To aid mission scientists in flight planning, software was written to create plots of gridded fields in a form that is viewable by Google Earth, along with proposed flight tracks and upcoming Aura satellite instrument sampling loci.

This research task contributes to the development of the computing infrastructure of the Branch as well. During the reporting period, software was written to streamline a standardized system administration structure by generating system configuration files from a set of XML-formatted host description files. Work continued on introducing the Gentoo version of the Linux operating system into the Branch's data system and administrative environments. Also, a proposal was written and submitted to the NASA ROSES program to modernize certain aspects of the Branch's data system.

Objectives for the Coming Year

Work will continue on evaluating the foundations of the quasi-conservative coordinate analysis technique, expanding the analysis to more months and new meteorological data sets. The technique can then be applied to measurements from the MLS and HIRDLS instruments on board the Aura satellite.

Development of the gtraj trajectory model will continue. In March 2007, a poster presentation will be made at the Modeling, Analysis, and Prediction (MAP) meeting to describe the model, its current status, and future plans. Working with the GSFC SIVO staff, more testing and debugigng will be done, and new modules will be created to read additional data sets and apply new interpolation methods. Documentation of the existing code modules will continue.

Preparations will continue for the TC4 mission. When the mission takes place in summer 2007, high-altitude meteorological and flight planning support will be provided for the mission at the field site. Back trajectories will be calculated from locations along flight paths and provided to other researchers. Analysis of the meteorological context of the CR-AVE mission will be finished, and the results written up for publication.

If the proposal is funded to modernize the Atmospheric Chemistry and Dynamics Branch's scientific data system, then work will begin on that activity as well in the fall of 2007.

Task 910-00-008: **Chemical Data Assimilation**

GEST Investigator: David Lary

Collaborators: Mark Schoeberl (GSFC, Code 610.0), Anne Douglass (GSFC, Code 613.3), Lynn Sparling (UMBC), Richard Stolarski (GSFC, Code 613.3)

Abstract

New earth observation platforms require data validation. Data assimilation is ideally suited to assist in this as it provides objectives metrics of agreement between observations and numerical models. This is particularly useful when the assimilation system has already been used to study data from existing validated platforms with which one can compare the metrics from the new as yet unvalidated platforms. This is particular relevant to the recently launched NASA EOS Aura platform. In addition, data assimilation can be of use in creating an autonomous Objectively Optimized Observation Direction System (OOODS). In particular, to have a fleet of smart assets that can be reconfigured based on the changing needs of science and technology. The research team is developing an OOODS designed as a sensor web element (plug-in) that is of use both now and for future NASA observing systems.

Description of Research

David Lary has been involved in two areas of research. The first area is the use of probability distribution functions and multi-constituent chemical data assimilation, with particular emphasis on EOS Aura validation. The second area is the use of neural networks to parameterize and accelerate various aspects of atmospheric chemical simulation.

Accomplishments during the Reporting Period

Much of the work has made use of AutoChem software http://www.autochem.info/ (written by David Lary). AutoChem has won five NASA awards (http://www.autochem.info/Awards.html) and was the subject of a NASA tech brief (http://www.nasatech.com/Briefs/Nov05/GSC_14862_1.html).

The first multi-year multi-constituent analyses ever-produced using data assimilation is now available at www.CDACentral.info. This covers more than a decade from the launch of UARS to the present, and was performed using the AutoChem software.

An autonomous Objectively Optimized Observation Direction System (OOODS) is of great utility for NASA's observation and exploration objectives. In particular, to have a fleet of smart assets that can be reconfigured based on the changing needs of science and technology. The researchers are developing an OOODS designed as a sensor web element (plug-in) that is of use both now and for future NASA observing systems. The OOODS integrates a modeling and assimilation system within the sensor web allowing the autonomous scheduling of the chosen assets and the autonomous provision of analyses to users. The OOODS operates on generic principles that could easily be used in configurations other than the specific examples described here. Metrics of unknowns (state vector uncertainty) are used to define what needs to be measured and the required mode, time and location of the observations, *i.e.*, to define in real time the observing system targets. Metrics of how important it is to know this information (information content) are used to assign a priority to each observation. The metrics are passed in real time to the sensor web observation scheduler to implement the observation plan for the next observing cycle. The same system could also be used to reduce the cost and development time in an Observation Sensitivity Simulation Experiment (OSSE) mode for the optimum development of the next generation of space and ground-based observing systems. This research is being sponsored by a three-year HASA ESTO proposal.

Objectives for the Coming Year

The coming year will be dominated by three major activities. The first will be continued Aura validation. The second major activity will be to

develop generic neural networks for a variety of applications in Earth Science. The third activity is the continued development of the autonomous OOODS.

Task 916-01-017: **Ozonesonde Launches from Houston, Texas and Valparaiso, Indiana for INTEX-B and Aura Validation**

GEST Investigator: Gary A. Morris

Collaborators: P. K. Bhartia (GSFC, Code 613.3), Mark Schoeberl (GSFC, Code 610.0), Bojan Bojkov

Abstract

Thirty ozonesondes from Northwest Indiana and 30 ozonesondes from Houston, Texas were launched in support of INTEX-B and Aura validation. In conjuction with the ozonesonde launches, total column measurements were recorded using the Microtops II instrument. All data are published to the web and submitted to the Aura Validation Data Center. These measurements, combined with trajectory analysis and satellite observations, provide insight into the transport of pollution from the Mexico, the West Coast and the Pacific Rim into the central U.S., an example of which occurred in mid-July during INTEX-A. This data also will be useful in validating profile measurements of ozone, water vapor, and temperature from MLS, TES, and HIRDLS and profile and column measurements of ozone from OMI.

Description of Research

At this time, analysis of one event from the first summer of ozonesonde launches from Houston, Texas has been completed and published the results in the *Journal of Geophysical Research* [Morris *et al.*, 2006]. During the summer of 2004, the researchers' launches were part the INTEX Ozonesonde Network Study (IONS), a component of the Intercontinental Transport Experiment (INTEX). Twenty-five ozonesondes were launched between July 10 and August 13, 2004 from the campus of Rice University, about 4 miles south of downtown Houston. This data can be found on the website http://www.ruf.rice.edu/~ozone and as part of the IONS campaign at http://croc.gsfc.nasa.gov/intex/intex_ozonesonde.html. Analysis of an event in mid-July 2004 indicated that smoke from forest fires in Alaska interacted with local ozone pre-cursor sources to produce 50 – 100% enhancements in ozone between the surface and 5 km over Houston.

Accomplishments during the Reporting Period

Ninety ozonesondes were launched from Houston and several other sites in Southeast Texas with funding both from NASA and the State of Texas. All of this data is posted on the web at http://www.rice.edu/ozone. Twenty-eight ozonesondes were launched from Valparaiso, Indiana. All of this data is posted on the web at physics.valpo.edu/ozone. Morris published a paper on the impact of Alaskan and Canadian fires on Houston ozone pollution levels during the summer of 2004 in the *Journal of Geophysical Research* [Morris *et al*., 2006].

Objectives for the Coming Year

Ozonesonde launches from Rice University in Houston, Texas in support of Aura validation will continue with a total of 30 launches supported by NASA funding. Analysis of the data will examine partitioning of ozone pollution sources between local, remote, and stratospheric. An additional set of 30 ozonesondes will be launched in Panama as part of TC-4 this summer. Again, this data will be important for instrument validation for the Aura satellite.

Task 916-37-173: **Stratosphere-Troposphere Exchange**

GEST Investigator: Mark A. Olsen

Collaborators: Anne R. Douglass (GSFC, Code 613.3), Mark R. Schoeberl (GSFC, Code 610.0), Richard S. Stolarski (GSFC, Code 613.3), William Gallus, Jr. (Iowa State Univ.)

Abstract

Stratosphere-troposphere exchange (STE) and the stratospheric circulation are primary topics of this research. In particular, the influence of climate change on the circulation is investigated. Model simulations show that the trends in sea surface temperatures (SSTs) play a significant role in strengthening the Brewer-Dobson circulation and STE. The stratospheric circulation and STE trends are not annually uniform but are greatest during winter and spring. Another study examines the STE of ozone using observationally derived ozone fields. Although the results of the ozone STE seasonal cycles are in good agreement, the magnitude of the annual STE are biased high relative to previous studies. Olsen and his colleagues have also shown that a significant amount of mean tropospheric ozone maxima may be attributable to STE. Finally, initial results from a new project show that there is a global moist bias in the upper-troposphere/lower-stratosphere of the operational GFS and NAM analyses compared with new satellite observations.

Description of Research

The exchange of air and chemical species across the tropopause has implications to many atmospheric chemistry and climate problems. In addition, the tropopause region significantly influences the radiative properties of the atmosphere. Thus, it is important for research models to accurately represent stratosphere-troposphere exchange (STE). This research focuses on the analysis of STE in global atmospheric data sets and model output. Science issues addressed include ozone trends in the upper-troposphere/lower-stratosphere; seasonal and interannual trends in STE of total mass and ozone mass; the importance of STE to climate change; and the transport of water vapor from the troposphere to the stratosphere.

Accomplishments during the Reporting Period

The research team extended the results of several studies conducted during previous years. The trends in transport across the extratropical 380 K surface have been examined in a fifty-year integration of the GEOS-4 general circulation model (GCM). Observed SSTs used at the lower boundary drive the modeled trends. The annual transport increases 3% and 2% per decade in the NH and SH, respectively. However, the trends are greatly seasonally dependant. In the NH, the trend is greatest during the spring at 5% per decade compared to the minimum of 1% per decade in the fall. A seasonal dependence of an STE trend will impact the observed trends of stratospheric trace gases.

Olsen and his colleagues examined the output from a 34-year integration of the GEOS-4 GCM. This simulation is identical to the aforementioned fifty-year integration except that an increasing trend in atmospheric CO_2 is included in the modeled radiative heating. The trends in the STE and stratospheric circulation of the two models are compared. They found that the STE trends are not significantly different. This indicates that the change to the SST-induced wave forcing is a primary mechanism by which the stratospheric circulation is expected to strengthen under a greater CO_2 burden. They also found that the magnitude of the radiative cooling in the polar stratosphere from increasing CO_2 dominates the greater dynamical heating forced by the SSTs. By implication, the fidelity of simulations of the 21st century atmosphere strongly depends on the realism of the SSTs, whether prescribed or interactive.

A new study estimates ozone STE using two diagnostic methods with ozone fields derived from observations by the Microwave Limb Sounder (MLS) on the Aura platform. One

method is based on Lagrangian trajectories while the other is Eulerian-based. The annual STE calculated from both diagnostics tend to be biased high relative to estimates from previous studies. One possible reason for the bias is that MLS observations are limited to altitudes above 215 hPa. The seasonal cycle results from both diagnostics are in good agreement with each other and other studies. This study also shows that mean tropospheric ozone maxima tend to occur near locations of significant ozone STE. Thus, STE may be responsible for a significant fraction of mean tropospheric ozone anomalies. However, not all STE maxima are associated with distinct maxima in the tropospheric ozone field. The reason for this is unknown and requires further investigation.

The transport of water vapor from the troposphere to the stratosphere is the subject of a new project. Mesoscale and global models will be used in conjunction with satellite observations of water vapor. Initially, Olsen compared Aura MLS water vapor measurements in the upper-troposphere/lower-stratosphere with GFS and NAM analyses over a four month period (May-August). He found that a moist bias is present in both model analyses compared to the satellite estimates. This bias is worst at the highest levels. Probability density functions suggest a much narrower distribution in the MLS data. In particular, it appears both model analyses contain points that have much higher water vapor mixing ratios than found by satellite. Averages taken over subsets of the GFS domain including the tropics, midlatitudes and polar regions all reveal similar biases.

Objectives for the Coming Year

The GEOS-4 GCM with stratospheric chemistry will be used to produce a new simulation with latter twentieth century source gas boundary conditions and annually repeating SSTs. The results of this integration will be compared to existing, complementary simulations to further investigate the mechanisms responsible for strengthening the Brewer-Dobson circulation that is predicted by climate models with increasing greenhouse gases. An increase in the stratospheric circulation has yet to be detected in the real atmosphere. The simulation output will also be examined for what observations may be used as evidence for any such change. The previous ozone STE investigations will also be refined by using climatological upper-tropospheric/lower-stratospheric ozone to supplement the MLS-based observations. Finally, Olsen will continue the water vapor transport project by comparisons of Aura MLS water vapor fields with other satellite-based measurements. Model experiments detailing the water transport will also begin.

Task 916-54-206: **The NASA Global Modeling Initiative (GMI) and Process-oriented Model Evaluation**

GEST Investigator: Susan Strahan

Collaborator: Jose Rodriguez (GSFC, Code 613.3), Anne Douglass (GSFC, Code 613.3), Bryan Duncan

Abstract

New diagnostics of transport processes in the upper troposphere and lower stratosphere (UT/LS) have been developed from satellite and aircraft trace gas data sets. They have been used to evaluate two simulations of the GMI Combo chemistry and transport model (CTM), one using meteorological fields from a general circulation model (GCM) and the other using fields from a data assimilation system (DAS). The diagnostics identified many realistic features in the Combo-GCM simulation and support the use of this model in the study of UT/LS phenomena. Evaluation of the Combo-DAS showed surprising realism in the UT/LS, making this model very useful for the interpretation of Aura satellite data. Several multi-decadal GMI simulations were used to assess model uncertainties involved in predicting future ozone recovery.

Description of Research

This research focuses on the development of diagnostics from aircraft and satellite trace gas measurements, and their application to simulations of GMI chemistry and transport models. The trace gas analyses improve understanding of the dynamical and chemical processes controlling atmospheric composition. When applied to model simulations, the analyses help to define model requirements for credibility. That is, which resolution, which meteorological fields, and/or which set of chemical reactions does a model require to agree with observations. The GMI models are used to investigate anthropogenic influences on atmospheric composition and estimate possible future composition trends based on changes in surface emissions.

Accomplishments during the Reporting Period

A suite of diagnostics was developed for evaluating transport and its seasonal variability in the upper troposphere and lower stratosphere (UT/LS). Diagnostics were derived from analyses of Aura MLS O_3, SPURT (European aircraft campaign) N_2O, CO, O_3, and CO_2, and ER-2 N_2O and CO_2 data. These data analyses diagnose transport processes such as the balance of descent, horizontal mixing, and variability at high latitudes, ascent rate in the tropics, seasonal variations in transport from the tropical upper troposphere into the lowermost stratosphere, and the degree of coupling between the extratropical stratosphere and troposphere.

The process-oriented diagnostics noted above were used to evaluate transport characteristics of the GMI Combo CTM that used meteorological fields from the GEOS-4 GCM. The evaluations identified many realistic features in this model. The new diagnostics and model evaluation [Strahan *et al.*, 2007] directly support a collaborative study on the effects of biomass burning pollution in the lowermost stratosphere that used this model [Duncan *et al.*, 2007].

The GMI Combo CTM has also been integrated with time-averaged assimilated meteorological fields from the GEOS-4 DAS. Evaluation of this simulation using the new diagnostics for the lowermost stratosphere revealed substantial improvement in DAS transport characteristics. Previous DAS winds were very ‘noisy’ and caused excessive horizontal mixing and vertical dispersion [Tan *et al.*, 2004]. The new, time-averaged DAS winds have characteristics much more like the GCM winds, suggesting that CTM simulations using these winds (2004-2006) will have the credibility needed for the interpretation of AURA satellite data.

The issue of predicting future ozone recovery was explored using 3 GMI stratospheric CTM simulations. These simulations had the same source gas boundary conditions for 1980-2025 but different meteorology and resolution. Ozone recovery was gauged by the model levels of reactive chlorine and ozone loss in the Arctic lower stratospheric vortex. By applying diagnostics that assess polar transport processes [Strahan and Polansky, 2006], the GEST investigator found that the lower resolution model version has two important credibility problems: it has a leaky vortex that can’t produce nearly complete O_3 loss (because it cannot maintain the necessary high levels of Cly) and the leakiness causes the model to respond faster to reductions in chlorine, allowing it return to 1980 levels sooner. This work showed that models used to predict ozone recovery must demonstrate strong vortex mixing barriers.

Objectives for the Coming Year

A major focus in the coming year will be production and analysis of new simulations using assimilated and forecast meteorological fields for the time period of the NASA Aura satellite (mid-2004 to the present). The research team plans to use these simulations to analyze and interpret AURA trace gas measurements; provide new, high quality simulations to the GMI and AURA Science Teams to support their data analyses; and determine if simulations using forecast meteorological fields improve the ability to realistically simulate the troposphere or stratosphere.

A general science goal is to understand the composition of the UT/LS and how it is influenced by changes in atmospheric composition. Development of transport

diagnostics will continue, and use of the diagnostics will be extended to projects involving the SPARC Chemistry-Climate Validation working group. Management of GMI continues as an additional focus of this effort.

Task 910-00-008: **Assimilation Studies**

GEST Investigator: Clark Weaver

Collaborators: Arlindo da Silva (GSFC, Code 610.1), Randy Kawa (GSFC, Code 613.3), Lorraine Remer (GSFC, Code 613.2), Brent Holben (GSFC, Code 614.4)

Abstract
This task's goal is the development of an assimilation/retrieval system for atmospheric aerosols and ocean chlorophyll. The assimilation system utilizes radiances in the visible and near infrared as measured by the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on the Earth Observing System (EOS) satellite platforms. A secondary effort is the development of an algorithm that retrieves CO_2 profile information for a hypothetical Lidar instrument.

Description of Research
This task concentrates on the retrieval of absorbing and scattering aerosols over ocean using satellite radiances. A retrieval/assimilation system has been developed that simultaneously obtains absorbing aerosol properties and ocean chlorophyll concentrations over dark ocean using 10 MODIS channels. This algorithm can use precomputed radiances or it can run a radiative transfer model directly. The retrieved aerosol properties are being compared with AERONET coastal sites.

Accomplishments during the Reporting Period
Under this task a CO_2 Lidar retrieval algorithm has been developed for a hypothetical instrument. Given the number and frequencies of Lidar channels, and the instrument signal to noise, this algorithm determines the retrieved vertical profile along with its uncertainty. It will be very useful in the instrument design.

Objectives for the Coming Year
In the coming year the retrieval algorithm will be modified to accept AERONET alumcantar intensities. The goal will be to have an algorithm that will retrieve aerosol information from MODIS and AERONET observations using the same radiative transfer model with the same aerosol assumptions. Work will begin on constructing the 30 year aerosol record.

Task 613-70-242: **Nitrogen Dioxide from OMI Spectral Data**

GEST Investigator: Mark O. Wenig

Collaborators: James Gleason (PI, GSFC, Code 613.3), Eric Bucsela, Edward Celarier (SGT)

Abstract
In 2006, Wenig continued developing the OMI NO_2 level 2 to level 3 data processing algorithm. Two gridded NO_2 data products were created, global maps of the total vertical column densities and global maps of the tropospheric vertical column densities, both on a 0.25º x 0.25º grid. For the gridding process, involving an averaging technique which is based on the measurement errors, the viewing geometry and the OMI ground pixel size, as well as the fractional cloud cover, a detailed analysis of the OMI NO_2 data had been performed. The data sets which consists of daily and monthly maps, are now available on a website which also features the possibility of viewing the data using Google Earth.

Description of Research
The goal of this task is to use remote sensing techniques to further the understanding of the role of trace gases in tropospheric chemistry and air quality. This task utilizes global NO_2 data measured with the Ozone Monitoring Instrument

(OMI) that is on board the EOS-AURA satellite. This satellite was launched in July 2004, so that the imaging spectrometer OMI provides almost 3 years of daily high resolution (~13*24 km^2 at nadir) NO_2 vertical column density maps. The DOAS based retrieval algorithm includes an estimation of the stratospheric and tropospheric fraction of total NO_2 column, an air mass factor (AMF) correction based on detected tropospheric NO_2 enhancements, and the generation of the gridded data product. This data product is used to learn more about dynamical and chemical processes that drive the observed variations in the image sequences.

Accomplishments during the Reporting Period

The tessellation of the OMI NO_2 orbit data is the last step of the generation of the level 3 data product. This product consists of different data sets, including total NO_2 Vertical Column Densities (VCDs), tropospheric NO_2 VCDs. Both data sets were corrected for the shielding effect of clouds, which means that the column amount below the clouds which is not detected by the instrument, called the ghost column, is estimated and added.

Since the OMI orbits overlap at higher latitudes and so do the ground pixel within one orbit at the beginning and end of the scan lines, several measurements have to be averaged. In order to calculate the optimal weights for all OMI pixels lying on the same grid cell, the numerical errors of the VCDs had been analyzed. Systematic uncertainties, for example caused by clouds, are incorporated into an effective error measure that is then used to determine the weights for the averaging process. Additional the effect of the varying ground pixel size has been analyzed and incorporated into the averaging process.

This weighting scheme turned out to be especially useful for high resolution (0.05º x 0.05º or higher) annual averages. Different emission types (*e.g.*, industrial, traffic, even ship emissions) could be made visible using this technique.

Objectives for the Coming Year

The operational OMI NO_2 Level 3 data will form the basis for validation studies. For one of the planned validation studies, data from a Brewer MK3 double monochromator in direct-sun mode and the Airborne Compact Atmospheric Mapper (ACAM), both located at GSFC, will be used. For another comparison data from EPA NOx emission reports will be used.

It is also planed to use the OMI NO_2 Level 3 data and simulated basis functions to map NO_2 emissions. The idea is to model localized grid point emissions and to use the results of these simulations to create a set of basis functions that can be superimposed to represent OMI data, using inversion techniques to determine source strengths for each grid cell. With this project, Wenig seeks to reduce the uncertainties in nitrogen emission inventories. This technique can also be applied to OMI SO_2 and aerosol data.

Grant 00001365: **Measuring Sulfur Dioxide Emissions Using Spectral Data from Ozone Monitoring Instrument (OMI)**

GEST Investigator: Kai Yang

Collaborators: Nickolay A. Krotkov, Arlin J. Krueger (JCET), Simon A. Carn (JCET)

Abstract

A new algorithm has been developed, called the Linear Fit (LF) algorithm, for fast and accurate retrieval of SO_2 under the full range of conditions observed by OMI, and a new soft calibration method, called the sliding median technique, for correction of both along track and cross-track biases. Combining these new developments and the existing Band Residual Different algorithm, Yang has created a software package and delivered it as a PGE to the OMI Science Investigator-led Processing System (SIPS) for operational and near real time processing of OMI data. It has been demonstrated that the OMI SO_2 data from this PGE has improved greatly compared to the

provisional data generated just a year ago. The public data set is suitable for measuring anthropogenic SO_2 emissions and quantification of SO_2 tonnage from volcanic degassing and eruptions. The near real time has been used for detecting and tracking of volcanic clouds in support of aviation control service.

Description of Research

Major contributions to SO_2 in the atmosphere come from both anthropogenic activities and natural phenomena, which include combustion of fossil fuels, smelting of ores, burning of biomass, oxidation of organic materials in soils and dimethylsulphate (DMS) over oceans, and degassing and eruptions of volcanoes. The emitted SO_2 eventually turns into sulfur acid when it combines with water or sulfate aerosol when it is oxidized, usually in a period that varies from hours to weeks or even months depending on the composition of its atmospheric environment. The atmospheric SO_2 and its conversion products are air pollutants when they are near the ground (within the boundary layer), but when they are elevated into the free troposphere or the stratosphere, their lifetimes increase and they can trigger noticeable changes in regional weather pattern or even the global climate in cases of large enough loadings.

It is important to quantify the spatial and temporal distribution of atmospheric SO_2 by measuring its column amount over the globe. Doing so would facilitate efforts to identify of emission sources of SO_2, separate its natural and anthropogenic contributions, and characterize their respective variations and identify their respective trends (if any). Also a critical application for detecting and tracking volcanic SO_2 clouds in near real time is to provide automatic alarms for mitigation of aviation hazards. The Ozone Monitoring Instrument (OMI), a Dutch and Finnish contribution to NASA's EOS mission, is the most advanced instrument making measurements today for these applications.

OMI has combined the hyper-spectral measurements similar to those made by the Global Ozone Monitoring Experiment (GOME) and the Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) with improved viewing capabilities, including daily contiguous global coverage with a high spatial resolution not achieved by any of its predecessors. OMI accomplishes this by the use of two-dimensional charge coupled device (CCD) detectors to measure backscattered radiances in spectral and spatial dimensions simultaneously, covering the ultraviolet (UV) (270-365 nm) and visible (365-500 nm) ranges at high spectral sampling and resolution with a swath width of 2600 km at a nadir spatial resolution of 13 km x 24 km. Having all these advanced characteristics, OMI provides an unprecedented measurement sensitivity to a number of atmospheric trace gases, including SO2, which is the subject of this research.

Accomplishments during the Reporting Period

Deriving SO_2 column amount from satellite BUV measurements poses a unique challenge for retrieval algorithm development, due to the huge range in loading, the uncertainty in vertical distribution, and the interference from the ever-present ozone absorption in the same spectral range. During the reporting period, Yang and his colleagues developed a new algorithm, called Linear Fit (LF) algorithm. This algorithm is closely connected with the TOMS/OMI total ozone algorithm, which has evolved over 25 years to produce the present high quality data that are used in international assessments of ozone change. The algorithm uses a set of discrete UV bands centered at six TOMS wavelengths and four additional bands centered at the local minima and maxima of SO_2 absorption cross sections in the wavelength range between 310.8 nm to 314.4 nm. This algorithm starts with a linearization point that consists of zero SO_2 amount and estimates of ozone and a wavelength independent surface reflectivity derived using the TOMS total ozone algorithm, and then adjust these quantities to minimize the difference (residuals) between the measured and the computed sun-normalized radiances. The researcher's forward calculations employ accurate radiative transfer model that accounts for the polarized multiple Rayleigh scattering and rotational Raman scattering (known as the Ring effect), ozone and SO_2

absorptions, and spectrally dependent surface reflectivity. The built-in algorithm flexibility allows using different sets of band measurements depending on estimated SO_2 loading, column ozone and other observational conditions. When the atmospheric SO_2 loading is low (<10 DU), which is typical for anthropogenic sources, the shortest and most sensitive to SO_2 bands are used to provide maximal algorithm sensitivity. For strong volcanic degassing and eruptions, SO_2 loading can be very large, so that longer and less sensitive UV bands are used in the fitting. Yang has also developed a new soft calibration method, called sliding median technique, for correcting biases in residuals resulting from non-perfect instrument calibration as well as from forward model simplifications.

Combining the LF algorithm with the Band Residual Difference (BRD) algorithm developed in the previous reporting period and employing the sliding median technique for soft calibration, the research team delivered production software, referred to as a PGE, to the SIPS for operational and near real time retrieval of SO_2. This PGE works well under all the conditions observed by OMI, ranging from low concentration of anthropogenic SO_2 in the planetary boundary layer (PBL) to heavy loading of SO_2 in volcanic plumes in the stratosphere resulted from explosive eruptions. The data sets produced under routine processing have been released to the public and are available at http://disc.sci.gsfc.nasa.gov/data/datapool/OMI/Level2/OMSO2/, while the data sets produced in the near-real time system are pulled to NOAA in support of aviation control service for better planning of airline routes.

The quality of publicly released SO_2 data has improved greatly compared to that of the provisional data produced a year earlier. Long-period global average has revealed even the weak anthropogenic SO_2 pollutions at the 0.1 DU level and heavy anthropogenic SO_2 pollutions can be routinely measured. Low-level SO_2 emissions from degassing volcanoes are monitored daily, and volcanic SO_2 from explosive eruptions are tracked and quantified. An example that demonstrated the success [Carn *et al.* 2007] of the SO_2 retrievals from OMI is the measurement of SO_2 tonnage and its subsequent decay from the eruption of Soufriere Hills volcano, Montserrat on 20 May 2006. The SO_2 cloud from this eruption was tracked for over 3 weeks and a distance of over 20,000 km, illustrating that a better accuracy in measurement and higher sensitivity in detection have been achieved. This also means that false alarms and missed detection of volcanic clouds are reduced, making this product more useful for aviation control service.

Objectives for the Coming Year

The researcher's focus will be on the development of an advanced algorithm for simultaneous retrieval of ozone and sulfur dioxide in an effort to enhance detection sensitivity, reduce artifact, and improve retrieval precision and accuracy. Other activities will include the refinement of the automatic product quality assessment schemes, monitoring the instrument performance, and improvement of soft-calibration techniques to maintain consistent product quality over time. The synergy of combined OMI (UV) retrievals with that from AIRS (infrared) will be explored, and techniques for ash detection using measurements form OMI and AIRS will be developed.

Task 613-78-267: **A Global Modeling Initiative (GMI) Study of the Long-Range Transport of Pollution Using Fused Carbon Monoxide Measurements from EOS**

GEST Investigator: Yasuko Yoshida

Collaborator: Bryan N. Duncan

Abstract

Research was primarily focused on evaluation of the Global Modeling Initiative's (GMI) 3-D chemical tracer model (CTM). The model simulations are compared with aircraft and surface observations.

Description of Research

The GMI working group has been developing a CTM to be used for assessment of the impact of various natural and anthropogenic impacts on atmospheric composition and chemistry. Evaluation of GMI Combo model, which is a new version using a combined stratospheric-tropospheric chemical mechanism, is a high priority of the activities under this task.

Accomplishments during the Reporting Period

Yasuko Yoshida started her appointment with GEST this year. Nevertheless, she has several important accomplishments to report. The GMI Combo simulations are evaluated by comparing the model's output with aircraft and surface observations over the Pacific Ocean, the U.S. and western Europe. The model-simulated atmospheric cabon monoxide (CO) was compared with data measured by Measurement of ozone and water vapour by an Airbus in-service aircraft (MOZAIC) and Japan Air Line (JAL). The researchers' model ozone (O_3) was evaluated using surface measurement data provided by U.S. EPA and the Cooperative Programme for Monitoring and Evaluation of Long-range Transmission of Air Pollutants in Europe (EMEP).

Objectives for the Coming Year

Yoshida will construct new biomass burning emissions including consideration of pyro-convection from Canadian boreal forest fires. Emissions from boreal wildfires are known to impact air quality in the U.S.; an optimal representation of emissions from boreal fires is necessary in order to assess their impacts [Turquety *et al.*, 2007]. The new emission inventory will be evaluated using the GMI CTM simulation and surface and satellite observations. The comparisons between the model simulation and observations will be focused on carbon monoxide measured using the Atmospheric Infrared Sounder (AIRS) instrument over North America.

Task 916-21-144, 916-43-181: **The Validation of Aura Ozone Measurements Using Cloud Slicing; The Development of Tropospheric Ozone Data Products from AURA OMI/MLS and Their Scientific Evaluation**

GEST Investigators: Sushil Chandra and Jerry Ziemke

Collaborators: P. K. Bhartia (GSFC, Code 613.3), Joanna Joiner (GSFC, Code 613.3), Lucien Froidevaux (JPL), Xuexi Tie (NCAR)

Abstract

Ozone measurements from the OMI and MLS instruments on board the Aura satellite are used to derive global measurements of tropospheric ozone on an almost continuous basis beginning with August 2004 to the present time. They are also compared with ozone fields derived from the Global Modeling Initiative's Chemical Transport Model (COMBO CTM) developed at Goddard. The models and observations show interesting similarities with respect to zonal and seasonal variations. However, there are notable differences which are also highlighted. Ozone data in conjunction with water vapor data from the Aura MLS are used to study the effects of intra-seasonal and El Nino related changes in the troposphere.

Description of Research

The objective of this research is to continue efforts for producing global maps of tropospheric column ozone (TCO) based on measurements of total column ozone from OMI and stratospheric column ozone (SCO) from MLS instruments on the Aura satellite. TCO is determined using the tropospheric O_3 residual method, which involves subtracting SCO from total column ozone measured from the MLS and OMI instruments respectively. SCO is also determined using the convective cloud differential (CCD) method [Ziemke *et al.*, 2006] over most of the globe and is used for cross calibration of MLS measurements with respect to OMI. As members of the OMI Science Team, Chandra and Ziemke provide extensive validation of these data using all available

measurements from SAGE for validating SCO and from ozonesonde for validating TCO. A second objective of this proposal is to construct a nearly continuous database for SCO and TCO from 1979 to the present time by combining Nimbus-7, EP TOMS, and Aura measurements. These data are used to address several key questions ranging from the effects of regional pollution to the recovery of stratospheric ozone.

Accomplishments during the Reporting Period

Ozone measurements from OMI and MLS instruments were used to derive global measurements of tropospheric ozone on an almost continuous basis beginning with August 2004 to the present time. These data have been used to study the seasonal and zonal characteristics of the observed ozone fields [Ziemke *et al.*, 2006]. They are also compared with ozone fields derived from the Global Modeling Initiative's Chemical Transport Model (COMBO CTM) developed at Goddard. The models and observations show interesting similarities with respect to zonal and seasonal variations. However, there are notable differences, particularly over the vast regions of Saharan desert. The significance of these differences is currently being studied.

In a related study, the researchers used another global model, MOZART-2 (Model of Ozone and Related Chemical Tracers, version-2), to analyze and interpret satellite measurements of TCO and tropospheric NO_2 column (TNO_2) in Eastern and Southeastern Asia during 1997 [Tie *et al.*, 2006]. The analysis of satellite and model results showed that the industrial emissions of NOx ($NO+ NO_2$) contribute about 50-80% to TNO_2 in the eastern Asia. However, its contribution to TCO ranges from 10% to 30%. Biomass burning and lightning NOx have small effect on TCO in central and eastern Asia but they have a significant impact on southeastern Asia. The varying effects of NOx on TCO are attributed to relative abundance of volatile organic compounds (VOCs) with respect to total nitrogen in the two regions.

As a part of the scientific validation of their data, the GEST investigators are studying the effects of intra-seasonal and El Nino related changes on TCO derived from the OMI/MLS residual method. This study combines TCO measurements with H_2O measurements from the MLS instrument on the same satellite. They have just completed their analysis for the 2004 El Nino [Chandra *et al.*, 2007]. Although it was a weak El Nino from a historical perspective, the availability of the global data from OMI and MLS enabled the researchers to study its effect both inside and outside the tropical region. The observed changes in ozone and water vapor during a weak El Nino suggest that the atmosphere is a very sensitive to small perturbations in sea surface temperature.

Objectives for the Coming Year

Chandra and Ziemke will continue with previous year topics, which include both validation and the analysis of TCO data to characterize seasonal, intra-seasonal, and El Nino related variability. They will also study the TCO variability on shorter time scales to characterize the possible effects of local pollution.

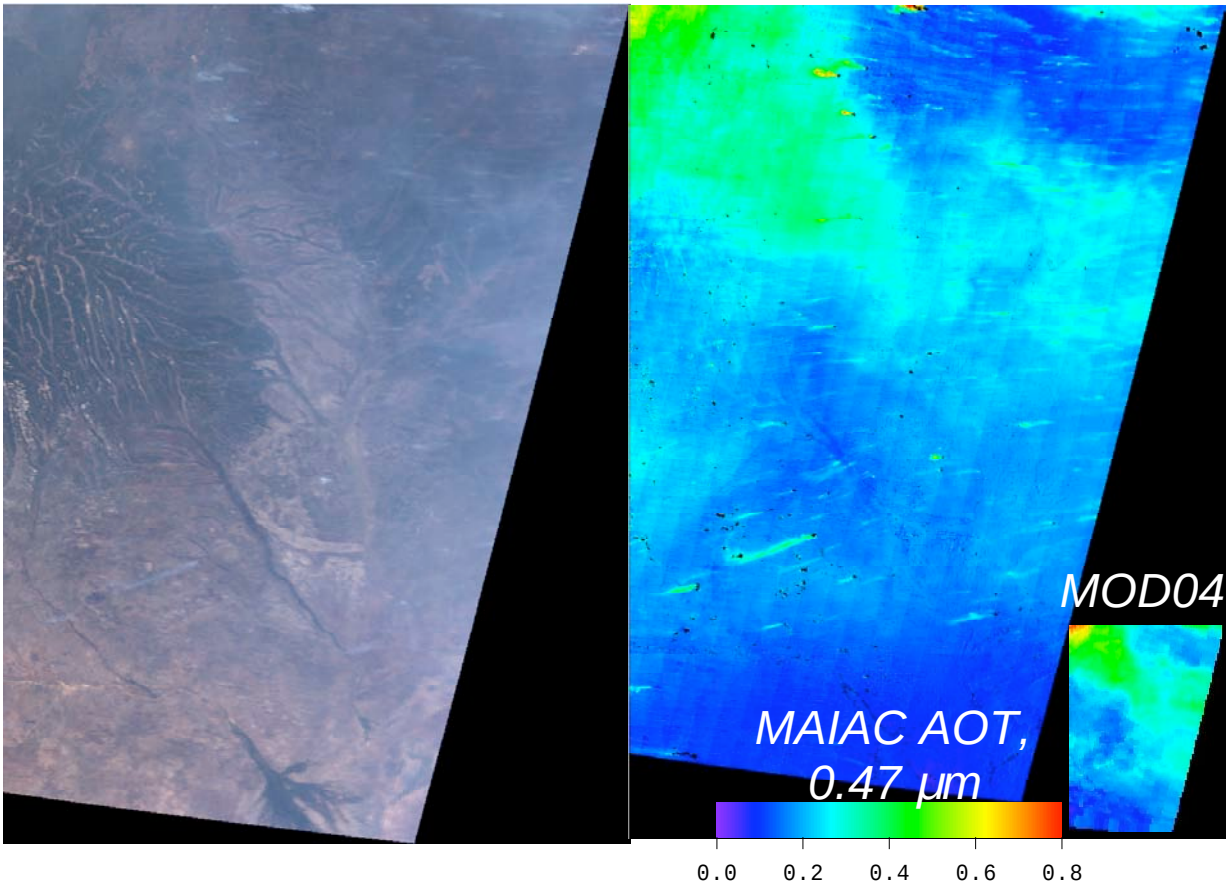
OMI/MLS tropospheric ozone from their analyses has been distributed to many NASA and non-NASA scientists on an offline personal request basis. An objective for the coming year is to make the data more available to the general community via the Goddard tropospheric ozone web page.

The researchers plan to revisit the cloud slicing technique by incorporating cloud-top pressure data from OMI. Their objective is to derive ozone distribution above cloud tops and to study the possible effects of clouds on tropospheric ozone.

Finally, they plan to continue the use of the COMBO-CTM model by coupling with Aura measurements for delineating sources and sinks of ozone in the troposphere.

This page intentionally left blank

Terrestrial Physics Research Group



Biomass burning season in Zambia, Africa. The MODIS TERRA RGB image (left) shows dozens of fires over the area of 900x1200 km^2 for day 205 of 2005. A high spatial resolution (1 km) of the new processing algorithm MAIAC developed for MODIS by Lyapustin and Wang allows identification and tracing of individual smoke plumes. MAIAC aerosol optical thickness at 0.44 μm is shown on the right. For comparison, the inset shows the standard MODIS aerosol product, MOD04, which has a spatial resolution of 10 km. [Figure courtesy of Alexei Lyapustin.]

Terrestrial Physics Research Group

GEST Center scientists conduct multi-disciplinary research in many areas related to the remote sensing of the Earth. GEST Center scientists are collaborating with NASA and other researches on developing retrieval algorithms for the data interpretation, modeling techniques to represent physical processes, assimilation methods used to combine observations and models, and new instruments.

Assaf Anyamba's research focuses on the land surface patterns of inter-annual variability using time series vegetation index data derived from measurements made by Polar orbiting satellite series, SPOT Vegetation and MODIS Vegetation Index measurements. At the short time scale, El Niño / Southern Oscillation (ENSO) is a major mode of interannual climate variability influencing precipitation response patterns and vegetation dynamics in the global tropics. This research aims at understanding the dynamics and land surface response patterns to ENSO as revealed by satellite time series measurements of vegetation. Climate data sets including global sea-surface temperature measurements (SST), outgoing longwave radiation (OLR) and combined satellite and rain-gauge are used to validate the observed land surface anomaly patterns and to determine SST forcing on the vegetation response. All these measurements are employed to understand dry and wet cycles, examination of the relationships between ENSO and global vector-borne disease outbreak patterns and monitoring global agricultural regions.

Allen Chu's research is focused on intercontinental transport of pollutants from Asia to North America. The transport of aerosols including dust, smoke, and pollution can reach as far as the Eastern U.S. and beyond. Modeling has been always an important part of the evaluation. However, there are discrepancies found mostly attributed to emission (especially biomass burning) and distribution. The INTEX-B field campaign held in April-May 2006 at Hawaii and Alaska was to study Asian pollution that could be entrained into the troposphere and affect U.S. air quality. The objectives of the 3D-Air Quality Study are to investigate spatial and vertical distribution of aerosols that affects air quality in the U.S. using both satellite and ground-based active and passive measurements. Aura validation is focused on the validation of total and absorbing optical depths derived by OMI.

Charles Gatebe's study seeks to characterize aerosol surface radiative properties using multi-spectral and multi-angular radiation field measurements. This involves a detailed assessment of the Cloud Absorption Radiometer (CAR) data from selected field campaigns. This effort is tied to development of a new algorithm for inverting CAR multi-spectral and multi-angular radiance measurements by modifying the AERONET inversion code of Sun/Sky radiance.

Elena Georgieva's research focuses on the development of differential radiometers using Fabry-Perot interferometric technique for remote sensing determination of various atmospheric trace gases. Fabry-Perot interferometry (FPI) is a well known, powerful spectroscopic technique and one of its many applications is to be used to measure greenhouse gases and also some harmful species in the atmosphere. With this technique, absorption of particular species is measured and related to its concentration. A solid Fabry-Perot etalon is used as a frequency filter to restrict the measurement to particular absorption bands of the gas of interest. She has developed an instrument for use as ground based, airborne and satellite sensor for gases such as carbon dioxide, oxygen, and water vapor.

Hongbin Yu's research shows how aerosols affect the Earth's energy budget directly by scattering and absorbing radiation and indirectly by acting as cloud condensation nuclei. Past assessment efforts of aerosol direct forcing and intercontinental transport were done through modeling efforts and large uncertainties exist. Enhanced new satellite passive sensors (*e.g.*, MODIS, MISR, POLDER) introduced in the last decade, the emerging measurements of aerosol vertical distributions from space-borne Lidars (*e.g.*, GLAS and CALIPSO), and a number of intensive field experiments conducted around the world provided the opportunity to attempt long term and measurement-based assessments. The goal is to assess

aerosol direct radiative forcing and aerosol intercontinental transport through an integration of multiple satellite observations and measurements from intensive field campaigns supplemented by model simulations.

Kyu-Myong Kim's research goal is to understand the effect of aerosol radiative forcing on the global monsoon water cycle. Various satellite observations including MODIS, TOMS, and TRMM as well as in-situ observations are being used to diagnose the relations between aerosol distribution and the evolution of monsoon water cycle. Modeling experiments forced with aerosols from GOCART model are also conducted to understand the mechanisms involved.

The research within the framework of the globally distributed Aerosol Robotic Network (AERONET) is centered on the analysis of measurements made by automatic sun-sky scanning radiometers. GEST researcher Thomas Eck analyzed aerosol optical properties and long-term monitoring results in central Alaska and on the Arctic coast of Alaska with the emphasis on the spatial and temporal dynamics of aerosol in the region. He performed a thorough analysis of AERONET data collected from a mesoscale network of 12 AERONET sites during the UAE2 field campaign conducted in the summer of 2004 in the United Arab Emirates.

Alexander Smirnov's research was focused on the refinement of AERONET cloud screening algorithm and associated sensitivity study which allowed estimating its impact on the operational processing and long-term statistics. Organization of the ship-based optical depth data acquisition and performed analysis of the new data and historical dataset collected by the SIMBIOS project was an important step in reestablishing NASA's ship-based optical depth measurement network.

Hyung Rae Kim continues an Antarctic Comprehensive Model (ACM) study to finish the internal part and to design external field modeling of the geomagnetic components. Spherical cap harmonic expansions that represent internal field is explicitly implemented up to maximum index of 150 (equivalent 80 km wavelength or to order 450 for global spherical harmonics, in the region below 60°S latitude). The extended ACM is about to reduce the external magnetic field components to better represent the internal geomagnetic field from near-surface and satellite data in the Antarctic.

The main research objective for Alexei Lyapustin and Yujie Wang is the development of a new Multi-Angle Implementation of Atmospheric Correction (MAIAC) algorithm for processing of MODIS measurements. MAIAC is a generic algorithm that simultaneously retrieves the aerosol optical thickness and surface bi-directional reflectance using the 16-day time series of gridded MODIS L1B measurements over land. The new algorithm is generic and works globally over all surface types, including bright deserts, with the temporary exception of snow.

The primary focus of Inge ten Kate's research is to experimentally test different theoretical models of electrical discharge in the Martian dust storms and breakdown processes in the Martian atmosphere due to this electrical discharge, using a dedicated simulation facility.

Jeffrey Joseph's study includes geological samples from Earth served as analogs to Mars' geological samples during the development of a derivatization process. They were tested for its efficacy in allowing identification of amino acids by Gas Chromatographic Quadrupole Mass Spectrometry.

It should be clear from this brief summary and the detailed reports that follow that the GEST Terrestrial Physics Research Group is at the forefront of research activities in many important areas, with results from these investigations making their way into the literature and research underway at other institutions.

Alexander Smirnov

Task 923-06-092: **Studies of Earth's Surface Interannual Variability Using data from Satellites and Distributed Ground Stations**

GEST Investigator: Assaf Anyamba

Collaborators: Compton J. Tucker (GSFC, Code 614.0), Christopher O. Justice (Univ. of Maryland), Doorn (USDA/FAS), Curt Reynolds (USDA/FAS), Lt. Jean-Paul Chretien (DoD/WRAIR-GEIS), Kenneth Linthicum (USDA-Center for Medical, Agricultural & Veterinary Entomology), Maj. Jason Richardson (USAMRU & GEIS-Kenya), Rasmus Fensholt (Univ. of Copenhagen, Denmark)

Abstract

This research focuses on the land surface patterns of interannual variability using time series vegetation index data derived from measurements made by National Oceanic and Atmospheric Administration (NOAA) Polar orbiting satellite series, SPOT Vegetation and MODIS Vegetation Index measurements. At the short time scale, El Niño / Southern Oscillation (ENSO) is a major mode of interannual climate variability influencing precipitation response patterns and vegetation dynamics in the global tropics. This research aims at understanding the dynamics and land surface response patterns to ENSO as revealed by satellite time series measurements of vegetation. Climate data sets including global sea-surface temperature measurements (SST), outgoing longwave radiation (OLR) and combined satellite and rain-gauge are used to validate the observed land surface anomaly patterns and to determine SST forcing on the vegetation response. In addition, new remote sensing measurements from the Meteosat Second Generation (MSG): a geostationary satellite are being validated, to improve the quality of measurements from earth surface sensing. All these measurements are employed to understand dry and wet cycles, examination of the relationships between ENSO and global vector-borne disease outbreak patterns and monitoring global agricultural regions.

Description of Research

The primary objective of this research is improve the understanding of the land surface response patterns to interannual forcing associated with ENSO forcing using long-time series satellite vegetation measurements. This work is of critical relevance to NASA-GSFC work on ecosystem dynamics and applied agricultural and environmental monitoring, activities of the United States Department of Agriculture /Foreign Agricultural Service (USDA/FAS) in global agricultural monitoring and United States Agency for International Development (USAID) Famine Early Warning System Network (Program) program. Additionally, the research is a contribution to of NASA's applications programs on Public Health, and the Department of Defense’s Global Emerging Infections Surveillance System (GEIS). The research utilizes an array of satellite and surface observations, including vegetation index measurements from NOAA-AVHRR, SPOT Vegetation, MODIS and LANDSAT, global sea-surface temperature (SST), outgoing longwave radiation (OLR) and combined rain-gauge and satellite precipitation estimates to determine the linkages between SST variability, precipitation patterns and biosphere response patterns at a variety of time and space scales.

Accomplishments during the Reporting Period

Remotely sensed measurements from SPOT Vegetation sensor, combined gauge-satellite rainfall estimates and outgoing longwave radiation data were used to study precursor climate conditions associated with the large scale Chikungunya epidemic along the East African coast and the western Indian Ocean Islands during the period 2004-2006. Unusually dry, warm conditions preceded the outbreaks, including the driest since 1998 for some of the coastal regions. Infrequent replenishment of domestic water stores and elevated temperatures may have facilitated Chikungunya virus transmission. These results suggest that drought-affected populations may be at heightened risk for Chikungunya fever, and underscore the need

for safe water storage during drought relief operations [Chretien *et al.*, 2007]. The dry conditions in 2005 and early 2006 over East Africa were followed by above-normal rainfall in late 2006 continuing into early 2007. The elevated rainfall conditions were associated with the development of warm ENSO conditions in the eastern Pacific Ocean in association above normal SST in the western equatorial Indian Ocean (WIO). Using various data sets and a persistence risk mapping model, Anyamba provided an alert and early warning of the likely outbreak of Rift valley fever (RVF) East Africa [Anyamba *et al*., 2006] and a global outlook of likely vector-borne disease risks from late 2006 to early 2007 [Anyamba *et al.*, 2006]. In order to improve the quality if remote sensing land surface measurements, Anyamba is working towards deriving various land surface parameters from the Spinning Enhanced Visible and Infrared Imager (SEVIRI) sensor on-board the new Meteosat Second Generation (MSG) satellite in Geostationary orbit off West Africa. He has demonstrated that, in cloud-prone areas like equatorial West Africa the use of Normalized Difference Vegetation Index (NDVI) data for vegetation monitoring is hampered by persistent cloud cover especially during the rainy season. The utilization of data from MSG-SEVIRI will allow NDVI to be derived with a 15-minute temporal resolution. In West Africa, Polar Orbiting Environmental Satellite (POES) MODIS (combined TERRA and AQUA) produces on average ~85% cloud-free pixels per scene during the entire 3-month rainy season using 16-day composite periods. SEVIRI MSG data can provide >98% cloud-free data during the entire rainfall season using a 3-day composite period. The exploitation of MSG land surface measurements will lead to substantially improving various aspects of satellite-based vegetation monitoring and other environmental applications in cloud-prone areas around the world [Fensholt *et al.*, 2007]. Towards this effort, the research team is undertaking a ground-based validation of MSG measurements over Africa. Currently they are continuing with a comparative evaluation of different vegetation indices from MODIS (NDVI, EVI), AVHRR-NDVI and SPOT Vegetation NDVI data as part of the research and development work to support the USDA/Foreign Agricultural Service agricultural monitoring activities.

Objectives for the Coming Year

The GEST researcher will continue work on the comparison of various vegetation indices from MODIS, SPOT Vegetation and AVHRR NDVI time series to provide a coherent multi-satellite data base for agricultural and environmental monitoring purposes and start work on development of vegetation index time series data from MetOp satellites. The existing work on RVF monitoring will continue in support DoD/GEIS activities with a detailed analysis and evaluation of the forecast and RVF outbreak patterns over East Africa during 2006-2007. They will also start working on analyzing of time series data being generated from in-situ measurements from the MSG validation towers located in Senegal and Kenya. Other work will include managing GSFC/GIMMS contributions in support of the Application of NASA EOS MODIS Data to Agricultural Assessment and Forecasting by the USDA Foreign Agricultural Service as part of the FAS/UMD/GSFC activities for this program and continue support to USAID/FEWSNET and DoD/GEIS Program activities.

Grant NNG06GB21G:	**Forecast and Analysis of Aerosol Distribution and Transport Using MODIS Near Real Time and Geostationary Satellite Measurements and Trajectory Model for INTEX-B**
Grant 6-92U-9606:	**Analyze and Evaluate the Model Results Using Satellite and Remote Sensing Observations (ICAP-Phase 3)**
GEST Investigator:	D. Allen Chu
Collaborator:	Lorraine Remer (GSFC, Code 613.2)

Grant NNG06GA73G:	**Simultaneous validation of OMI and CALIPSO Using Ground-Based Lidar, AERONET, and Satellite Optical Depth Measurements**
Grant NNS06AA02A:	**Three-Dimensional Air Quality System (3D-AQS)**
GEST Investigator:	D. Allen Chu
Collaborator:	Raymond Hoff (PI)

Abstract

Intercontinental transport of pollutants from Asia is a growingly urgent issue in springtime in North America. The transportation of aerosols including dust, smoke, and pollution can reach as far as the Eastern U.S. and beyond. Modeling has been always an important part of the evaluation. However, there are discrepancies found mostly attributed to emission (especially biomass burning) and distribution. The NASA INTEX-B field campaign and EPA ICAP-3 project are focused on the evaluation of the transport of Asian pollutants. The former used DC-8 aircraft as a tool to sample aerosols and gaseous pollutants and the latter intercompared CMAQ model results with MODIS.

The objectives of 3D-AQS are to study spatial and vertical distribution of aerosols that effects air quality in the U.S. using both satellite and ground-based active and passive measurements. Aura validation is focused on the validation of total and absorbing optical depths derived by OMI.

Description of Research

Asian dust outbreaks are clearly observed by satellite from source to downwind. Not only can dust be seen to cross the Pacific Ocean to the U.S. but also pollution and smoke aerosols carried by prevailing westerly winds. However, the transport routes can vary model by model. The ICAP-3 project is to quantify the differences between modeled and measured AOD within the domain from 120°E to 120°W of the Pacific Ocean. To characterize the differences, the monthly mean AOD of CMAQ, and GOCART are compared. It is understandable that AOD values may be different because of different methods being used to convert mass concentration to optical depth. Provided that meridional mean differences (averaging over latitudes from 0° to 90°N) are on the same order as standard deviations (< 0.02) obtained from these two models, the zonal mean differences, especially greater than 30°N, can only be caused by zonal flows shifted relatively in one model as opposed to another. As the transpacific mechanism (*i.e.*, jet streams created by Aleutian low and Pacific High pressure systems) weakens from spring to summer, zonal mean differences also become less pronounced. In contrast, MODIS retrieved AODs show significantly larger zonal mean AODs than those derived from both models. Some are attributed to lower-than-reality model emission rate and some are due to overestimated AOD retrievals because of dust nonsphericity and cloud-enhanced radiation beneath aerosol layers. Although more restrictive cloudmask help reduces the differences, more investigations in emission sources and temporal variability are needed.

The INTEX-B field campaign held in April-May 2006 at Hawaii and Alaska was to study Asian pollution in the downward direction that could be entrained into the troposphere and affect U.S. air quality. A NASA DC-8 flying laboratory was used to house a suite of in situ and remote sensing instruments to measure concentrations of aerosol and gaseous pollutants. A total of nine scientific flights (plus 2 transit flights) were conducted in the northeastern Pacific Ocean to sample pollution plumes for model comparisons and also accommodate validations for Aqua and Aura products.

3D-AQS is to facilitate satellite data (including MODIS, GOES, OMI, CALIPSO) into EPA air quality monitoring systems. New products, such as 5-km, 2-km, and 1-km MODIS AOD products are planned to generate for urban areas. CALIPSO Lidar measurements are used to provide the aerosol vertical profile in tandem with horizontal distribution obtained from passive satellite sensors. OMI–derived total optical depths are intended to be compared to MODIS high-resolution (*e.g.*, 5 km) AOD products for studying spatial variability within OMI footprints as a part of Aura validation project. The I-95 corridor between GSFC, HU (Howard Univ.) and UMBC is the focus of this study.

Accomplishments during the Reporting Period

The evaluation of intercontinental transport study in 2001 was completed based upon MODIS aerosol products and GOCART and CMAQ model results. A manuscript is being prepared to submit to *JGR-Atmospheres*. Chu participated and completed aerosol trajectory forecasting for the NASA DC-8 in the INTEX-B field campaign held in Hawaii and Alaska from March to May 2006. Events of dust outbreaks were selected for radiative forcing analysis. The use of DC-8 Lidar and in-situ aerosol profiles and properties (*e.g.*, size, absorption, hydration) enables the study of aerosol radiative forcing above clouds.

The MODIS aerosol operational algorithm was modified to produce MODIS high-resolution AOD products. The high-resolution AOD products were shown to be sensitive to small-scale clouds (*e.g.*, cumulus clouds) such that less AOD retrievals were derived as a result. Significant improvements were found at the edge of pollution plumes and the gradient between sources and downwind.

Objectives for the Coming Year

The major tasks of 3D-AQS are 1) to complete the evaluation of MODIS high-resolution (5-km, 2-km, and 1-km) products against 10-km standard products in the urban and rural regions over the continental US, and 2) to develop and validate the retrieval of the height of aerosol layers. In terms of intercomparing with Aura OMI-derived aerosol loading, the spatial variability within OMI footprints is also planned, dependent upon the maturity of the OMI aerosol products.

The study of aerosol radiative forcing will be focused on the effects of aerosols over clouds in INTEX-NA, INTEX-B and NAMMA, including biomass burning and dust aerosols.

Task 923-03-067: **AERONET Ground Based Remote Sensing of Aerosol Optical Properties**

GEST Investigator: Thomas F. Eck

Collaborator: Brent N. Holben (GSFC, Code 614.4)

Abstract

Eck traveled to Guam and Taiwan from April 3-14, 2006 for AERONET project activities, where he established a new AERONET site at the University of Guam, Mangilao on the central east coast. He participated in a seminar and a workshop on April 10 -11, 2006 at the National Central University in Chung-Li, Taiwan and in Taipei. Eck traveled to Singapore from July 19-22, 2006 to meet with the director (Kwoh Leong Keong) and head of research (Dr. Liew Soo Chin) of the Centre for Remote Imaging, Sensing and Processing (CRISP) of the National University of Singapore. Eck discussed the

establishment of an AERONET site at CRISP, and as a result monitoring in Singapore has commenced in November 2006. He attended the Western Pacific Geophysics Meeting (co-sponsored by the AGU) from July 24-27, 2006 in Beijing, made a presentation and chaired a session. Eck made a presentation on analysis of aerosol optical properties and long-term monitoring in central Alaska and on the Arctic coast of Alaska at the AGU Fall Meeting in San Francisco in December 2005, presenting analyses on the spatial and temporal dynamics of aerosol in the region. Five peer-reviewed journal papers co-authored by the GEST investigator were published during this time period.

Description of Research

The primary motivation for the investigation of the optical properties of atmospheric aerosols within AERONET is for application to studies of the effects of aerosols on the atmospheric radiation balance and climate and for the validation of satellite retrievals of aerosol properties. The research in this GEST activity is centered on the analysis of measurements made by automatic sun-sky scanning radiometers that are globally distributed as a part of the NASA managed Aerosol Robotic Network (AERONET; project leader: Brent N. Holben, GSFC). The measurements of spectral direct sun intensity and sky radiance distributions are utilized to infer a complete description of the column integrated optical properties of the aerosols. These ground-based remote sensing retrievals of aerosol optical properties are analyzed to better understand the dynamics of aerosol properties as a function of source region, transport, aging processes, and interaction with clouds.

Accomplishments during the Reporting Period

A presentation titled “Overview of AERONET and its Application in S and SE Asia” was given by Brent Holben and Tom Eck at the International Workshop on Regional Atmospheric Environmental Monitoring and Long Range Transport, April 11, 2006 at Taipei, Taiwan sponsored by the Taiwan EPA, National Science Council, National Central University, U.S. EPA, NASA and NOAA. Eck presented analyses of the AERONET data collected in Thailand and Vietnam from 2003 through 2005, focusing on the temporal and spatial variability of aerosol optical properties and transport of aerosol from various source regions such as China and India. He participated in the Training Workshop on AERONET and MPLNET, April 10, 2006 at the National Central University in Chung-Li, Taiwan at which a talk was presented on the download options from the AERONET website and various data processing and analysis options. He also attended the opening ceremony of the Lulin Atmospheric Background Station (LABS) at a mountain top observatory on Lulin Mountain (2868 meters) in Central Taiwan on April 13, 2006.

Eck collaborated with various researchers at GSFC and elsewhere (China, Brazil, and Italy) and co-authored five papers on studies of non-spherical aerosol remote sensing, sea salt optical depth, effect of smoke on irradiance and subsequent interaction with the forest canopy, aerosols in Beijing, and spectral variation of aerosol optical depth.

The GEST investigator wrote the first draft of a journal paper on the analysis of AERONET data collected from a mesoscale network of 12 AERONET sites during the UAE2 field campaign conducted in the summer of 2004 in the United Arab Emirates, to be submitted to the *Journal of Geophysical Research*. This paper includes comparisons of AERONET Version 1 versus version 2 almucantar retrievals, dynamics of aerosol absorption as a function of Angstrom Exponent, and the spatial and temporal variation of aerosol optical depth across the region. He traveled to Singapore from July 19-22, 2006 to meet with the director (Kwoh Leong Keong) and head of research (Dr. Liew Soo Chin) of the Centre for Remote Imaging, Sensing and Processing (CRISP) of the National University of Singapore. They discussed the establishment of an AERONET site at CRISP and CRISP agreed to become a partner in the federated network, providing their own CIMEL sun-sky radiometer. Their instrument was received at GSFC, repaired and calibrated, and it has been monitoring since November 2006. Eck attended the Western Pacific Geophysics Meeting (co-sponsored by the AGU) from July 24-27, 2006

in Beijing and made a presentation. He also participated in a tour and discussions on atmospheric monitoring at the Xianghe Observatory (supported by the Institute of Atmospheric Physics, Beijing and the University of Maryland, College Park) located ~90 km southeast of Beijing. Eck chaired the Aerosol and Climate: Impact on Regional and Global Energy and Water Balance and Cycles III Posters session at the 2006 Western Pacific Geophysics Meeting, 24-27 July 2006 in Beijing, China. He made a presentation on July 24, 2006 in this session on Aerosol Optical Properties in Southeast Asia from AERONET Observations and Computation of Clear Sky Direct Radiative Forcing. Eck attended the AGU Fall Meeting in San Francisco from December 11-15, 2006, presenting analyses on the multi-year data record (13 year interval) of aerosol optical depth at the Bonanza Creek site in central Alaska and the analysis of particle size and absorption for the high AOD years of 2004 and 2005, as well as analyses of the AOD at the arctic coastal site of Barrow.

Objectives for the Coming Year

A primary objective will be completion of a paper for a special issue of the *Journal of Geophysical Research (JGR)* on the analysis of data collected from the mesoscale network of AERONET sunphotometers located in the UAE in summer of 2004. This region often exhibits complex mixtures of pollution aerosol and non-spherical desert dust aerosol. Therefore this analysis utilizes retrievals from the enhanced Version 2 spheroid particle-shape retrieval algorithm developed by Dubovik, which also includes surface albedo and bidirectional reflectance distribution function (BRDF) products from MODIS as an input to the retrieval.

Another objective for the coming year is to complete the analysis of data from AERONET monitoring sites in Southeast Asia (Thailand and Vietnam) in order to study the dynamics of biomass burning and urban/industrial aerosol optical properties and the transport of aerosols in this region. A paper on this work will be written and submitted to *JGR*, which will include the analysis of measured aerosol optical depth and retrievals of aerosol size distributions and single scattering albedo from sites that are dominated by fine mode aerosols (pollution and smoke).

Task 900-03-041: **Characterization of Aerosols and Bidirectional Reflectance Distribution Function from Airborne Radiation Measurements**

GEST Investigator: Charles K. Gatebe

Collaborator: Michael D. King (GSFC, Code 610.0), James J. Butler (GSFC, Code 614.4)

Abstract

Charles Gatebe continued to work on the NASA's Cloud Absorption Radiometer (CAR) Project and took part in an international field experiment in Mexico, the Intercontinental Chemical Transport-Phase-B/Megacity Initiative: Local and Global Research Observations (March 2006). He flew on NASA's Jetstream-31 aircraft and made measurements of spectral and angular distribution of scattered light by clouds and aerosols, and provided bidirectional reflectance of various surfaces, and imagery of cloud and Earth surface features in Mexico. These data together with those obtained during two other previous field experiments: the Chesapeake Lighthouse and Aircraft Measurements for Satellites, July – August 2001, and Southern African Regional Science Initiative 2000, August – September 2000 will be used to study aerosol-surface radiative effects and to validate satellite retrievals. In addition, Charles Gatebe presented preliminary results at several international and national conferences. He also conducted extensive laboratory tests to characterize geometrical effects in the calibration of the CAR and continued to mentor and train students at undergraduate and graduate levels.

Description of Research

This study seeks to characterize aerosol surface radiative properties using multi-spectral and multi-angular radiation field measurements. This involves a detailed assessment of the CAR data from selected field campaigns. This effort is tied to development of a new algorithm for inverting CAR multi-spectral and multi-angular radiance measurements by modifying the AERONET inversion code of Sun/Sky radiance. In particular, the AERONET algorithm is adapted to the CAR geometry and spectral range to include a description of the surface bidirectional reflectance distribution function (BRDF) and directional radiance measurements at several vertical levels. The modification enables simultaneous retrieval of detailed surface and vertical variations of complete optical aerosol properties at discrete spectral wavelengths in the ultraviolet, visible, and near-infrared window regions of the solar electromagnetic spectrum. In addition, the study includes tests and validation of the new algorithm for different types of aerosols from mineral dust, marine, biomass burning, and industrial emissions. The main test data is drawn from the CAR multi-spectral and directional measurements made during the Southern African Regional Science Initiative 2000 (SAFARI 2000; August–September 2000), the Chesapeake Lighthouse and Aircraft Measurements for Satellites (CLAMS, July-August 2001) and the Intercontinental Chemical Transport-Phase-B (INTEX-B)/Megacity Initiative: Local and Global Research Observations (MILAGRO; March 2006). An important component of this study involves conducting co-located surface-based measurements with the Surface Measurements for AERONET, airborne measurements with the CAR, and satellite measurements with the Moderate-resolution Imaging spectroradiometer (MODIS) and Multi-angle Imaging Spectroradiometer (MISR), among other platforms.

Accomplishments during the Reporting Period

Gatebe was the principal investigator for CAR during INTEX-B field experiment in Mexico. The CAR flew aboard Sky Research Jetstream-31 aircraft and measured spectral and angular distribution of scattered light by clouds and aerosols, and provided BRDF of various surfaces, and imagery of cloud and Earth surface features. A total of 14 missions were flown from 1-21 March with Gatebe flying seven of those. He trained two support staff (Tom Arnold and Gala Wind) and a student (Juliao Cumbane) on the operations of the CAR, and after the experiment he documented the entire mission at the following websites: http://atmospheres.gsfc.nasa.gov/jpserver/web/default and http://car.gsfc.nasa.gov/data/.

Gatebe hosted a PhD student, Juliao J. Cumbane from Mozambique at NASA Goddard from 2 January-27 May, 2006. He trained him how to operate the CAR, calibrate it, process and analyze the data. He also helped Juliao develop a research proposal for his PhD based on CAR measurements over southern Africa. Juliao is investigating vertical distribution of atmospheric aerosol from slant columns at different elevation angles using CAR measurements. In addition, Gatebe mentored Daniel Kaufman from the University of Maryland, College Park during the 2006 Summer Institute on Atmospheric, Biospheric, Hydrospheric, and Solar and Space Plasma Sciences from 15 June – 18 August and during Winter break from 28 December 2006 – 19 January 2007.

The representation of surface BRDF continues to be a major factor in radiative transfer models. In order to understand the impact of spatial scale variability on BRDF representation, Gatebe initiated laboratory measurements of BRDF from samples (soil, fresh leaves, dry leaves and leaf litter) at Goddard Space Flight Center Diffuser Calibration Facility. He is collaborating with Georgi T. Georgiev (Science Systems and Applications, Inc., Lanham, MD) and James J. Butler (Hydrospheric and Biospheric Sciences Laboratory, NASA GSFC).

Gatebe conducted extensive laboratory tests to characterize geometrical effects in the calibration of the CAR, which involved measurements of three spherical integrating sources at NASA Goddard Space Flight Center's Radiometric Calibration Facility to help improve calibration accuracy of the CAR instrument. He collaborated with John W. Cooper (Science

Systems and Applications, Inc., Lanham, MD) and Dr. James J. Butler (Hydrospheric and Biospheric Sciences Laboratory, NASA GSFC).

Under this task, Gatebe participated in the following conferences: The 4th International Workshop of Multiangular Measurements and Models, Sydney, Australia (20-25 March, 2006), the American Meteorological Society, 12th Conference on Atmospheric Radiation, Madison, Wisconsin, USA (10-14 July, 2006) and the 1st MILAGRO Science Meeting, Boulder, Colorado, USA (23-25 October, 2006).

Objectives for the Coming Year

Gatebe will use a new inversion algorithm for CAR developed under a previous NASA grant to retrieve simultaneously an extended set of aerosol parameters (both below and above the aircraft) and surface BRDF from combined multi-angular and multi-spectral data from CAR, AERONET, and Ames Airborne Tracking Sunphotometer (AATS) acquired during three international field experiments: INTEX-B, March 2006, CLAMS, July – August 2001, and SAFARI 2000, August – September 2000.

The new inversion algorithm involves fitting the measured radiance field to a discrete ordinates radiative transfer model—assuming a plane-parallel, vertically homogenous atmosphere (or multi-layered atmosphere with known vertical profile of aerosol extinction coefficient) and driven by an extended number of aerosol parameters. Currently, surface reflectance is implemented through either (i) a Lambertian approximation—for any type of surface, (ii) a vegetation surface model using the Rahman, Pinty and Verstraete model – a parametric BRDF model that idealizes the BRDF values through a simple non-linear equation requiring the values of three parameters estimated from the remote sensing data, or (iii) the modified isotropic Cox-Munk model for a rough ocean. The modeled single scattering albedo of aerosol is driven by a wavelength dependent aerosol complex index of refraction and a particle size distribution (in the size range: $0.05 \leq r \leq 15$ μm) in the total atmospheric column. Using such a general aerosol model allows derivation of aerosol properties with minimal assumptions in the retrieval algorithm. Only spectral and size smoothness constraints are applied, preventing unrealistic oscillations in either parameter.

He plans to modify the algorithm to include the RossThick-LiSparse BRDF model that is used in MODIS retrievals. Thus, retrievals of the columnar aerosol size distribution, effective radius, and surface area and volume distribution, using CAR, AERONET and AATS transmission spectra will be obtained, plus the surface BRDF from the CAR reflectance spectra.

Task 550-74-257: **Development of Active and Passive Sensors for Remote Sensing Applications**

GEST Investigator: Elena Georgieva

Collaborators: William Heaps (GSFC, Code 550.0), Emily Wilson (GSFC, Code 554.0)

Abstract

This research focuses on the development of differential radiometers using Fabry-Perot interferometric technique for remote sensing determination of various atmospheric trace gases. Fabry-Perot interferometry (FPI) is a well known, powerful spectroscopic technique. One of its many applications is to measure greenhouse gases and some harmful species in the atmosphere. With this technique, absorption of particular species is measured and related to its concentration. A solid Fabry-Perot etalon is used as a frequency filter to restrict the measurement to particular absorption bands of the gas of interest. With adjustment of the thickness of the etalon separation (in frequency) of the transmitted fringes can be made equal to the almost constant separation of the gas absorption lines. By adjusting the temperature of the etalon, which changes the index of refraction of its material, the transmission fringes can be brought into nearly exact correspondence with absorption lines of the particular species. With the alignment of between absorption lines and etalon fringes, changes in the amount of a species in the atmosphere strongly affect the

amount of light transmitted by the etalon and can be related to the gas concentration.

Description of Research

The instrument that has been developed detects the absorption of various atmospheric trace species in direct or reflected sunlight. This instrument employs a Fabry-Perot interferometer which makes use of two features to achieve high sensitivity. The first is high spectral resolution enabling one to match the width of an atmospheric absorption feature by the instrumental band pass. The second is high optical throughput enabled by using multiple spectral lines simultaneously. For any species that one wishes to measure, this first feature is available while the use of multiple spectral features can be employed only for species with suitable spectra and freedom from interfering species in the same wavelength region. Georgieva and her colleagues have developed an instrument for use as a ground-based, airborne and satellite sensor for gases such as carbon dioxide (1570 nm), oxygen (762 nm and 768 nm lines sensitive to changes in oxygen pressure and oxygen temperature) and water vapor (940 nm). The current goal is to develop an ultra precise, inexpensive, ground based device suitable for wide deployment as a validation instrument for the Orbiting Carbon Observatory (OCO) satellite.

The first channel of the instrument is measuring the carbon dioxide column through absorption of sunlight at 1.57 μm. In this design, sunlight passes through the atmosphere where it undergoes absorption by atmospheric carbon dioxide. The light is then introduced into the instrument and split into two sub channels. The first sub channel simply measures the total light intensity. This sub channel responds to changes in overall intensity arising from changes in atmospheric transmission, changes in atmospheric CO_2, and when viewing surface reflected light, changes in ground albedo. The second sub channel is identical to the first except that it includes a solid Fabry-Perot etalon tuned to pass light at the wavelengths that CO_2 absorbs and reflect light at other wavelengths. This sub channel responds to albedo and atmospheric transmission changes just as the first channel but proportionately much more strongly to changes caused by changing CO_2. The ratio of the signals of the two sub channels can be used to infer the atmospheric CO_2 abundance. Set of off axis parabolic (OAP) gold mirrors focuses light onto InGaAs detectors for the CO_2 sub-channels and Si detectors for the other two oxygen channels, which have a very similar design to the CO_2 channel. For bringing light into the instrument, fiber bundles were used, which intentionally scrambled the incident light to remove spatial information.

The flight-hardened version of the instrument was tested at two separate flight campaigns: at NASA Dryden Research Center and at New Hampshire Polar Aura Validation campaign on NASA's DC-8 research airplane.

Accomplishments during the Reporting Period

The past year's research was focused on laboratory work with a flight hardened version of the instrument, building additional channels with reduced dimensions and theoretical simulations. In addition to laboratory validation of the FPI instrument, the researchers continuously perform daily ground-based measurements of the actual atmospheric column in a variety of atmospheric conditions using a fiber coupled sun tracker. The initial tests indicate that the instrument can detects changes in the CO_2 column as small as 2.3 ppm with a one second average and better than 1 ppm in less than 10 seconds averaging capability. The airborne instrument using light reflected off the ground has a precision of about 2%. The detection limit for the oxygen column pressure changes is as small as 0.88 mbar. Water vapor has been measured in the lab and from the ground. The precision is a few percent for one second averages.

The instrument is characterized by high signal to noise ratio, fast response and great specificity. The researchers have performed simulations and instrument designs for systems to detect also CO, $13CO_2$, CH_4, CH_2O, NH_3, SO_2, N_2O, NO_2, and O_3. The most recent laboratory version of a new $13CO_2$ channel at 2.1 μm intended to measure the carbon isotope ratio in the Mars' atmosphere is under development. Isotope ratios

of carbon and oxygen are important for understanding the evolution of the Martian atmosphere and the history of volatiles on Mars. The current existing measurements for the atmospheric CO_2 isotope ratios show a large scatter and uncertainties.

Recent studies were presented at the SPIE Annual meeting in San Diego, AGU meeting in San Francisco and published at Optical Engineering and Measurement Science and Technology.

Objectives for the Coming Year

The researchers' principal goal is to demonstrate the ability of the Fabry-Perot Interferometer to make ultra precise determinations of the total column abundance for CO_2 and O_2, maintaining calibration over an extended period. Additionally, they wish to demonstrate the extension of the capability of this instrument to additional carbon containing species—specifically $13CO_2$, CH_4, and CO. This will have multiple impacts.

In another area of research, Georgieva is interested in developing a small-size channel for CO_2 capable of doing simultaneous measurements with the AERONET (Aerosol Robotic Network) at NASA/GSFC to study the hypothesis that atmospheric aerosols affect the regional terrestrial carbon cycle.

Task 923-39-175: **NPOESS Preparatory Project (NPP) System Calibration / Product Validation Studies**

GEST Investigator: Bruce Guenther (PI)

Collaborators: H. Ouaidrai (SSAI), James Butler (GSFC, Code 614.4), X. Xiong (GSFC, Code 614.4), W. Esaias (GSFC, Code 614.3), K. St. Germain, Integrated Program Office Algorithm Division Chief (NOAA, Department of Commerce.), R. Murphy (George Mason Univ.), James McCarthy (Northrop Grumman Space Technologies)

Abstract

This research involves continuing development and oversight of the NPOESS-NPP Visible/Infrared Imaging Radiometer Suite (VIIRS) sensor engineering, development of the Government Team for the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Program in the area of sensor calibration and Environmental Data Product validation (cal/val). The GEST investigator also is involved in training of the NPOESS System Prime Contractor in tracking engineering development and calibration in support of sensor performance for scientific research and climate data set development. The research includes identification and application of Earth Observing System lessons learned in cal/val to the NPOESS Preparatory Project (NPP) and NPOESS cal/val program. This research also provides the primary scientific input to the NPOESS Program office to lead the determination of implications of sensor design and performance on derived Environmental Data Products.

Description of Research

The research bridging any gaps between research and engineering communities in working on the sensor development of the VIIRS. Research involves organization and direction of the NPOESS Performance Community, organizing diverse perspectives of the community into consensus positions and advocating those perspectives for improved design, analysis and testing of the sensor. The research also includes application of research and engineering standard approaches into the NPOESS contractor assessment of Level 2 operational data products.

Accomplishments during the Reporting Period

This year the GEST PI was named the VIIRS Sensor Scientist by the NPOESS office, and his inputs are being handled by the NPOESS engineering organization as the Government Principal Investigator for VIIRS. Workshops

were held to review the VIIRS engineering model data results, and additional testing requirements were identified and installed into the VIIRS test program for the Flight Units as a result of these workshops. Initial NPOESS uncertainty budgets were developed within the product assessment tools for the first time this year. The GEST investigator served on the Northrop Grumman VIIRS Independent Review Team.

Objectives for the Coming Year

Testing of the NPOESS Preparatory Project VIIRS flight model begins this year, and the primary objective involves reaching final sensor design, performance and characterization processes to meet data product requirements. Advancing analysis techniques and reporting approaches for the engineering analyses into public workshops and publications is a goal for this year as well.

Task 699-78-268: **Mission Related Research in Support of the Mars Science Laboratory and the Sample Analysis at Mars Instrument Suite**

GEST Investigator: Jeffrey C. Joseph

Collaborator: Paul Mahaffy (PI, GSFC, Code 699)

Abstract

Research was performed on National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL) geological samples from earth which served as Mars analogue geological samples. Derivatization of amino acids in the NASA-JPL Mars analogue samples was assessed by Gas Chromatographic Quadrupole Mass Spectrometry (GC-QMS). The Sample Analysis at Mars (SAM) Neutral Gas and Ion Mass Spectrometer (NGIMS) test model was evaluated for its capability to adequately characterize the isotope ratios of CO_2 which is a principal component of Mars' atmosphere. The CO_2 scrubber component of the SAM sample handling and instrument suite was also tested for efficacy using the SAM NGIMS test model.

Description of Research

Analyses of geological samples for NASA-JPL in support of the Mars Science Laboratory (MSL) and its SAM instrument suite were performed. Geological samples from Earth served as analogs to Mars' geological samples during the development of a derivatization process being tested for its efficacy in allowing identification of amino acids by GC-QMS. The mass spectra of the derivatized and then analyzed samples were qualitatively interpreted for the presence of amino acids. The goal of this research was to optimize the derivatization procedure and instrumental analysis in preparation for sample handling and mass spectral analyses to be performed on Mars' geological samples by the NASA MSL-SAM mission.

Analyses of CO_2 using the SAM-NGIMS test instrument was performed to support the proposal to use certain channels of the SAM Tunable Laser Spectrometer (TLS) for analyses of CO_2 in atmosphere of Mars.

Evaluation of the CO_2 Scrubber unit was performed on the SAM-NGIMS test instrument which provided mass spectral data and pressure data related to the adsorbance of CO_2 by the Scrubber Unit.

Accomplishments during the Reporting Period

The NASA SAM research performed thus far this fiscal year has been necessary in preparation for the proposed 2009 deployment of the Mars Science Laboratory. The Mars analogue geological samples that were analyzed provided support for the hypothesis that derivatization of amino acids using the derivatization reagent N-tert.-butyldimethylsilyl-N-methyl-trifluoroacetamide (MTBSTFA) creates derivatives of otherwise nonvolatile amino acids which are sufficiently volatile to be separated and analyzed by GC-QMS. It is also thought that the same result may be achieved for separations and analyses of such species as carboxylic acids and nucleobases. Additionally, the one step derivatization of nonvolatile amino acids,

carboxylic acids, and nucleobases by reaction with MTBSTFA produces volatile derivatives that do not decompose under the pyrolysis analysis. Research on derivatization, separation, and analyses of carboxylic acids and nucleobases is presently underway since these compounds can also serve as indicators of extinct or extant chemical and/or biological processes on Mars.

The study of the CO_2 isotope ratios of the 44 Atomic Mass Unit (AMU) to the 45 AMU and to the 46 AMU molecular ion peaks was performed in order to demonstrate the extent of the capability of SAM NGIMS to characterize the CO_2 isotope ratios at least as well as the performance of the SAM TLS. Initial results for the isotope ratios interpreted from NGIMS spectra have been acceptable upon comparison to literature values. Presently further experiments are planned to demonstrate reproducibility of the NGIMS results.

The CO_2 scrubber tests are aimed at demonstrating the efficiency of the test model (also referred to as the engineering model) of the CO_2 scrubber unit that will be employed in the MSL. The tests not only demonstrate the efficacy of various adsorbents (*e.g.*, Calcium Oxide or Calcium Carbonate) but also the proper mechanical operation and efficacy of the physical construction of the engineering model of the CO_2 scrubber unit. The research also focused on determining the optimal operating temperature T1 to create the most efficient adsorbance of CO_2 onto, for example, CaO (Reaction 1) as well as the optimal operating temperature T2 to regenerate the adsorbent CaO (Reaction 2).

Reaction 1: $CaO + CO_2$ Yields (under T1) > $CaCO_3$

Reaction 2: $CaCO_3$ Yields (under T2) > $CaO + CO_2$

Ideally the T1 and T2 would be optimized so that the lowest amount of energy would be consumed in the MSL and SAM instrument suite.

Objectives for the Coming Year

Joseph will continue research in support of the NASA MSL SAM mission.

Grant NNG04GQ44G: **Antarctic Comprehensive Model from Airborne, Shipborne, Ground, Satellite Magnetometer Data**

GEST Investigator: Hyung Rae Kim

Collaborator: Patrick Taylor (GSFC, Code 698.0)

Abstract

An Antarctic Comprehensive Model (ACM) study is secondary continued to finish the internal part and to design external field modeling of the geomagnetic components. Spherical cap harmonic expansions that represent internal field is explicitly implemented up to maximum index of 150 (equivalent 80 km wavelength or to order 450 for global spherical harmonics, in the region below 60°S latitude). The most recent global spherical harmonic CHAMP model was computed at n and m 90 or 440 km wavelength [Maus *et al.*, 2006]. Their internal geomagnetic field model, called as MF4, was more representative of the field in equatorial and mid-latitudes (up to ±60°) than the high latitudes since MF4 only partially accounted for the complicated external fields predominant in Polar regions. The extended ACM is about to reduce the external magnetic field components to better represent the internal geomagnetic field from near-surface and satellite data in the Antarctic. The external field modeling techniques were already developed by many researchers.

Description of Research

The main and its secular variations of the geomagnetic field were successfully modeled by de Santis *et al.* [2002] and Gaya-Piqué *et al.* [2005] using a spherical cap harmonic analysis with the degree and order of 13. However, for the spatially high-resolution, the crustal field components, higher order and degree of spherical harmonics coefficients are required to represent. For spherical cap harmonics for the

cap size of 30° over Antarctica, harmonic expansion of index 150 (corresponding to 450 in global spherical harmonics), will produce a 80 km wavelength resolution at the surface. This factor will expedite the computation speed because the number of the unknowns for the spherical cap harmonics is only 11 % of the ones for the global spherical harmonics that are corresponding to representing the equivalent wavelengths of the anomalies. The maximum order has been increased to about 0.75° wavelengths at the surface. The external field modeling will be characterized by the polar external field components applying spherical cap harmonic expansions from the ground observatory and satellite dawn/dusk data in which Polar Electrojet (PEJ) are mostly present. Langel *et al.* [1996] was implemented to model the induced field from the magnetospheric currents using Magsat data. Ritter *et al.* [2004] also found PEJ magnetic field signatures in CHAMP satellite data, inferring that the Polar ionospheric and field-aligned current fields had a good agreement with the ground observatory network data. Based on these studies, Kim will develop the external field model in the region south of 60°S latitude, using a spherical cap harmonic analysis. Torta *et al.* [1997] produced the spherical cap harmonic model for only the ionospheric current field and its induced field from the European observatory data and Weimer [2001] constructed field-aligned current model from DE-2 and ground data using the spherical cap expansions. The concurrent measurements from several satellites orbiting at different local times and locations (future SWARM constellation mission) will permit explicit modeling of these external fields because the gradient measurements from SWARM data will be useful to regularize FAC that tends to show great disturbance in these component measurements. Therefore, the researchers will have the computer analyses ready in advance of the SWARM mission.

Accomplishments during the Reporting Period

The investigator presented a comprehensive crustal magnetic model both at AGU Spring meeting in Baltimore in May 2006, and at the First Swarm International Science Workshop in Nante, France. This presentation was a part of the result for the internal geomagnetic field representations over Antarctic continent and its surroundings. For the external components, Kim and his colleagues presented a couple of abstracts in European Geophysical Union assembly held in Vienna, Austria, about comparison between magnetic external field variability from CHAMP and altimetry-derived ionosphere electron counts over the Antarctic.

Kim worked with colleagues on the GRACE gravity interpretation over Wilkes Land, Antarctica, and presented results on the giant impact related to discontinuity of Earth geologic history to the media as well as the Scientific Committee of Antarctic Research (SCAR) meeting at Hobart, Australia. He also took part in research collaboration regarding the role of geologic control on glacial drainage to map major geological boundaries on ice covered areas in Greenland. A publication of this research has been accepted. Additional publications, included the potential field gradient study works using Gauss-Legendre integration in collaboration with OSU colleague is in-press at *Geophysical Journal International* (for gravity) and submitted (for magnetics). A paper regarding the geomagnetic field modeling from KOMSAT satellite data is in press at *Journal of Geophysical Research*. Finally, Kim awaits the decision on a pending proposal where he is listed as a Co-PI for the NASA/ROSES program (Earth Surface and Interiors).

Objectives for the Coming Year

The investigator plans to present the results on XXIV IUGG assembly in Perusia, Italy and ISAES in Santa Barbara, California, both in summer. Especially in ISAES, as an active member in ADMAP Working Group (WG), he will work a new generation of ADMAP to renew the data compilation of the near-surface magnetic survey observations that were not included in the first compilation. Also, the ADMAP WG will accommodate with WDMAM group to compile all the near-surface magnetic data available for geophysical applications. He will prepare for a new proposal to NSF about geopotential analysis of Antarctic using not only current CHAMP and GRACE data, but also future SWARM and GOCE mission data, for

better understanding subsurface of the Antarctic regions. This investigation will focus mainly on how these geopotential data features would affect the environmental changes on the Antarctic.

He expects to hear the result on the proposal submitted to Earth Surface and Interior (Co-PI) sponsored by NASA, this coming March and to get started researching the related topics.

Task 613-71-249: **Aerosol-Water Cycle Interaction**

GEST Investigator: Kyu-Myong Kim

Collaborator: William K.-M. Lau (GSFC, Code 613.0)

Abstract

It has been demonstrated that absorption of solar radiation by dust coated with black carbon in the southern slopes of Himalaya heats atmosphere and initiate dry convection which draws warm, moisture airs from Indian Ocean and bring rain to the northern India in May and June. Based on the atmospheric general circulation model forced with seasonally varying three dimensional aerosol distribution obtained from GOCART model, the "Elevated Heat Pump (EHP)" hypothesis is proposed as a plausible mechanism of aerosol-monsoon water cycle interaction. A diagnosis of the model reanalysis and the satellite data, as well as in situ observation, has been conducted to support the proposed EHP hypothesis. Results are consistent with the key features of the EHP effect in showing that absorbing aerosol is associated with a) anomalous warming of the upper troposphere over the Tibetan Plateau in May and June, b) an advance of the monsoon season, with increased rainfall coming to northern India during May, and c) subsequent enhancement of the monsoon rain over India in June-July. EHP also plays significant role in western African monsoon.

Description of Research

Goal of this research is to understand the effect of aerosol radiative forcing on the global monsoon water cycle. Various satellite observations including MODIS, TOMS, and TRMM as well as in-situ observations are being used to diagnose the relations between aerosol distribution and the evolution of monsoon water cycle. Modeling experiments forced with aerosols from GOCART model are also conducted to understand the mechanisms involved. Immediate focus will be on the relative roles of "Global Dimming effect" and "Elevated heat-pump effect" on monsoon circulation over Indian sub-continent and West African monsoon region.

Accomplishments during the Reporting Period

The investigator and PI worked on the relative roles of the "global dimming" and "Elevated Heat Pump (EHP)" in regional monsoon water cycle over Indian subcontinent. Based on the GCM experiments with and without aerosol radiative forcing, the "Elevated Heat Pump (EHP)" hypothesis is proposed as a plausible mechanism of aerosol-monsoon water cycle interaction. During pre-monsoon season (April to May), dust transported from deserts adjacent to the Asian monsoon region accumulate against the southern slope of the Tibetan Plateau. Due to the shortwave absorption by dust and black carbon, the atmosphere over northern India is heated relative to the region to the south, setting the stage for an anomalous large-scale circulation response. The aerosol-induced heated air rises over the southern slope of the Tibetan Plateau, and draws warm and moist low level inflow from the Indian Ocean. As a result, the region of convective instability shift to the north and eventually enhanced local Hadley circulation with rising motion (increased rainfall) over northern India, and sinking motion (reduced rainfall) over the northern Indian Ocean.

Results from the diagnostics of observation are consistent with the key features of the EHP effect proposed in showing that the anomalous high concentration of absorbing aerosol during the pre-monsoon season is associated with a) anomalous warming associated with the

development of a large-scale anticyclone in the upper troposphere over the Tibetan Plateau in May and June, b) an advance of the monsoon season, with increased rainfall coming to northern India during May, and c) subsequent enhancement of the monsoon rain over India in June-July.

Because of the increased loading of the black carbon from anthropogenic sources in the northern India, the relationship predicted by EHP may hold on decadal to climate change time scales. To explore the EHP effect on the long-term trend of rainfall over India, further diagnostics are conducted with Indian sub-regional rainfall data. Consistent with EHP hypothesis, the May-June rainfall has been increased in the most part of central to northern India during last 50 years. Increase is most prominent over central north-east India. On the other hand, the summer rainfall in July and August has been decreased all Indian sub-continent except north-east India. The result indicates that EHP effect is stronger in pre-monsoon season in the region of heavy aerosol loading.

Effects of Saharan dust and El Nino on the various measures (frequency, accumulated cyclone energy, and intensity of storm) of tropical storm and hurricane over Atlantic Ocean are investigated from historical records of hurricane track data and dust concentration observed from Barbados Island. Both dust and El Nino have significant influences on the all measures in genesis region of eastern tropical Atlantic Ocean. Over all, El Nino has stronger influence primarily through increase in the vertical wind shear. Dust influences on tropical storm statistics in intensification region of central Atlantic Ocean where storms and hurricane usually intensify, remain essentially the same, or vary slightly in the different categories. However, El Nino influence is substantially diminished in the same region. The result supports the notion that Saharan dust may be an important factor, more so than El Nino, in suppressing tropical storm/hurricane activities in the West Atlantic and Caribbean region. By comparing two distinctive years, active hurricane season in 2005 and below normal season in 2006, increased dust loading over Atlantic Ocean was found to cool sea surface temperature in the vast area of the Central Atlantic Ocean and prevent development/initiation of storms. The results are published in the latest issue of *EOS Trans. AGU*.

Objectives for the Coming Year

Further studies on the effect of aerosol radiative forcing on the water cycle over Indian subcontinent and the western African monsoon region will be conducted based on in situ and satellite observation as well as simulation of atmospheric general circulation model with prescribed aerosol radiative forcing. For the India subcontinent, snow depth over Tibet, rainfall, and various other in situ data over northern India will be diagnosed to study 1) the role of high mountains in EHP and 2) the impact of EHP on long-term climate variation over northern India and Tibet. For western African monsoon region, the focus will be on the possible large-scale climatic impact of Saharan dust on the hydrologic cycle and the mid-summer drought over Caribbean during boreal summer. The effect of aerosols on the diurnal variation of rainfall over western Africa, eastern Atlantic Ocean and Caribbean will also be studied.

Task 923-32-162: **Development of Atmospheric Correction algorithm for MODIS, and Algorithm Analysis for Land Surface and Atmospheric Products for VIIRS**

GEST Investigator: Alexei Lyapustin

Collaborator: Yujie Wang

Abstract

A new Multi-Angle Implementation of Atmospheric Correction (MAIAC) algorithm has been developed for processing of MODIS measurements. MAIAC is a generic algorithm that simultaneously retrieves the aerosol optical

thickness (AOT) and surface bi-directional reflectance using the 16-day time series of gridded MODIS L1B measurements over land. The new algorithm is generic and works globally over all surface types, including bright deserts, with the temporary exception of snow. MAIAC products include cloud mask, water vapor, aerosol optical thickness at 0.47 μm and 0.66 μm and Angstrom parameter, surface spectral bidirectional reflectance factor (BRF) and albedo for the reflective land and ocean MODIS bands. All products are generated uniformly at 1 km resolution in gridded format. The initial comparison of the aerosol optical thickness with AERONET measurements for different types of aerosol, including urban/continental (USA, Europe), biomass burning (Africa, Brazil), dust (Saudi Arabia, China), shows a very good agreement.

Description of Research

The main objective of this research is developing an advanced aerosol retrieval - atmospheric correction algorithms for the EOS MODIS imaging spectrometer.

The contemporary paradigm of remote sensing from the whisk-broom low-orbit sensors (AVHRR, MODIS etc.) is pixel-based and relies on a single-orbit data. It produces a single measurement for every pixel characterized by two main unknowns, AOT and surface reflectance. This lack of information constitutes a fundamental problem of the remote sensing which cannot be solved without either a priori assumptions, *e.g.*, about spectral regression coefficients for the Dark Target method [Remer *et al.*, 2006; Vermote *et al.*, 2002], or ancillary data, such as a global surface reflectance database for the Deep Blue method [Hsu *et al.*, 2004]. The approximate nature of these a priori constraints and use of common simplifications in the radiative transfer model, such as Lambertian model of surface reflectance, limit the accuracy and/or applicability of the current operational aerosol/atmospheric correction algorithms.

The goal has been to develop the algorithm for the simultaneous retrieval of the aerosol optical thickness and surface bidirectional reflectance, achieving the quality of climate data records. This research shows that the simultaneous retrievals is possible when using the time series of gridded top of the atmosphere MODIS measurements, given that the surface reflectance is spatially variable and changes little in short time intervals, whereas aerosols change in time, as compared to the frequency of spaceborne observations, and have a mesoscale (60-100 km) range of the global variability [Anderson *et al.*, 2003]. Theoretically, the researcher's approach is based on the semi-analytical Green's function solution for the radiative transfer in atmosphere with anisotropically reflecting surface [Lyapustin and Knyazikhin, 2001; Lyapustin and Wang, 2005].

Accomplishments during the Reporting Period

During the past year, Lyapustin and Yujie Wang developed the new algorithm for the atmospheric correction of MODIS data over land: the Multi-Angle Implementation of Atmospheric Correction (MAIAC). MAIAC is designed to simultaneously retrieve the aerosol optical thickness and surface bi-directional reflectance using the 16-day time series of gridded MODIS L1B measurements. The separability of atmospheric and surface parameters is achieved by using the time series of measurements providing the multi-angle coverage, and an image-based rather than pixel-based processing.

The new algorithm is generic and works globally over all surface types, including bright deserts, with the temporary exception of snow. MAIAC products include cloud mask, water vapor, aerosol optical thickness at 0.47 μm and 0.66 μm and Angstrom parameter, surface spectral bidirectional reflectance factor (BRF), direct BRF, and albedo for MODIS land bands 1-7, and ocean bands 8-14L, which are not saturated over land. The BRF and albedo are derived from the time series of measurements, whereas the direct BRF is derived from the last measurement only. All products are generated uniformly at 1 km resolution in gridded format. The suite of products is fully compliant with energy conservation principle in a sense that the radiative transfer computations with retrieved

parameters reproduce measurements with high accuracy.

The cloud mask, aerosol retrievals, and atmospheric correction are completely new algorithms free from conventional assumptions about the surface that generally limit the accuracy of products. MAIAC algorithm uses up to 16 days of gridded MODIS measurements to make simultaneous retrievals of AOT and surface BRF/albedo. A requirement of consistency of the time series of retrieved BRF provides an additional constraint enhancing quality of both surface and aerosol retrievals.

The new algorithm is described in detail in the Algorithm Theoretical Basis Document (ATBD), which can be found at: http://neptune.gsfc.nasa.gov/bsb/subpages/index.php?section=Projects&content=SHARM, in the section MAIAC ATBD.

Objectives for the Coming Year

Lyapustin's effort, supported by NASA EOS and GOES-R grant funding, will be focused on four tasks: optimization of the atmospheric correction algorithm MAIAC for the operational processing of MODIS data; extensive validation of aerosol retrievals globally, and global analysis of the algorithm performance; extensive cross-comparison of the MAIAC cloud mask, aerosol optical thickness, and surface BRF and albedo with MODIS operational products MOD35, MOD04, and MOD09/MOD43 for the different world regions and globally representative set of conditions; and cross-calibration analysis of MODIS on the TERRA and AQUA platforms using the ASRVN albedo product.

Task 923-03-067: **AERONET - Ground Based Remote Sensing of Aerosol Optical Properties**

GEST Investigator: Alexander Smirnov

Collaborator: Brent N. Holben (GSFC, Code 614.4)

Abstract

Research performed during the last fiscal year focused on the refinement of AERONET cloud screening algorithm and associated sensitivity study that allowed estimating its impact on the operational processing and long-term statistics. AERONET activity and data collection in the countries of the former Soviet Union afforded a noteworthy analysis of aerosol optical properties. Aerosol optical depth diurnal variability in East Asia was a subject of a special study for the 2006 Western Pacific Geophysics Meeting in Beijing. Release of Version 2 of the AERONET inversion algorithm necessitated establishment of criteria for quality assured products. Organization of the ship-based optical depth data acquisition and performed analysis of the new data and historical dataset collected by the SIMBIOS project was an important step in reestablishing NASA's ship-based optical depth measurement network. Four peer-reviewed papers co-authored by the GEST investigator were published during this time period.

Description of Research

Remotely measured atmospheric aerosol optical parameters are important for various applications including computations of radiative forcing and satellite remote sensing. Aerosol optical depth, which may be derived from measurements of attenuated direct solar radiation, as well as the aerosol size distribution and single-scattering albedo, which may be derived from combined aerosol optical depth and solar almucantar sky radiance data, are pivotal parameters defining the aerosol optical state of the atmosphere. The major advantage of these kind of remote sensing measurements over direct in-situ aerosol sampling or laboratory analysis is their large-scale (column integrated quantities) and non-intrusive nature.

Accomplishments during the Reporting Period

The foundation of the AERONET measurements program is aerosol optical depth. The automated cloud screening algorithm has been successfully deployed operationally since 1998 however certain shortcoming became evident in process of data archive growth. Certain tools and

thresholds were tested to improve the performance of the cloud screening procedure and recommendations were made. Sensitivity tests showed that any changes in the current algorithm (if done without an appropriate care) would alter the established statistics either yearly or monthly or both. However, certain recommendations can be made and a modified algorithm (if implemented) will increase a number of accepted measurements, especially in the conditions of highly variable urban/industrial aerosol, and on the other hand will preserve the existing integrity of the AERONET database and long-term statistics. The major challenge, however, is an automatization of the data quality assurance, in other words automated data transfer from Level 1.5 to Level 2. This is a subject of the future research.

Aerosol Robotic Network activity in Russia, Moldova, Estonia, Belarus, and Ukraine can be considered as an example of the mutually beneficial collaborative effort. The results and prospective were summarized in the invited presentation at the International Symposium on Atmospheric Radiation in Saint Petersburg, Russia. Smirnov and Holben suggested that the Russian Academy of Sciences provide the unsolicited financial support for the AEROSIBNET (Russian part of the AERONET), the organization of the regional calibration center and processing hub, and a separate budget for instrument acquisition.

The AERONET inversion products provide pivotal information for understanding aerosol optical properties particularly given the wide global distribution of sites. The Version 2.0 input and post inversion screening criteria have been redefined based on analysis of a decade of observations, improved capability and flexibility of the inversion algorithm to handle variable input parameters and a more thorough understanding of the instrumental measurements and algorithmic requirements. Further analysis of the data is required to refine the calibration criteria and clearly development of quality assurance thresholds will remain an ongoing process as instruments and algorithms develop.

Study of the long-term regional aerosol variability is important especially in the areas where AERONET monitoring stations are absent. Atmospheric optical properties over the oceans are still scarce. Substantial radiative effects of the sea-salt aerosol, better understanding of the climate change; very few systematic measurements over the oceans create a demand for more data acquisition. The researchers suggested the establishment of the Oceanic Aerosol Network as a new component of the Aerosol Robotic Network (AERONET) that adheres to AERONET calibration and processing. Ship-based measurements can at least partly fill the gap in the knowledge regarding global aerosol distribution over the oceans and complement island-based AERONET sites. Smirnov and his colleagues plan to reestablish NASA's ship-based aerosol optical depth measurement network by deploying hand-held sun photometers on various ships of opportunity; developing an archival system, similar to the AERONET browser, but specifically designed for "moving" objects (*i.e.*, ships); developing a calibration protocol; developing stand alone processing, utilizing AERONET's Version 2 algorithm; and developing a centralized archiving and distribution system allowing for public domain, web-based access. The suggested Oceanic Aerosol Network (AERONET – OAN) will provide important information for the Ocean Color community as well as global ocean and global climate studies.

Objectives for the Coming Year

The researchers will focus on the development and implementation of the modified AERONET cloud screening procedure, reestablishment of the NASA's ship-based optical depth measurement network, expanding data collection over the oceans, and data analyses.

Task 915-50-193: **Laboratory Investigations on Electrical Discharge and Methane Destruction in the Martian Atmosphere**

GEST Investigator: Inge L. ten Kate

Collaborator: Paul R. Mahaffy (GSFC, Code 699.0)

Abstract

The primary focus of this research is to experimentally test different theoretical models of electrical discharge in the Martian dust storms and breakdown processes in the Martian atmosphere due to this electrical discharge, using a dedicated simulation facility. The construction of this facility is underway. Other projects involved organizing the GSFC contribution at a family day at the National Air and Space Museum, entitled "Are we alone in the Universe?", and participating in the organic contamination work for the Sample Analysis on Mars instrument (SAM).

Description of Research

Methane has been detected in the Martian atmosphere by means of different, independent techniques, from orbit [Formisano *et al.*, 2004] as well as earth based telescopes [Krasnopolsky *et al.*, 2004]. Different theories have been proposed to explain the variability in the amount of methane (CH_4) in the Martian atmosphere. One proposed mechanism that could destroy CH_4 is breakdown through electric discharge. This discharge could be induced by electric fields generated by dust particle interaction in dust storms and dust devils [Farrel, Delory, and Atreya, 2006]. Theoretical models describe the processes that could occur on the Martian surface, giving estimates of breakdown voltages and reaction schemes of particles generated by these processes [Farrel, Delory, Atreya, 2006; Melnik & Parrot, 1998; Hackam, 1969].

In order to test these predicted breakdown scenarios, a laboratory setup was built to simulate these processes. The facility consists of two chambers, one of which is kept at hard vacuum (10^{-7} Torr), and has a quadrupole mass spectrometer (QMS) connected to it. The second chamber—the actual discharge chamber—is mounted inside the QMS chamber. This chamber will be kept at a Martian ambient pressure. Discharge processes are induced in this chamber by creating a voltage difference inside the chamber and a hole in the chamber is positioned right in front of the QMS detector, such that breakdown products created by the discharge can be directly measured, avoiding wall and inter-particle interaction.

Goals of this research are to investigate breakdown products of different gas mixtures as functions of voltage difference and the effect of dust on these breakdown processes. This research is performed in support of the Sample Analysis on Mars instrument (SAM) that is currently under development at GFSC, planned to fly to Mars in 2009.

Accomplishments during the Reporting Period

This research project was started in September 2006. So far, a system is under development and first results are expected in the near future.

The National Air and Space Museum family day contribution consisted of a poster display and several demonstrations, and 15 people of GSFC participated in this event. Over 500 visitors participated in the demonstrations and talked to the GSFC representatives. The SAM contamination work started off with an oral presentation at the AGU fall meeting. This presentation led to an invited paper on this issue, which is currently under construction.

Objectives for the Coming Year

An experimental campaign is planned, in which the breakdown processes of different gasses in the Martian atmosphere will be investigated as function of mixture composition and electric field. After analyzing the discharge processes in a dust free atmosphere, the facility will be modified to enable the introduction of dust, and the experiments will be repeated in order to investigate the effect of dust in the discharge processes.

Task 923-32-162: **Multi-Angle Implementation of Atmospheric Correction for MODIS (MAIAC) and AERONET-based Surface Reflectance Validation Network (A-SRVN)**

GEST Investigator: Yujie Wang

Collaborator: Alexei Lyapustin

Abstract

Lyapustin and Wang have developed a new MODIS atmospheric correction algorithm, which uses multi-temporal observations and an image-based rather than pixel-based processing. The new algorithm retrieves aerosol optical thickness simultaneously with surface bidirectional reflectance and albedo. It is generic and works over the dark vegetated and bright non-vegetated world regions with the current exception of snow-covered areas. The algorithm has internal water vapor retrievals and a new cloud mask algorithm. MAIAC products include cloud mask, water vapor, aerosol optical thickness at 0.47 μm and 0.66 μm and Angstrom parameter, surface spectral bidirectional reflectance factor (BRF) and albedo for the reflective land and ocean MODIS bands. All products are generated uniformly at 1 km resolution in gridded format. An initial validation shows that the retrievals agree well with AERONET measurements. In order to evaluate the performance of the algorithm, Wang and Lyapustin also continued to develop the AERONET-based Surface Reflectance Validation Network (A-SRVN), which is an indirect approach of validation of surface reflectance product around Aerosol Robotic Network (AERONET) sunphotometer sites. The idea is to collect the best ancillary information on atmospheric aerosol and water vapor, and perform an independent atmospheric correction of satellite measurements based on accurate radiative transfer theory that is not constrained by the time requirements of operational processing. Since this A-SRVN system simultaneously collects and processes long time MISR, MODIS and future VIIRS data over a relatively large area, it has great merit in inter-sensor calibration analysis, long-term trend analysis of sensors, and validation of heterogeneous land surface products.

Description of Research

The main objective of this research is developing an advanced aerosol retrieval - atmospheric correction algorithms for the EOS MODIS imaging spectrometer.

The contemporary paradigm of remote sensing from the whisk-broom low-orbit sensors (AVHRR, MODIS, etc.) is pixel-based and relies on a single-orbit data. It produces a single measurement for every pixel characterized by two main unknowns, AOT and surface reflectance. This lack of information constitutes a fundamental problem of the remote sensing which cannot be solved without either a priori assumptions, *e.g.*, about spectral regression coefficients for the Dark Target method [Remer *et al.*, 2006; Vermote *et al.*, 2002], or ancillary data, such as a global surface reflectance database for the Deep Blue method [Hsu *et al.*, 2004]. The approximate nature of these a priori constraints and use of common simplifications in the radiative transfer model, such as Lambertian model of surface reflectance, limit the accuracy and/or applicability of the current operational aerosol/atmospheric correction algorithms.

This research shows that the simultaneous retrievals is possible when using the time series of gridded top of the atmosphere MODIS measurements, given that the surface reflectance is spatially variable and changes little in short time intervals, whereas aerosols change in time, as compared to the frequency of spaceborne observations, and have a mesoscale (60-100 km) range of the global variability [Anderson *et al.*, 2003]. Based on the semi-analytical Green's function solution for the radiative transfer in

atmosphere with anisotropically reflecting surface [Lyapustin and Knyazikhin, 2001; Lyapustin and Wang, 2005], the GEST investigators have developed the new MAIAC algorithm that simultaneously retrieves aerosol optical depth and surface BRF from multi-temporal MODIS images.

Wang and Lyapustin also continued to develop the A-SRVN system for the validation and inter-comparison of the new algorithm. This includes collecting best ancillary information on atmospherics aerosol and water vapor through AERONET stations, developing generic sensor/resolution independent aerosol retrieval - atmospheric correction algorithm and comparing retrieved surface reflectance with MISR/MODIS surface reflectance products. This system can automatically receive MISR and MODIS Level 1B subsets over a 32x32 km^2 area around the 166 AERONET sites globally, and perform an independent atmospheric correction of satellite measurements based on accurate radiative transfer theory that is not constrained by the time requirements of operational processing.

Accomplishments during the Reporting Period

Over the past year, the researchers developed the new algorithm for the atmospheric correction of MODIS data over land: the Multi-Angle Implementation of Atmospheric Correction (MAIAC). The new algorithm started from the development of a new efficient processing system to support image and time series based analysis. First, an improved gridding algorithm is developed to reproject/resample MODIS L1B TOA reflectance and geometry data into user defined grid. Then a “moving window” algorithm is implemented to manage and manipulate the gridded multi-temporal images. This system is efficient, flexible and yet provides easy-to-use data structures for further algorithm development.

With the support of this processing system, a new cloud mask algorithm, which is based on the multi-temporal spatial texture analysis, is implemented. Further more, a new AOT retrieval algorithm, which uses the information of multi-pixel blocks and multi-temporal images, was also implemented. Last, a time-series based pixel level atmospheric correction algorithm is implemented. MAIAC products include cloud mask, water vapor, aerosol optical thickness at 0.47 μm and 0.66 μm and Angstrom parameter, surface spectral bidirectional reflectance factor (BRF) and albedo for the reflective land and ocean MODIS bands. All products are generated uniformly at 1 km resolution in gridded format. The suit of products is fully compliant with energy conservation principle in a sense that the radiative transfer computations with retrieved parameters reproduce measurements with high accuracy.

This new algorithm has been tested over both 50x50km subsets surrounding AERONET stations and several large-scale areas such as north-east America, Zambia Africa, Arabian peninsular and Amazonian area. Preliminary results show great performance. The new algorithm is described in detail in the Algorithm Theoretical Basis Document (ATBD), which can be found at: http://neptune.gsfc.nasa.gov/bsb/subpages/index.php?section=Projects&content=SHARM, in the section MAIAC ATBD.

The researchers also continued to develop the A-SRVN system. Approximately seven years of MISR data and three years of collection 5 MODIS data has been accumulated. Based on this, they analyzed the calibration difference between MISR and MODIS sensors and found that the band gain differences are 5.8% in the blue, 3.1% in the green, and 1.8% in the red band.

Objectives for the Coming Year

Wang’s effort, supported by NASA EOS and GOES-R grant funding, will be focused on following tasks: optimization of the atmospheric correction algorithm MAIAC for the operational processing of MODIS data; extensive validation of aerosol retrievals globally, and global analysis of the algorithm performance; extensive cross-comparison of the MAIAC cloud mask, aerosol optical thickness, and surface BRF and albedo with MODIS operational products MOD35, MOD04, and MOD09/MOD43 for the different world regions and globally representative set of conditions; cross-calibration analysis of MODIS

on the TERRA and AQUA platforms using the A-SRVN albedo product; and comparison of the MODIS and MISR BRF/Albedo products using the A-SRVN system.

Task 913-57-211: **Measurement-based Assessments of Aerosol Direct Radiative Forcing and Intercontinental Transport**

GEST Investigator: Hongbin Yu

Collaborators: Mian Chin (GSFC, Code 613.3), Lorraine Remer (GSFC, Code 613.2)

Abstract

Current assessment of the aerosol direct forcing as reported in the Intergovermental Panel on Climate Change (IPCC) Third Assessment Report is largely model-based and has large uncertainties. There has been compelling evidence for the intercontinental and hemispheric transport of tropospheric aerosols. Such large-scale transport has important implications for climate change, air quality, human health, and biogeochemistry, as suggested mainly by model simulations. Long term, measurement-based studies are necessary to adequately assess the aerosol radiative forcing and environmental implications on scales from local to global. In recent years, a great deal of effort has gone into improving measurements and datasets. It is thus feasible to shift the estimates of aerosol forcing and long-range transport from largely model-based to increasingly measurement-based. The goal is to generate a measurement-based climatology of aerosol direct forcing and of import and export fluxes of aerosols over major dust and pollution inflow/outflow regions and assess the role of long range transport of aerosols on regional and global air quality and climate forcing.

Description of Research

Aerosols affect the Earth's energy budget directly by scattering and absorbing radiation and indirectly by acting as cloud condensation nuclei and, thereby, affecting cloud properties. The overall forcing by anthropogenic aerosols is likely to be negative (*i.e.*, cooling effect) and may be comparable in magnitude to the positive forcing (*i.e.*, warming effect) by anthropogenic greenhouse gases. Aerosols can transport thousands of miles downwind, thereby having important implications for the environment and climate change on a wide range of scales, from local to regional to hemispheric and to global scale. Past assessment efforts of aerosol direct forcing and intercontinental transport were done through modeling efforts and large uncertainties exist. Enhanced new satellite passive sensors (*e.g.*, MODIS, MISR, POLDER) introduced in the last decade, the emerging measurements of aerosol vertical distributions from space-borne Lidars (*e.g.*, GLAS and CALIPSO), and a number of intensive field experiments conducted around the world provided the opportunity to attempt long term and measurement-based assessments. Such satellite-based methods can play a role in extending temporal and spatial scale of field campaigns and evaluating and constraining model simulations. On the other hand, model simulations and measurements from field campaigns can provide parameters that satellites don't observe. The goal is to assess aerosol direct radiative forcing and aerosol intercontinental transport through an integration of multiple satellite observations and measurements from intensive field campaigns supplemented by model simulations.

Accomplishments during the Reporting Period

The GEST researchers assessed a number of satellite-based, model-satellite-integrated, and model-based estimates of aerosol direct forcing on both global and regional scales, as documented in a comprehensive paper [Yu *et al.*, 2006]. In the paper, Yu also assessed current measurement capabilities in characterizing aerosols and estimating the direct effect, discussed outstanding issues, and proposed future research. This paper has been highlighted in the U.S. Climate Change Science Program's (CCSP) report *Our Changing Planet* for FY 2007 and has been serving as a major resource in the preparation of the IPCC Fourth Assessment Report. Two of outstanding issues identified

include the estimate of aerosol direct forcing in the presence of clouds and the aerosol-induced heating rate profiles, both depending critically on vertical distributions of aerosol and cloud. Yu and his colleagues have been working toward better estimates of vertical distributions of aerosol forcing in both clear-sky and cloudy-sky conditions by examining available GLAS observations and conducting sensitivity analysis with the GOCART model. Such data analysis and model simulations have formulated a submitted proposal of an integrated study of 3-D distributions of aerosols and their direct radiative effects using passive (*e.g.*, MODIS) and active (CALIPSO) observations from the A-Train and GOCART simulations.

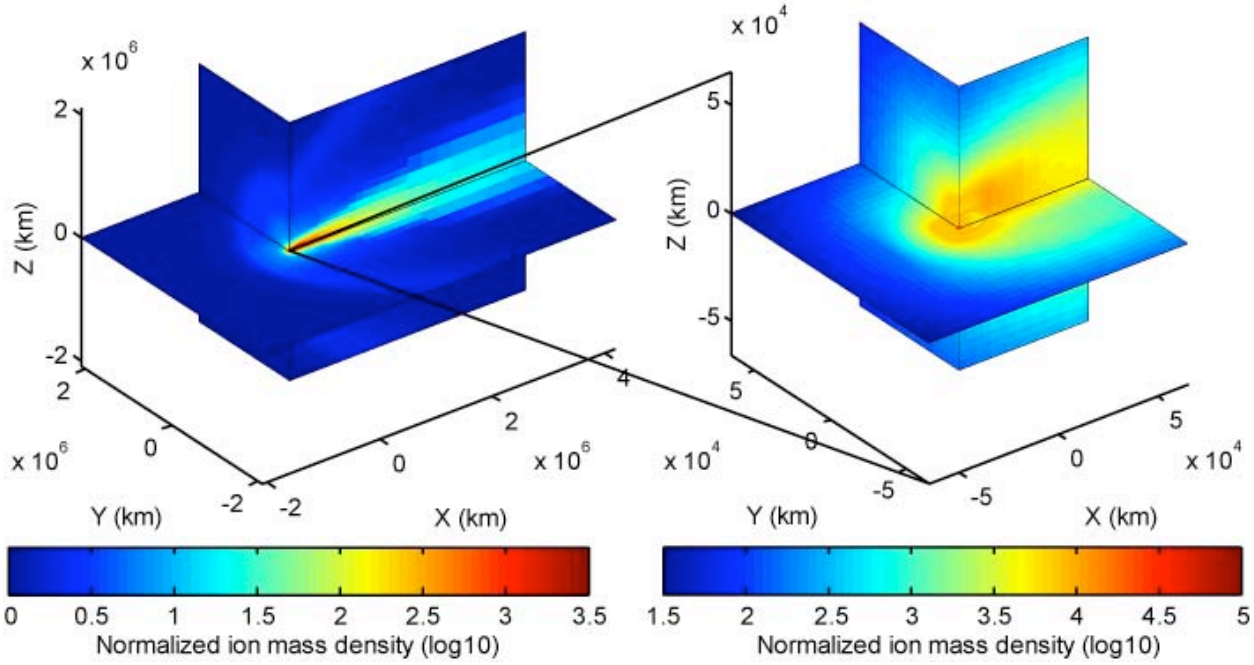
Kaufman *et al.* [2005] developed an algorithm to distinguish pollution aerosol (a mixture of industrial/urban pollutants and smoke) from dust by taking advantage of MODIS's multi-wavelength capability that separates fine- and coarse-mode aerosol. Yu improved the algorithm by accounting for seasonal and geographical variations of fine-mode fraction (FMF) of maritime aerosols, instead of using a constant FMF globally as in Kaufman *et al.* [2005]. Such modification can result in more than 20% changes in the derived pollution aerosol optical depth in some regions and seasons. The derived pollution aerosol optical depth was then used to calculate the aerosol mass loading and mass fluxes in the whole atmospheric column by integrating relative humidity observations from AIRS, aerosol vertical profiles from GLAS, and a suite of measurements from intensive field campaigns, such as mass extinction efficiency, swelling in the ambient environment, and major transport heights of pollution aerosol. The method was applied to the North Pacific region and has assessed seasonal and interannual variations of the pollution mass fluxes exported from East Asia to the northwestern Pacific Ocean and imported to the West Coast of North America. It is estimated that about 30% of pollution aerosol exported from East Asia can reach the West Coast of North America by the mid-latitude strong westerly. The pollution transport is strongest in spring, followed by winter. During 2002-2005, the pollution flux was strongest in 2003, due mainly to the recorded intense boreal forest fires from Eurasia. The overall uncertainty associated with the estimated pollution flux is estimated at 50-72%. The MODIS-based estimates agree reasonably well with GOCART simulations.

Objectives for the Coming Year

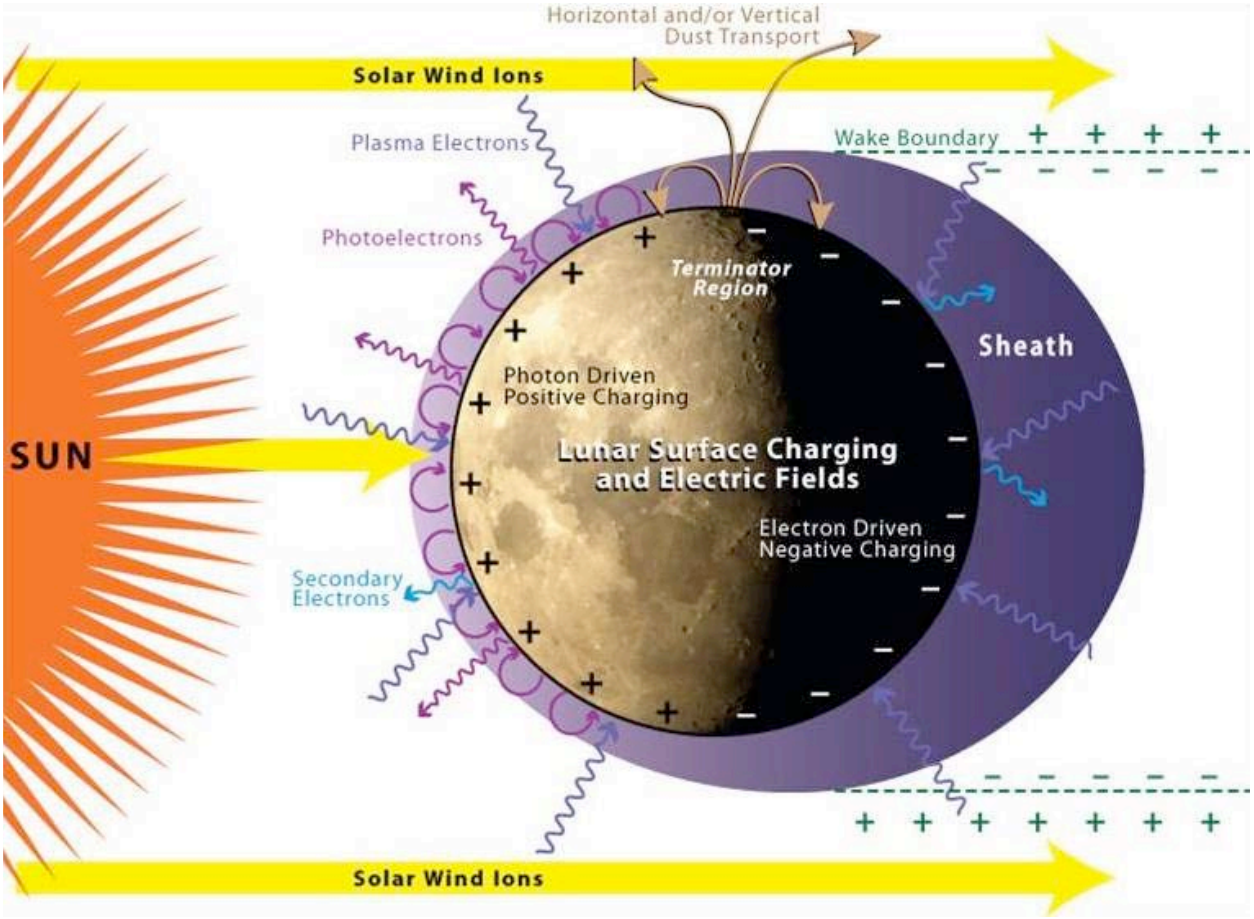
Yu and his colleagues plan to further improve the characterization of pollution aerosol by integrating emerging A-Train datasets. Continuous and global observations of aerosol vertical distributions from CALIPSO will be used to determine aerosol transport heights. Polarization measurements from POLDER can be used to better separate pollution from dust. They will extend the intercontinental transport analysis to dust aerosol and to other regions.

This page intentionally left blank

Heliophysics Research Group



Example of results from the ACASIM model: 3-D structure of Comet 1P/Halley's normalized ion mass density (logarithmic value). The ion mass density is normalized to its value in the unperturbed solar wind (7 ions/cc). [Figure extracted from Benna and Mahaffy, 2006, Planet & Space Sci., in press.]



Schematic of the near-surface lunar plasma environment in the solar wind. The surface of the Moon typically becomes electrostatically charged positive in sunlit areas (photoemission of electrons) and negative in shadowed regions (high electron fluxes). In addition, a void or "plasma wake" forms downstream of the Moon due to the solar wind being a supersonic flow, which has a significant impact on surface charging on the lunar nightside. [Figure courtesy of Tim Stubbs, credit UC Berkeley and NASA/GSFC.]

Heliophysics Research Group

The Heliophysics division was created in a NASA wide reorganization just over a year ago to study the new science of the Sun-Solar System connection. Following the formation of the Heliophysics Division at GSFC, GEST recognized that the best approach to meet the needs of the new division was to copy this organizational structure by setting up a parallel Heliophysics Research Group within GEST. The term Heliophysics comes from the prefix helio, which means 'of the Sun and environs' and the noun physics, 'the science of matter and energy and their interactions.' As outlined in NASA Heliophysics Roadmap [February 2006] the three science objectives of the division are:

- Open the Frontier to Space Environment Prediction:
  Understand the fundamental physical processes of the space environment - from the Sun to Earth, to other planets, and beyond to the interstellar medium.

- Understand the Nature of Our Home in Space:
  Understand how human society, technological systems, and the habitability of planets are affected by solar variability interacting with planetary magnetic fields and atmospheres.

- Safeguard the Journey of Exploration:
  Maximize the safety and productivity of human and robotic explorers by developing the capability to predict the extreme and dynamic conditions in space.

The GEST Heliophysics group was set up in early 2006, with three initial members –Judit Pap, Timothy Stubbs, and Phillip Webb. From those beginnings, the Heliophysics Group has grown in size to currently consist (as of February 2007) of eleven research scientists and one research associate. The members of the group undertake research into many areas covered by the Heliophysics Division, from the surface of the Sun (Judit Pap) and how long-term solar variations can affects the Earth's climate (Raimund Muscheler), the Moon's surface (Timothy Stubbs), planetary magnetospheres (Mehdi Benna), the Earth's magnetosphere (Scott Boardsen, Jan Merka, Yongli Wang, Seiji Zenitani, and Tom Norak), plasmasphere (Phillip Webb), ionosphere (Hamed Bekerat), to geomagnetically induced currents within the Earth caused by space weather in the ionosphere (Antti Pulkkinen). In the past year the members of the GEST Heliophysics group have authored or co-authored a total of 28 peer reviewed articles, presented or been a co-author on 88 conference presentations and seminars, and have been either the principle investigator or co-investigator on 36 submitted grants.

The GEST Heliophysics members are a very dedicated group of individuals who also work well as a team. The monthly Group meetings, in the form of a lunch, are well attended and have a very enjoyable atmosphere in which there are many exchanges of ideas and news. These meetings have provided good feedback between the Heliophysics group and the GEST council. Guest attendees at the monthly meetings have included the GSFC Heliophysics Division director James Slavin and GEST Director Ray Hoff.

Heliophysics is a very dynamic and active field within NASA and the wider space physics community. As a group, we look forward to been able to support and extend the research and development of the new Heliophysics division in the coming years.

Phillip Webb

This page intentionally left blank

Task 673-81-279: **IFM-Modeled Response of the High-Latitude Ionosphere to Auroral Dynamics Based on Auroral Observations Acquired with the Visible Imaging System (VIS) on the Polar Spacecraft**

GEST Investigator: Hamed Bekerat

Collaborator: John Sigwarth (PI, GSFC, Code 674)

Abstract

Global physics-based numerical models for the high-latitude ionosphere require inputs for the magnetospheric forcing. Over the last decades, several statistical models for the high-latitude magnetospheric convection and the auroral precipitation have been developed and used to drive ionospheric models. However, due to the statistical nature of these models, they represent the average characteristics of the true convection and precipitation pattern. Recently, with the availability of global auroral image sequences from the Visible Imaging System (VIS) on the Polar spacecraft, these limitations can be overcome. The scale lengths and sampling rates from the VIS are in line with the requirements of global ionospheric models such as the Ionosphere Forecast Model (IFM) to study the adverse effect of geomagnetic storms and substorms on the ionosphere. These images have been used to calculate global maps for the auroral precipitating electron energy flux and characteristic energies. These images will be used as inputs to an ionospheric model and the adverse effects of auroral dynamics on the high-latitude ionosphere will be investigated.

Description of Research

The goal of this study is to use auroral images acquired by Visible Imaging System (VIS) on the Polar spacecraft during magnetic storms and substorms to study the response of the high-latitude ionosphere to auroral dynamics. The images obtained from the VIS will be used to calculate global maps for the corresponding auroral parameters, *i.e.*, electron energy flux and average energies. Then, these maps will be used to drive the Ionosphere Forecast Model (IFM). As a reference against which to compare the IFM ionospheric simulations, the same runs will be repeated using the Hardy statistical model for the auroral precipitation. The Hardy model uses the 3-hour Kp index as an input to generate global maps for the energy flux and average energy of the precipitating electrons. From the comparison of the two simulations the researchers will be able to quantify the impact of auroral dynamics (*i.e.*, magnetic storms and substorms) on the high-latitude plasma parameters including the plasma densities, temperatures, topside plasma scale heights, and NO+/O+ transition heights.

Accomplishments during the Reporting Period

The first step in this research was to identify cases for study in which the aurora was highly dynamic. To accomplish this goal, Dr. John Sigwarth at GSFC provided a large database of VIS images. Hundreds of image sequences were inspected and many cases in which the aurora was highly dynamic were identified. However, these were raw images that require a lot of cleaning. Dr. Sigwarth has developed image processing software for the VIS images,. Time was spent in getting familiar with the image processing software and it was then used to clean many of the VIS image sequences that will be used in the study. The second step toward achieving the goal of this task was to use the VIS images acquired in the previous step to calculate global maps for the electron precipitation parameters (*e.g.*, electron energy flux and average energy) needed to drive the IFM. The characteristics of the precipitating auroral electrons, energy flux and average energy, that cause the auroral brightness during geomagnetic storms and substorms are reflected in the auroral images acquired by the VIS. The Lumerzheim model was used to calculate global maps for the energy flux and characteristic energies of the precipitating auroral electrons from the corresponding VIS images. These maps will be used in the future to drive the IFM. The goal is to have a large data set of VIS images that can be used for study. Work is still been undertaken on identifying more cases for study

in which the aurora is highly dynamic. Also, Dr. Schunk at Utah State University (USU) has been working on preparing a version of the IFM that is suitable for the needs of this study and it should be available for use in the near future.

Objectives for the Coming Year

The main goal for the next year is to investigate the adverse effects of the auroral dynamics on the ionosphere. To accomplish this goal, global maps for the electron precipitation parameters calculated from the corresponding VIS images during magnetic storms and substorms will be used as inputs to the IFM, and the corresponding plasma parameters: 3-D electron densities (Ne), and 3-D temperatures (Te and Ti), auxiliary parameters such as NmF2 and hmF2, topside plasma scale heights, and NO+/O+ transition heights will be calculated. Next, as a reference against which to compare IFM ionospheric simulations obtained using the VIS images, the same simulations will be repeated but this time using instead of the VIS images, statistical patterns for the precipitation parameters obtained from the Hardy statistical model for the auroral precipitation will be used. From the comparison of the two simulations, the impact of auroral dynamics (*i.e.*, magnetic storms and substorms) on the high-latitude plasma parameters will be quantified. Such a study will allow the response of the ionosphere to auroral dynamics to be elucidated and provide theoretical guidance for the interpretation of storm and substorm observations in the ionosphere

---

Task 699-71-247: **Numerical Modeling to Improve the Performances and the Scientific Return of Space-borne Mass-spectrometers**

GEST Investigator: Mehdi Benna

Collaborator: Paul Mahaffy (PI, GSFC, Code 699)

Abstract

Space-bone mass-spectrometry is one of the major in-situ techniques used to study the atmospheres and surfaces of planets. This research aims to improve the performance of these instruments by modeling the environment in which they operate and by studying new technical improvements and designs. During the last year, a new model of the atmosphere of comet Halley and comet Grigg-Skjellerup were built and the resulting models are being extended to study the atmosphere of Enceladus and support the Cassini mission. Numerical models of the SAM quadrupole mass-spectrometer and its supporting gas flow system were built, which allowed a detailed understanding of the behavior and the capabilities of this complex instrument to be understood.

Description of Research

The main goal of this research is to provide an end-to-end study of space-borne mass-spectrometry techniques. This research is multidisciplinary and combines scientific and technical aspects. The focus of scientific aspect was given to modeling the magnetospheres of planets, icy moons and comets, which are the target of most of the planetary missions. The objective is to help understand, through these models, the environments where space-borne mass-spectrometers operate, and thus, provide a better theoretical background to interpret the collected data. The technical aspect focused on studying new designs to improve the performance of quadrupole mass-spectrometers (QMS) and their dependant systems. This class of mass-spectrometers has always been a cornerstone on major space missions (*e.g.*, Giotto, Contour, Nozomi, Cassini, MSL.).

Accomplishments during the Reporting Period

On the scientific level, the validation of ACASIM-3D, a new advanced MHD-chemistry model that simulates the interaction between the solar wind and comets was completed [Benna and Mahaffy, 2006a]. This model was used to investigate in more detail the data obtained during comet Halley and comet Grigg-Skjellerup flybys. The results [Benna and Mahaffy, 2006b;

2006c] showed good agreement between the model and the Giotto measurements for the spatial variation of a various parameters including density, velocity, and temperatures of ions, neutrals and electrons. The model was also extrapolated to the case of 67P/Churyumov-Gerasimenko for its perihelion passage of 2015 to provide a preliminary assessment of the structure of the coma of this comet. This allowed the extraction of additional constraints on the orbit of the spacecraft Rosetta, which would ultimately help maximize the science return of the mission.

The ACASIM numerical code was also extended to study the interaction between the atmosphere of Enceladus and the magnetosphere of Saturn. The resulting model (ENCAM) is currently being used to investigate more precisely the structure of Enceladus' tenuous atmosphere in the light of the recent data recorded by several Cassini's instruments (during the first two close flybys of Enceladus: February 17th and March 9th 2005). The initial results of this research led to the confirmation of the hypothesis that a neutral plume emission from the southern polar terrain of the moon is the source of the density peaks detected by the Ion Neutral Mass spectrometer (INMS) and the Dust Analyzer (CDA) instruments.

On the technical level, a high-fidelity SIMION numerical model of the Quadrupole Mass-Spectrometer (QMS) of the SAM experiment (MSL mission) was completed, which allowed a detailed understanding of the behaviors and the capabilities of this instrument to be reached. This model helped in the optimization of the ion and electron optical systems, which doubled the sensitivity of this instrument and reduced its energy spread.

This year marked also the start of a new study that focuses on modeling the behavior of gas flows in capillary leaks. This study is critical to the SAM instrument and is helping to assess and optimize the instrument's performance. An innovative approach using equivalent electrical circuits to model the gas flows was adopted and the initial results allowed the SAM team to optimize QMS and GC (Gas Chromatograph) operations to enhance the quality of the data. A validation phase of this model using a Lab Test Unit at GSFC is ongoing and should provide a robust simulator that will support the flight model integration and testing.

Objectives for the Coming Year

On the scientific level, studying the interaction between the atmosphere of Enceladus and the Kronian magnetosphere using the ENCAM model will continue as well as providing models to support the CASSINI-INMS investigation. If funds are approved (NASA grant), the model will be extended to study the magnetosphere of Mercury in the framework of the Messenger mission. On the Technical level, Benna plans to complete the SAM Gas Simulator (SAMSIM), which will allow the model to provide support to the integration and calibration of the instrument.

Task 612-71-248: **Coupling Between Mercury's Exosphere and Magnetosphere and the Study of Planetary Magnetospheres**

GEST Investigator: Scott Boardsen

Collaborators: James Slavin (PI, GSFC, Code 670), James Green (NASA HQ), Nick Omidi (Univ. of San Diego)

Abstract

The primary focus of this work has been preparation for the first MESSENGER swing-bye of Mercury in January of 2008. Because of the strong overlap between Mercury's sodium exosphere with the magnetosphere, an analysis of Mariner-10 data during its two 1970's Mercury encounters was undertaken to look for evidence of ion cyclotron waves created by Na+ pickup ions. None, however, were found. There are a number of factors that could explain the lack Na+ cyclotron waves, one is that the mass loading of Mercury magnetotail by heavy ion is not as important as previously suggested.

Conclusive evidence will not be available until insertion of MESSENGER into orbit about Mercury in 2011. A statistical study of the latitudinal beaming of Kilometric Continuum (KC) radiation generated within the Earth's magnetosphere was undertaken and compared with the predictions from linear mode conversion. In all 80 cases investigated, the match between theory and observation was poor. This strongly suggests that linear mode conversion theory is not the primary mechanism for the generation of KC. Finally, work was done studying magnetic flux tubes in the Earth's magnetotail using Cluster spacecraft data, and on science validation of ST5 satellite magnetometer data.

Description of Research

Due to the strong spatial overlap of the sodium and potassium exospheres with the magnetotail, it has been predicted that Mercury's magnetosphere can be strongly mass loaded by the photo-ionization and pickup of these heavy atoms. In preparation for the up coming arrival MESSENGER and Bepi-Colombo missions to Mercury, an analysis of Mariner-10 data during its two 1970's Mercury encounters has been undertaken to look for evidence of ion cyclotron waves created by Na+ pickup ions. Kilometric continuum (KC) radiation is free space mode radiation believed to be the extension to higher frequencies of non-thermal continuum (NTC) radiation. Unlike its lower frequency counter part, which is generated primarily on the dawnside plasma pause and whose intensity is highly correlated with geomagnetic activity, predicting under what conditions and where KC radiation will be observed is poorly understood. Using multiple satellite (primarily IMAGE and GEOTAIL) observations, the latitudinal and longitudinal emission characteristics of this radiation is being studied and a comparison been made with theory.

Accomplishments during the Reporting Period

Mercury's geospace should contain an abundance of heavy pick-up ions and these ions tend to generate plasma waves. In preparation for the upcoming MESSENGER encounter with Mercury, Mariner 10 magnetometer data has been retrieved, re-calibrated and examined for ion cyclotron waves and mirror mode instabilities. No such waves or instabilities were found. This could mean that the heavy ions are lost too rapidly from the system and thus it could be concluded that heavy ions do not play an important role in Mercury's plasma physics. There are, however, a number other possibilities that could explain this negative result. The gyroperiod is very low and the transversal of the magnetosphere was so fast that at most it would be possible to only resolve a few oscillation periods in each key magnetospheric region. Also, Mercury was near aphelion during both swing-byes where theory predicts that the exospheric tail is less pronounced and that the generation of pickup ions in the tail should have been at a minimum. Clearly more than the 30 minutes of data available from the two Mariner-10 swing-byes is required. Mercury will be in an optimal position in terms of exopsheric tail formation during MESSENGER's first swing-by in 2008. But transversals of Mercury will be rapid on all swing-byes. Once in orbit the dwell time of MESSENGER in key magnetospheric regions will increase by a factor of 10 to 100. Collaboration with Dr. Nick Omidi has begun on performing hybrid simulations of the pickup ion process in Mercury's magnetosphere/ magnetosheath.

Work was undertaken using Cluster spacecraft data to study magnetic reconnection in the Earth's magnetotail to investigate the question of how well the current computed using the tetrahedral configuration of the four Cluster spacecraft satisfies the force free equilibrium approximation that is commonly used to model flux ropes. Science validation of ST5 was undertaken to confirm that aurora were observed at the magnetic footprints of ST5 spacecraft measured field-aligned currents.

A statistical study was performed in which the observed latitudinal structure of Kilometric Continuum (KC) radiation patterns was compared with the structure predicted by linear mode conversion theory (LMCT). It was concluded that, in general, the plasmapause would have to be located at unrealistic positions in order for the LMCT predicted radiation pattern to match the observed pattern and,

therefore, it was concluded that LMCT is not the primary generation mechanism of KC.

Objectives for the Coming Year

The objectives for the coming year are to refine the analysis tools developed during the previous year in preparation for the Mercury swing-by of MESSENGER on January 14, 2008. An analytic/empirical model of Mercury's geospace (magnetosphere and exosphere) will be developed that can be used to characterize with respect to the geospace region the expected pickup-ion distribution, the expected plasma waves instabilities (ion cyclotron, mirror mode etc), their frequencies, wavelengths, and Doppler shifts. Work will be undertaken with Dr. Omidi on hybrid simulations of Mercury's magnetosphere in which exosphere models will be coupled with hybrid plasma simulations through photo-ionization.

A study of the effects of the (irregular) shape of the plasma pause on the observed fine structure of KC will be undertaken. This will be done by generating simulated spectra from pseudo plasma density maps derived from EUV images that will be compare with GEOTAIL observations of KC. Since LMCT fails to explain KC, direct generation theory will be tested as an alternative explanation for the generation of KC.

Task 612-67-235: **Solar wind and Magnetospheric Environment**

GEST Investigator: Jan Merka

Collaborators: Adam Szabo (PI, GSFC, Code 672), Thomas Narock

Abstract

Jan Merka joined GEST on March 15, 2006 to undertake a study of the solar wind and its interaction with Earth magnetosphere. One of the topics he worked on was data assimilation of solar wind observations with a 3-dimensional numerical MHD model ENLIL with a goal to provide more realistic description of solar wind and interplanetary field (IMF) structure at Earth. Jan Merka also initiated and leads a multi-year effort to build a distributed data environment for magnetospheric data called Virtual Magnetospheric Observatory (VMO). The VMO aims to provide a one-stop portal for finding available data including documentation sufficient for successful utilization of data for research and analysis. Furthermore, he actively collaborated on another virtual observatory (VxO) effort, the Virtual Heliospheric Observatory (VHO), that is directed towards the Heliospheric scientific community. Both VHO and VMO currently offer prototype web-interfaces as technology test beds and demonstrations of data search capabilities.

Description of Research

The development of an assimilative solar wind model aims to use data from all available solar wind monitors at 1 AU to reconstruct a more representative solar wind profile across the magnetospheric cross-section using modern, self-consistent MHD modeling and data assimilation techniques. The results will provide more accurate solar wind and IMF profiles for space weather predictions and magnetospheric studies, especially in the case of asymmetric solar wind/IMF input conditions. The VHO and VMO were established as a part of the VxO environment by the NASA Heliophysics Division in order to provide the scientific community with integrated access to well documented data and related services. Each VxO observatory is a multi-institutional effort to achieve wide community consensus and acceptance of the data environment and services. Ultimately, the VxOs will streamline the data discovery and allow researchers to focus more on data analysis instead of spending much of their time searching for available and relevant data sets.

Accomplishments during the Reporting Period

Jan Merka, PI of the NASA LWS grant Solar Wind Input into the Magnetosphere: Assimilation of Multi-spacecraft Data, led the development of an assimilative solar wind model NINLIL. During the year, a proof-of-concept implementation of single-point data

assimilation using the optimal interpolation method was tested. The assimilation provided an improved description of solar wind/IMF structure but also demonstrated a need for more accurate (realistic) error covariance matrices. It was concluded that Ensemble Kalman Filter (EnKF) method will simplify obtaining error covariance matrices describing more accurately the time and space evolution of the system. Furthermore, the EnKF method does not require model linearization as do some other methods, *e.g.*, 3-D VAR or 4-D VAR.

The NASA-funded development of Virtual Magnetospheric Observatory (PI: Jan Merka) commenced in 2006 with the development of prototype Middleware with basic data search capabilities. The VMO will be a part of the VxO environment where individual, discipline specific VxOs will provide single point, transparent access to distributed resources. In order to search and compare different data sets, they must be described using a standard data model. The VMO group chose the SPASE data model for its relative maturity and space physics community acceptance. Nevertheless, attempts to describe an initial selection of magnetospheric data sets indicated a need for modifications and enhancements to the SPASE model. The VMO findings and work were pivotal to SPASE progression from version 1.0.0 in July 2006 to the much more comprehensive and usable draft version 1.2.0 at the end of 2006 (1.2.0 release is expected by April 2007). NASA funded two projects tasked to work on the VMO environment, one lead by Jan Merka at NASA GSFC and the second lead by Raymond Walker at the University of California, Los Angeles (UCLA). The two teams joined their efforts to eliminate redundancies in development work, so as to provide more features and faster service to the space science community. One main web portal was created at http://vmo.nasa.gov that provides documentation resources and data search interfaces, the portal is hosted at NASA/GSFC while UCLA provides back up hosting.

During the first year of the VMO project, a prototype Middleware was created to demonstrate metadata management, simple user queries (time, position, data product, measurement type) and query result delivery. The prototype was made publicly accessible for community testing and feedback collection. Initial testing suggested that the internal registry's architecture is well designed, although some inefficiencies in data querying were also identified as the amount of metadata in registry increased during the year.

Jan Merka also closely collaborated with the Virtual Heliospheric Observatory (VHO), which serves the Heliospheric community. The VHO web interface was redesigned to employ the same content management system (CMS) as the VMO. Both VMO and VHO initiated design and deployment of common components (Middleware, data set documentation, application programming interfaces, etc.) that will be used by both VxOs, with components tuned for VHO or VMO constituencies. The benefits of such an approach include resource sharing, faster development, more testing/debugging and, last but not least, simplified communication/data exchange between the VHO and VMO.

Objectives for the Coming Year

In the solar wind data assimilation efforts, the major task will be to implement the EnKF method on the simulation domain stretching from the L1 point to Earth and to assimilate data from ACE, IMP 8, INTERBALL-1, GEOTAIL, SOHO, and WIND spacecraft for selected events. The second major task will be further development and management of the Virtual Magnetospheric Observatory (VMO), in particular, registration of many new data sets and creation of the corresponding SPASE descriptions, development of common data query language for communication among VxOs, data providers and VxO-related services, extension of query capabilities, web interface improvements and collaboration with other VxOs towards an integrated data environment. By the end of year 2007, the VMO will offer selection of data products and query capabilities suitable for some magnetospheric research topics. Furthermore, the Virtual Heliospheric Observatory (VHO) will employ components developed and tested together with the VMO

team. An ongoing effort will be close collaboration with the SPASE data model group to implement modifications or new features as needed in order to fully describe new resources.

Task 612-67-235: **Development of Virtual Observatories for Heliophysics**

GEST Investigator: Thomas Narock

Collaborators: Jan Merka (PI), Adam Szabo (GSFC, Code 672)

Abstract

Virtual Observatories, first developed within the astronomical community, have become prevalent within the NASA Heliophysics data environment. These distributed computing systems aid researchers in the search and retrieval of vast quantities of distributed heterogeneous datasets. By applying a common set of semantics and the latest information technology and computer science practices, the seemingly disparate data sets can be made to appear as a unified data environment. Within NASA's Heliophysics Division efforts are underway to develop discipline specific Virtual Observatories to service each community. Specifically, this work focuses on the magnetospheric community and its data sets.

Description of Research

The central goal of the project is to develop a fully functional Virtual Observatory for the magnetospheric physics community named the Virtual Magnetospheric Observatory (VMO). Such a goal requires in-depth knowledge of relevant data sets in addition to related computer science technology. As such, the effort requires understanding of the data from the parameters down to the data storage format while conducting a parallel effort into researching such areas as grid computing, database design and semantic web applications. In addition to these areas a main component of the project involves validation of the system by conducting new science that was previously difficult or impossible to accomplish. The final stages will consist of using the data sets as a coherent system to study large-scale and global magnetospheric physics problems.

Accomplishments during the Reporting Period

As the project commenced efforts were focused on identify and adequately describing data products of interest. Initial collaborations were established between the group and data product principal investigators. Additionally, efforts were made to join the international consortium Space Physics Archive Search and Extract (SPASE). The SPASE group is an international collection of space physics data providers and researchers aimed at developing a space physics data model. This data model will consist of agreed upon terms and definitions that will be used throughout Heliophysics as the lingua franca. Frequent teleconferences were held with SPASE consortium to relate the needs of the VMO and to gain insight into data documentation and archiving. Additionally, participation was made in the SPASE meeting held in November at the University of California, Los Angeles (UCLA).

An initial prototype of the VMO was developed using magnetospheric magnetometer data from three spacecraft. This prototype was demonstrated at the American Geophysical Union Fall meeting in San Francisco and gave the community a glimpse of what is to come. In addition, it provided the team with valuable feedback from the community as to the directions they would like to see the VMO evolve.

Interactions with the SPASE and magnetospheric physics communities have led to new partnerships and collaborations. Specifically, it was deemed that the VMO technology was relevant to other communities and that independent projects would fit nicely if folded in with VMO development. As such, new teams were formed and several new proposals have been submitted.

Objectives for the Coming Year

Work will continue on the Virtual Magnetospheric Observatory (VMO). This includes a prototype demonstration at the Spring American Geophysical Union meeting as well as participation in the international SPASE conference in England in the summer of 2007. Additionally, technology collaborations will continue with UCLA to further develop the VMO software. Furthermore, it is planned to present this technology at various conferences as well as to peer reviewed journals.

Grant NNG06GA58G: **Solar Irradiance Variability and Its Origin**

GEST Investigator: Judit Pap (PI)

Collaborators: Dean Pesnell (GSFC, Code 671), Douglas Rabin (GSFC, Code 671), Adam Szabo (GSFC, Code 672), Robert Caffrey (GSFC, Code 400)

Abstract

In the past year work has been performed by the investigator under three NASA grants. The objectives and results of two grants funded investigations addressing the phenomenon of solar variability and its connection to climate/space weather change are outlined herein. The first investigation is to develop an understanding of the relationship between variations in solar irradiance and the magnetic fields of active solar regions measured by the Solar and Heliospheric Observatory (SOHO)/ Michelson Doppler Imager (MDI) experiment and full-disk magnetic field strength data from Kitt Peak Solar Observatory. A second investigation addresses the issue of the differences in the level of solar maxima and minima at various cycles, especially at the time of cycle 23 when the level of solar magnetic activity was low but both total and UV irradiance showed high irradiance maximum levels. Current results also show that there are significant differences between total solar irradiance and various solar activity indices used for irradiance modeling during the declining portion of cycle 23. A study of geoactive sunspots was started as well.

Description of Research

The research studies variations in solar output using observations from various surface and space-based sources, such as Kitt Peak and Solar and Heliospheric Observatory (SOHO). To analyze these ground and space-borne data, state-of-the-art image and time series analysis techniques are being developed in conjunction with the work performed at the National Solar Observatory. Results serve to both characterize the variations in solar output, examining the links between different indices, and to understand the reasons for the variations. The ultimate goal is to understand the physical origin of irradiance variations to reconstruct past solar-induced climate changes. A new collaborative effort has also started with scientists from Lockheed Martin to study the evolution of sunspots that involves the use of Solar-B data.

The PI's work includes leading several international efforts and collaborations with a number of scientists in different institutions as well as efforts to place small instruments on commercial platforms.

Accomplishments during the Reporting Period

During the last year, work continued to study the origin of solar irradiance variations. Results show that both total irradiance (integrated over the entire solar spectrum) and UV irradiance increased more during the weak solar cycle 23 than the rest of the magnetic indices. Photometric results indicate that during solar cycle 23 less and smaller sunspots and faculae occurred in general, except for a few large activity outbursts. Although less sunspot darkening would explain the high total irradiance values during the weak cycle 23 it cannot, however, explain the high UV irradiance values, indicating that other physical processes are present. It has also been found that during the declining portion of solar cycle 23, total solar irradiance, similar to the full disk magnetic flux, has already reached the same minimum level as during the last cycle. In contrast, the UV

irradiance, He-line equivalent width at 1083 nm, the CaK index, 10.7 cm radio flux and the sunspot number still were above their minimum level. These results indicate that that it is necessary to better understand the physical origin of the irradiance surrogates used for long term irradiance modeling and thus to better predict the past and future climate changes.

To further study this problem, analysis of the high-resolution MDI images has continued. It was found by using magnetic field and intensity values to identify sunspots and faculae for the time interval including the maximum of cycle 23 that it may separate the strong facular fields from the weaker network fields. Further studies on this topic are in progress. Comparison of the SOHO/MDI sunspot and faculae area and intensity data were also compared to the results derived from the PSPT images taken at the Rome Solar Observatory's Solar Physics Group. During the last year, further collaboration has been developed with scientists at the National Solar Observatory at Kitt Peak using the new SOLIS data to analyze solar magnetic activity. In addition, the work described above was part of a three-year effort financed by the International Space Science Institute in Bern, Switzerland.

During the last year, Judit Pap continued to study the debated question: whether total irradiance was higher during the minimum of cycle 21 than during the minimum of cycle 22. It has been found that the “declining trend” in the ERBS total irradiance during solar minimum is related to the effect of sunspots. The relationship between various total irradiance data was studied in detail and a new factor adjusting the ACRIM I data to the ACRIM II level was calculated. For this purpose, Pap developed a new method based on time series decomposition techniques, while one of the mostly used composite, to the so-called PMOD composite, includes empirical models when compiling the composite. The results showed that total irradiance may indeed be somewhat higher during the minimum of cycle 22 than during cycle 21, however the difference is within the current measurement accuracy. The differences found between the minimum level of total irradiance and other solar indices used in modeling should be further investigated.

Also during the last year, Pap developed a successful proposal to publish a book by the Cambridge University Press on solar variability and space weather (Editors: Tom Bogdan, Judit Pap, Dean Pesnell, Werner Schmutz and Doug Rabin). In addition, she was heavily involved in programmatic tasks, such as working on the relation between SOHO and SDO/HMI. She won a Group Achievement Award to UARS from NASA. Pap has also been nominated to stand election to president or vice president for SCOSTEP.

Judit Pap continued to lead Working Group 1 of Theme 4, “Space Climatology,” of the SCOSTEP “Climate and Space Weather of the Sun-Earth System” (CAWSES) program. She worked with the SCOSTEP Bureau as one of the U.S. National Disciplinary Scientists on solar-terrestrial physics. She was also a member of an international research group: “Solar Magnetism and Irradiance Variations” which was a three-year effort within the International Space Science Institute, Bern, Switzerland. Judit Pap is also part of an NSF funded U.S.-Slovakian program to study solar variability, flares and CMEs.

Objectives for the Coming Year

The key objective for the coming year is to continue the intercomparison of various total solar irradiance data sets, now to be including the SORCE/TIM total irradiance and SORCE/SIM spectral irradiance data starting in 2003 and to improve the currently available composite. An additional major task is to study evolving complex sunspot groups which play a major role in solar eruptive events. As a Co-I on SDO/HMI, the PI will closely work with scientists from Stanford University and Lockeed Martin. She also started to develop science collaborations with scientists at the University of Montana which will be further pursued this year.

Task 612-74-254: **Ionospheric Modeling**

GEST Investigator: Antti Pulkkinen

Collaborators: Michael Hesse (PI, GSFC, Code 674), Maria Kuznetsova (GSFC, Code 674), Lutz Rastätter (GSFC, Code 674), Risto Pirjola (Finnish Meteorological Institute, Finland), Ari Viljanen (Finnish Meteorological Institute, Finland)

Abstract

A process for using ionospheric output of global magnetohydrodynamics (MHD) models in geomagnetically induced current (GIC) computations was introduced and applied to a real space weather event. It was shown by using user-relevant metrics that the state-of-the-art MHD models may have potential as a GIC forecasting tool. Accurate GIC modeling requires a good knowledge about the investigated conductor system and the ground conductivity structure. New methods for extracting this knowledge from observations were introduced and applied to GIC and geomagnetic data; significant improvements to earlier modeling efforts were demonstrated.

Description of Research

Geomagnetically induced current (GIC) affecting the normal operation of long technological conductor systems is a manifestation at ground level of space weather. During space weather events the Earth's near space current systems experience large spatiotemporal variations reflected also in the variations of the Earth's geomagnetic field. These variations produce induce GIC in conductors operated at the surface of Earth. Electric transmission grids and buried pipelines are common examples of such conductor systems. GIC can cause problems such as increased corrosion rate of pipeline steel and damaged high-voltage power transformers.

First-principles modeling of GIC from the solar wind to the surface of the Earth were investigated. The activity involves not only the coupling of different pre-existing models but also general optimization of GIC modeling problem by means of, for example, data assimilation and model development. The ultimate goal of the work is to move toward utilization of the geospace modeling capabilities in forecasting of the ground effects of space weather. The user aspect of the research emphasizes the need for end products that can be transitioned to operations with minimal adjustments.

Accomplishments during the Reporting Period

Pulkkinen *et al.* [2006, submitted to *Annales Geophysicae*] introduced a new general process that can be used to couple the ionospheric output of global MHD codes to geomagnetic induction and GIC models. As the goal of the work is to move toward operational GIC forecasts, Pulkkinen *et al.* [2006, submitted to *Annales Geophysicae*] also considered metrics that take into account the decision making process facing the user of the forecasts. The new process and the selected utility-based metrics were applied to the space weather event of October 24-29, 2003. It was demonstrated that despite the modest magnetohydrodynamics (MHD) model setup in terms of used spatial resolution, some of the important characteristics of the near space current systems can be captured by the modeling process and that the process can be used to give realistic GIC forecasts. It is also worth noting that the experience acquired from the GIC study was used in the metrics study by Taktashvili *et al.* [2007, submitted to *Space Weather*].

Accurate information about the topology and electrical parameters of the investigated conductor system experiencing GIC and knowledge about the ground conductivity structure are fundamental for accurate GIC modeling. Thus, following the philosophy of the research activity, Pulkkinen *et al.* [2007, submitted to *Earth, Planets and Space*] developed techniques that can be used to invert this information from GIC and geomagnetic observations. New techniques were applied by using observations from the space weather event of October 24-November 1, 2003. It was shown

that the optimized geomagnetic induction and GIC model parameters significantly improved the modeling accuracy.

As the ultimate goal of the research activity is to set foundations for operational GIC forecasting system, an experimental GIC computation system capable of using real-time global MHD computations carried out at Community Coordinated Modeling Center (CCMC) at GSFC was established. In the future the system will be become part of the CCMC's real-time space weather computations package. In addition to above-mentioned activities, a general public Wikipedia article on GIC was established in collaboration with European colleagues. The article can be accessed via link http://en.wikipedia.org/wiki/Geomagnetically_induced_current.

Objectives for the Coming Year

The first objective of the coming year will be to start the semi-operational usage of the experimental real-time forecasting system established. Experiences from the operations will be used to improve the model setup and the products provided to potential end-users. Along the same lines, contacts with the power grid industry will be used to estimate the quantitative value of the forecasts and to develop forecasting products that are intelligible for the end-user.

Another major objective will be to assimilate the observations of the geomagnetic activity with the MHD-based forecasts. Some background work carried out on this indicates that the Bayesian probabilistic coupling of the observations and modeling may be the most feasible approach.

Task 612-68-238: **Modeling of the Lunar Dust-Plasma Environment**

GEST Investigator: Timothy Stubbs

Collaborators: William Farrell (GSFC, Code 695), Richard Vondrak (GSFC, Code 690), Michael R. Collier (GSFC, Code 673), Jasper Halekas (UC Berkeley), Gregory T. Delory (UC Berkeley)

Task 612-71-248: **Survey of Cusp Electrodynamics Using FAST Data; Cluster Cusp Studies**

GEST Investigator: Timothy Stubbs

Collaborators: Robert F. Pfaff (GSFC, Code 674), Charles W. Carlson (UC Berkeley), James P. McFadden (UC Berkeley), Melvyn Goldstein (GSFC, Code 673), Wayne Keith (McMurry Univ.)

Abstract

Significant development has occurred in the modeling of lunar surface charging and dust transport; in particular, the derivation of an analytical expression for the secondary emission of electrons from a planetary surface due to ambient plasma electrons. The results from this research continue to be applied to the assessment of the dust nuisance and potential hazard that will be faced during future exploration of the Moon. In addition, this theoretical work has been applied to Mercury with some interesting results. The successful implementation of code for data retrieval and analysis has enabled preliminary statistical studies of FAST satellite plasma data. Initial results indicate some important insights into the formation of the low latitude boundary layer. Analysis of Cluster satellite data in the mid-altitude cusp has indicated that this region is highly variable on short spatial and temporal scales. A technique has also been developed to identify conjunctions between Cluster and DMSP satellites using the Tsyganenko 2001 model and AACGM coordinates.

Description of Research

One area of research is to understand how solar irradiation and the ambient plasma environment at the Moon results in the lunar surface

becoming electrically charged, and, in turn, how this drives the transport of charged dust. These phenomena likely occur on all airless regolith-covered bodies in the Solar System. In addition, this work is also important for lunar exploration since the charged dust is known to be a nuisance, and could potentially be a hazard. Another research area is to map the dayside plasma characteristics at altitudes where the solar wind-magnetosphere system couples with the ionosphere under various interplanetary and seasonal conditions. Finally, multi-point measurements from the Cluster satellite quartet are being used to try and differentiate between spatial and temporal structure in the mid-altitude cusp. The cusp regions form due to the coupling between the solar wind and magnetosphere, and as such are very important for understanding mass and entry transfer between these systems.

Accomplishments during the Reporting Period

In the work on the 'Modeling of the Lunar Dust-Plasma Environment', the focus has been more on surface charging mechanisms; in particular, on the role of secondary electron emission (ionization of the surface by the incoming ambient plasma electron) on current balance and equilibrium electric potential. This has resulted in the first analytical expression for secondary electron emission due to a Maxwellian plasma. A study of the predicted lunar potentials under various conditions has been completed, and is currently being prepared for publication, along with predictions during a space weather event known as a coronal mass ejection (CME). Similar studies are underway which include the new expression for secondary electron emission. As regards the dust transport work, the researchers developed a semi-empirical model of dust concentration in the exosphere as a function of altitude, grain radius and surface potential. This suggests that the mass of dust in the exosphere can be ~ 1000 kg above the lunar dayside, which is comparable with the mass of the exospheric gases. The lunar research has been presented to various NASA advisory groups in order to help determine what the agency needs to achieve so that it can safely explore the Moon. This work has been the subject of several news stories, including an article in Air and Space magazine.

In anticipation of NASA's MESSENGER mission, this lunar work has also been applied to Mercury. The most obvious difference between these two celestial bodies is the fact that Mercury appears to have a global magnetic field, as inferred from Mariner 10 data. Mercury's magnetosphere has a hot plasma sheet population that results in significant surface charging. In this interaction, secondary electron emission is especially significant in determining the equilibrium surface potential. Dust transport calculations suggest that the finest component of the hermean regolith could be lost due to electrostatic processes.

One of the most exciting aspects of the 'Survey of Cusp Electrodynamics using FAST data' is also one of the most challenging: that is performing a statistical analysis on over 10 years of high-resolution plasma data. The entire FAST (Fast Auroral SnapshoT Explorer) satellite dataset is available online via a secure site at UC Berkeley. Access to this, together with the preparation of the necessary batch download software and code, has permitted some preliminary retrieval and analysis of data. In the initial analysis the researchers identified the various dayside regions found in previous studies. Of particular interest was a region in the morning sector equatorward of the cusp that has previously been identified as the low-latitude boundary layer (LLBL). In the FAST data, the LLBL appeared at about the same energies as the cusp near noon in the ion data, but not in the electron data. Further analysis so far suggests that the observed ion population had $E \times B$ drifted toward dawn from the magnetotail; while the electrons in this region, seen at much higher energies, had followed different drift orbit trajectories. Understanding this distribution of plasma has important consequences for predicting plasma transport and dynamics within the magnetosphere.

The "Cluster Cusp Studies" have involved multi-spacecraft, multi-instrument analysis of individual traversals of the cusp region, as well as the development of a technique to find conjunctions between Cluster spacecraft in the magnetosphere and the fleet of DMSP (Defense Meteorological Satellites Program) satellites in

the topside ionosphere. For the case study analysis, routines have been developed to take data from several different instruments aboard the Cluster spacecraft and plot them in a format suitable for comparison and analysis. In addition, the application of various techniques has been used to help differentiate between spatial and temporal structure in the dynamic cusp region. Analysis appears to indicate that despite the data from three closely-spaced spacecraft in the cusp looking quite different, these differences appear to be largely caused by boundary motion, as opposed to spatial variations. The method to find conjunctions between the Cluster spacecraft and DMSP satellites has found that a combination of the Tsyganenko 2001 model and AACGM coordinates is currently the best combination for the cusp region.

Objectives for the Coming Year

With regards to lunar dust-plasma research, the GEST investigator plans to complete the current surface charging studies, so that the effects of secondary electron emission can be focused on. The dust transport models will be further developed, such that estimates of the flux of charged dust ejected from the surface into the exosphere can be determined. A continuing objective is to take the new insights gained from this research and apply them to the technical challenges of exploring the Moon. With the demonstration of the ability to perform statistical analyses on large quantities of FAST data, the data will be sorted by interplanetary conditions and season in order to better understand cusp electrodynamics and magnetosphere-ionosphere coupling. The current Cluster case study is nearing completion, which will allow the developed techniques to be applied to other events in order to begin to disentangle the temporal and spatial structure of the mid-altitude cusp.

Task 612-68-239: **ST5 Data Calibration and Field Aligned Current Dependence on Solar Wind and Geomagnetic Conditions**

GEST Investigator: Yongli Wang

Collaborators: Guan Le (PI, GSFC, Code 674), James Slavin (GSFC, Code 670), Scott Boardsen

Abstract

Dr. Wang worked with Dr. Guan Le to calibrate NASA ST5 mission magnetic field observations, solving special challenges related to data calibration of multi-spacecraft low-altitude observations. They provided level 1 ST5 magnetometer data to collaborators in several institutions. Using calibrated ST5 data, Dr. Wang also worked on large-scale Field Aligned Currents (FAC) statistics to understand their characteristics including magnitude, morphology, distribution, and motion, as well as their dependence on solar wind and geomagnetic conditions. Research continued into multi-spacecraft Flux Transfer Events (FTE) statistics using Cluster observations, where it was found that clear control of FTEs solar wind dependence by geophysical parameters. Also, work continued on magnetotail bubble simulation studies using the Birn magnetotail model where it was found that complex structures and dynamics related to magnetic bubble evolution in the magnetotail.

Description of Research

During the successful operation of the NASA ST5 mission between March 22 and June 30, 2006, large amount of high-resolution (8/16 Hz) magnetic field data were obtained. Dr. Wang worked with Dr. Guan Le and the ST5 engineering team to calibrate the data. The ST5 data set were surveyed and ~2500 clear Field Aligned Currents (FAC) were identified during ST5 mission. Solar wind and geophysical control of FTEs have been reported in many studies. Based on previous work on Cluster Flux Transfer Events (FTE) with more than 1200 events, Dr. Wang and his collaborators systematically investigated this topic and obtained new findings. Using various satellite data sets, Dr. Wang continued investigations into turbulences, acceleration, and deformation

of magnetic flux ropes, called bubbles, in the magnetotail.

Accomplishments during the Reporting Period

Most of Dr. Wang's research and data support work involves extensive processing, surveying, analyzing, and visualizing of large amount of satellite and ground observations, as well as simulation results. Many tasks, like coordinate transformations, empirical model field calculations, field line tracing, and synchronization of data with different time tags are used frequently, but they are very complex and time consuming to work on. Errors are likely to occur using conventional data processing methods, thus affecting efficiency and the quality of the scientific results. Current software packages in this field usually lack graphical interface, or the flexibility to use a uniform interface in different scientific projects. Considering the highly repetitive nature of many scientific applications in this field, instead of addressing all the above problems in each project, Dr. Wang developed a uniform IDL/Perl/Fortran package called Space Science Analysis and Visualization (SSAV), currently working on the Linux/Unix operating systems. It is designed systematically from ground up, with smooth data flow and uniform interface. SSAV consists of more than 1200 functions and its open sourced architecture allows for great flexibility for handling many different space science projects. Last year, Dr. Wang made major improvements to SSAV. SSAV is the most fundamental tool for most of his research and data support tasks. SSAV is also used by Dr. Wang's collaborators at NASA/GSFC, NASA/JPL, and UCSD.

A significant portion of Dr. Wang's time for last year was devoted to ST5 data calibration. Based on the magnetic field calibration code from Dr. Guan Le, Dr. Wang developed a dedicated ST5 data processing tool using SSAV with graphical interface and convenient control of calibration periods, parameters, and data flow. One-second spin averaged level 1 ST5 magnetic field data was produced in October 2006 with good quality for scientific investigations. These data were distributed to approximately a dozen research groups working on different projects. ST5 data was used to survey FACs during ST5 operations, of which about 2500 FACs were identified. Dr. Wang found that FAC speed in the ionosphere ranges from several 100 m/s to larger than 1 km/s. Higher Dst cases were found to correspond to larger FAC speeds in the ionosphere. ST5 FACs corresponded to wide ranges of solar wind and geomagnetic conditions. Dr. Wang found clear dependence of FAC ionosphere speed on solar wind VxBz and IMF clock angle, and there are no clear trends of FAC ionosphere speed on other solar wind conditions.

All former studies of FTEs imply that magnetopause reconnection is dependent on the conditions on the magnetopause and in the solar wind. Using Cluster satellite data, Dr. Wang and his collaborators found that the combined effects of geophysical parameters and solar wind conditions control FTEs. Further, they showed clear evidence that geophysical parameters control FTE dependence on solar wind conditions. However, they also noticed that such control is hard to be easily and unambiguously explained using the large Cluster FTE database. They believed that global model simulations, with well-controlled parameters that can separate different effects of the parameters, could be a likely solution to finally reveal the exact geophysical control of FTE dependence on solar wind conditions.

Further investigation of the propagation and dynamic evolution of bubbles in the magnetotail were undertaken. Dr Wang found complex tailward and earthward flows, as well as complex and massive current filaments. Dynamic reconnection structures are seen within closed magnetic field lines. Such structures resemble the tail reconnection geometry earlier proposed by other researchers. Dr. Wang found that satellites at different locations relative to bubble can see drastically different bubble structures. Such spatial structures, if exists, should be able to be detected by closely positioned multiple satellites, like Cluster and Themis.

Objectives for the Coming Year

An important objective for Dr. Wang is to work with Dr. Guan Le to further calibrate ST5 data. He will help remove data glitches and data jumps across data segment boundaries, and test some new algorithms to improve data quality. The resulting level 2 ST5 data will be saved in standard formats (like CDF) and posted on multiple data servers for public access. With the new level 2 ST5 data, Dr. Wang will develop a new method for fast FAC calculations requiring much less human intervention. Using the improved FAC database, Dr. Wang will further investigate the statistical properties of FACs, mainly their dependence on various solar wind and geomagnetic conditions. For continuing his FTE study, Dr. Wang will incorporate Polar and Themis observations. The much-increased FTE database will allow better statistical studies of FTEs, and enable improved qualification of the relations between the effects of solar wind and the geophysical parameters. For the magnetotail bubble study, Dr. Wang will implement his adaptive mesh refinement (AMR) MHD code. The new model will be used to simulate bubbles so that their dynamics and dependence on boundary and initial conditions can be systematically studied.

Task 612-65-223: **Studies of the Mesosphere, Ionosphere and Plasmasphere**

GEST Investigator: Phillip Webb

Collaborators: Richard Goldberg (PI, GSFC, Code 674), Robert Benson (GSFC, Code 673), Joseph Grebowsky (GSFC, Code 695)

Task 612-71-248: **Substorms in the Magnetotail**

GEST Investigator: Phillip Webb

Collaborator: James Slavin (PI, GSFC, Code 670)

Grant NNX06AH07G: **Automating Electron Density Determination from Magnetospheric Dynamic Spectra**

GEST Investigator: Phillip Webb (PI)

Collaborators: Robert Benson (GSFC, Code 673), James Green (NASA HQ), Richard Denton (Dartmouth College), Jerry Goldstein (Southwest Research Institute)

Abstract

In the past year work has been undertaken in four different research areas: (1) the analysis of data collected by the DROPPS (Distribution and Role of Particles in the Polar Summer Mesosphere) sounding rocket campaign that previously showed that ice particles in polar mesospheric summer echoes (PMSE) have sizes of the order of a few nanometers has be refined and improved; (2) an initial study has been undertaken into determining the occurrence and location of substorms in the magnetosphere using Interplanetary Monitoring Platform – 8 (IMP-8) satellite data, (3) a previously developed technique to extract O^+/H^+ transition altitude by fitting ionospheric electron density (N_e) topside profiles obtained from satellite topside sounders has been used to analyze the International Satellites for Ionospheric Studies (ISIS) hand-scaled topside sounder N_e data set that encompasses a period of greater than two solar cycles (22 years); and (4) the automatic fitting technique previously developed to determine plasmaspheric N_e from IMAGE RPI dynamic spectra has been refined, with an initial version of the data base cover five years of data being made available to the scientific community.

Description of Research

The goals of the current four research areas under investigation are: (1) the study of the formation of nanometer-sized ice particles seeded by atmospheric meteoric particles whose presence are believed to be responsible for polar mesospheric summer echoes (PMSEs) in the Earth's atmosphere; (2) determine the location, both temporal and spatial, and physical properties of substorms in the magnetosphere; (3) the analysis of electron density (N_e) profiles in the Earth's topside ionosphere obtained from satellite sounders to extract ion composition information; (4) the development of an automatic fitting technique to extract N_e from dynamic spectra collected by the IMAGE satellite's RPI instrument.

Accomplishments during the Reporting Period

An investigation of the data collected by the DROPPS (Distribution and Role of Particles in the Polar Summer Mesosphere) rocket program has continued. Two NASA sounding rockets were launched during early July, 1999 from Andoya Rocket Range, Norway. The purpose was to investigate the polar summer mesosphere, particularly polar mesospheric summer echoes (PMSE). Both DROPPS payloads included front mounted side by side charge and mass Particle Impact Detectors (PID). Computer simulations have shown that the PID telescopes have the potential to detect atmospheric ice particles within the mesosphere having dimensions of a few nanometers (nm). Ice particles of nanometer size are believed to be responsible for PMSEs that were observed at an altitude of ~82-87 km over Andoya during the first DROPPS launch sequence. By comparing PID observations with the computer simulations information can be obtained concerning the properties of the PMSE particles, including their "rocky" core size, ice mantle thickness and distribution. In the past year these simulations have be refined, with the result that an analysis of the PID data on the first DROPPS flight suggests PMSE particles consist of a rocky core (believe to be of meteoric origin) of radius ~1.5 nm and an outer ice mantle of thickness 6–10 nm.

An initial study has been undertaken into determining the occurrence and location of substorms in the Earth's magnetotail using Interplanetary Monitoring Platform – 8 (IMP-8) satellite magnetometer data. The data cover the period from 1973 through to 2000, with IMP-8 passing through the magnetotail once every 12.5 days. An analysis program was developed that automatically selected out likely substorms events and presented them to the user for manual verification purposes. The user then selected the events that appeared to be of interested and they were stored into a data base for future use.

A technique to extract O^+/H^+ transition altitude (where the H^+ and O^+ number densities are equal) from ionospheric topside ionograms by fitting electron density (N_e) profiles to analytical H^+ and O^+ functions [Webb *et al.*, 2006] has been used to analyze the International Satellites for Ionospheric Studies (ISIS) hand-scaled topside sounder N_e data set that encompasses a period of greater than two solar cycles (22 years). The resulting O^+/H^+ transition altitude dataset consists of fits to ~ 160,000 separate topside sounder N_e profiles. This database will be a unique resource allowing investigations to be undertaken into variations in the topside ionosphere due to such factors differing local time, latitude, and solar-storm conditions.

Development of an automated fitting technique to extract plasmaspheric N_e from dynamic spectra obtained from the Radio Plasma Imager (RPI) on the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) satellite (*e.g.*, Benson *et al.* [2004]) has continued. This technique is often able to provide *in-situ* N_e measurements along extended portions of the orbit of IMAGE. The fitting technique has been thoroughly tested and has been used to assemble an initial version of the RPI N_e data base covering five years of data from the start of 2001 to the end of 2005 (IMAGE stopped transmitting to ground stations on December 18, 2005). This is being made available to the scientific community.

Objectives for the Coming Year

A major component of the coming year's research will be a new project working on magnetometer observations from the ESA/NASA Cluster satellite constellation.

Magnetometers measure variations in the local magnetic field, allowing information about ionospheric and magnetospheric currents to be derived. Another major aim is to publish the results of the projects that have been undertaken in the past year in refereed journals. The winning of a proposal to the NASA New Investigator Program will allow work to continue for the next three years on further refining the dynamic spectra fitting technique and applying it to similar data sets collected from other satellite missions.

Task 674-80-277: **Kinetic Modeling of Magnetic Reconnection**

GEST Investigator: Seiji Zenitani

Collaborator: Michael Hesse (PI, GSFC, Code 674)

Abstract

Seiji Zenitani joined GEST to undertake a simulation study of magnetic reconnection, one of the frontier problems in space and astrophysical plasmas. His research explores advanced applications of magnetic reconnection from the viewpoint of cross-scale coupling, by carrying out super computer simulations. Understanding fundamental mechanism of magnetic reconnection is a main goal of the NASA's coming Magnetospheric MultiScale (MMS) mission and the results from this research will play a role in preparing for the observations MMS will provide.

Description of Research

The complexity of magnetic reconnection problem is due to the various spatial/time scales of physics that couple to each other: magnetohydrodynamics-scale (MHD) phenomena, intermediate ion scale or microscopic electron scale, for example, have to be taken into account. For example, the global reconnection rate is controlled by micro dynamics in the magnetic diffusion region. In this research the scientists will investigate theoretical applications of magnetic reconnection problems by using high-resolution particle-in-cell (PIC) simulations: 1) relativistic magnetic reconnection with a guide field, 2) magnetic reconnection with heavy ions and 3) magnetic reconnection in ion and relativistic-electron plasmas. These topics are expected to involve additional scale dynamics in addition to the standard ion-scale and electron-scale, to obtain insights to this important issue: What is the critical scale in the magnetic reconnection problem?

Accomplishments during the Reporting Period

As a first step, Zenitani worked on the relativistic magnetic reconnection problem with a guide field (current-aligned magnetic field) condition, whose main application is high-energy astrophysical places. It is known that particle acceleration takes place along the X-line in the case of relativistic magnetic reconnection. In the guide field condition, it is found that the particle acceleration goes on despite the weaker electric field because the guide field "traps" the particles in the acceleration region. In order to estimate the complete acceleration scenario, Zenitani is comparing the typical "scale" of the diffusion region: the typical Debye length and the gyro radius by the guide field. He has also developed his PIC (particle-in-cell) simulation code to run on NASA's NCCS super computer with MPI facilities.

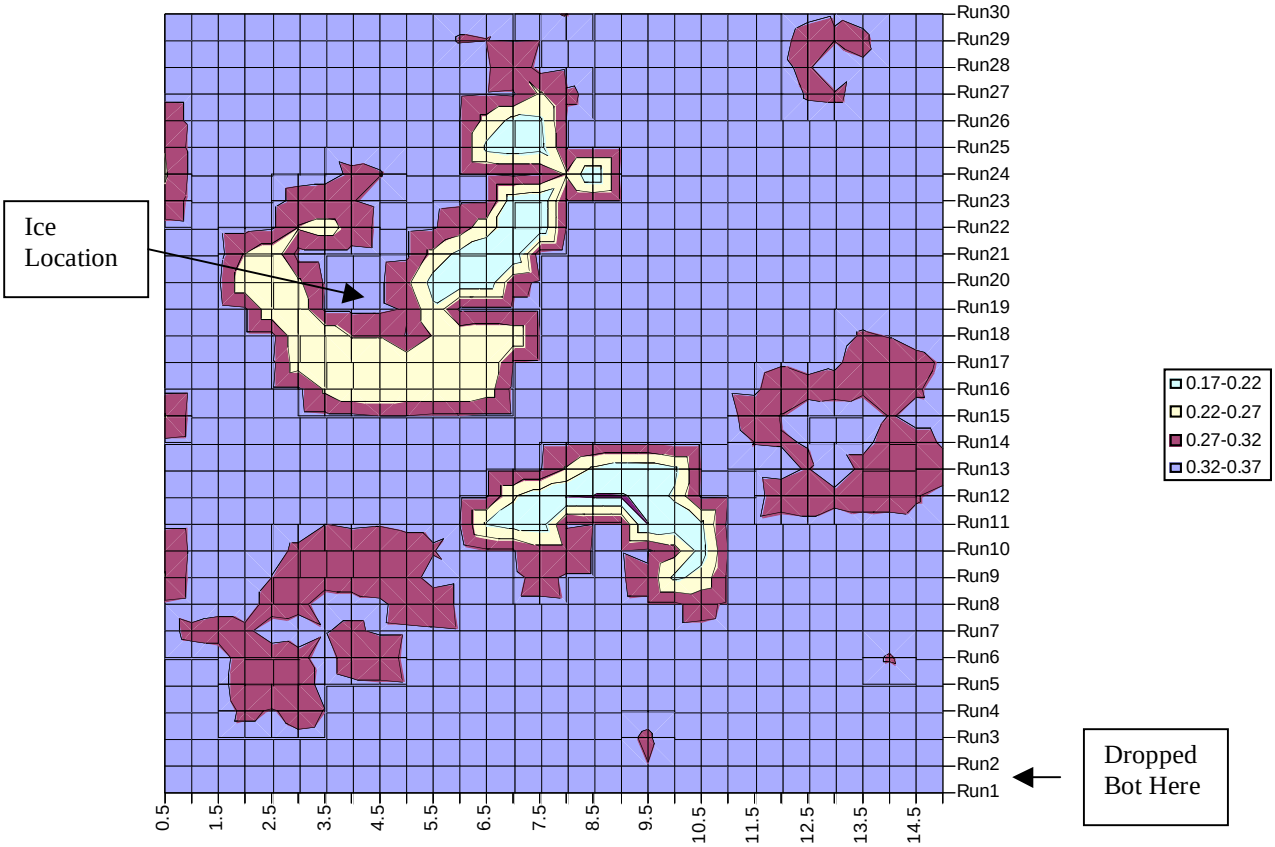
Objectives for the Coming Year

First, Zenitani will complete his research on the guide field effect on the particle acceleration by relativistic reconnection. Next, he will investigate magnetic reconnection with heavy ions, taking into account O+-rich situation of the substorm time in the Earth's magnetosphere. This problem is rather challenging, because it requires further computational costs in order to resolve the time scale of heavy ions, in addition to those of electrons and ions. This work will be undertaken on the NCCS's super cluster computing system. Also, Zenitani will compare the plasma behaviors measured by several space satellites: Cluster, THEMIS and the upcoming Magnetospheric MultiScale (MMS) mission, whose main target is to understand the fundamental physics of magnetic reconnection.

This page intentionally left blank

Information Science and Educational Technology Research Group

"Fundamentals of Lunar Robotics" was offered to the Anne Arundel County STEM cohort as SCIE 510. During the course, GEST Instructional Designer Laurie Cook simulates Lidar topography of the lunar surface using an ultrasound motion detector and a mock lunar landscape. [Photo courtesy of Dr. Susan Hoban.]



Topography map of the lunar landing used for pre-programmed mission in "Fundamentals of Lunar Robotics." This is the graphic result that was generated after 30 runs using the "simulated lidar" (ultrasound motion detector) to read the topography of the mock lunar landscape. [Figure courtesy of Dr. Susan Hoban.]

Information Science and Educational Technology Research Group

With the advent of digital detectors and the subsequent application of large format and hyperspectral imaging in Earth and space science, the skyrocketing need for computing power and intelligent data analysis and archiving has become of paramount interest to NASA. At the GEST Center, the end-to-end data collection, assimilation and analysis process is studied from the computer and information science perspective. The application of emerging technologies for the benefit of education is also an important component of the Information Science & Educational Technology (IS&ET) Faculty Group.

These activities also contribute to the U.S. and International 10-year GEOSS (Global Earth Observing System of Systems) implementation plan adopted at the third Earth Observation Summit in February 2005 in Brussels, Belgium. To aid this international effort, the U.S. national Science and Technology Council's Interagency Working Group on Observations (IWGEO) has prepared a strategic plan as a first step toward the development and implementation of the U.S. Integrated Observing System (IEOS). The U.S. plan mirrors the international GEOSS by focusing on nine societal benefit areas, and an end-to-end integrated systems approach.

Ultimately, the information and knowledge from NASA's Earth and space science missions is to be communicated to scientists, educators, learners, the general public and makers of science policy. GEST faculty contribute policy-level scientific planning and technological guidance to NASA HQ's Science missions in the area Earth system science. GEST faculty also work to provide effective multimedia materials for the communication of NASA science concepts to scientists, educators, students and the public at large. It is now well established that a critical national need exists to address the issue of flagging performance of our nation's students in science and mathematics. Decreasing numbers of students in the U.S. are embarking upon careers in science, technology, engineering, and mathematics (STEM)—a trend that contributes to our national shortage of well-trained scientists, engineers, and computer scientists. This problem is of paramount interest to NASA. GEST researchers investigate the effectiveness of information technologies in addressing these issues of national importance and apply the results to the professional development of STEM educators.

Susan Hoban

This page intentionally left blank

Task 606-73-250: **The Analysis and Characterization of Citric Acid and Homologs in Carbonaceous Meteorites**

GEST Investigator: Benita Bell

Collaborator: George Cooper (PI, NASA Ames Research Center)

Abstract

Carbonaceous meteorites are among the oldest objects in the solar system (approximately 4.6 billion years old) and provide the only record available for the laboratory study of a wide range of organic chemical processes in the Early Solar System. The goal of this project is to analyze for 4.6 billion year old citric acid and homologs in carbonaceous meteorites. Citric acid and citric acid homologs have been identified in the Murchison and Murray carbonaceous meteorites. The importance of citric acid in contemporary biology is well known. The citric acid cycle is the central oxidative pathway in respiration, producing carbon dioxide and other products. Metabolic fuels are catabolized in this process. The demonstration that a series of citrate and related compounds are indigenous to carbonaceous meteorites would add another set of biologically important compounds to the list of those delivered to the early Earth and possibly necessary for the origin and/or evolution of life. Two compounds, citric acid and one of the two possible isocitric acids have been identified in an apparent series of citric acid homologs. Mass spectra of two other compounds match a literature spectrum for methyl citric acid. Spectra of other compounds suggest that a series of homologs are present. However, definitive identifications of these compounds must await synthesis of laboratory standards. The technical approach and methodology have been determined for the laboratory analysis. In addition, two universities (Tennessee State University and the Polytechnic University of Puerto) have been identified to collaborate on the project.

Description of Research

Bell works with Dr. George Cooper to synthesize laboratory standards to aid in the definitive identification of citric acid and homologs. Currently, methyl citric acid is being synthesized. However, definitive identifications of this compound and higher homologs must await synthesis of laboratory standards. The apparent build up of the carbon chain by $-CH_2-$ units (*i.e.*, forming higher homologs) would be consistent with other meteorite homologous series of compounds [Pizzarello *et al.*, 2006]. The initial analyses of these compounds must be molecular and then, as with meteorite sugar acids, the next step will be to examine enantiomeric and isotope ratios. In the majority of cases in organic chemistry “enantiomers” of a chiral compound are defined as its two non-superimposable mirror images (*e.g.*, “D and L”). GC-MS and LC-MS will be the analytical methods to determine what compounds are present (molecular analyses) and the enantiomeric ratios. If time allows, we will begin preparation for GC-isotope ratio MS (GC-IRMS) measurements. In addition, to identify what compounds are present, molecular analysis can also help to confirm whether the compounds are actually extraterrestrial. For example, if several of the compounds are rare or unknown on Earth, isotope analysis would reveal the 13C/12C isotope ratio that would confirm whether the compounds are actually extraterrestrial and also show possible relationships of these compounds to other meteorite compounds. The researchers have definitively identified two compounds, citric acid and one of the two possible isocitric acids in an apparent series of citric acid homologs [unpubl. data]. Mass spectra of two other compounds match a literature spectrum for methyl citric acid. Spectra of other compounds suggest that a series of higher homologs are present. For this project the instruments are already running and after the molecular analyses are complete, it must be determined what GC conditions (including reagents) will separate enantiomers of citric acid homologs.

This astrobiology research project will serve as a model project to subsequently, in the future, involve faculty and students from Minority Institution Astrobiology Collaborative (MIAC) institutions. Bell is co-founder of MIAC and currently serves as Co-Director for MIAC. MIAC is a virtual collaboration of faculty and students from minority institutions focused on achieving common research and educational goals in astrobiology. The long term goal of this project is to provide research opportunities to involve faculty and students from underrepresented institutions to work on astrobiology-related projects at NASA Ames Research Center with Dr. George Cooper and/or other scientists conducting astrobiology research. The aim is to expose underrepresented faculty and students to this interdisciplinary field of science and thereby increase the number of underrepresented scientists in the global workplace.

Accomplishments during the Reporting Period

Bell is Co-Director for the Minority Institution Astrobiology Collaborative (MIAC) which is an initiative whose focus is to expand astrobiology research and educational opportunities to faculty and students at underrepresented or minority colleges and universities. MIAC is the first "virtual collaboration" of minority institutions focused on astrobiology. Bell has developed the research project methodology and design (technical approach) for the analysis of citric acid and homologs. The methodology involves the molecular and isotopic measurements of the individual compounds. A sample of the meteorite has already been passed through the cation and anion exchange resins. This and further meteorite samples of citrate homologs obtained from preparative anion exchange resins will be injected into a Dionex ion chromatograph (conductivity detector) equipped with one or two preparatory sized anion exchange columns. The sample compounds are then eluted from the columns with a buffer, e.g., carbonate, pH~8 and collected individually or as groups (*e.g.*, Cooper *et al*. [1997]). Compounds are injected directly into the chromatograph and detected with conductivity detection because of their anionic character. Small portions of each sample eluted from the ion chromatograph will be injected into the GC-MS to verify that the compounds of interest are free of chromatographic interferences. LC-MS analyses will only begin after GC-MS. GC-MS has already been proven to be able to identify several citric acid homologs. However LC-MS may be just as good or better in separation of enantiomers with far less need of preparative procedures such as compound derivatizations.

The GEST investigator has also identified the institutions, Tennessee State University (TSU) and the Polytechnic University of Puerto Rico (PUPR), that will subsequently participate in the project at NASA Ames. Research capabilities of each institution have been identified that will allow faculty and students to have access to the lab at NASA Ames via videoconferencing to begin their involvement in the project. Bell has also worked with TSU and Dr. Todd Gary, Co-Director for MIAC, to expand astrobiology education to the K-12 community. She assisted in developing an astrobiology pilot curriculum for one of the largest school systems in the nation. The GEST researcher has also recruited faculty from underrepresented universities to engage in research through the NASA Minority Institution Research Support (MIRS) program and the NASA Astrobiology Institute (NAI) faculty sabbatical program. The goal of the NAI-MIRS program is to strengthen the visibility and participation of minority institutions in the field of astrobiology. The NAI-MIRS program will strengthen the national infrastructure among minority institutions, resulting in an increase in diversity at all levels of the NAI. By connecting minority institution faculty to established researchers in the field of astrobiology, it will generate new collegial interactions, enlist additional academic institutions in the NAI's participant base, and provide the minority institution and students with lasting professional connections.

Bell has helped to translate research at Goddard into practical ways to teach astrobiology in the classroom. She designed an astrochemistry course to be taught at TSU, which is the premier institution for astrobiology education and outreach. MIAC currently consists of eight institutions in the collaborative and the goal is to

expand the collaborative within the next year to include more institutions, especially Hispanic and Native American institutions.

Objectives for the Coming Year

The next phase of the project will be to characterize the Gas Chromatography (GC) and Liquid Chromatography (LC) properties of citric acid and homologs and determine which method, GC or LC is the ideal method for further analyses. If one method is far superior to the other then this is the one that will be used for the analyses. It is possible, especially for enantiomer analysis, that a combination of these methods will be required. Initially, the researchers must find which columns and derivatizing reagents will best separate the individual compounds as well as the enantiomers of the chiral compounds. Enantiomer analysis alone is also valuable in determining the source (earth vs. extraterrestrial) of these compounds. For example, non-biological (extraterrestrial or laboratory) synthesis of chiral compounds generally produces equal amounts of D and L enantiomers, whereas living organisms nearly always produce only one, or far more of one enantiomer.

At present, a meteorite fraction containing the target compounds has been frozen. An initial analysis by GC of a small portion of this fraction will determine whether further purification of the sample fraction is required. Further purification will be required if there are too many other compounds. The initial purification of this sample was done with ion chromatography (IC). IC will also be used if further purification is required. When the above characterizations are complete, molecular and enantiomer analysis of a large portion of the meteorite extract will be undertaken. After this, the next phase of the project will be isotope measurements which will require further purification of the compounds. Much more isolation of the compounds is required for isotope analysis than initial preparation for the molecular/enantiomer analysis.

Grant NNJ05JL87G: **Earth+: Dynamic NASA Earth Science Exploration For Blind Learners**

GEST Investigators: Susan Hoban, Daniel Laughlin, Laurie Cook

Collaborators: Robert Shelton (NASA JSC), Nicolas Linares (Univ. of Puerto Rico)

Abstract

The goal of Earth+ is to advance science and math education for blind students by developing a map sonification capability to be used as a mission planning tool. This tool will be integrated in existing standards-based, science and math activities currently used with sighted students. An Earth+ model lesson will be developed for an “extreme Earth science” scenario requiring decision making based on remote sensing. Test audiences have been identified through the National Federation of the Blind and the Maryland School for the Blind. GEST researchers will integrate the Map Sonification Tool into an educational module and develop an evaluation plan.

Description of Research

Spatial thinking is an essential part of intelligence and very conspicuous in the subject of science. Analysis and interpretation of scientific data are frequently approached through visual representation, even at the simplest level, such as interpreting graphs and images. An additional modality for the interpretation of spatial data may involve the use of sound queues, thus suggesting an alternative approach for teaching science to blind learners. A tool for using sound to explore mathematical representations, MathTrax (http://prime.jsc.nasa.gov/mathtrax/) has been developed by Shelton *et al.* at the NASA Johnson Space Center (JSC). GEST researchers are currently working with Shelton's team to build on the foundation of MathTrax to develop a tool to facilitate the exploration of two-dimensional image data. The tool will be applied to an educational setting to teach concepts in Earth science to visually impaired learners.

Accomplishments during the Reporting Period
Laurie Cook represented the GEST Team at the Project Meeting in Puerto Rico, where the beta version of the software was rolled out to teachers for the first time. Two example Earth science lessons were developed by the GEST Team to demonstrate the prototype. The prototype was then alpha tested on students at Escuela Elemental Peña Pobre in Naguabo, Puerto Rico and Escuela Elemental Furgencio Piñero in Juncos, Puerto Rico.

Objectives for the Coming Year
Further work with blind students in Puerto Rico and Maryland is anticipated. A third sample lesson will be developed and a Teachers Guide will be written to accompany the software. A workshop to demonstrate Earth+ is scheduled for schools in Baltimore, MD.

Task 930-03-068: **Science Information Systems**

GEST Investigator: Susan Hoban

Collaborator: Nand Lal (GSFC, Code 672.0)

Abstract
Work under this task includes participation in NASA's Applied Information Systems Research Program on issues relating to information science and educational technology for NASA's science missions. Activities include research and development in advanced technologies for NASA missions and science research programs.

Description of Research
With the data deluge produced by the advent of digital detectors and the increasing computing power available to scientists on their desktops and in centralized computing centers, there is a growing need for efficient and effective software tools to facilitate analysis, interpretation, and management of science data. This task seeks to study and support the development of such tools, particularly as they pertain to NASA's missions and scientific research programs. Of particular interest is the concept of a Virtual Observatory and related technologies, such as the Semantic Web and Fault-Tolerant Computing.

Accomplishments during the Reporting Period
The GEST investigator organized the annual Principal Investigator's Meeting, held October 3–5, 2006, in College Park, MD.

The GEST investigator continues collaboration on a redesign of the content management system for the Applied Information Systems Research program, and is working with colleagues at Ames on the infusion plan for the AISRP Code Repository.

Objectives for the Coming Year
A workshop for investigators of Applied Information Systems Research Program will be organized, and participation in the annual panel review will take place in May 2007. A redesign of the content management system for AISRP will continue.

Task 690-70-243: **Planetary Data Systems**

GEST Investigator: Susan Hoban

Collaborator: Ed Grayzeck (GSFC, Code 690.1)

Abstract
Work under this task includes participation in NASA's Planetary Data System on issues relating to information science and educational technology for using data from NASA's planetary missions to advance education in science, technology, engineering and mathematics. The GEST investigator is working with the Goddard collaborator to design and implement an educational program that will encourage college students to pursue Planetary

Science through the use of data from NASA's planetary missions.

Description of Research

NASA's Planetary Data System is the ultimate repository for all data from NASA's planetary science missions. The GEST investigator is working with the Goddard collaborator to design and implement the NASA Planetary Data System College Student Investigator initiative. This activity is supporting college student interns at Planetary Data System nodes to design and conduct research projects based on data from NASA's planetary missions.

Accomplishments during the Reporting Period

The NASA Planetary Data System College Student Investigator (CSI) handbook and the Mentors Factsheet were developed. The first cohort of CSI students were hired in late January 2007 as the result of a competitive application process. Monthly telecons with the CSI student and their mentors at the PDS nodes are held on the first Monday of each month.

Objectives for the Coming Year

The GEST investigator will continue working with the CSI Students using email and monthly telecons. The students will present their work at the 39th Annual Meeting of the Division of Planetary Sciences, to be held in Orlando, FL, 7–12 October 2007. The GEST investigator will represent the Planetary Data System at various NASA Education and Public Outreach forums as well as non-NASA sponsored conferences and workshops.

Task 130-05-085: **NASA Learning Technologies**

GEST Investigator: Daniel Laughlin, Susan Hoban, Marcianna Delaney

Collaborator: Robert Gabrys (GSFC, Code 130.0)

Abstract

The GEST faculty in this task participate in the NASA Learning Technologies (NLT) project. After nearly a decade of working as a subordinate branch of NLT, the GEST team was selected to coordinate the NLT project office for this NASA-wide project. NLT serves as the research and development arm for NASA Education and seeks to infuse innovative technologies with NASA mission content and best learning practices. The GEST team collaborates with GSFC's Education Director, NASA Headquarters eEducation Program Executive and project leads at other NASA Centers. A particular area of focus for NLT in recent years has been the application of computer games and synthetic environments as learning media.

Description of Work

A national need exists to address the issue of flagging performance of our nation's students in science and math. Decreasing numbers of students in U.S. are embarking on careers in science, mathematics, engineering and technology. This trend contributes to a growing national shortage of well-trained scientists, engineers and computer scientists. This problem is paramount to NASA. As an agency NASA cannot function without a regular and ample supply of new scientists, engineers and computer scientists. NASA's Learning Technologies supports the enhancement of science education through the development of information technology based educational tools using NASA-related information. These tools assist formal and informal educators, as well as motivated independent students, enhance the quality and appeal of science and mathematics curriculum. Recent NLT projects have created a virtual scanning electron microscope, streamlined the online delivery of scientific visualizations, created virtual field trips of Mars analog sites with imbedded video clips of leading scientists explaining the environment, and developed a math description engine and sonified graphing calculator that give blind students the ability to work with higher order mathematics. Acting as the NLT project office for NASA, the GEST team awards and tracks projects, interfaces with project managers at NASA Centers, represents NASA eEducation at

internal NASA meetings and national and international conferences and learning technologies expert summits. The NLT project office has developed a national reputation for expertise particularly in the area of educational applications of computer games and synthetic environments.

Accomplishments during the Reporting Period

Laughlin gave an invited lecture on NASA and Virtual Worlds at the International Spaceflight Museum in Second Life as Second Life avatar Greyark Hightower. This presentation was blogged and posted on Slashdot.com. Laughlin was an invited panelist on the convergence of computer games and space exploration at the 2006 International Space Development Conference along with educational gaming experts Michael Zyda of USC and Jerry Heneghan, CEO of Virtual Heroes. Laughlin was an invited panelist at the Internet2 Annual Members Conference on a panel on the emerging uses of educational games and Internet2.

Objectives for the Coming Year

The GEST faculty at NASA Learning Technologies will continue to coordinate the project office and lead NASA's efforts to harness the power and potential of computer games and synthetic environments as learning media. In 2007, a new solicitation is expected to result in the award of funds to begin work on a NASA-based, educational massively multiplayer online game that will break new ground in research and development.

Task 130-05-085: **NASA Learning Technologies (NASA Exploring Space Challenges and the Digital Learning Network)**

GEST Investigator: Marcianna Delaney, Susan Hoban

Collaborators: Robert Gabrys (GSFC, Code 130.0), Shane Keating (Global Science and Technology)

Abstract

The NASA Exploring Space Challenges is a national program of design challenges for all grade levels in the primary and secondary schools, which support many of the national education standards for science, mathematics, technology and the arts. Delaney coordinates this project with significant contributions from Shane Keating, the GSFC DLN Coordinator, and A. Owens, the teacher consultant on this project (http://esc.nasa.gov). NASA’s Digital Learning Network (DLN) is a video conferencing and web casting system dedicated to educational use. Delaney serves as the Goddard representative on the DLN Content Committee and is also a primary presenter for the Goddard DLN.

Description of Work

Six Challenges were put in place for the 2006-07 school year, each of which challenges students to embrace imagination and knowledge. In March 2006, Space Operations Mission Directorate out of NASA Headquarters requested Delaney to design a curriculum piece for Space Operations Mission Directorate’s latest module addition to the International Space Station. Delaney developed Mission: Name the ISS Node 2 Challenge, an educational activity that required students to work collaboratively to design and create their own model of the Node 2, with correct scale proportions, using their classroom or school hallway. Students submitted an electronic scrapbook of their model with an essay describing the name they chose for the Node 2. Over 3000 students participated in this activity. The public announcement of the winning name occurred on March 15, 2007 by four astronauts of the STS-120 mission.

Other Challenges for the 2006-07 school year were Mission: Moon Math, Mission: Fuel Your Imagination, Mission: Lights, Camera Action, Mission: Design a Lunar Base and a Teacher Challenge. Moon Math required students to explore the Moon through measurement and includes interactive videoconference events. This past year this Challenge had approximately

300 student participants. Fuel Your Imagination required students to write their own fictional story, but with real science, math or engineering facts. Lights, Camera Action! is a Challenge specifically for NASA's Explorer Schools to produce their own music video highlighting how NASA has had an impact on their school. A pilot Challenge called Design a Lunar Base is an activity for students work as teams to design, propose and build their own lunar habitat. Finally, the Teacher Challenge accepted proposals from pre-service and K-12 educators on a Challenge themed around hurricane investigations.

Accomplishments during the Reporting Period

Delaney developed content for three new Challenges for the 2006-07 school year. In addition to presenting at two professional conferences this year, Delaney also presented at five teacher professional development workshops during the summer of 2006.

Objectives for the Coming Year

Delaney will continue to manage the NASA Exploring Space Challenges and continue to develop new NASA ESC content for the next school year. New content is also planned for the DLN with the assistance of the new manager of the Goddard Educator Resource Center.

Task 130-05-085: **NASA Learning Technologies (Fundamentals of Lunar Exploration)**

GEST Investigators: Susan Hoban, Anuradha Koratkar, Laurie Cook

Collaborators: Robert Gabrys (GSFC, Code 130.0), Anne Spence (UMBC), Shirley Zongker (UMBC), Willard Smith (Tennessee State Univ.)

Abstract

Professional development for Science, Technology, Engineering and Mathematics (STEM) educators is developed and delivered in the context of lunar exploration.

Description of Research

Two courses for STEM educators have been developed, "Fundamentals of Lunar Exploration" and "Fundamentals of Lunar Robotics." These courses are designed to strengthen educators' basic STEM skills and provide concepts for classroom activities. "Fundamentals of Lunar Exploration" focuses on the requirements for sustained human presence on the Moon, while "Fundamentals of Lunar Robotics" is centered on the principles of robotic exploration.

Accomplishments during the Reporting Period

The two STEM courses so far developed were offered in the summer at UMBC in an intensive, eight-day format. In the Fall, "Fundamentals of Lunar Robotics" was offered to the Anne Arundel County STEM cohort as SCIE 510. A day-long workshop based on content from "Fundamentals of Lunar Exploration" was offered at the National Science Teachers Association regional conference in Omaha, NE. This workshop was followed by four 1-hour long web seminars during November.

A proposal was submitted to NASA, and accepted, to work with the national engineering education organization, Project Lead the Way, to infuse the content of these courses into a STEM implementation that would be offered alongside the Project Lead the Way "Aerospace Engineering" course (high school) and the "Gateway to Technology" course (middle-school).

Objectives for the Coming Year

Two short-duration (3-day) workshops will be offered using content derived from the "Fundamentals of Lunar Exploration" course, one at Stevens Institute of Technology in Hoboken, NJ, and the other at Tennessee State University in Nashville, TN. SCIE 510 (Robotics) will be offered in the Summer and Fall terms at UMBC. Work will begin on the STEM infusion activity with Project Lead the Way. A proposal will be submitted to NASA for the development of vertically integrated engineering challenges in K-12 education to strengthen the NASA engineering pipeline.

Task 130-67-234: **Advanced Multi-media/Information Technologies**

GEST Investigators: Andrew Freeberg, Stefanie Misztal, Silvia Stoyanova

Collaborators: Wade Sisler (GSFC, Code 130.0), David Stroud

Abstract

GEST media specialists seek to make important links between scientists and the public in a variety of ways. By providing news media and independent producers with press releases, public domain video files, and resource collections, important NASA science stories reach the eyes of hundreds, thousands, or even millions. Some of the highlights and innovations for this past year include frequent collaboration with international film and television broadcasters, a Goddard specific YouTube channel and Google video network, and video/internet support for various NASA mission and science stories. All of these products are steadily increasing public awareness of NASA science by capturing the interest and support of audiences in up-and-coming technological venues.

Description of Research

The media specialist acts as a liaison between NASA scientists and the general public by illustrating exciting scientific advances with groundbreaking visuals and engaging stories. Focusing on television, print media, and web-based products, the goal is to communicate scientific research to a diverse audience that increasingly seeks information about world events in the on-demand world of the Internet as well as through traditional news outlets. By creating multimedia that is both entertaining and educational, these products will raise awareness about ongoing NASA science amongst policymakers, taxpayers, and future NASA scientists.

Accomplishments during the Reporting Period

Video files are one major product NASA Television creates for encouraging media coverage. These short five-to-ten minute videos are a collection of animation, visualization, and video footage sequences separated by slates that tell of a news piece NASA is involved with. Generally video files accompany a press release or web feature. Freeberg produced a number of these video files during the FY 06-07 that received significant media coverage. This includes three videos produced during the last Antarctic Ozone Hole season. Between these three stories, the estimated Nielson audience well exceeded 20 million impressions. Other video files produced by Freeberg, Misztal, and Stoyanova included “NASA Technology Helping Injured U.S. Troops,” “Scientists Puzzle Over Reactive Martian Soil, Could Electric Dust Devils be the Culprit?” “NASA Looks Back at Hurricane Katrina One Year Later,” “Scientists Reveal Clues of ‘Antarctic Plumbing,’” and “NASA Joins USGS to Produce Best-Ever Views of Antarctica.”

Freeberg and Stoyanova collaborated to produce another resource for the public on the topic of atmospheric ozone in the form of an Ozone Resource web page. This site compiles all of the stories and multimedia from NASA in the last several years concerning both stratospheric and tropospheric ozone. It has informational videos, a news archive, an “Ozone 101,” and a link to the Ozone Hole Watch page where you can see images of the current Antarctic Ozone Hole that are updated daily (http://www.nasa.gov/vision/earth/environment/ozone_resource_page.html).

Freeberg worked with Dr. Thronson on the script of a video on the Crew Exploration Vehicle, recorded the narration and edited together the final piece.

GEST media specialists also produced content designed for popular webcast sites such as YouTube and Google Video. For example, the striking animations produced for the recent THEMIS satellite launch not only garnered an extraordinary amount of recognition in the news but also gained an extensive following via streaming video outlets. As Goddard’s first effort at creating a high-profile movie trailer, the video was designed specifically to direct casual viewers on YouTube and Google to the

mission's website for a more in-depth look at the satellite. The video has been viewed by over 8,000 people (http://youtube.com/goddardtv).

Objectives for the Coming Year

The first high-definition resource tapes will allow independent producers to use top-quality NASA visuals in a new generation of HD production. Aimed for release at the start of April, "Earth Science in HD" will be a collection of NASA data visualizations ranging from polar ice to global fire observations. With the start of the International Polar Year (IPY), a project, called the Landsat Image Mosaic of Antarctica (NASA/USGS/NSF/BAS), will be developed as an effective visual product to this end. Finally, increased video support for proposed and planned missions will play a big role in the coming year.

Task 130-67-234: **Advanced Multimedia/Information Technologies**

GEST Investigator: David B. Stroud

Collaborators: Wade Sisler (GSFC, Code 130.0), Robert Gabrys (GSFC, Code 130.0), Susan Hoban, Jeffrey Halverson (JCET), Joycelyn Thomas Jones (GSFC, Code 587.0), Karen Elinich (Franklin Institute)

Abstract

The role of the Senior Education Technologies Producer is to research and develop emerging multimedia/information technologies for science, science communication and education. The principle objective of this investigation is develop innovative uses of these technologies to increase science productivity on NASA missions, enhance NASA scientist's ability to effectively communicate scientific findings and to facilitate and enhance NASA's education efforts. This year, these efforts were expanded to include collaborations with other UMBC departments such as the Imaging Research Center, New Media Studios, Computer Science and the Center of Excellence in STEM Education.

Description of Research

The Advanced Multimedia/Information Technologies team supports media development and dissemination for NASA Goddard with two distinct, yet integrated, methods. The first is through the use of traditional media to support science communication efforts. The other focuses on the exploration, development and use of emerging media technologies for science education. The goal of this research is to develop new best practices standards in science education and science communication.

Accomplishments during the Reporting Period

The mediaViewer is a stand-alone media viewing application that was developed at NASA/Goddard. It is utilized as a "Media Jukebox" for the aggregation, navigation and viewing of various media types, including: videos, animations, still images and text. It can be distributed either on the web or as a standalone interactive. The updates, nearing implementation, are to connect the mediaViewer to a central database, through the use of middle-ware. The outcome of this activity will produce a central repository for all data (media), an administrative front-end for the collection the data, and an easy to use administrative tool for the creation and implementation of customized mediaViewers. Jones, (Database and Middleware Programmer) and Stroud (creator, designer and programmer of the mediaViewer) are the principles on this project that supports NASA's IPY initiative.

In November, Stroud and Dr. Jeff Halverson (JCET) produced a 1.5-hour live, interactive lecture that took an in-depth look at the life cycle of hurricanes for a professional development event for in-service teachers. This activity was part of ongoing research into the use of emerging cyber-infrastructure—particularly Internet2—as a new channel for teacher professional development.

Stroud assembled and directed the team: a practicing scientist; a STEM education specialist; and a science video producer to develop the visually and intellectually immersive presentation around myriad scientific visualizations produced by NASA/GSFC's Scientific Visualization Studio in support of NASA missions.

Objectives for the Coming Year

The principal goal for Stroud is the continued research and development of the integration and use of Internet2 with traditional broadcast media, for science education and professional development. Part of this process will be to build an infrastructure of technology and community. Emphasis will be placed on building a development team comprised of members of UMBC faculty and staff that will include: GEST and JCET Scientists, STEM Educators, Digital Story Tellers, and Scientific Visualizers/Animators. Stroud will also be exploring the development of partnerships with science centers that will act as regional centers for Educator Professional Development centers that utilizes NASA science resources.

Task 902-00-005: **Science (Coordination) Director, Global Water Cycle Program of the U.S. Climate Change Science Program (CCSP) and interfaces with all CCSP science programs, and support to NASA/HQ Earth Sciences (Terrestrial Hydrology, Modeling, Observing Systems, Applications Program, and Decision Support Activities)**

GEST Investigator: Sushel Unninayar

Collaborator: Lola Olsen (PI, GSFC, Code 610.2)

Abstract

This task provides policy-level scientific planning and technological support to NASA HQ's Earth Science Enterprise (ESE) on interagency (U.S.) and international programs and projects dealing with all aspects/themes of the U.S. Climate Change Science Program (incorporating the U.S. Global Change Research Program (USGCRP) and the President's initiative on Climate Change Research (CCRI)); the World Climate Research Program (WCRP); the International Geosphere-Biosphere Program (IGBP); the Integrated Global Observing Strategy (IGOS) and the recently initiated International Group on Earth Observations following the Earth Summit on developing a plan for the creation of a Global Earth Observation System of Systems (GEOSS); the Global Climate Observing System (GCOS); the international WCRP Global Energy and Water Cycle Experiment (GEWEX); the new Global Observing Systems' initiative of the World Meteorological Organization (WMO/GOS); NASA/ESE's and GCRP/CCRI's cross-cutting climate modeling, observing systems, and data assimilation initiatives; follow-up on the environmental themes of the UN Committee on the Peaceful Uses of Outer Space Scientific and Technical Subcommittee (UN-COPUOS/STSC); interfaces with the UN Framework Convention on Climate Change (UNFCCC); interfaces with the science assessments of the Intergovernmental Panel on Climate Change (IPCC); and interactions with the boards, committees, and panels of the National Academies of Sciences (NAS), the National Research Council (NRC), and others.

Description of Research

NASA Headquarters assigned this task to GEST through the Global Change Data Center (GCDC) in GSFC's Earth Science Directorate (Code 600). It provides the necessary scientific, technological, and research leadership support required by the White House's Office of Science and Technology Policy (OSTP)'s Committee on Environment and Natural Resource's (CENR). The task also supports NASA HQ in a variety of other NASA/ESE's internal, interagency, and international programs, such as the Global Water and Energy Cycles Program (GEWEC); U.S. participation in the GCOS, as called for by the Conference of Parties (COP) to the UNFCCC; the science assessments of the IPCC, the

international WCRP/GEWEX program, the international IGOS, and now the Earth Observing System (EOS)-GEOSS, the Committee on Earth Observation Satellites.

Accomplishments during the Reporting Period

Work over the reporting period involved: (1) Continued and extensive interactions with all science elements of the U.S. Climate Change Science Program (CCSP—incorporating the USGCRP and the Presidential initiative on CCRI) regarding the development and implementation of the long-term strategic scientific plans as directed by the OSTP and the Office of Management and Budget (OMB). The CCSP also represents, de facto, the U.S. response to the UN Committee of Parties (COP) dealing with UN Convention on Climate Change (UNFCCC), which has not yet been ratified by the U.S; Science (Coordination) Director, Global Water Cycle Program (GWC); (3) Developed integrated priority projects (Interagency—GWC) for FY07, FY08, and FY09 (in proposal stage); (4) Proposed a new science implementation strategy to accelerate the interagency implementation plan for the Global Water Cycle (GWC) focusing on three integrating themes, and involving the Interagency Working Group's (IWG's) Science Steering Group (SSG), and the external research and applications communities. This activity begins a new focus on an End-to End (observations/research—modeling/prediction—applications/decision support) approach to meet the current emphasis placed on the CCSP program by the CCSP-Principals, OSTP, and OMB among others..

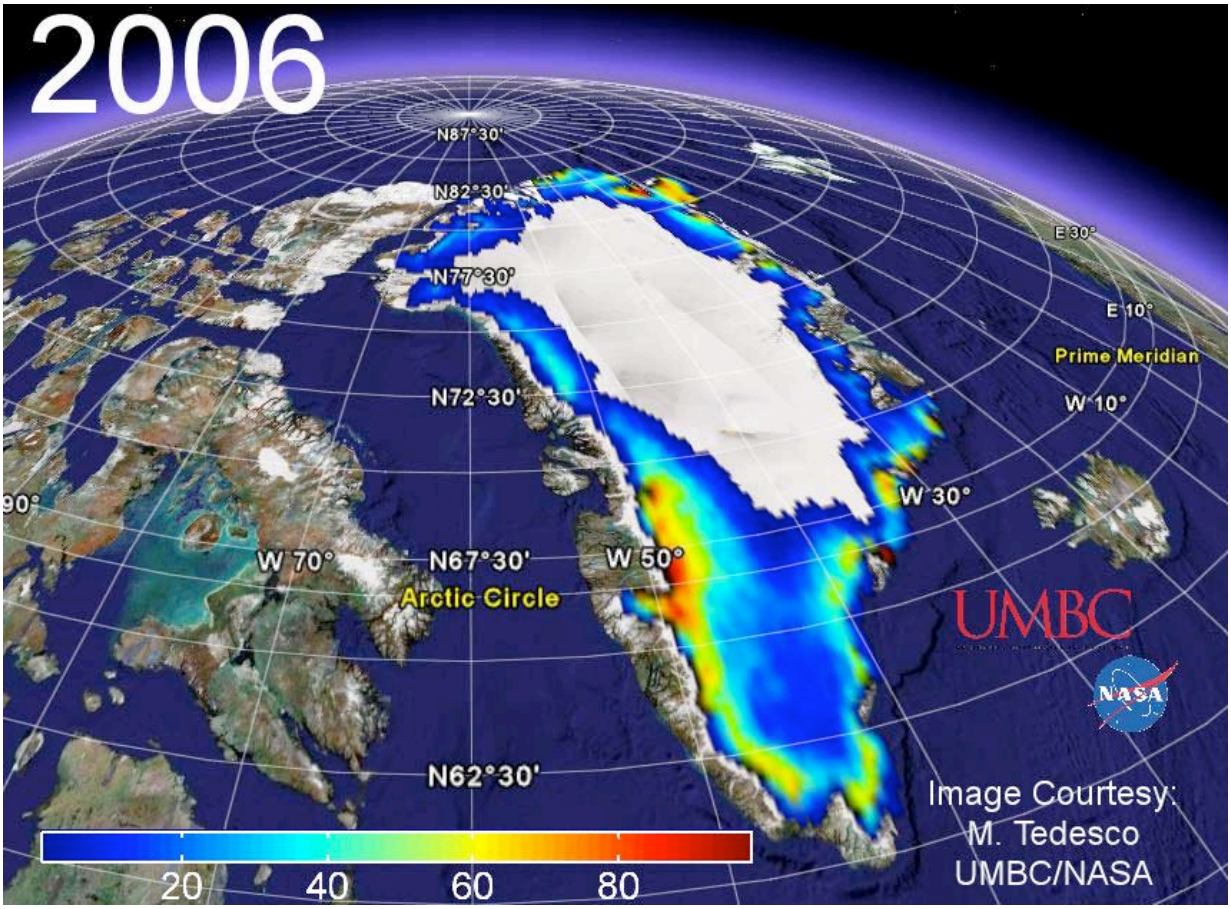
Objectives for the Coming Year

Unninayar will be planning the implementation of the FY07 Interagency (GWC) Priority field campaign led by DOE to improve the parameterization of cloud formation processes, aerosol-cloud interaction, cloud-radiation feedback, and interactions with land surface/hydrological processes that control surface fluxes. He will also be involved in the initial science planning for the implementation of the GWC-FY08 Priority (prototype observing/modeling system to close the atmospheric-land surface & sub-surface/hydrology budgets on the scale of a river basin). He will design and finalize proposals for the GWC FY09 Priority.

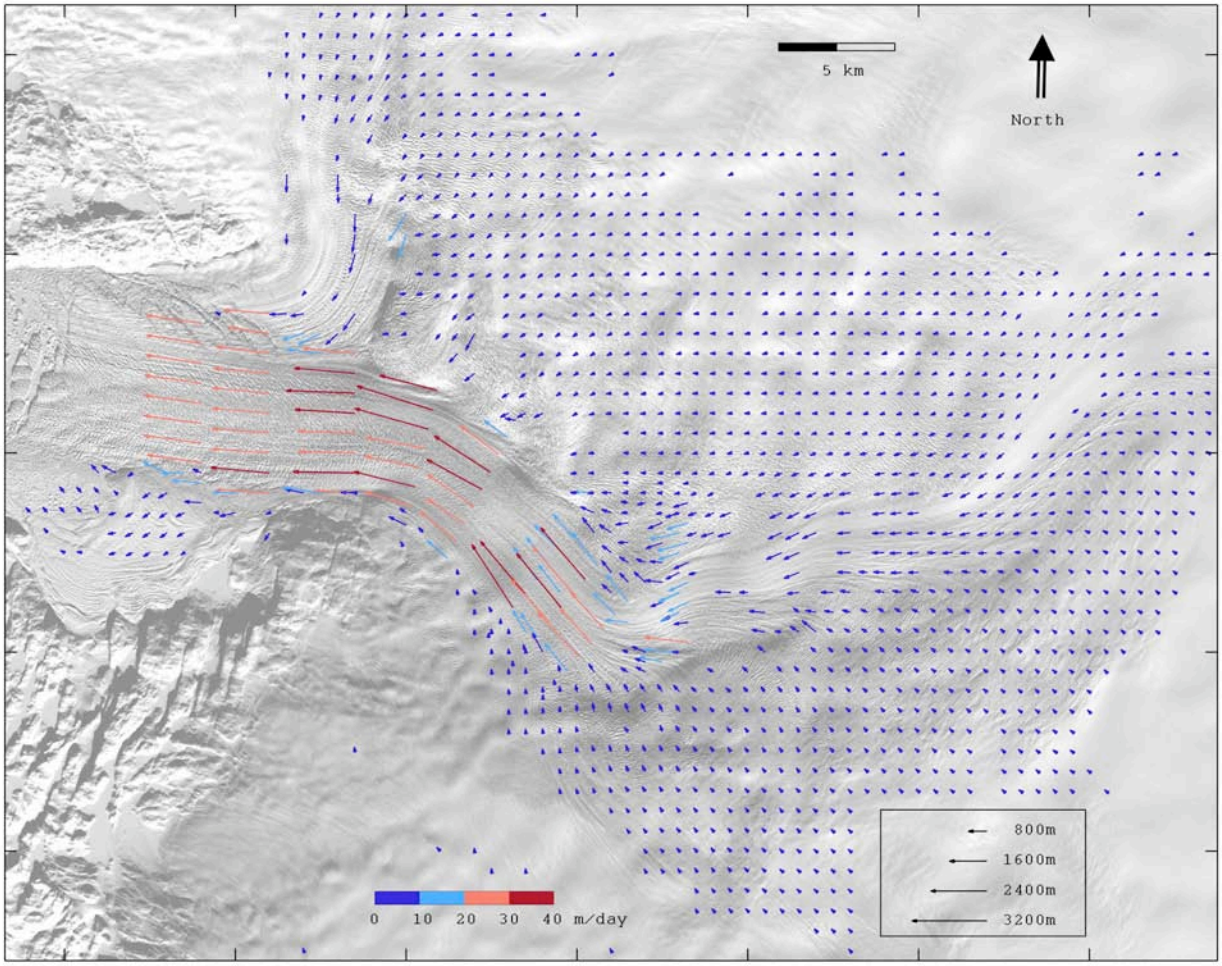
In general, Unninayar will continue scientific coordination of the interagency CCSP/GWC and interlinks with Atmospheric Chemistry (AC), Climate Variability and Change (CVC & US-CLIVAR), Carbon Cycle (CC), Land Use and Land Surface Change (LULC), Ecosystems (Eco), Human Contributions and Decision Support Systems (HCR/DSS); among other national and international programs

This page intentionally left blank

Hydrological Sciences Research Group



Snow melt on the Greenland ice sheet can be monitored by microwave data from space-borne instruments orbiting around the Earth at an altitude of approximately 800 km. Such data have been collected since the late 1970's. Quantifying the 2006 melting provides updated information for the assessment of global climate changes. The figure shows the number of days when melting occurred for the year 2006 with blue indicating few days and red many days. [Figure provided by Marco Tedesco.]



March 4 – May 23, 2002 (80-day) ice displacement (arrows) and velocity (colors) for the Jacobshavn Glacier in Greenland (69N, 50W) plotted over a Landsat image dated March 4, 2002. Ice movement derived from Landsat data using the cross-correlation method. [Figure provided by Boris Yurchak and Waleed Abdalati.]

Hydrological Sciences Research Group

Water is the central theme of the GEST Hydrological Sciences Research Group. The group integrates research into the terrestrial hydrosphere and biosphere with studies of the oceans, the atmosphere, and the cryosphere. The research is conducted in the context of Earth System Science and encompasses satellite remote sensing, modeling, and data assimilation.

The group's research into remote sensing includes the development of satellite instruments as well as retrieval algorithms for the cryosphere, the biosphere, and the oceans using satellite-based radars, passive microwave radiometers, and visible/infrared sensors. Much of this work has focused on defining the uncertainties associated with the retrieved variables. The research furthers our understanding of how remote sensing observations can be more effectively coupled with models in data assimilation systems. Ocean remote sensing research conducted includes observing sea surface salinity (Paolo de Matthaeis), ocean biology parameters (Mary Russ, Alex. Chekalyuk), and waves (Yunhe Zhao) from satellites and airborne instruments, with a focus on the development of retrieval algorithms and validation against in situ measurements. For the cryosphere, remote sensing from satellites is the key to deriving global estimates of snow conditions on the ground (Marco Tedesco) and the movement of glaciers (Boris Yurchak) and sea ice (Yunhe Zhao). These efforts are important contributions that ultimately help assess the rapid changes that are occurring in the Earth's cold regions. Moreover, research is underway on how best to measure the light use efficiency of plants (Qingyuan Zhang). Finally, the group is involved in the development of a satellite-based instrument that detects and corrects for radio-frequency interference in microwave radiometers (Priscilla Mohammed).

Modeling and data assimilation of land surface processes and the atmosphere is another main research area. A major element of this effort is the integration of land surface and mesoscale atmospheric models at local, regional, and global scales into the award-winning NASA Land Information System (LIS) software. The LIS framework is widely used in science investigations that focus on analyzing optimal fields of land surface states, and energy and water fluxes, as well as for the development of new modeling concepts. Several group members are involved with development and applications of LIS. For example, progress is being made in the use of LIS products to improve flood and drought risk analysis and forecasting for water resources management in the Columbia River basin (Kristi Arsenault). A related applications effort assesses LIS products against a toolbox for estimating evapotranspiration from the U.S. Bureau of Reclamations. Land surface models within the LIS framework have been coupled to high-resolution atmospheric models such as the Weather Research and Forecasting model and the Goddard Cumulus Ensemble model (Joseph Eastman). Processing of precipitation observations within LIS has been improved and a runoff routing component is under development (Matthew Garcia). A project that is integrating the high resolution modeling of land-atmosphere ammonia exchanges into LIS is another example of on-going LIS development (Yihua Wu).

The data assimilation effort merges remote sensing data of different land surface variables (such as soil moisture and snow) with corresponding outputs from land surface models. Such improved estimates of land surface conditions can then be used, for example, to initialize numerical models of weather and global climate. The group is conducting cutting-edge research into the assimilation of satellite-based soil moisture, snow, land surface temperature, and terrestrial water storage data into land surface models (Jiarui Dong, Rolf Reichle). Advancing knowledge regarding the global water cycle is a truly interdisciplinary effort that integrates broad-based hydrological science research both within NASA and the wider scientific community. Through its involvement with the NASA Energy and Water Cycle Study (Robert Schiffer), the group lends programmatic support to NASA and the research community. By taking holistic approaches, the group seeks to acquire and integrate a diverse set of remote sensing, model, and field measurements over a range of different spatiotemporal scales to enhance the understanding of physical processes and, eventually, improve our ability to predict future Earth system changes from local to global scales.

Rolf Reichle

This page intentionally left blank

Grant NAG5-13260: **The Use of NASA Land Data Assimilated Products to Improve Flood and Drought Risk Analysis and Forecasting for Water Resources Management in the Columbia River Basin**

GEST Investigator: Kristi R. Arsenault

Collaborators: Paul Houser (George Mason Univ./CREW), Steven Hunter (DOI/USBR), David Matthews (USBR-Retired), Warren Sharp (DOI/USBR)

Task 974-52-199: **NASA National Applications for Water Management**

GEST Investigator: Kristi R. Arsenault

Collaborators: David Toll (PI; GSFC, Code 614.3), Edwin Engman (SAIC)

Abstract

The main focus of this research is to help expand water resource management agencies' in-situ databases with more spatially distributed observed and modeled moisture and energy flux variables using NASA's suite of satellite and model products. These products which include Land Information System (LIS) land surface model output and satellite data from MODIS are being further developed to be benchmarked and eventually incorporated into such agencies' operational decision support systems (DSSs). The LIS models have been customized to run with several enhanced MODIS products (*e.g.*, leaf area index, snow cover) to help validate and benchmark the U.S. Bureau of Reclamation's DSSs. Terra and Aqua MODIS 500m snow cover products have been validated against in situ snow measurements, and these products are able to identify a majority of pixels as snow throughout the year when snow is observed on the ground, with algorithms associated with Terra performing better overall. In the suite of LIS LSMs, CLM2 captures the most realistic snowpack conditions throughout the year over the other models in Washington state, except CLM2 currently models a positive feedback process in which the snowpack ablates too late in the melt season. In the Middle Rio Grande River region, a few of the LIS LSMs were validated in riparian areas against the USBR's AWARDS ET Toolbox decision support tool and in-situ measurements. The measurements and the ET Toolbox capture the annual evapotranspiration (ET) variation in these riparian areas, however the LSMs greatly underestimate the (ET) throughout the year, even during the rainy seasons.

Description of Research

Current water resource management agencies, like the U.S. Bureau of Reclamation (Reclamation) rely mostly on point measurement data for many of their hydrological prediction and decision support systems (DSSs). In helping to expand their databases with more spatially distributed observed and modeled moisture and energy flux variables, LIS modeled and remotely sensed products, like snow cover, vegetation, land surface temperature, are being further developed to be benchmarked and eventually incorporated into Reclamation's operational DSSs, RiverWare and the AWARDS ET Toolbox. Also, the different satellite products are being tested in the LIS land surface models (LSMs) to try and produce more physically realistic data products, concentrating mostly on evapotranspiration, snow water equivalent, and runoff, which are identified as essential to water resource managers. The main research goals of the collaborative projects with Reclamation include developing integrated observation-based modeling systems that meet the needs of the Reclamation regional offices. Areas of interest for these projects include the Columbia River and the Middle Rio Grande River Basins.

Accomplishments during the Reporting Period

Several tasks accomplished this past year have focused mainly on the validation of different remotely sensed products and the land surface models (LSMs) incorporated in the LIS software

package. Key products from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument aboard the EOS Terra and Aqua satellites were further quality-controlled, enhanced and integrated into LIS LSMs (*e.g.*, CLM2, Noah).

The Aqua and Terra 500 m MODIS snow cover products (MOD10A1) were evaluated for the state of Washington for the years, 2002-2006. This snow cover product was evaluated against the USDA NRCS Snotel snow pillow stations within the same state. Probability of detection tables were generated and indicate that both satellite snow cover products do well in detecting the snow cover for most of the year, but the MODIS sensor did not detect snow when the Snotel stations measured snow about 30% of the time on average. The Terra MODIS snow cover algorithm does a better job in identifying more pixels as snow versus the Aqua MODIS algorithm due to a difference in spectral bands used in calculating the Normalized Difference Snow Index (NSDI), which is used to derive the snow cover product.

New LIS LSM experiments were conducted and compared for the Washington region. Based on the new results, the CLM2 model produces the most realistic snow conditions versus Noah 2.7 and Mosaic when compared against the Snotel datasets. However, CLM2 has an issue with not being able to melt the snowpack off early enough due to a positive feedback process captured in the model physics. Additional experiments were carried out with CLM2 and Noah 2.7.1 where it was shown that by using an improved local elevation dataset and setting more realistic snow albedo conditions that both models produced better snowpack conditions throughout the year. An additional study was performed with other collaborators where these same LSMs plus three additional ones, SNTHERM, VIC, and SSiB, were compared at three different Cold Land Processes Experiment station datasets in Colorado. The LSMs containing simpler snow physics schemes, like SSiB and Noah, produce realistic snow accumulation at one CLPX site, however, both of them show inaccuracy in the simulation of SWE amount and the snowmelt timing. The more complicated or multi-layer snow schemes, like VIC, CLM3 and SNTHERM, produce similar snow depth, SWE and the snowmelt timing. However, they show substantial discrepancy in snow ablation through snow sublimation and snow melting due to different internal snow physics treatment.

The collaborative project involving USBR in the Middle Rio Grande River region focused on comparing the USBR's AWARDS ET Toolbox evapotranspiration (ET) output with the LIS LSM modeled ET and against a few different eddy covariance flux tower sites set up and maintained by the University of New Mexico. Results show that the AWARDS ET Toolbox values for ET can almost approximate the observed values found at each measurement site throughout the year, whereas the LSMs underestimate ET consistently throughout the year, especially in the rainier seasons (*e.g.*, during the North American monsoon period). These particular sites are located in riparian areas, where the types of vegetation found in these areas are known to be able to tap into groundwater or wetter soils beneath the surface and be able to transpire more water to the atmosphere. The AWARDS ET Toolbox vegetation parameters are tuned for the riparian areas, giving this model an advantage over the LIS LSMs. Through different sensitivity studies, the LSMs reveal that they do not model photosynthesis and transpiration processes well enough and allow for bare soil and canopy water evaporation to dominate as components in the total ET calculations. For example, one experiment was conducted where the greenness fraction parameter in Noah 2.7.1 was tripled in value throughout the year. However the total ET values changed very little with transpiration only slightly increasing, whereas canopy evaporation became the main dominant process and bare soil evaporation experienced a compensating decrease to the rise in canopy evaporative processes.

Objectives for the Coming Year

For this coming year, newer methods of better connecting the modeled and observed atmospheric fields, which are used to drive the LIS LSMs, to the way snowpack physics are

modeled in the LSMs will be implemented in LIS. For example, issues with the way modeled atmospheric temperature lapse rates are affecting snow accumulation and ablation processes will be addressed. The processed and validated MODIS snow cover and snow albedo products will finally be assimilated into CLM2 and Noah LSMs in 1km LIS experiments. The fully tested and validated LSM output will be delivered to the USBR offices in Denver, CO, and Yakima, WA, to be tested and benchmarked against their current model operations. Further LSM experiments will be conducted for the intermodel and satellite-derived ET studies for the Middle Rio Grande River Region. The LIS LSMs and other MODIS ET-derived products will be validated in non-riparian areas against independent observations, including eddy covariance flux towers and a network of scintillometers. Finally, the Validation and Verification and the Benchmark reports for RiverWare and AWARDS ET Toolbox are aimed to be completed this coming year, based on the work described above.

Task 972-21-143: **Superactive-Active-Passive (SAP) Analysis of Phytoplankton Pigment Group and Physiological Variability in Coastal Ocean**

GEST Investigator: Alexander M. Chekalyuk

Collaborator: John Gerlach (GSFC WFF)

Abstract

This research addresses two priority NASA research topics: “Dynamics in coastal zones” and “Identification of phytoplankton taxonomic or functional groups from space or airborne sensors.” It also contributes to “Providing the scientific basis for next generation ocean and ice remote sensing technologies.” The project research goals are:

1. To develop new laser fluorescence methods for improved airborne/shipboard phytoplankton pigment characterization in coastal environments

2. To integrate the new methods and instruments with the pump-and-probe laser fluorescence technique for assessment of phytoplankton physiology

3. To initiate operational utilization of the new suite of analytical techniques for “observing variability and change in coastal regions”

Research activities included an analysis of data acquired from optically-diverse water types over a range of excitation wavelengths during previous shipboard and airborne laser fluorescence measurements in the Middle Atlantic Bight (MAB), the Chesapeake and Delaware Bays, and the Delaware River. Results of microscopic and HPCL sample analyses were used for interpretation of the laser fluorescence measurements. Field hyperspectral measurements were made of laser-stimulated emission (LSE) in a broad range of marine, coastal and estuarine environments, including the Middle Atlantic Bight, Delaware River, Delaware Bays, Pacific coastal zone of California, California current and Monterey Bay (5 field campaigns). Chekalyuk conducted an analysis of the new data sets, as well as planning future project activities, giving presentations at scientific meetings, and publication preparation. The results include (i) further refinement of fluorescence analysis of seawater constituents in optically complex coastal and estuarine environments and (ii) initial operational utilization of the project developments for observing variability and change in coastal regions.

Description of Research

The project research addresses optical complexity and diversity of marine environments that require advanced analytical methods. Research activities included development of new analytical algorithms and instruments, laboratory analyses, and shipboard field measurements. The research effort was focused on spatial and temporal variability of

marine ecosystems, their driving forces and impacts; biological carbon sources and sinks in the ocean; natural and human environmental impacts and their consequences in coastal areas; and spatial/temporal gaps in satellite validation/calibration over meso- and synoptic scales. Superactive-Active-Passive (SAP) analysis development and initial operational utilization have yielded valuable bioenvironmental information to enhance understanding of coastal and estuarine ecosystems and shown potential for improving capabilities of monitoring marine environments.

Accomplishments during the Reporting Period

A significant part of the research effort was focused on development and refinement of SAP analytical algorithms with regard to specifics of the diverse coastal aquatic environments. Analysis of the extensive field measurements conducted in the diverse aquatic environments has yielded the following key solutions to improve assessments of phytoplankton pigment, group and physiological variability in optically complex coastal and estuarine waters: (i) hyperspectral measurements of broadband (400-800 nm) water laser-stimulated emission (LSE) with at least two, blue and green, excitation wavelengths; (ii) spectral deconvolution (SDC) for improved quantitative assessments of phytoplankton pigments and photo-physiological status; (iii) correction of phytoplankton photo-physiological assessments for potential "spectral contamination" of variable fluorescence measurements from non-chlorophyll constituents.

The observed spectral variability within the phycobiliprotein (PBP) pigment group reflected the respective structural changes of PBP-containing cyanobacteria and cryptophytes. These observations indicate that the additional information about phytoplankton pigments and functional groups can be retrieved from the proposed SAP spectral measurements in marine environments. The feasibility and robustness of the enhanced multi-component SDC procedure were tested in the reported period. As shown during the initial Advanced Laser Fluorometer (ALF) deployments, the SDC-retrieved constituent bands can be used for accurate assessment of the constituent concentrations. The researchers found an excellent linear correlation ($R^2 = 0.98$) between the SDC retrievals of chlorophyll-a (Chl-a) fluorescence and independent HPLC measurements of Chl-a concentration in the water samples collected in the Chesapeake Bay, the York River (Virginia) and the South Slough (Oregon) estuary. Normalization of Chl-a fluorescence peak to the intensity of water Raman scattering provides accounting for regional optical variability, which was tested for the extended data set that also includes measurements conducted in the coastal zone of the MAB, the lower Delaware Bay and the adjacent MAB area.

Significant spectral variability observed for PBP and Chl-a in vivo fluorescence in the range of marine and coastal environments was attributed to the structural changes in phytoplankton assemblages indicated by high performance liquid chromatography (HPLC) and microscopic sample analysis. Basic quantitative characterization of phytoplankton community structure was shown to be feasible by the in vivo SDC LSE analysis. In particular, it provides potential for discrimination and quantitative assessment of dominant and some subdominant phytoplankton groups in coastal algal assemblages (*e.g.*, diatoms vs. dinoflagellates, and cyanobacteria vs. cryophytes). Most of these observations were conducted in estuarine and coastal areas. The initial measurements in diverse coastal environments have shown significant spectral variability in the pigment fluorescence consistent with the above observations, and indicated that there is potential for more detailed ALF characterization of the cyanobacteria and phytoplankton in the ocean.

The field deployments have shown the feasibility and utility of flow-through pump-during-probe (PDP) measurements of variable fluorescence (Fv/Fm) and revealed a broad range of its variability, 0.1-0.6. The SAP spectral measurements indicated that there might be significant non-Chl background in the area of Chl-a fluorescence peak produced by chromophoric dissolved organic matter (CDOM) and phycocianin (PC) that might result in Fv/Fm underestimation due to 'flattering' the induction

curve. A unique feature of the SAP measurements is real-time spectral correction for the non-Chl background for accurate assessments of phytoplankton photo-physiology. Another important methodological result of the SAP field deployments is the demonstration of fast and accurate physiological assessments in turbid waters using sampling from the surface exposed to bright ambient light.

The SDC analysis provides for improved assessments of CDOM and relevant variables in seawater. CDOM fluorescence retrievals showed good correlation ($R^2 = 0.79$) between dissolved organic carbon (DOC) and Raman-normalized CDOM fluorescence. In April - June 2006, promising new data was acquired on CDOM fluorescence variability in diverse water types, including the Pacific coastal zone of California, California Current, Delaware River, Delaware Bay, and MAB. Three spectrally distinct CDOM chromophores were resolved and regionally interpreted in the ALF CDOM spectral signatures, thus providing the spectral information to improve estimations of other critical variables including Chl-a, PBPs, and Fv/Fm.

The methodological research and technological developments are targeted to be integrated into the major NASA, NSF and NOAA programs. The resarchers have already initiated interagency collaboration and integration into process studies and operational monitoring of the California Current Ecosystem Long Term Ecological Research (CCE LTER, NSF), California Cooperative Oceanic Fisheries Investigations (CalCOFI, NOAA), and Microbial Observatory (NSF) programs.

Objectives for the Coming Year

The accuracy of the SDC assessments of Chl-a concentration will be evaluated in a broader range of oceanic environments, including oligotrophic areas with support of HPLC pigment analyses. The SDC LSE capacity for the detailed PBP pigment characterization may provide additional potential for discrimination of cyanobacteria with specific PBP composition. During project Phase 2, the researchers plan to explore whether the spectral shifts in emission are due to the taxa, cell size, or acclimation requires analysis of the supporting field data sets and laboratory work on similar species. Feasibility of underway SAP physiological assessments in more diverse marine environments, including off-shore waters that may have more severe nutrient or light stress, or where communities have different mechanisms for photoacclimation, will be also investigated. Feasibility of using the SAP CDOM/DOC fluorescence retrievals and assessments of seawater turbidity for a broad range of water types and environmental conditions will be also studied. The CDOM fluorescence measurements will be converted into quinine sulfate equivalent units via laboratory calibration as part of the experimental project program.

Task 975-34-167: **Remote Sensing of Sea Surface Salinity from Space**

GEST Investigator: Paolo de Matthaeis

Collaborator: David Le Vine (GSFC, Code 614.6)

Abstract

This work is in support of the Aquarius mission to measure global sea surface salinity (SSS) from space for climate studies. The science instruments will include an L-band radiometer, whose received signal is sensitive to salinity, and a scatterometer that corrects for the effect of the ocean's surface roughness. The retrieval of salinity is a complex process that involves the accurate processing of the radiometer measurements, and requires a good understanding and estimation of all environmental and geophysical effects producing errors.

Description of Research

The goal of NASA's Aquarius mission is to measure global sea surface salinity (SSS) from space for large-scale and climatic studies. The science instruments will include a set of three

radiometers to perform L-band (1.413 GHz) measurements of brightness temperature, which are sensitive to salinity, and a scatterometer that corrects for the effect of the ocean's surface roughness induced by the surface wind. The retrieval of salinity is a complex process that requires the knowledge of other environmental information and an accurate processing of the radiometer measurements. In addition to the previously mentioned effect of the surface wind and temperature, other contributions such as the emission from the atmosphere, the Faraday rotation in the ionosphere, and the presence of down-welling radiation from the celestial background that is reflected from the surface into the radiometer affect the accuracy of the Aquarius measurements. The presence of rain and land within the antenna footprint should also be taken into account. Therefore, for a correct retrieval of the SSS, a model needs to be developed that includes all these effects.

Accomplishments during the Reporting Period

A number of error sources that affect brightness temperature measurements by the Aquarius antennas has been identified and investigated. Given the polarimetric nature of the Aquarius radiometer, special attention has been given to study how these errors influence different polarizations.

First, the effect of coordinate transformation on the brightness temperature vectors has been examined, and described by means of transformation matrices. In particular, both the use of different definitions of polarization vectors on the Earth surface and in the antenna reference frames, and the integration over antenna patterns have been addressed.

Second, the Faraday rotation of the electromagnetic field in the ionosphere and its resulting influence on the brightness temperature vectors has been examined using the Stokes parameter representation of the electromagnetic field [Le Vine *et al.*, 2007]. When antenna pattern characteristics are included, the first Stokes parameter is no longer completely independent of Faraday rotation. In addition, the rotation angle obtained using the second and third Stokes parameters is biased relative to the Faraday rotation at boresight. Therefore, an alternative approach is used that employs measurements of the third Stokes parameter. When taking into account realistic antenna patterns, a bias in the retrieved angle occurs with the use of this method, due in part to changes in geometry over the footprint of the main beam of the antenna, and to cross-polarization coupling. However, the biases are relatively stable over an orbit, allowing a correction by comparing with an independent measurement of Faraday rotation, such as a footprint pass over a reference site where the true Faraday rotation is known.

A study of the radiometric emission from the atmospheric limb at the edge of the Earth visible disk, which could potentially enter the radiometer antenna, has also been performed. This atmospheric limb is modeled as a layer of atmosphere with temperature and pressure profiles given by the U.S. Standard Atmosphere. In addition, the atmosphere is considered dry, with the only absorption due to the oxygen molecules. Two models for the oxygen absorption coefficient have been considered, the single-line approximation, and the Rosenkranz 2 model. At first, no variation with the geographic location is assumed in the temperature and pressure profiles. Results for this simplified case applied to a sample Aquarius orbit indicate that the error induced by this atmospheric limb is on the order of a few mK. The model has then been modified to consider geographic variation in the temperature and pressure profiles and included into the Aquarius simulation algorithm [Jacob *et al.*, 2006].

Investigation of the scattering from the ocean surface has been continued and applied to the estimation of specular reflection and sunglint entering the radiometer antennas, and simulations have been performed using a sample Aquarius orbit. A two-scale model is under development for the scattering from the composite sea surface. Preliminary results show that the sun contamination is generally within Aquarius specifications, but can sometimes be too large, depending on the season of the year.

Objectives for the Coming Year

A better electromagnetic scattering model for the sea surface is needed. The current model will be improved to better take into account the composite scale properties of the ocean surface. In addition, comparisons will be made with the results obtained using the Integral Equation Method. These models will be used to more accurately quantify the error caused by the sunglint effect.

The simulation model of the Aquarius instrument currently includes only the microwave radiometer. The ocean surface scattering model will serve as a basis to build such a simulator for another of the Aquarius instruments, the radar scatterometer.

Task 974-52-198: **Land Information System (LIS) Data Assimilation on Remote Sensing Snow Product, and Evaluation of the Factors in the Modeling of Water and Energy Fluxes Within the Framework of Land Data Assimilation Systems**

GEST Investigator: Jiarui Dong

Collaborators: Christa Peters-Lidard (PI, GSFC, Code 614.3), David L. Toll (PI, GSFC, Code 614.3), John Eylander (AFWA), Rolf Reichle, Sujay V. Kumar, Randal Koster (GSFC, Code 610.1)

Abstract:

The Land Information System (LIS) is the next generation of Land Data Assimilation System (LDAS) for the Air Force Weather Agency (AFWA) combining real time precipitation observations and analyses, global forecast model data, vegetation, terrain, and soil parameters with the operational Noah soil and snow hydrology model to generate an analysis of soil moisture, soil temperature, snow water equivalent, and other important land surface characteristics. Dong's research for this project is focusing on improving the data assimilation schemes in LIS and assimilating the MODIS snow cover and passive microwave AMSR-E snow water equivalent (SWE) into the LIS system.

Evapotranspiration (ET) has been identified by the U.S. Bureau of Reclamation Reclamation and EPA (and other agencies such as USDA and NOAA) as critical for determining water availability affecting various applications. Dong is attempting to improve LDAS ET through LIS land surface models by incorporating primarily MODIS satellite derived products for a NOAA-GAPP project.

Description of Research

In the western United States, over half of the water supply is derived from mountain snowmelt, where the snow delays runoff and provides water in the spring and summer, when it is needed most. However, little is known about the spatial and temporal variations of critical processes like snowmelt and runoff in these mountainous areas. Thus, a remote sensing approach is a practical snow cover mapping solution for high heterogeneity regions. Assimilating remotely sensed observations into the LIS will result in improved analyses of land surface state variables. Dong's research is focusing on assimilation of MODIS snow cover and AMSR-E SWE observations over the United States at high spatial resolution into the LIS system.

The overall objective of Dong's research for the NOAA-GAPP project is to provide the improved ET and surface water and energy fluxes within the framework of Land Data Assimilation Systems (LDAS) to federal agencies such as the U.S. Bureau of Reclamation, the EPA, and the USDA. Also, the North American Regional Reanalysis (NARR) may provide an extremely valuable data set to address regional and long-term variations in the water fluxes and are an integral part of the study. Satellite derived data are used and evaluated to further improve and develop ET and surface water and energy balance estimates.

Accomplishment during the Reporting Period

Snow pack is an integrated response to both climate and land surface complexity. Understanding the satellite-based snow retrieval uncertainty is critical for its successful utilization, and quantifying the uncertainties in a meaningful way is an important prerequisite to undertaking assimilation. Dong successfully implemented the extended Kalman filter (EKF) and a preliminary ensemble Kalman filter (EnKF) into the LIS Noah model for the AFWA project, and performed the identical twin experiments on SWE data assimilation. The work has been presented in the AFWA final review meeting and was included in the Final Report to AFWA [Peters-Lidard *et al.*, 2006, Kumar *et al.*, 2006]. For the practical application, as a first step, Dong performed the analysis on Moderate Resolution Imaging Spectroradiometer (MODIS) snow cover and LST, *in-situ* meteorological records, ground snow water equivalent measurements, and land surface characteristics to investigate the error structure of these recently developed MODIS snow cover products. Analysis of the MODIS snow cover data set over the period from 2000 to 2005 was undertaken for Colorado State in the western United States. A journal paper is in preparation.

Dong continued working on the analysis of NARR and North American LDAS data versus GAPP *in-situ* reference data for land surface water and energy flux estimation from different model approaches. The comparison revealed a partitioning problem in sensible heat and latent heat fluxes in most models during summer season. Possible factors include model forcing, land cover classification and model physics, all affecting the energy fluxes are investigated through LIS over the South Great Plains reference sites for the period from October 2002 to December 2004. Model forcing data, land cover classifications and model physics had significant influences on the energy flux estimation. This work has been presented in conference meetings [Dong *et al.*, 2006c, Toll *et al.*, 2006a,b] and a journal paper is in preparation.

In addition, the GEST investigator participated in the evaluation of the NASA LIS implementation of Noah 2.7.1 by comparing it to NCEP's version. The LIS Noah 2.7.1 was successfully released to the LIS user community.

The GEST researcher had two journal papers accepted for publication. Dong *et al.* [2006a] performed an observation-based study to further investigate the impacts of vegetation and cold season processes on soil moisture persistence and climate feedbacks. Investigation of soil moisture persistence at the seasonal timescale shows a strong correlation between soil moisture in spring and the subsequent precipitation in summer over forest dominant area and between cold season precipitation accumulation in winter and soil moisture in the following spring. Dong *et al.* [2006b] successfully applied the extended Kalman Filter (EKF) method to assimilate the SMMR snow water equivalent observations. This innovative approach is suitable for assimilating remotely sensed AMSR-E observations and overcomes the difficulty associated with model layer geometry and unique snow processes related to growth and ablation. A series of numerical experiments have demonstrated that assimilation of remotely sensed SWE estimates results in improved SWE estimates when compared to in-situ measurements.

Objectives for the Coming Year

In the coming year, Dong will work on the NOAA National Weather Service River Forecast System (NWSRFS) project. He will also work on the Agricultural Water Resource Decision Support (AWARDS) system and the ET Toolbox – New Mexico project. The objective of NWSRFS project is to improve NOAA/NWS river forecast decision support with NASA satellite and land information system products, and transfer the NASA remotely-sensed and modeled snowpack information along with the modeling and data assimilation capabilities of LIS to the NWSRFS component models. Dong will conduct the satellite data assimilation including MODIS snow cover and LST and passive microwave sensed AMSR-E snow water equivalent.

Task 974-52-196: **Coupling High Resolution Earth System Models Using Advanced Computational Technologies**

GEST Investigator: Joseph L Eastman

Collaborator: Christa Peters-Lidard (PI, GSFC, Code 614.3)

Abstract

The first objective of this research project is to apply advanced computational technologies to the problem of coupling high-resolution (*e.g.*, 1 km) Earth system models. The second goal is to investigate the linkage of the land surface and atmosphere and the effects on convective modeling. The Land Information System (LIS) is a high-resolution, high-performance land surface modeling and data assimilation system to support a wide range of land surface research activities and applications. Using advanced computational technologies and software tools, LIS has been coupled to other high resolution atmospheric models, including the Weather Research and Forecasting (WRF) and Goddard Cumulus Ensemble (GCE) models. Through the coupled modeling system, the researcher is examining the effects of different land surface models and the assimilation of different datasets on cloud resolving convective modeling results.

Description of Research

The two-way interaction of the land surface and the atmosphere occurs over wide ranging spatial and temporal scales. These interactions over multiple scales are communicated through the exchange of water, energy, and carbon. The ability of the land surface and atmospheric models to represent these exchanges through parameterizations and physically based algorithms is critical to understanding and predicting the land-atmosphere continuum in terms of climate and allocation of resources on both short and long time scales. In the short term the capability to accurately simulate and predict the evolution of convective systems is of primary concern to weather forecasters and emergency planners. The goal of a coupled land surface and atmospheric modeling system is to improve this capability through high resolution modeling and the assimilation of new, emerging high resolution satellite data into this system.

Accomplishments during the Reporting Period

The work in the past year has focused on the evaluating the forecast skill of coupled LIS and WRF (LISWRF) modeling system. The use of LIS as the land surface model (LSM) component of the atmospheric models allowed the use of multiple LSMs in testing the coupled systems. This coupled system has been maintained to keep pace with new versions of WRF and require integrity checks for each new release through idealized simulations. Following the previous years work in which it was found that there was a significant dependence on radiation update frequency, and a subsequent publication related to this work, investigation focused on the role of radiation frequency at different spatial scales for a case day. The results indicated that the impact of update frequency at mesh sizes 10 km or greater was minimal. This was due to the use of cumulus parameterizations at these scales that lack strong interaction between radiation and developing convective systems. At 1 km scales this interaction is captured through the explicit modeling of different hydrometeors and their adjustment and feedback to radiation tendencies. It was also found that the divergence of the convective systems at varying radiation frequencies was considerably less for an actual case day than in the idealized case, mainly due to constraining effects of nudged boundary conditions. These results are currently being written up for submission to a peer reviewed journal.

Another aspect of the project focused on the improving the forecast ability of LISWRF by assimilating high resolution land and forcing data into LIS to produce the land surface initial conditions (ICs). The WRF standard initialization program (WRFSI) uses the land and surface data from the ingested meteorological model to produce the ICs, despite the mismatch of resolution and LSMs employed in this model. Overall, the LIS

generated ICs did lead to an improvement in model forecast skill. Through improved land and soil state heterogeneity and subsequent communication of mesoscale fluxes the temporal and spatial forecasts were found to statistically better. The other aspect of this LIS assimilation was the possible improvement by using finer land surface parameter datasets, higher resolution forcing, longer spin-up integration times, and more sophisticated LSMs. The results indicated little sensitivity to higher resolution parameter and forcing datasets. The main limiting factor was the resolution of precipitation forcing. At the time of the completion of this project, the finest precipitation forcing was roughly one-eighth of a degree. Since that time a new dataset has been incorporated that forces the precipitation at 4 km. This higher resolution data indicates an improvement over its coarser counterpart. It was also found that the length of the spin-up integration led to significant divergence in the model solution. This divergence was magnified as the length of LISWRF forecast was increased. The results suggest this is due to the memory of the lower soil model moisture and temperature states. Recent literature typically uses a spin-up length of roughly 18 months to 2 years for multi-day forecasts. A major finding of this work was that this needs to be increased to decadal time scales for a noticeable improvement in forecast skill for meteorological integrations longer than 24 hours. As the integration length is increased the recently added telescopic nesting capability of LISWRF has proved valuable. This is a direct result of the need to capture upstream synoptic events as they propagate through the model domain over longer the longer integration times. These findings are currently being incorporated into a manuscript that also evaluates the importance of the strength of synoptic forcing along with the ICs in model forecast ability.

Another significant finding of the project was regarding the level of sophistication of the LSM employed in the forecast. Two LSMs were evaluated, the relatively simple Noah model and the sophisticated Community Land Model (CLM) for a case day that occurred during the International H_2O Program (IHOP) field project. The forecast skill was evaluated using over 100 stations from the Oklahoma Mesonet surface data network. Surprisingly the results were inconclusive, with the CLM producing only slight improvements the spatial and temporal location of the onset of convection, while the Noah model showed slight improvements in the surface temperature forecasts.

Objectives for the Coming Year

During the next year the LISWRF system developed in this project will be incorporated into other projects investigating the water and energy cycle at fine scales. Included in this are investigations into the planetary boundary layer and further enhancement of high resolution convective modeling. Also the pursuit of funding is under way to implement ecological and carbon models into the LIS software system. These models also include the ability to incorporate human socio-economic aspects and there effects on climate.

Task 614-66-228: **Enhancement and Application of Hydrometeorological Functionalities in the NASA-GSFC Land Information System (LIS)**

GEST Investigator: Matthew Garcia

Collaborators: Christa D. Peters-Lidard (GSFC, Code 614.3), James Geiger (GSFC, Code 587.0), Sujay Kumar, Yudong Tian, Jing “Lily” Zeng (SAIC), John Eylander (AFWA), Joseph Santanello (ESSIC), David Mocko (SAIC), David Gochis (NCAR), David Yates (NCAR), John McHenry (Baron), Tom Burnet (Baron), Carlie Coats (Baron), Jerry Condrey (Baron)

Abstract

Garcia has participated in two specific projects during the reporting period that involve enhancements to the meteorological and hydrological capabilities and functionalities of the NASA-GSFC Land Information System

(LIS). Activities oriented on these projects, and in relation to several project proposals, in the reporting period have contributed substantially to Mr. Garcia's principal goal of full LIS-based land-surface hydrologic capability for the purposes of research investigations on, and applications to, remote sensing of the terrestrial precipitation in the hydrologic cycle and eventual application to flood and water resources management problems.

Description of Research

In the reporting period, the GEST investigator has performed work for the Air Force Weather Agency in support of improvements to LIS meteorological input capabilities. Specifically, Garcia has developed a program for surface precipitation gauge network and gridded-field analyses, including the incorporation of climatological precipitation fields on a monthly basis at various high-resolution scales of interest. An early portion of this work was presented at the 2006 AGU Joint Assembly and was submitted to the AGU journal Water Resources Research soon thereafter in conjunction with related work in the USDA-ARS Walnut Gulch Experimental Watershed, Arizona. That publication is currently in review. Later portions of this work were presented by Dr. C.D. Peters-Lidard on behalf of Mr. Garcia at the 2007 AMS Annual Meeting.

Garcia also continued collaborative involvement in a project with scientists at NCAR and Baron Advanced Meteorological Systems oriented on the application of distributed hydrological models for land surface and stream routing processed in a national system for Romania under their Destructive Waters Abatement (DESWAT) Program. This work has involved the integration and development of software components for the enhancement of hydrologic functionality in the Noah LSM component of LIS. Early results from this work were presented at the 2006 AGU Joint Assembly, and portions of this work oriented on a specific Appalachian headwater case study were presented on behalf of Mr. Garcia by Mr. John McHenry at the 2007 AMS Annual Meeting and are being organized for submission to the AMS Journal of Hydrometeorology during 2007.

Accomplishments during the Reporting Period

In extension of previous work in support of the ARMS research described in earlier reports, a computational method for the detailed analysis of surface (precipitation) gauge networks was developed by Garcia. This program supports the evaluation and comparison of spatial interpolation functions for the distribution of precipitation observations at gauged sites to other locations in a study region. It has been found that the relatively simple inverse-distance method of spatial interpolation retains greater accuracy, determined as a measure of the resemblance of a field generated with only a portion of the gauge network present to that produced by the full network, than a more sophisticated method of spatial interpolation (multiquadric-biharmonic) that has previously been compared favorably with geostatistical analysis methods. Further work with AFWA has led to improved precipitation processing capabilities, including the assimilation of high-resolution monthly climatological precipitation datasets over the conterminous U.S. and the development of downscaling procedures for coarse-scale satellite-based precipitation measurements to regions and resolutions of interest.

Finally, the GEST researcher has continued participation in a collaborative effort at the improvement of hydrologic functionality in the NASA-GSFC Land Information System by the incorporation of software enhancements by DESWAT project partners at NCAR, including the Unified Noah land surface model and the Noah Distributed hydrologic enhancements to that LSM for the lateral redistribution of storm runoff and soil moisture. In collaboration with NCAR and Baron AMS project partners, Mr. Garcia developed a stream routing methodology for linkage with the Unified Noah Distributed components of this LIS-R (routed) version that handles both the initial spatial analysis of the target watershed domain as well as the execution of traditional stream flow routing algorithms. Early results from LIS-R simulations of a case study precipitation event in an Appalachian headwater basin are highly encouraging and were presented at the 2006 AGU Joint Assembly and on behalf of Mr. Garcia by BAMS

colleagues at the 2007 AMS Annual Meetings, and are in preparation for a manuscript submission to the AMS Journal of Hydrometeorology during 2007.

Objectives for the Coming Year

In the coming year, Garcia will continue with the development and maintenance of enhanced hydrologic functionalities in LIS for application to the DESWAT project and to the preparation of case-study results and related manuscripts for submission and publication in AMS and AGU journals.

Garcia also plans for increased involvement in projects with the Air Force Weather Agency, with whom the LIS team is currently focusing much of its work. Project-related tasks will include the completion and integration into LIS of climatologically-aided downscaling methods for precipitation fields as well as enhancements to those procedures, including bias adjustment and improvement of the existing AFWA product suite generation. Attention will be given to case study and large-scale study preparation for project reviews as well as for submission and publication in AMS and AGU journals. Current aspects of the precipitation processing system are planned for presentation at the 2007 AGU Joint Assembly in Acapulco, Mexico.

Task 555-71-245: **A Double Detector for RFI Mitigation in Microwave Radiometers**

GEST Investigator: Priscilla Mohammed

Collaborators: Jeffrey Piepmeier (PI, GSFC, Code 555), Joseph Knuble (GSFC, Code 555)

Abstract

The double detector is part of an analog radio frequency interference suppression system that can potentially be used to detect and mitigate radio frequency interference (RFI) in conventional radiometers. The detector, which uses the principle of kurtosis to discriminate between natural thermal emission and non-Gaussian signals, was shown to approximate the kurtosis of input. The double detector system comprises a square-law diode detector with short integration time for measuring the total power out of the radiometer, followed by a second diode detector which acts as a higher-order statistical fourth-moment detector. The theoretical response to continuous-wave and pulsed RFI was derived and the result was tested in two experiments. The technology is compatible with existing direct-detection radiometer designs.

Description of Research

Man-made emissions, termed radio frequency interference (RFI), can corrupt microwave radiometer measurements. High level RFI can saturate the receiver thereby denying measurements over specific regions, or worse, low-level RFI can artificially increase brightness temperatures unknown to the user. Even when operating strictly within passive allocations, an RFI-free environment is not guaranteed since active services dominate surrounding spectrum. RFI detection in space-borne radiometers is commonly done in post-processing using image statistics and expected spectral or polarization characteristics of surface brightness temperatures. Hardware-based RFI detectors or mitigators are currently not in use.

A double-detector (DD) for microwave radiometers is based on the concept of using the kurtosis statistic as a non-Gaussian (RFI) identifier. Using the kurtosis as the basis, the DD was conceived as an extension to a conventional direct-detection radiometer using common RF components. The goal was to provide a detector that approximates the kurtosis statistic which can be easily added to radiometer designs.

Accomplishments during the Reporting Period

Interference-free signal power measured by the square-law detector consists of naturally occurring thermal emission, including that from the sky, plus thermal noise generated in the radiometric system which are all modeled using Gaussian distributions. Gaussian signals have a constant relationship between their power or the

second central moment and their fourth central moment. The ratio of the fourth central moment to the square of the second central moment is called the kurtosis and is equal to three if the input is Gaussian, even with varying input power. The deviation of this quotient from its constant value of three is an indicator of the presence of non-Gaussian RFI. This fact was used as the basis for the theoretical development of detection using the DD.

The received signal is first input to a microwave detector, the output of which is a baseband video frequency (VF) signal. The output voltage v1, measured through a video amplifier is proportional to the power of the input signal. A second detector and video amplifier measures v2, the power in the VF signal which includes the fourth central moment of the input signal. The ratio of v2 to v12 can be used to approximate the kurtosis which is referred to as the pseudo-kurtosis or pk. The pk, assuming a Gaussian input, was modeled as var(y)/<y>2 where the operators var and <•> denote variance and expected value, respectively. As with the true kurtosis described in the previous paragraph, the pk is constant under varying input power for a Gaussian input. Using this model for system detection, the standard deviation associated with the moment ratio, pk, was calculated.

An arbitrary interferer was added to a Gaussian input at the first detector and the pk was modeled to observe its behavior for specific interferers over a range of interference to noise ratios (INR). Plots were made to study the pk versus INR for interferers such as continuous wave (CW), as well as pulsed-sinusoids with varying duty cycles. For example, from this study it was determined that if there is no interference (just a Gaussian input) the pk reduces to unity, thus a deviation from this constant is an indicator of non-Gaussian RFI. The pk detector is insensitive to interferers which are modeled by Rayleigh statistics such as fading due to moving stations. Also if the duty cycle of a pulse is exactly 50%, then pk = 1 and the interference is undetected. Data from a laboratory experiment which measured the response of the DD to a Gaussian plus CW input was then used to validate the corresponding theoretical response.

In the previous sections linearity is assumed in the derivation of the moment ratio. However, before the pk can be used as an RFI detector, the inherent nonlinearities in the system must be characterized and removed. The first detector output was modeled using a polynomial expansion which can be a second or third order depending on the dynamic range of the system. The second detector output was then modeled as a higher order polynomial. These polynomial expansions sufficiently described the nonlinearities and linearized pk were calculated for experimental data.

Over the course of two weeks in April and May 2006, the double detector system was interfaced with the Passive Active L-band Radar/Radiometer (PAL) at the Jet Propulsion Laboratory to collect field data. This afforded the opportunity to test the system in a real RFI environment since PAL detects mainly pulsed RFI from nearby airport radars. Approximately 1.5 terabytes of data were recorded and later analyzed. The analysis included linearization and calibration of data which was reduced to 0.5-second integration time series of antenna brightness temperature and pseudo-kurtosis, pk. Also included was a comparison to a conventional pulse blanking technique.

To summarize, accomplishments included development of a theoretical basis for detection. This was done in conjunction with the PI, Jeff Piepmeier. Software simulations were developed for detection of various interferers and experimental data were used to validate these results. The nonlinearities in the system were sufficiently characterized and a correction algorithm was applied to all experimental data before further processing. Analysis of field data demonstrated that the system acted as an RFI detector. A pulse blanking algorithm was used to detect and remove RFI and the results compared to that of the RFI detector which uses the pseudo-kurtosis for detection.

Objectives for the Coming Year

The GEST investigator will analyze more of the field data that was collected by the RadSTAR-A (L-band imaging scatterometer) in receive mode over the Delmarva Peninsular in the vicinity of the NASA Wallops Flight Facility. This will provide an additional opportunity to observe the system response to an RFI environment.

The rest of the year will then be focused on post-detector spectral analysis. RFI can be detected by monitoring changes in several sub-band outputs of the post-detector spectrum and spectral blanking could be possibly applied. The use of various numbers of sub-band outputs will be studied via simulation and using the post-detector spectral analysis for frequency blanking the RFI, will be investigated. Hardware to perform the spectral analysis will also be built and tested.

Task 971-00-002: **Land Data Assimilation at the NASA Global Modeling and Assimilation Office**

Grant 00001252 **Assimilation of AMSR-E Data and Application to the Initialization of Soil Moisture Reservoirs in a Seasonal Forecasting System**

Grant 00001513 **Global Estimates of Evaporation from Variational Assimilation of Multi-platform Land Surface Temperature into a Dynamic Model of the Surface Energy Balance**

Grant 00002755 **Assimilation of GRACE Derived Terrestrial Water Storage Variations**

GEST Investigator: Rolf H Reichle

Collaborators: Michele Rienecker (PI, GSFC, Code 610.1), Wade Crow (USDA), Gabrielle De Lannoy (Ghent Univ., Belgium), Dara Entekhabi (MIT), Randal Koster (GSFC, Code 610.1), Sarith Mahanama, Matt Rodell (GSFC, Code 614.3), Ben Zaitchik (Univ. of Maryland)

Abstract

An advanced land data assimilation system is being developed at the NASA Global Modeling and Assimilation Office. The system is designed to merge satellite observations of land surface states—such as surface soil moisture and land surface temperature—into model estimates of land surface conditions. With this assimilation system, the research team demonstrated a long assumed property of global soil moisture fields derived from data assimilation: that the assimilation product is superior to either satellite data or model data alone [Reichle *et al.*, 2006]. Similarly, Reichle and his colleagues demonstrated that assimilation of satellite-based, large-scale terrestrial water storage observations improves estimates of groundwater variability [Zaitchik *et al.*, 2007]. Bias estimation for soil moisture data assimilation was also addressed [De Lannoy *et al.*, 2006]. Moreover, they demonstrated the synergies that could be derived from multiple space-borne water cycle observations (surface soil moisture and precipitation) [Crow *et al.*, 2006]. In a study related to seasonal climate prediction, the team analyzed the impact of deep soil temperature memory to variability elsewhere in the climate system, memory that may provide some skill to sub-seasonal forecasts [Mahanama *et al.*, 2007].

Description of Research

Research for this project at the NASA Global Modeling and Assimilation Office (GMAO) involves the development, implementation, and testing of an advanced land data assimilation system—a system that is designed to merge satellite measurements of land surface states (*e.g.*, soil moisture, land surface temperature, or snow) with corresponding estimates from land models that integrate surface meteorological observations (including precipitation and radiation). The improved estimates of land

surface conditions from the assimilation are then used to initialize GMAO seasonal climate forecasts. Since atmospheric dynamics are chaotic at time scales beyond two weeks, seasonal climate forecasting relies strongly on the correct initialization of the slow components of the Earth system, namely the oceans and the land surface. Another application of land assimilation is the production of land surface temperature estimates that are needed, for example, by the NASA Clouds and the Earth's Radiant Energy System instrument team.

Accomplishments during the Reporting Period

During 2006, Reichle continued with the development of an advanced land data assimilation system that makes use of soil moisture retrievals from the Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E) for operational seasonal forecast initialization. Key science issues addressed during the report period were the analysis of AMSR-E soil moisture retrievals and comparison with retrievals from the historic Scanning Multichannel Microwave Radiometer (SMMR). The comparison indicates that there are severe biases between the two satellite retrieval data sets in the time mean soil moisture retrievals as well as in higher-order moments. The assimilation results demonstrated at the global scale that—after suitable a priori scaling to address the biases—soil moisture fields derived from data assimilation are superior to estimates based on the land surface model or the satellite data alone [Reichle *et al.*, 2006].

Reichle and his colleagues also investigated various options for on-line bias estimation within a soil moisture assimilation system [De Lannoy *et al.*, 2006]. Using *in situ* soil moisture observations in a small agricultural field and the Community Land Model (CLM2.0), they found that it is possible to estimate soil moisture bias explicitly and derive superior soil moisture estimates with on-line bias estimation. In a biased model, however, low errors in soil moisture estimates may require large and frequent increments that may in turn negatively impact the water balance and output fluxes.

In a project with colleagues at USDA, NASA, and MIT, Reichle established the synergies that could be derived from multiple space-borne water cycle observations [Crow *et al.*, 2006]. In particular, simultaneous surface soil moisture and high-frequency precipitation retrievals provide complementary (*i.e.*, nonredundant) sources of information for constraining estimates of land surface conditions in land data assimilation systems. Soil moisture-based enhancements to satellite precipitation products may prove especially valuable given known difficulties with using low-frequency microwave observations to retrieve rainfall over land.

In collaboration with scientists at the NASA Hydrological Sciences Branch, the researchers demonstrated that the assimilation of data from the Gravity Recovery and Climate Experiment (GRACE) system of satellites yielded improved estimates of groundwater variability in the Mississippi river basin, as evaluated against independent measurements [Zaitchik *et al.*, 2007]. Data assimilation was moderately successful at horizontally disaggregating basin-scale GRACE data. At smaller spatial scales, the performance of the assimilation system was highly sensitive to the level of error ascribed to the GRACE observations.

In a study related to seasonal climate prediction, Reichle analyzed the impact of deep soil temperature memory to variability elsewhere in the climate system, memory that may provide some skill to sub-seasonal forecasts [Mahanama *et al.*, 2007]. The results show that interactive deep soil temperature significantly increases surface air temperature variability. An interactive deep soil temperature, however, reduces the variability of the hydrological cycle (evaporation and precipitation), largely because it allows for a negative feedback between evaporation and temperature.

In addition to the listed peer-reviewed references, research progress was documented in presentations at the 2006 Spring and Fall meetings of the American Geophysical Union, the 2006 IEEE International Geoscience and Remote Sensing Symposium, and the 2007

Annual Meeting of the American Meteorological Society.

Objectives for the Coming Year

One objective for the coming year is to incorporate AMSR-E surface soil moisture retrievals into the quasi-operational GMAO seasonal climate prediction system. Another objective for next year is to bring the development of land surface (skin) temperature retrievals to maturity so that sensitivity studies with the land assimilation system can be conducted in the context of the on-going GMAO "MERRA" reanalysis project. This effort will be a first step towards a fully coupled land-atmosphere assimilation system that includes soil moisture, snow, and land surface temperature. Finally, the GEST investigator will continue to enhance the land assimilation system. Development of modules for adaptive estimation of model and observation error parameters has already started and will provide improved error characterization, which in turn will ultimately yield improved estimates of land surface conditions.

Task 971-60-215: **Dissolved Organic Carbon and Chromophoric Dissolved Organic Matter in Surface Waters in Support of NASA's New Investigators Program (NIP) Project**

GEST Investigator: Mary Elizabeth Russ

Collaborator: Antonio Mannino (PI, GSFC, Code 614.7)

Task 614-81-280: **A Comprehensive Plan for the Long-Term Calibration and Validation of Oceanic Biogeochemical Satellite Data (Cal/Val) Project in Support of the Ocean Color Calibration and Validation Office**

GEST Investigator: Mary Elizabeth Russ

Collaborator: Stanford Hooker (PI, GSFC, Code 614.8)

Abstract

Primary storage of organic carbon within all ocean environments is in the form of dissolved organic carbon (DOC). The fate of DOC is not well constrained in coastal ocean environments, such as the Chesapeake Bay (CB) and the Mid-Atlantic Bight (MAB). Understanding the composition, size, and turnover rates of the distinct DOC fractions in these areas, is necessary to complete the global carbon cycle. In support of the NIP project, degradation rates of labile and semi-labile DOC and the impact of the microbial community on the absorption of chromophoric dissolved organic matter (CDOM) are quantified. Photo-oxidation experiments were also developed to address the possible link between the degradation of CDOM and the production of labile DOC. A main mission of the Cal/Val project is to review protocols, determine uncertainties budgets, and establish performance metrics for optical and biogeochemical methods and measurements used to calibrate and validate satellite data. Within this task, the development of workshops and the participation in round-robins are also utilized to achieve this goal. An Optical Properties Analysis Laboratory (OPAL) is being designed to incorporate both optical and biogeochemical measurement collection and analysis, in order to provide adequate validation of remotely-sensed data with coincidental in-water radiometry and in situ biogeochemical samples.

Description of Research

NASA's NIP project focuses on understanding the temporal and spatial variability of dissolved organic matter (DOM) and CDOM in the surface waters of the CB and MAB. The approach is to use satellite data products, field measurements, and laboratory experiments to examine the

distribution, sources, and sinks of DOM and CDOM, and to develop empirical relationships to quantify DOC from CDOM absorption, and improve carbon cycle models to more accurately predict how natural processes and anthropogenic activities impact coastal ecosystems. A primary Cal/Val project objective is to provide a series of performance metrics, to be available to the ocean optics scientific community, for determination of the calibration and validation quality of the data measured. High-quality data collected and processed within these established guidelines will be archived and accessed by scientific researchers through the NASA SeaWiFS Bio-Optical Archive and Storage System (SeaBASS) database, thereby creating a continuing time-series compilation of data for satellite validation and global climate research.

Accomplishments during the Reporting Period

As part of the NIP project, three microbial lability (duration ~190 days) and three photo-oxidation experiments (duration of 14 or 21 days) were completed during this reporting period from surface water collected within the CB, MAB, and Delaware Bay. These experiments complete the series started in the spring of 2005, and entail both a spatial (coastal to open ocean) and temporal (March 2005 to July 2006) study of the regions. Final degradation rates for the three microbial experiments completed during this period had equal rates during November 2005 and May 2006 (on average 0.017 ± 0.004 day^{-1} and 0.013 ± 0.003 day^{-1}, respectively) for the CB and MAB stations, and higher rates within the CB mouth (0.020 ± 0.030 day^{-1}) as compared to the coastal or inner shelf MAB stations (on average 0.006 ± 0.003 day^{-1}) in July 2006. For all stations and days sampled, the CB mouth station had the highest percent DOC degraded, as opposed to the coastal or inner shelf MAB stations, after both 60 and 150 day periods. Spectral slope determinations suggest a homogeneous terrestrial DOM composition within the CB in November 2005 and May 2006 and for the CB and inner shelf MAB station in July 2006. DOM was of a marine composition within the inner shelf MAB in November 2005 and May 2006. Compiled results show that the inner shelf MAB had less labile DOC compared to the CB during November 2005 and May 2006. Fall mixing of the water column or a decrease in summer MAB ecosystem production may have created these conditions in November, and in May, the MAB may have been sampled after the spring phytoplankton bloom, which is reportedly as early as March. In July 2006, the CB had more labile DOC than the coastal or inner shelf MAB, which may be the result of an extreme rain event that occurred days prior to sampling. Extensive terrestrial run-off may have increased nutrient loading to the CB and increased phytoplankton production, thereby introducing a fresh labile source of DOC to the region. The influence of this rain event is also seen in the three photo-oxidation experiments completed during this reporting period. During May of 2006, a greater marine influence in DOC composition was present and a lower degree of photo-bleaching occurred within the inner shelf MAB compared to the CB. In contrast, after the extensive rain event in July 2006, the results, based on spectral slopes and CDOM absorption, show a comparable terrestrial influence in DOC composition throughout the CB and inner shelf MAB, and equal degrees of photo-bleaching present at all stations.

A final point to both the microbial lability and photo-oxidation experiments is the contrast in CDOM absorption and DOC concentration results between the two types of experiments. DOC concentrations decreased from 8 to 20 % from the initial concentrations and CDOM absorption did not significantly change during the microbial lability experiments, whereas in the photo-oxidation experiments, DOC concentrations remained constant throughout the duration of the experiments and CDOM absorption (at 355 nm) was reduced between 70 to 45 % in May 2006 and 78% in July 2006 within approximately a week. These combined results suggest an uncoupling between DOC and CDOM sources and sinks within the CB and MAB regions.

Work on the Cal/Val project is in a planning and preparation stage. During this reporting period, the NASA strategic planning document entitled “A Comprehensive Plan for the Long-Term Calibration and Validation of Oceanic

Biogeochemical Satellite Data" was reviewed and revised. Current ocean optics protocols have been initially reviewed and general divisions and structure for revised protocols drafted. A location has been procured for the Optical Properties Analysis Laboratory (OPAL) and the initial set-up and ordering of supplies and equipment is proceeding.

Objectives for the Coming Year

With the completion of the microbial lability and photo-oxidation experiments a manuscript is in preparation for submission to a peer-reviewed journal during the next reporting period. A NASA technical memorandum is also being compiled and will be published in the 2007 period, which will outline the series of Biophysical Interactions in Ocean Margin Ecosystem (BIOME) and Chesapeake Bay Plume (CBP) cruises. Protocol review and revision will proceed, and a series of workshops will start and round-robins continue, which are designed to address a community consensus of sampling methods for optic and biogeochemical parameters and a quantification of uncertainty budgets associated with these oceanic measurements. OPAL will continue to be designed and equipped during the next time period and initial scientific research projects, proposed with calibration and validation objectives, begun.

Task 974-52-200: **NASA Energy and Water Cycle Study (NEWS) Science Integration Team (NSIT)**

GEST Investigator: Robert Schiffer

Abstract

This task covers continuing programmatic support to the NASA Energy and Water Cycle Study (NEWS) Project Office, co-located at the George Mason University, and for participation on the NEWS Science Integration Team (NSIT). The NEWS activities planned and coordinated by the NSIT are comprised principally of product-driven investigations, exploration-driven investigations and integrative efforts studies. These include: Product-Driven Investigations: Systematic research investigations intended to combine and interpret past and current observations, derive global analysis and prediction tools and products and identify technological and observational requirements to guide future NASA investments; and Discovery-Driven Investigations: Fundamental investigations to identify key missing elements and explore new scientific frontiers to improve capabilities and knowledge of the energy and water components of the Earth system. Furthermore, NEWS serves as the primary interface and liaison with other NASA water and energy cycle related system components, and is charged with integrating the results of the NEWS investigations within the overall NASA Earth Science Program.

Description of Research

Specific activities undertaken include: assisting in overall project scientific and implementation planning and management, particularly the development and updating of the NEWS Implementation Plan. Specific Schiffer responsibilities include a leadership role in the development of a phased research program exploiting current capabilities, integrating improvements in the observation-prediction system, and leading to a comprehensive end-to-end water cycle prediction system; providing external international coordination linkages with relevant activities including the WCRP Global Energy and Water Cycle Experiment (GEWEX), the Integrated Global Water Cycle Observations (IGWCO) theme of the Integrated Global Observing Strategy (IGOS), and the Global Earth Observation System of System of Systems (GEOSS); assisting in developing performance metrics for evaluating scientific progress and reporting project accomplishments; supporting monitoring ongoing NEWS scientific investigations by serving as a designated point of contact for the project with selected investigators; and contributing to research solicitation development and proposal review processes, including participating as a member of NEWS peer review panels

Accomplishments during the Reporting Period
Schiffer played the central role in drafting NEWS scientific requirements, coordinating the peer review process for selecting NEWS investigations, and serving as principal editor of the current version of the NEWS Implementation Plan.

Objectives for the Coming Year
The primary objective is to produce an updated version of the NEWS Implementation Plan for external review by the scientific community. The Implementation Plan will reflect recent NASA programmatic decisions that are forcing reconsideration of the timeline for achieving the long-term NEWS goal of documenting and enabling improved observation-based predictions of the water and energy cycle consequences of Earth system variability and change.

Task 975-31-154: **Electromagnetic Models for Microwave Remote Sensing of Snow and Applications**

Grant 00002262: **Analysis and Correction of Brightness Temperatures for Atmospheric Effects and Forest Cover for Microwave Remote Sensing of Snow**

Grant 00002264: **Improved Passive Microwave Snow Retrievals of Snow Depth and Snow Water Equivalent Over Land and Sea Ice Through the Incorporation of Electromagnetic Modeling and Temporal Information**

Grant 00002322: **Blending of Existing Snow-Cover Products to Produce a Snow Extent / Snow Depth Product: Estimation of Ripening/Melt Onset from Microwave Observations and Validation**

GEST Investigator: Marco Tedesco

Collaborators: Ed Kim (GSFC, Code 614.6), Thorsten Markus (GSFC, Code 614.6), James Wang (GSFC, Code 614.6)

Abstract
Retrieval of snow parameters from space-borne instruments is important for many human-related activities. Measured backscattering coefficients or brightness temperatures are strongly influenced by snow parameters such as depth, grain size, and fractional volume. The development and improvement of the algorithms for the retrieval of SWE and snow depth from space-borne data is as important as the development of electromagnetic models. Generally, the effects related to the atmospheric absorption and emission are small at the frequencies of interest (19 and 37 GHz, or similar frequencies), although the brightness temperatures at the two frequencies are affected in a different manner. As a consequence, the spectral gradient (defined as the difference between the 18.7 and 36.5 GHz brightness temperatures) obtained from space-borne data can be different from that one obtained using brightness temperatures at the surface. On the other side, the presence of forest within the observed pixel would mask the upcoming radiation from the snowpack. Also, forest cover influences the polarization of the observed radiation, creating polarization mixing effects. It is therefore important to study how the atmosphere affects the capability to retrieve snow depth and/or SWE from AMSR-E brightness temperatures as well as the spatial and temporal dynamic behavior of snow parameters, including the use of multiple satellites' datasets such as visible/infrared data.

Description of Research
During the past year, Tedesco and his colleagues continued the study for improving microwave radiative transfer models of snow, ice, and frozen soil by using data ground-, airborne-, and satellite RS observations collected during Cold Land Processes Experiment (CLPX) in 2002-03.

The effect of atmosphere on retrieval performance was studied by comparing the retrieved values with values collected on the ground by automatic stations. The researchers studied the effect of the correction on brightness temperatures for atmospheric effects by means of a simplified radiative transfer equation whose parameters are stratified using rawinsonde data collected from a few stations.

Tedesco also studied how changes in snow physical properties, primarily grain size growth, can lead to significant errors in the retrieval of snow depth or snow water equivalent. The objective of this study was to investigate how these error sources can be accounted for using radiative transfer modeling and temporal information. This will improve the understanding of how the evolution of the snowpack along the season affects the brightness temperatures, which, in turn, will be useful to improve current retrieval techniques that use static coefficients, both in space and time. Using radiative transfer modeling, Tedesco quantified the expected changes in brightness temperatures due to grain size growth and to investigate how temporal information and correspondingly dynamic algorithm coefficients can be used to improve snow retrievals. This research supports the development of improved, daily snow cover/SWE maps globally at 25-km resolution, the development of a global snowpack ripening/melt onset component and the validation of the new products by means of ground measurements at local and regional scales.

Accomplishments during the Reporting Period

The analysis of the CLPX data collected at different scales continued from the previous year, including modeling through electromagnetic models driven by snow inputs parameters derived from field measurements. The data collected by the Polarimetric Scanning Radiometer (PSR) over the Intensive observation Scale Areas (1 km x 1 km) have been modeled by using the Dense Medium Radiative Theory.

The performance of four different microwave emission models was compared. These models include: (i) the DMRT, (ii) the Helsinki University of Technology (HUT) model, (iii) the Strong Fluctuation Theory (SFT) model, and (iv) the Microwave Emission Model of Layered Snowpacks (MEMLS) of the University of Bern). The aim of this study was to compare the performance of the physical assumptions made for the different models to evaluate the capabilities of the models to reproduce the measured brightness temperatures.

The brightness temperatures of melting/refreezing cycles have been also modeled by means of a DMRT based model. Tedesco also analyzed data that were collected on ground by the University of Michigan's Truck-Mounted Radiometer System (UMTMR) at 19 and 37 GHz during the 4th Intensive Observing Period (IOP4) in March 2003. Conditions during IOP4 (unlike during the earlier IOP3) included both wet and dry periods, providing a valuable test of DMRT model performance. Observations of upwelling and downwelling tree radiobrightness were used to formulate a simple model for the effect of trees within the field of view.

Moreover, the research team performed a comparison of Moderate Resolution Imaging Spectroradiometer (MODIS) snow cover area (SCA) and microwave SCA with and without correcting for the atmospheric effects. They also studied the potential improvement for the retrieval of SWE from the combination of microwave active and passive data. Results, reported in both a published letter and an accepted full length paper, show that snow depth and SWE retrieval can be improved when using a combined active-passive approach.

In another project, Tedesco developed and published a semi-analytical algorithm for the retrieval of grain size from MODIS infra-red and visible data in collaboration with a European colleague. Results show that the method works satisfactory when validated with ground measurements but more evaluation of the application from satellites data is required. This is mostly due to the error introduced by the atmospheric correction on satellite data when ancillary information is not available.

Finally, Tedesco applied a technique based on the difference between nighttime and daytime brightness temperatures to derive snowmelt extent and duration over the Greenland ice sheet for the period 1988–2005. Results are in agreement with literature techniques although the technique proposed shows an increased sensitivity to the diurnal melting cycle with improved results.

Objectives for the Coming Year

Tedesco will continue work on the development and implementation of both theoretical emission models and retrieval techniques. He will continue investigating how grain size growth, and changes in atmospheric conditions can be accounted for in order to improve the current retrieval techniques by making use of static coefficients, both in space and time. An investigation on the use of the 85-89 GHz channels for detecting shallow snow cover will be started. Tedesco will continue analyzing how the combination of multiple satellite datasets can improve remote sensing of snow. His team will continue improving the retrieval of surface grain size and soot concentration in snow by using a recently developed theoretical tool that uses snow particles as fractals. Finally, he will also continue developing and improving techniques for melt detection over the Greenland ice sheet.

Task 974-44-183: **High Resolution Modeling of Land-Atmosphere Ammonia Exchanges**

GEST Investigator: Yihua Wu

Collaborators: Christa D. Peters-Lidard (GSFC, Code 614.3), Donna Schwede (EPA)

Abstract

Land-atmosphere ammonia exchanges have significant impacts on atmospheric chemistry, acidification of ecosystems and biodiversity of terrestrial ecosystems, and can cause regional atmospheric pollution and associated public health impacts, in addition to shifts in nutrient balance and in composition of plant species. Understanding and predicting these impacts is of interest to a large community served by both NASA and the EPA. To that end, an interagency partnership has been established to focus on this critical problem.

Description of Research

The goal of this project is to merge and leverage existing model capabilities for biochemical deposition (EPA) and land-atmosphere (NASA) observation and modeling to account for the bi-directional ammonia exchanges at high resolution by considering nitrogen transfers, transformations and equilibrium in both soils and plants. One objective of the work is to use a common software framework. By adopting a common framework, NASA's unique observational and modeling assets can be applied, as implemented in the existing Land Information System (LIS), for potential use in the EPA's Models-3/Community Multiscale Air Quality modeling and decision support system.

Accomplishments during the Reporting Period

A new multi-layer canopy resistance model to study the bi-directional ammonia exchanges between the atmosphere and biosphere has been developed [Wu *et al.*, 2006a]. This new model explicitly treats different sources and sinks both within the canopy and at the ground. It can estimate component fluxes, such as flux from/to stomata, cuticle, and ground. This new model is based on the Multi-Layer BioChemical deposition model, and incorporates a parameterization for the ammonia stomatal compensation point to consider the bi-directional exchange of ammonia. The new model considers the effects of leaf temperature and apoplastic concentrations of ammonium and hydrogen ions on the ammonia stomatal compensation point, and accounts for the effects (*i.e.*, feedback) of ammonia emission and deposition on the dynamics of apoplast ammonium and hydrogen ion concentrations. The new model also considers effect of leaf surface water [Wu *et al.*, 2006b]. The new multi-layer canopy resistance model can estimate both atmospheric deposition and emission from the plant and soil. The development of the capability to model bi-

directional pollutant fluxes is an important advancement over surface-exchange models currently used by the EPA which are typically uni-directional.

The new model has potential applications in secondary aerosol studies. Ammonia is a major contributor to secondary aerosol formation in the atmosphere. Ammonium aerosol effects on Earth's radiative balance may impact weather and climate change. Ammonia aerosol can cause regional atmospheric pollution, decrease visibility, and affect human health. The new model also has potential applications in ecosystem modeling. The bi-directional exchange of ammonia between the atmosphere and biosphere can influence the nitrogen status of terrestrial and aquatic ecosystems, and can cause shifts in plant species composition. The new model may provide the coupling between ammonia exchanges and plant photosynthesis. Ammonia deposition to and emission from plants can cause disturbances of intercellular ammonium and hydrogen ion concentrations. High concentrations of free ammonium are toxic to plants and need to be detoxified. Adverse effects of ammonia deposition on vegetation occur when the rate of foliar uptake of ammonia is greater than the rate and capacity for *in vivo* detoxification by the plants. Meanwhile, hydrogen ion disturbance could lead to stomatal movement. Therefore, the feedback mechanism proposed and implemented in the new model does not only improve model prediction capabilities but also links ammonia exchanges and plant photosynthesis.

The new ammonia model has been implemented in standard, platform-independent FORTRAN. The model can be compiled and run on Windows, Unix/Linux and IBM-SP platforms. The code has been compiled with four different compilers (Compaq Visual Fortran, Intel Fortran, G77 Fortran and Lahey Fortran). The finalized code was delivered to the EPA, and a final report for this EPA funded research was also delivered.

Objectives for the Coming Year

The first objective is to finish the incorporation of the new model into the latest version of the NASA LIS system (V4.3.1). Secondly, Wu plans to investigate the effects of land use patterns on the bi-directional exchanges of ammonia between the atmosphere and biosphere.

Task 614-73-251: **Analysis of Synthetic Aperture Radar Data of the Antarctic and Greenland for Glaciological Research**

GEST Investigator: Boris S. Yurchak

Collaborator: Waleed Abdalati (PI, GSFC, Code 614.1)

Abstract

Velocity observations of glaciers provide valuable information about climate conditions and possible consequences because the mass balance is partly determined by the flow rate of these outlets. Due to the inaccessibility of the Polar Regions, satellite remote sensing provides a powerful tool for performing these observations. The ability to measure velocities of fast-moving glaciers is a key methodological issue in the experimental studies of Polar Regions by remote sensing. There are two main remote sensing approaches to measure ice flow velocity from space. The InSAR technique has great potential and it is in use now by several research teams. The cross-correlation method is easier for application and better suited to data acquisition moments of the same site on the earth in pass repeated mode. The velocity estimate is based on ice displacement for several months and thus describes the real mean velocity for the analyzing period. This method can be applied to Synthetic Aperture Radar (SAR) and optical data as well. The algorithm and software for data processing and displaying have been developed. The software contains four programs written in IDL. This tool has been tested and applied to measurement of ice flow velocity for one of fastest Greenland glaciers, Jakobshavn Isbræ, in Spring 2002 and 2003. The retrieved

data demonstrate notable changes in the velocity field pattern of 2003 when compared with 2002, matching known differences in the glacier's behaviors in these seasons according to literature data. Enhancements of the software and analysis of data obtained are in progress.

Description of Research

Cryospheric research within the Cryospheric Sciences Branch (CSB) addresses the physics of ice sheets and glaciers, sea ice, snow on ice and land, and their roles in the global climate system. The mission of the CSB is to increase the understanding of this ice cover and its connection to the rest of the climate system. One of the main goals of the Branch is to measure the mass balance of land ice, and its implications for sea level rise. Due to the remoteness and difficult accessibility of the Polar Regions the remote sensing observations are perhaps the best source of information. In particular, velocity observations of glaciers provide valuable information about ice flow rates that contribute to the mass balance assessment. The ability to measure velocities of fast-moving glaciers is one of the key methodological issues in the experimental studies of Polar Regions by remote sensing. The current research is focused on developing a technique (including software) for determining the ice flow velocity of a glacier by cross-correlation analysis of a pair of time-separated satellite images, evaluation and interpretation of the ice flow velocity profiles and vector field in terms of the mass balance issue.

Accomplishments during the Reporting Period

There are two important parts in the cross-correlation procedure: the method of input data filtration and the method of output data rejection. The algorithm developed for data processing in the current work includes "unsharpen masking" filtration for input data processing, thresholding and discrimination factor calculation for the rejection of not reliable estimates of a location of maximum correlation function within the scanned test window. The size of the test window is variable. Practically, 400x400 pixel and 600x600 pixel test windows have been applied in the current work. The scanned chip's side size also is variable and was established equal to 29, 49 and 69 pixels. The moving average procedure within a box of variable size can smooth the output vector field. A 3x3 box was used for data displaying in the current work. This method can be applied to SAR and optical data as well.

The entire software has been written in the Interactive Data Language (IDL). It manipulates two files ("master" and "slave") extracted from a pair of initial satellite image files and contains four programs for: (1) data extraction for test window from the initial satellite image; (2) correlogram calculation that includes data filtration, calculation of a 2-D field of correlation coefficients, determination the location of its maximum, calculation the discrimination factor, thresholding and recording the results in a file; (3) data processing that used the previous file to plot the valid data for each chip size, plot the composed vector field, smooth the data, plot the smoothed vector field, calculate the errors of the averaged estimates of displacement and velocity, plot the smoothed velocity profiles across the mainstream of ice flow; (4) data annotation that is used to display the output vector field of displacement (velocity) as a field of arrows that allows to highlight the lines ice currents.

The developed software has been tested on the available Landsat data. The velocity field of adjusted areas to the fast Greenland glacier Jakobshavn Isbræ was calculated and plotted for Spring 2002. Results exactly map several siding tributaries of mainflow and their characteristics. Secondly, the profiles along the centerline of the mainstream ice flow have been calculated for Springs 2002 and 2003. The time delay period was 80 and 57 days for seasons 2002 and 2003, respectively. The retrieved data demonstrate the notable changes in the velocity field pattern of 2003 when compared with 2002 matching known differences in the glacier's behavior in these seasons according to literature data. The software showed excellent results in a case of data processing of relatively slow movement related to the neighboring areas around the mainstream. Retrieving the higher mainstream velocities turned out to be a more complicated procedure due to the loss of correlation. It was

concluded that about a one month time period between the images is optimal for an assessment of mainstream velocity. Further enhancements of the software and physical analysis of the retrieved data are in progress.

Objectives for the Coming Year

The first objective will be to validate the discovered high velocity values of the mainstream in the 2003 season based on independent data of other glacier's indices. Secondly, Yurchak plans to make the rejection of unreliable data more robust. Finally, he plans to apply SAR and, possibly, MODIS data for a firn/equilibrium line migration assessment for Greenland.

Task 971-32-161: **Air-Sea-Ice Interaction**

GEST Investigator: Yunhe Zhao

Collaborators: Antony K. Liu (PI, GSFC, Code 614.2), Ming-Kuang Hsu (STINT, Taiwan)

Abstract

The wavelet-transform-based Arctic sea ice tracking procedure was modified and used to derive the sea ice motion in the Antarctic from AMSR-E 89 GHZ brightness temperature data for four study periods in 2004 and 2005. The comparison of the derived sea ice motion patterns in the Weddell Sea with the ice thickness patterns from the ICESat team shows that they are consistent, indicating that the two datasets reflect real sea ice motion and thickness well. Based on SAR images from ERS-2, ENVISAT, and RADARSAT collected in the South China Sea (SCS) from 2003 to 2005, an internal wave distribution map in the Luzon Strait was compiled; internal waves were observed in the Babuyan Channel in the Luzon Strait and were studied to help determine the generation sources of nonlinear internal waves in the SCS. For tracking and monitoring ocean features with short coherent time periods, the researchers continued their study on using high spatial resolution satellite images from multiple sensors with short data acquisition time offsets to achieve the high temporal resolution needed for the application. The use of geosynchronous satellite images that had very high temporal resolutions for monitoring ocean features was also investigated. SAR images collected in 2005 over the Spratly Islands in the SCS were processed and compared with navigation maps to study the accuracy of the maps for ship safety and environmental monitoring.

Description of Research

This research focuses on satellite ocean and sea ice remote sensing data analysis and imaging processing, especially by wavelet analysis of satellite data from SSM/I, QuikSCAT, and AMSR-E for sea ice motion, deformation, and dynamics in the Arctic. The objectives are to develop effective and efficient algorithms for deriving sea ice motion and deformation from satellite data for sea-ice dynamics and joint research on climate variability study based on these data sets. The goals are to study the environmental effects on sea ice dynamics and to further understand the physical processes in the earth climate system.

Accomplishments during the Reporting Period

Previous studies have shown that the Arctic sea ice motion derived from SSM/I, NSCAT, QuikSCAT, and AMSR-E data by a wavelet-transform-based Arctic sea ice tracking procedure are in good agreement with those derived from Arctic buoy data. However, in the Antarctic, most of the sea ice cover consists of first year ice with small-scale and short-lived features. Thus, for deriving sea ice motion in the Antarctic, short sliding windows together with high spatial resolution data must be used. With AMSR-E 89 GHZ 6.25 km resolution brightness temperature data now available, the wavelet-transform-based sea ice tracking procedure was modified to drive sea ice motion in the Antarctic from the data by using a one-day sliding window for tracking fast motion and a two-day sliding window for slow motion. The derived Antarctic sea ice motion patterns in the Weddell Sea for

four study periods were compared with the ice thickness patterns from the ICESat team for cross-calibration. The comparison shows that they are consistent, indicating that the two data sets reflect the real sea ice motion and thickness well.

It is well known that nonlinear internal waves are very active in the northeast of the South China Sea (SCS). Luzon Strait is thought to be the generation source of most of the nonlinear internal waves in the area. However, internal waves in a close distance to the channels in the Luzon Strait were not previously observed from satellite or field measurement. This makes it difficult to identify the exact generation locations for the internal waves in the area. This study of SAR images from ERS-2, ENVISAT, and RADARSAT from 2003 to 2005 has led to the discovery of such internal waves. ENVISAT ASAR Wide Swath images on April 7 and May 7 of 2004 have captured the internal waves in the Babuyan Channel in the Luzon Strait, which are probably the ones closest to the channels in the Luzon Strait observed so far from SAR images. Based on the bathymetry and topography of the Babuyan Channel, the shallowest place in the Babuyan Channel is believed to be the generation location of these two internal wave packets. An internal wave distribution map in the Luzon Strait was compiled from the SAR images studied.

Tracking and monitoring ocean features with short coherent time periods from sequential satellite images requires that the images have very high spatial and temporal resolutions. Satellite images from a single sensor in a polar orbit usually do not meet the requirement. However, SAR images from the ERS-2 and ENVISAT have almost the same flight paths with approximate 30 minutes of separation time. Thus high spatial resolution images from these two SAR can be jointly used to achieve high temporal resolution. The study of this approach was continued and a paper was written that reports results from case studies. The use of geosynchronous satellite images that have very high temporal resolutions, such as the GOES-12 visible channel data, for ocean feature tracking was investigated.

The Spratly Islands in the SCS are occupied by several countries and regions. There is an urgent need to upgrade and improve the navigation charts for ship safety and environmental monitoring, and satellite remote sensing is the only way to obtain a synoptic view of all islands and reefs. SAR images collected in 2005 were processed and compared with navigation maps to study the accuracy of the maps in this area. Based on GPS survey and SAR images, the location of Tai-Ping Island shows a consistent shift to the south as compared with the navigation maps.

Objectives for the Coming Year

The development of the wavelet transform based tracking procedure for deriving ocean surface drift from pairs of ERS-2 and ENVISAT SAR images as well as from geosynchronous satellite data such as GOES-12 and simulated GOES-R visible channel data will be continued. Its tracking results will be validated and calibrated. The nonlinear internal wave generation and evolution processes in the SCS will be studied by using SAR images and concurrent long-term mooring data.

This page intentionally left blank

Global Energy and Water Cycle Experiment (GEWEX)

This page intentionally left blank

Task 971-32-161: **International Global Energy and Water Cycle Experiment (GEWEX) Project; International GEWEX Project Office (IGPO)**

GEST Investigator: Richard (Rick) Lawford

Collaborators: Soroosh Sorooshian (Univ. of California, Irvine), Pavel Groisman (National Climate Data Center), Jin Huang (NOAA), Chu Ishida (Japanese Aerospace and Exploration Agency), Toshio Koike (Univ. of Tokyo), Annukka Lipponen (UNESCO), Alice Aureli (UNESCO), John Roads (Scripps Institute of Oceanography), William Rossow (City Univ. of NY), Robert Schiffer, Paul Try (Science and Technology Corporation), Gilles Sommeria (WMO/GCOS Secretariat), Ronald Stewart (McGill Univ.), Vladimir Ryabinin (World Climate Research Programme), Ann Henderson Sellers (World Climate Research Programme), Avinash Tyagi (World Meteorological Organization), Peter van Oevelen (European Space Agency), Charles Vorosmarty (Univ. of New Hampshire), Yuping Yan (Beijing Climate Center), Olga Zolina (Univ. of Bonn), Wolfgang Grabs (World Meteorological Organization), Sam Benedict (Coordinated Enhanced Observing Period), Arthur Askew (International Association of Hydrological Sciences), Antti Herlevi (GEO Secretariat), Pavel Kabat (International Geosphere-Biosphere Programme), Susanna Eden (Univ. of Arizona), Einar-Arne Herland (European Space Agency), Jan Polcher (Laboratoire de Météorologie Dynamique du CNRS), Dennis Lettenmaier (Univ. of Washington), Eric Wood (Princeton Univ.), Christian Jakob (Bureau of Meteorology, Melbourne), Howard Cattle (CLIVAR), Jared Entin (NASA HQ), Lydia Gates (Global Water System Project), John Pomeroy (Univ. of Saskatchewan), Anna Medico (CONAE), Anni Reissell (iLEAPS), Bill Kustas (USDA), Norman Miller (Univ. of Berkley)

Abstract

The Global Energy and Water Cycle Experiment (GEWEX) of the World Climate Research Programme (WCRP) brings together a significant component of the world climate community in joint initiatives to advance understanding of the coupled hydrologic and atmospheric processes on a global scale and to apply global water cycle understanding, observations and models to the problems of climate and water resources around the world. Scientists from over 45 countries participate in major GEWEX projects aimed at quantifying the hydrologic cycle and energy fluxes by means of global measurements of atmospheric and surface properties; modeling the global water cycle and its role in the climate system; developing the ability to predict the variations of global and regional hydrologic processes and water resources and their response to environmental change; and fostering the development of observational techniques, as well as data management and assimilation systems. GEWEX activities involve understanding and modeling land-atmosphere coupling and cloud system processes, global data set development, water resource applications and the effective use of Earth Observations in climate science. Rick Lawford serves as Director of the International GEWEX Project Office, which is responsible for coordinating the activities of the GEWEX project and its interactions with WCRP and other global and national environmental programs, as well as space agencies and other research and operations groups. This position provides management, service and coordination functions for more than 1,500 scientists worldwide working on the water and energy cycle science and it supports the information and management needs of the World Climate Research Programme.

During 2006, Lawford transferred his responsibilities as chair of the Executive of the Integrated Global Water Cycle Observation (IGWCO) theme of the Integrated Global

Observing Strategy (IGOS) Partnership to Dr. Wolfgang Grabs (World Meteorological Organization (WMO)) but continues to chair the IGWCO Science Committee. He continues activities initiated by the National Aeronautics and Space Administration (NASA) and serves as a coordinator for the Northern Eurasia Earth System Partnership Initiative (NEESPI). During the past year, he also served as task leader for three tasks in the 2006 GEO Implementation Plan. In August 2006, he reduced his time commitment to GEWEX in order to undertake responsibilities at the Network Manager for the Canadian Drought Research Initiative (DRI) being led by McGill University and the University of Saskatchewan.

Description of Research

The research undertaken within GEWEX is directed at the development and application of planetary Earth science and observations to the problems of the world climate and to understand the global water cycle and its role in the supply of the world's water resources. In particular, efforts are directed at producing consistent descriptions of the means, variability and trends of the Earth's energy and water cycle variables, along with the generation of data sets for the development and validation of climate and hydrologic models and an understanding of the factors that account for temporal and spatial variations in these variables over weather to climate time scales. Metrics of scientific success include improvements in the ability to close regional and global water budgets through improved observations and modeling capabilities and the expanded use of satellite data in climate programs, Numerical Weather Prediction (NWP) forecasts and decision support systems.

GEWEX is an interdisciplinary study that requires close collaboration between meteorology, hydrology, atmospheric chemistry, oceanography and other disciplines to be successful. The principal tools used in this research involve the derivation and analyses of data sets derived from satellite and in situ data combined with state-of-the-art assimilation and modeling systems. GEWEX predictability studies and prediction system developments emphasize the contributions of land surface and cloud processes to water cycle predictability and rely on the use of mesoscale atmospheric models, coupled land atmosphere models and hydrologic models. The development of improved parameterizations depends on process understanding derived from field studies. GEWEX contributes to the development of global observation and data systems through the Coordinated Enhanced Observing Period (CEOP).

GEWEX places a strong emphasis on increasing our understanding of how energy and water cycle processes contribute to climate feedbacks. Studies of the role of clouds, precipitation and land surface processes in the climate system are undertaken to understand and quantify feedback processes in the climate system. To improve parameterizations, GEWEX collaborates with model developers in a cycle of model evaluation and model improvement. GEWEX provides key data sets through targeted field projects that are used in the evaluation of the models over a range of conditions. Field data are organized on web sites to facilitate the evaluation of the models by the modelers themselves. In addition, the value of these improvements is assessed in collaborative studies with the water resource and applications communities.

Rick Lawford's role is to provide guidance and advice on the programmatic aspects of these activities and to direct the office that coordinates these research activities, which plans for future activities and meetings, coordinates implementation, helps to synthesize the results and establishes processes for making the results useful for different communities. The information and synthesis roles are facilitated by the GEWEX web site (www.gewex.org), the organization of scientific meetings and conferences and the preparation of overview and review articles for different publications and conference presentations. The promotion of the program is done in the past through the GEWEX Newsletter and participation in committees involved in the development of observational systems. In addition, Lawford facilitates opportunities for GEWEX projects by liaising with potential funding agencies. Within the

framework provided by the program, he applies his expertise to gain a better understanding of regional and global water resource issues and to promote the development of better Earth Observation systems (especially space-based systems) that could support GEWEX science.

Accomplishments during the Reporting Period

In support of the development of GEWEX, Rick Lawford played a central role in formulating the plans, arrangements and program for the first pan-GEWEX meeting held in Frascati, Italy in October 2006. He was responsible for setting the agenda for this meeting, presenting key issues that needed to be addressed, chairing the concluding session, distilling out the critical conclusions and recommendations and following up on the major decisions.

During the past year, Lawford strengthened the framework for accountability and planning by continuing to lead the development of a roadmap for Phase II of the GEWEX project. This meeting was a unique experiment in bringing together all the leading scientists in different GEWEX panels to promote cross-panel activities and to gain commitment for the goals and deliverables outlined in the GEWEX Roadmap. This roadmap outlines the planned activities of GEWEX relative to each of its objectives over the next 6 years. The roadmap is the basis of on-going dialogue with each of the panels regarding the definition of milestones and for monitoring their progress in achieving the milestones.

Beyond the pan-GEWEX meeting, the Director is responsible for providing overall support for the GEWEX program in terms of organizing workshops, meetings and conferences; maintaining the website; publishing a regular Newsletter; overseeing preparations and setting the agenda for a GEWEX SSG-19 meeting; preparing minutes of meetings; and writing reports and articles to inform the science community about the project. During the coming year there will be a need to review the structure of GEWEX. Lawford is responsible for the documents from these meetings and ensures that they acted upon in a timely way. He will assist in the coordination of the implementation of GEWEX aerosol and climate responsibilities as well. During the past year, the GEWEX Scientific Steering Group (SSG) approved the initiation of a number of projects (LandFlux, Hydrologic Applications Project, aerosol and climate). As IGPO Director, Rick Lawford will be responsible for assisting the lead scientists in implementing these projects. It will be necessary to support the lead scientists and to ensure that the expectations of the GEWEX SSG are met in terms of the conditions placed upon these approvals. He will also oversee the restructuring of GEWEX arising from the GEWEX Hydrometeorology Panel (GHP) /Coordinated Enhanced Observing Period (CEOP) merger.

Rick Lawford supported the chair of the GEWEX SSG by contributing to the preparation of a number of science and programmatic talks, reports to the Joint Scientific Committee (JSC—includes the World Meteorological Organization (WMO), the International Council of Scientific Unions (ICSU), and the International Oceanographic Commission (IOC)) and Academy reviews, and drafted letters and inputs to Academy studies such as the Decadal Review. He has also supported the chair of the GEWEX SSG and the chairs of GEWEX panels by assisting in the development of meeting minutes and negotiating and/or carrying out follow-up on action items arising from meetings. Support to the SSG also includes coordination of preparations for the GEWEX SSG-19 meeting in Honolulu, Hawaii in terms of overseeing the logistics and meeting facilities, providing briefings and written material for SSG members and developing strategies to implement recommendations from the meeting.

During 2006, under Lawford's direction, IGPO documented and either assigned or tracked action items arising from GEWEX SSG and panel meetings, including sending out periodic reminders of required actions and ensuring that SSG feedback is received and acted on by the GEWEX panels. The GEWEX SSG held its January 2007 meeting in Honolulu at the East-West Center at the University of Hawaii. In coordination with Dr. McCreary's staff at the International Pacific Research Center, IGPO handled the logistical arrangements for the

meeting sent out invitations and developed the agenda. A meeting web site was also be established by IGPO.

Lawford completed negotiations with the Chinese Meteorological Administration for a Chinese GEWEX coordinator, Dr. Yuping Yan. He has had three meetings with Dr. Yan to develop a plan for increased GEWEX involvement in Chinese science, and planning for a 2007 GEWEX-China meeting is underway. He also worked closely with the European GEWEX coordinator, Dr. Peter van Oevelen, to strengthen European participation in GEWEX. In collaboration with Lawford, the European GEWEX coordinator represented GEWEX and reported on program activities at a number of European meetings and participated in other international coordinated activities (such as the International Geosphere-Biosphere Programme (IGBP)-International Land Ecosystem-Atmospheric Processes Study (iLEAPS) and the World Climate Research Programme (WCRP)-Climate Variability and Predictability (CLIVAR) program.

Together with the Chair of the GEWEX SSG, Lawford is seeking to establish a consensus for a process for planning the Sixth International Global Energy and Water Cycle Conference in an effort to support the broad scientific community. Current plans are to hold the meeting in South America (possibly Buenos Aires) and to make it collaborative with iLEAPS.

In order to enhance the communication of GEWEX science to the community, papers from the GEWEX Science Conference have been selected and finalized for a special issue of the Journal of Hydrometeorology in 2007. Rick Lawford served as the Guest Editor for this process and received and oversaw the review process for more than 25 papers. Out of this total, 12 papers reached the final publication stage. He also led the production of an overview paper for the special issue.

During 2006, Lawford promoted GEWEX in the scientific community by organizing several workshops and scientific sessions at international conferences. In particular, sessions related to GEWEX were organized for the Earth System Science Partnership Conference in Beijing, China, the World Water Forum IV in Mexico City, Mexico and the Fall American Geophysical Union (AGU) meeting in San Francisco, California. In addition, he informed the scientific community about GEWEX goals and activities by providing more than 10 seminars and talks on GEWEX at universities and international and national science conferences and meetings. In addition, he has developed overviews of the GEWEX project that have been consolidated into journal articles such as “U.S. Contributions to the CEOP” [Lawford *et al.*, 2006] and “Past and future GEWEX contributions to large-scale hydrometeorology” [Lawford *et al.*, 2007]. Lawford has also had some interaction with the media over the past year, most notably a one-hour interview on climate and water on the China Weather TV channel.

During 2006 Lawford provided GEWEX and water cycle inputs to a number of documents in 2006, including the WCRP roadmap exercise; the WCRP questionnaire for the International Group of Funding Agencies for Global Change Research (IGFA); three proposals (two for NASA and one for the National Oceanic and Atmospheric Administration (NOAA)); and the Integrated Global Water Cycle Observations (IGWCO) reports to the Committee on Earth Observation Satellites (CEOS) and the Integrated Global Observing Strategy—Partners (IGOS-P). He also developed a summary of GEWEX anthropogenic related activities for the WCRP strategic framework and, on behalf of GEWEX, completed summary inputs to a survey done to support this framework. In addition, he reviewed proposals for NASA and NOAA and articles for AGU and American Meteorological Society (AMS) journals. Also, Rick Lawford prepared GEWEX and IGWCO for the Joint Scientific Committee Meeting of WCRP for the pan-GEWEX meeting and the GEWEX SSG.

In March 2006, Lawford participated in the World Water Forum IV in Mexico City where GEWEX co-sponsored a session with the International Association of Hydrological

Sciences (IAHS) and the United Nations Educational, Scientific and Cultural Organization (UNESCO). GEWEX also co-sponsored a side event on remote sensing and water management with the Group on Earth Observations (GEO) Secretariat and sponsored a booth (staffed by Jose Marengo, Lawford and others) that provided information on WCRP, GEWEX and related activities to 15,000 people who attended the conference.

During the past year, Lawford continued to strengthen the links between GEWEX and other closely related Earth System Science Partnership (ESSP) activities, including the Global Water System Project (GWSP), CLIVAR and iLEAPS. In particular, Lawford worked with CLIVAR to develop a paper for the management of monsoons within WCRP and launched a review of the programmatic connections between GEWEX and iLEAPS. The recommendations from the monsoon paper were adopted by the JSC and implemented in GEWEX and CLIVAR. In preparation for the next JSC meeting Lawford has worked with colleagues in CLIVAR and the JSC to develop another paper for the JSC-28 meeting on monsoons as a WCRP cross-cut.

The GEWEX Office provides support for international program activities taking place in the Washington, DC area. Robert Schiffer, who works with Lawford, assisted in organizing a visit by the Chair of the JSC, John Church, and the Director of WCRP, Ann Henderson Sellers, to Washington, D.C. Lawford also helped to organize meetings with agencies and provided briefings regarding the need for agency funding of specific projects (*e.g.*, the African Monsoon Multidisciplinary Analysis Project (AMMA).

Through the IGPO, Lawford has provided support for the GEWEX program by overseeing the preparation of four newsletters during the past year, as well as monitoring their distribution to more than 2,200 subscribers. Newsletter themes during 2005 included monsoons, extreme events, Earth Observations and the prediction of precipitation. In addition, he provides editorial overview for the minutes of panel meetings and the SSG. Lawford continues to guide other outreach activities including the maintenance of the GEWEX web site (http://www.gewex.org), which includes recent news, GEWEX document archives, background on GEWEX, meeting calendars and news, opportunities for employment, etc. On average, 600 people visit the web site every day. To facilitate more visibility for GEWEX data products, IGPO has begun to feature these products on its home page. IGPO frequently responds to requests for reviews of plans from WCRP and other environmental programs, provides inputs to WCRP planning documents and elsewhere, and responds to requests for information about the GEWEX program and data sets. Lawford has written letters of recommendation, visa request letters and other supporting letters on behalf of members of the GEWEX community.

During the past year, Lawford has continued to be responsible for the implementation of the IGWCO theme report and for leading in the provision of a number of Work Packages in the water area for the GEO. In April 2006, he transferred the responsibility for the Executive of IGWCO to WMO (Dr. Wolfgang Grabs). Lawford has worked closely with WMO to ensure a smooth transition and continues to chair the IGWCO Science Advisory Group (SAG). He also has led in planning the CEOP/IGWCO workshop that will be held at the National Academy of Sciences in March 2007. The SAG continues to be active and teleconference calls are being held periodically. During the past year, Lawford has been a spokesman for IGWCO, giving more than 8 presentations on IGWCO activities to different science and satellite groups. He collaborated with the Japan Aerospace Exploration Agency (JAXA) in organizing a Capacity Building workshop for Asia in Bangkok, Thailand in September 2006. More than 100 representatives from approximately 20 countries in East Asian came to discuss how they could benefit from the broader application of remote sensing data. Lawford also organized a smaller workshop for the Comision Nacional De Actividades Espaciales (Argentinean National Space Agency) (CONAE) held in November 2006 in Buenos Aires to develop a proposal to GEO for

an on-going capacity building program in Latin America.

Highlights of IGWCO in 2006 included an inter-comparison of high resolution precipitation products and for a workshop on remote sensing and water quality were advanced. In collaboration with the GWSP, IGWCO continues to promote the development of indicators to enhance the dialogue between scientists and policy makers.

Over the past year, Lawford also served as the coordinator for the Northern Eurasian Earth Science Partnership Initiative (NEESPI) program. Extensive support was provided for the International NEESPI planning meeting held in Vienna in February 2006. Through collaborations with NASA and the NEESPI chief scientist, progress was made in having NEESPI accepted as an GLP endorsed project and a GEWEX RHP. Lawford also helped in preparing background information and a briefing to the joint JSC/IGBP meeting in Pune India on NEESPI as an integrated ESSP regional project.

During the past year, IGPO continued to contribute to GEO as a topic leader for water. Inputs were provided to the 2005, 2006 and 2007 Work Plans. Lawford represents WCRP on the GEO User Interface Committee and serves as the task leader for Tasks WA-06-01, WA-06-06 and WA-06-7.

Objectives for the Coming Year:
Lawford's priority activities in 2007 will include:

- Support to panels in implementing new initiatives (such as the Hydrologic Applications Project (HAP), aerosols and climate, LandFlux and the CEOP/GHP merger),
- Implementation of the GEWEX Roadmap,
- Strengthening of the GEWEX coordination function in China,
- Support to the WCRP Strategic Plan,
- Strengthening agency support for GEWEX,
- Support to the organization of the Sixth International Global Energy and Water Cycle Science Conference,
- Staffing of the IGPO Director position, and
- Support to GEO and IGWCO, as required.

As a result of recent decisions in the WCRP, Rick Lawford is now responsible for coordinating the travel budget for the GEWEX meetings and the Monsoon cross-cuts across all of WCRP. As part of his efforts to make GEWEX science more visible, he will also make presentations and organize sessions on behalf of GEWEX at other conferences, including the Fall AGU meeting. He will also be responsible to provide GEWEX input to an extensive review of WCRP, lead by the ICSU.

Rick Lawford also will develop and support the implementation of the IGWCO theme by chairing the Scientific Advisory Group (SAG), representing WCRP on the theme executive committee and continuing to lead the implementation of the theme.

It is anticipated that a new Director will be hired during the coming year as Lawford has moved to Canada to undertake new responsibilities as a Network Manager for a Canadian Drought Research Initiative. Lawford is committed to continuing to serve until the new Director is in place and will support him or her as he or she take on these diverse responsibilities.

Goddard Visiting Fellows Program in the Earth Sciences

This page intentionally left blank

NASA Goddard Space Flight Center and GEST Visiting Fellows Program in the Sun-Earth Exploration

The Goddard Earth Sciences and Technology Center (GEST) and the NASA Goddard Earth Sciences Directorate solicited qualified Ph.D. scientists for collaboration in scientific research relating to the observation, analysis and modeling of physical processes within the earth-atmosphere system, and to relevant global change issues. Selected candidates were appointed as Visiting Fellows to pursue independent research in collaboration with scientists in the Laboratories within the Earth Sciences Directorate, and have full access to NASA computing facilities and other resources at either the Goddard Space Flight Center (GSFC) in Greenbelt, MD or at the Goddard Institute for Space Studies in New York, NY. This solicitation was aimed at all levels from post-doctoral to senior scientists, particularly, university faculty interested in sabbatical arrangements.

Research interests in the Earth Sciences Directorate include attaining knowledge and understanding of the components of the Earth system through experimental and theoretical studies using NASA technology, information science, and space observations. The approach includes instrument, algorithm and model development involving remote sensing and *in situ* measurements. GEST sought candidates for collaboration in scientific research in one of the following research theme areas of the Division:

- Aerosols
- Carbon Cycle
- Clouds and Precipitation
- Polar Climate Change
- Solar Impacts on Climate
- Terrestrial Water
- Weather and Short-term Climate Forecasting

Fifteen applications were received for the program for 2008. The GSFC program leads in these areas were asked to participate in the review of the proposals and mail reviews were received from Drs. Remer, Collatz, Koster, Fridland, Tao, Abladati, and Peters-Lidard. In addition to the civil servant reviewers, Omar Torres, Nick Krotkov, Forrest Hall and Marco Tedesco participated in the review as UMBC Faculty. We want to thank the reviewers for their inputs on the candidates. The candidates were discussed and ranked by a selection committee of Drs. Hoff, Hartle, Schiffer, Richards, and Smirnov.

For the 2007 Goddard Visiting Fellows selection, we are proud to announce the “Yoram Kaufman Visiting Fellowship,” in honor of Dr. Kaufman, and this fellowship was awarded in the area of Aerosol research. The inaugural Kaufman fellow is Professor Jun Wang of the University of Nebraska. Dr. Wang's research is in the area of aerosol data assimilation in numerical models. Dr. Wang will arrive in January 2008 and will be a part of the center until August 2008. He will work in the Climate Radiation Branch (Code 613.2) and his research will be reported in next year's report.

Additional selections for the 2008 program are:

- Professor Karen Mohr, State University of New York, Albany; Area of Research: Clouds and Precipitation and Terrestrial Water, Specialization: Hydrological inputs in land surface models, Potential branches and main collaborators: 613.1 (Tao), 614.3 (Peters-Lidard)

- Professor Martti Hallikainen, Space Technology, Helsinki University; Area of Research: Polar climate change, Specialization: Microradiometry of snow and ice, Potential branches and main collaborators: 614.6 (Tedesco, LeVine, Ed Kim)

- Dr. Cynthia Randles, new Ph.D., Atmospheric and Ocean Science, Princeton University under Ramaswamy, Area of Research: Aerosols, Specialization: biomass burning aerosols over Africa, Potential branches and main collaborators: 613.2 (Remer, Ichoku)

- Cuneyt Utku, new Ph.D., Electrical and Computer Engineering, George Washington University; Area of Research: Terrestrial Water; Specialization:L-band radiometry of the ocean and soil with application to Aquarius, Potential branches and main collaborators: 614.6 (LeVine), 614.3 (O'Neill)

We are pleased that we had a number of 2007 Goddard Visiting Fellows complete their research this year.

Dr. Raymond Muscheler completed his research with GEST in the Sun-Earth Connections research area. Dr. Muscheler did an admirable job of linking research between the Heliophysics Division (Code 697) and the Climate Radiation Branch (Code 613.2). Dr. Muscheler's research description is below.

Dr. Michael Schulz of the Laboratoire des Sciences du Climat et de l'Environment (LSCE/IPSL) at Saclay, France, completed his stay with the Atmospheric Chemistry and Dynamics Branch (Code 613.3). Dr. Schulz is the driving force behind the AEROCOM model intercomparison project. Dr. Schulz has prepared a report on his stay below.

Dr. Qingyuan Zhang arrived in July 2006 from the University of New Hampshire where he received his Ph.D. under the mentorship of Dr. Berrien Moore. Dr. Zhang's area of research is in the spectral properties of vegetation as observed from satellites. He has been working with Drs. Forrest Hall, Fred Huemmrich, and Petya Campbell of JCET and with Dr. Elizabeth Middleton of GSFC. Dr. Zhang has been offered an extended appointment with UMBC GEST and will stay with the Center. His report also follows.

Dr. Theodore (Tad) Anderson of the University of Washington arrived in September 2007 and has worked with both the Climate Radiation Branch (613.2) and the Atmospheric Chemistry Branch (Code 613.3). Dr. Anderson has also prepared a project report below.

Dr. Alexander Lipatov arrived in January 2007 from the University of Calgary in Canada. Dr. Lipatov has a long and distinguished career both in the U.S. and Russia and is widely known as a modeler of the magnetospheres/heliosheaths of the planets. He is currently working with Dr. Ed Sittler of the Geospace Physics Laboratory (Code 673) and Dr. Dick Hartle of Code 610.6. Dr. Lipatov did not prepare a report this year but will report in 2008.

Raymond Hoff, Director

Task: **Using Integrated A-Train and In-situ Observations to Study Climate Forcing by Anthropogenic Aerosols**

GEST Investigator: Theodore L. (Tad) Anderson

Collaborators: Lorraine Remer (GSFC, Code 913), Thomas Eck, Brent Holben (GSFC, Code 614.4)

Abstract

Improved quantification of climate forcing by aerosols is a high scientific priority, both for interpreting observed climate change over the 20th century and forecasting future change. The goal of this project is to implement a portion of the "A-Train strategy" [Anderson *et al.*, 2005a] recently articulated by a broad team of scientists for estimating direct climate forcing (DCF) by anthropogenic aerosols. The project focuses on two fundamental and challenging aspects of this problem: the separation of anthropogenic from natural aerosols and the separation of clear from cloudy conditions. Progress is anticipated via the integration of multiple A-Train sensors--including the new profiling Lidar on CALIPSO--along with sub-orbital remote and in situ capabilities. Specific tasks include (i) developing an improved satellite-derived sub-micron fraction product (at a minimum, one for which the uncertainty is better understood) for use in determining the global distribution of anthropogenic aerosol and (ii) assessing the nature and frequency of atmospheric states intermediate between clear and cloud. Such intermediate states are hypothesized to be exquisitely sensitive to aerosol perturbation and yet are ignored in current assessments of aerosol climate forcing.

Description of Research

Traditional estimates of DCF (*e.g.*, Charlson *et al.* [1991], Kiehl and Briegleb [1993]) relied almost exclusively on chemical transport models. More recent estimates incorporate global observations from satellites. In particular, estimates by Chung *et al*. [2005] and Bellouin *et al.* [2005] use the sub-micron fraction of aerosol optical depth, SMF , from MODIS as a means of distinguishing anthropogenic from natural aerosols. While useful as preliminary attempts at observation-based estimates of DCF, both these studies failed to consider the potential for large, systematic error in satellite-derived SMF, which has been widely documented [Levy *et al.*, 2003; Livingston *et al.*, 2003; Chu *et al.*, 2005; Anderson *et al.*, 2005b]. This project will test the following, new strategy aimed at an improved SMF product: 1) Use satellite sensors to refine knowledge of the Ångström exponent, å (*i.e.*, the wavelength dependence of optical depth), since this quantity can be rigorously validated via AERONET and airborne sun-photometer measurements, 2) Use *in situ* and AERONET measurements to derive relationships between å and SMF, 3) Use these derived relationships (which are expected to be regionally dependent) to convert satellite data on optical depth, and å into global maps of sub-m optical depth, s ub. These data will include estimated uncertainty and will thus be suitable for assimilation by chemical transport models.

An equally fundamental task for quantifying DCF is the separation of clear and cloudy regions. A recent study [Charlson *et al.*, 2007] suggests that various, operational cloud-clearing algorithms are mutually inconsistent and are biased by the presence of aerosols. Moreover, this study suggests that intermediate atmospheric states (neither "clear" nor "cloud") may be more prevalent in the boundary layer than previously thought and may be exquisitely sensitive to perturbation by aerosol. The addition of CALIPSO to the A-Train constellation of satellites provides a new approach to exploring these issues, as Lidar-derived vertical profiles reveal extremely tenuous scattering layers invisible to passive techniques. This project will combine CALIPSO Lidar data with spatially matched data from various passive sensors (MODIS and CERES) to investigate these issues. This aspect of the project is exploratory in nature.

Accomplishments during the Reporting Period

Dr. Anderson arrived in September and is spending 50% time at Goddard; therefore, this project is still in the spin-up stage. He has begun to develop working relationships with key Goddard scientists: Lorraine Remer for aerosol products from MODIS, Steve Platnick for cloud products from MODIS and CloudSat, Brent Holben and Tom Eck for aerosol properties from AERONET. He has written a variety of programs for combining the new, vertically-resolved CALIPSO Lidar data with the geographically resolved data from other A-Train sensors, especially MODIS, CERES, and CloudSat. In particular, he has developed spatial matching routines that permit quantitative comparison of retrieval products. Three papers are in progress. A submitted manuscript comparing AERONET to in situ optical properties over Southern Africa [Leahy *et al.*, 2007], a submitted manuscript outlining the potential consequences for aerosol climate forcing of intermediate states between clear and cloud [Charlson *et al.*, 2007], and a manuscript in preparation comparing CERES albedo to spatially matched retrievals of Lidar reflectivity from CALIPSO [Anderson *et al.*, 2007].

Objectives for the Coming Year

In the remaining months of this project, Anderson plans to (1) investigate the accuracy of the MODIS-derived å (wavelength dependence of aerosol optical depth) for the new Collection 4 retrieval product, (2) perform case-study comparisons of å-derived s ub (sub-m optical depth) versus the standard MODIS retrieval of s ub, and (3) integrate CALIPSO and MODIS data to investigate cloud-clearing bias in the MODIS aerosol retrievals and to study the prevalence of intermediate states between clear and cloud. While Anderson's term will expire at the end of August 2007, he fully expects to pursue the larger goals of this project in the coming years, building on the collaborations developed as a GEST visiting scientist.

Task 900-37-172: **Solar Activity Reconstructions and Investigations of the Solar Influence on Climate**

GEST Investigator: Raimund Muscheler

Collaborators: Caspar Ammann (NCAR), Katja Matthes (NCAR), Juerg Beer (EAWAG, Switzerland), Fortunat Joos (Univ. of Berne, Switzerland), Ian Snowball (Univ. of Lund, Sweden)

Abstract

There are indications that varying solar activity significantly influenced the climate during the last 10,000 years. However, it is unclear how the supposedly small solar irradiance forcing can significantly influence our climate. It can be shown that small solar irradiance changes can increase the likelihood for the climate system to switch between different meta-stable states. There is no indication that solar forcing had a significant influence on the strong climatic changes during the last ice age. In addition to the uncertain mechanisms behind the sun-climate link, there are different reconstructions of solar activity changes in the past that do not agree. It has been suggested that the present levels of solar activity can be regarded as exceptionally high. However, it was possible to show that this result is not supported by the radionuclide data and that today's solar activity is high but not exceptional with respect to the last 1000 years.

Description of Research

The goals of this research within the new Sun-Climate Center at NASA/Goddard are twofold: to improve estimates of past solar forcing on decadal to millennial time scales and to study the link between solar activity and climate changes. The main tools are cosmogenic radionuclides that are the most reliable recorders of past changes in solar activity before the period of direct solar observations. However, climate and geomagnetic influences on cosmogenic radionuclides have to be accounted for to obtain reliable solar activity records. The solar influence on climate can be studied with different approaches. The comparison of solar forcing and climate records gives indications of

the importance of the solar forcing for the Earth's climate. Sensitivity tests with climate models give independent clues about mechanisms and magnitude of the solar impact on climate.

Accomplishments during the Reporting Period

A new reconstruction of past changes in solar activity based on radiocarbon indicated that today's solar activity is high but not exceptional if compared to other periods during the last 1000 years [Muscheler *et al.*, 2007]. In addition, solar activity estimates for the last 10,000 years could be significantly improved by including 10Be from ice cores [Beer *et al.*, 2006; Vonmoos *et al.*, 2006]. The comparison of different radionuclide records shows that short-term changes in solar activity (on time scales of decades to centuries) can be reliably reconstructed. However, longer-term changes are uncertain since they are within the errors of the radionuclide and geomagnetic field data. Measurements of 10Be in other natural archives could help to further constrain the 10Be production rate and the solar influence on 10Be. It could be shown that sediments with very stable sedimentary conditions are suitable for 10Be measurements in order to isolate the solar signal [Ljung *et al.*, in press]. This opens the possibility to obtain solar activity estimates for time periods that are not covered by ice core records.

The comparison of ice core 10Be data with climate proxies measured in the same core revealed that the sun is most probably not the cause or trigger for the strong climatic changes during the last ice age [Muscheler and Beer, 2006]. The strong changes in climate during the last ice age, the so-called Dansgaard/Oeschger events, exhibit a periodicity that has led to the hypothesis that solar forcing was triggering these changes. However, after correcting for the climate influence on the 10Be deposition there is no significant radionuclide (solar) signal connected to the starts of the Dansgaard/Oeschger events.

There are indications that the sun influenced our climate during the last 10,000 years when the climate was generally more stable compared to the last ice age. It is difficult to explain such a solar influence with the supposedly small solar irradiance forcing. Renssen *et al.* [2006] suggest a solution to the problem. Their climate model of intermediate complexity has different meta-stable climate modes. The probability that the climate is in a certain mode is influenced by the total solar irradiance. Since changes between the different modes can occur naturally it does not need a strong external forcing to change the probabilities for the climate system to be in a certain mode.

Objectives for the Coming Year

After completing a one-year NASA/Goddard fellowship Raimund Muscheler has moved to Sweden. The objective is to continue the work (NCAR) and the Sun-Climate Center at NASA/Goddard. There is work in progress where the solar influence on climate is investigated with general circulation models. The model developed at NCAR is used to study the climate during the last 6000 years. Solar forcing is not the main focus of this study and the radionuclide-based solar irradiance does not change strongly during this run (in accordance to recent estimates of solar irradiance variations). Nevertheless, this study will provide further constraints about the potential of small solar irradiance changes to influence climate. Solar UV changes could more indirectly influence the Earth's climate which could help to explain the observations that the sun indeed influences our climate. Sensitivity studies with the same general circulation model will help to answer such questions. However, the focus of the research in Sweden will shift more to the interpretation of radionuclide records and to improve solar activity estimates based on 14C during the last ice age. High-resolution radiocarbon measurements will also provide more detail for how the strong climatic changes during the last ice age affected the carbon cycle.

Task: **Evaluation of Aerosol Models with Satellite Products**

GEST Investigator: Michael Schulz

Collaborator: Mian Chin (GSFC, Code 613.3), Lorraine Remer (GSFC, Code 613.2)

Abstract

A first phase of the AeroCom initiative has been accomplished in 2006. The published results document model diversity but the initial evaluation also gives confidence that the model ensemble average describes the aerosol life cycle better than individual models. Direct aerosol radiative forcing from models is slightly less negative than an observational based estimate. Reasons are to be found in differences in aerosol optical depth, forcing efficiencies and the contribution of positive forcing above clouds, the latter being incorporated in models but not in observations. Finally, the annual AeroCom workshop was organized together with NASA Goddard (Mian Chin) and Langley (Rich Ferrare) to plan joint future work. A priority emerging is to improve the evaluation of modeled aerosol size distribution, hygroscopic growth and indirect aerosol effects.

Description of Research

The goal is to improve the estimates of the aerosol radiative effects by a combination of model calculation and observational based characterization of the global aerosol. To overcome the structural constraints of individual transport models a specific aim here is to incorporate a set of different transport models from AeroCom in the analysis. Finally, within the reporting period, a specific goal was to reorient the AeroCom initiative towards an observational based reanalysis of the different model parameterizations. In order to obtain effective benchmark tests for models it is aimed to assess and integrate the available and especially the upcoming new datasets into such benchmark tests (Caliop, MODIS collection 5, Aeronet Version 2). The aim is to improve the evaluation of modelled aerosol size distribution, hygroscopic growth and indirect aerosol effects.

Accomplishments during the Reporting Period

The AeroCom initiative diagnoses multi-component aerosol modules in global modeling. In an initial assessment simulated global distributions for mass and mid-visible aerosol optical thickness were compared among 20 different modules [Kinne *et al.*, 2006]. At 0.11 to 0.14, simulated aerosol optical thickness values are at the lower end of global averages suggested by remote sensing from ground (AERONET ca. 0.135) and space (satellite composite ca. 0.15). Of particular concern are large model diversities for contributions by dust and carbonaceous aerosol, because they lead to significant uncertainty in aerosol absorption. In Textor *et al.* [2006] we analyze the life cycles of dust, sea salt, sulphate, black carbon and particulate organic matter as simulated by sixteen global aerosol models. The differences among the results (model diversities) for sources and sinks, burdens, particle sizes, water uptakes, and spatial dispersals have been established. Interactive parameterizations of the emissions and contrasting particles sizes of sea salt and dust lead generally to higher diversities of these species. We diagnose an extremely high diversity for the uptake of ambient water vapour that influences the particle size and thus the removal rates. Furthermore, we find little agreement among the model results for the partitioning of wet removal into scavenging by convective and stratiform rain.

Nine different global models with detailed aerosol modules have independently produced instantaneous direct radiative forcing (RF) due to anthropogenic aerosols [Schulz *et al.*, 2006]. The anthropogenic impact is derived from the difference of two model simulations with prescribed aerosol emissions, one for present-day and one for pre-industrial conditions [Dentener *et al.*, 2006]. The difference in the solar energy budget at the top of the atmosphere (ToA) yields a new harmonized estimate for the aerosol direct radiative forcing (RF) under all-sky conditions. On a global annual basis RF is $-0.22 Wm^{-2}$, ranging from +0.04 to $-0.41 Wm^{-2}$, with a standard deviation of

±0.16Wm−2. Anthropogenic nitrate and dust are not included in this estimate. No model shows a significant positive all-sky RF. The corresponding clear-sky RF is −0.68Wm−2. The cloud-sky RF was derived based on all-sky and clear-sky RF and modeled cloud cover. It was significantly different from zero and ranged between −0.16 and +0.34Wm−2. A sensitivity analysis shows that the total aerosol RF is influenced by considerable diversity in simulated residence times, mass extinction coefficients and most importantly forcing efficiencies (forcing per unit optical depth). The clear-sky forcing efficiency (forcing per unit optical depth) has diversity comparable to that for the all-sky/ clear-sky forcing ratio. While the diversity in clear-sky forcing efficiency is impacted by factors such as aerosol absorption, size, and surface albedo, we can show that the all-sky/clear-sky forcing ratio is important because all-sky forcing estimates require proper representation of cloud fields and the correct relative altitude placement between absorbing aerosol and clouds. The analysis of the sulphate RF shows that long sulphate residence times are compensated by low mass extinction coefficients and vice versa. This is explained by more sulphate particle humidity growth and thus higher extinction in those models where short-lived sulphate is present at lower altitude and vice versa. Solar atmospheric forcing within the atmospheric column is estimated at +0.82±0.17Wm−2. The local annual average maxima of atmospheric forcing exceed +5Wm−2 confirming the regional character of aerosol impacts on climate. The annual average surface forcing is −1.02±0.23Wm−2. With the current uncertainties in the modeling of the radiative forcing due to the direct aerosol effect we show here that an estimate from one model is not sufficient but a combination of several model estimates is necessary to provide a mean and to explore the uncertainty. The comparison to recent observational based estimates reveals differences in aerosol optical depth, forcing efficiencies and the contribution of positive forcing above clouds incorporated in models but not in observations.

An AeroCom workshop was organized October 17-19, 2006 in Virginia Beach together with Rich Ferrare, NASA Langley and the collaborators from NASA GSFC. The presentations are available (http://nansen.ipsl.jussieu.fr/AEROCOM/webvb06.html) and recommendations have been formulated at the end of the workshop, which emphasize the role of further model-data comparisons to obtain better estimates of the different aerosol radiative effects (http://wiki.esipfed.org/index.php/AeroCom/Recommendations).

Task 900-37-172: **MODIS Data 2.5km x 2.5km Scale Assimilation to Support NASA's Light Use Efficiency (LUE) Project and Radiative Transfer Model Inversion Project**

GEST Investigator: Qingyuan Zhang

Collaborator: Forrest Hall (JCET), Karl F. Huemmrich (JCET), Elizabeth Middleton (GSFC, Code 614.0), Guillaume Drolet (Université Laval, Canada), Hank Margolis (Université Laval, Canada)

Abstract

The MODIS daily acquisition area changes with view angles. It is essential to use information focusing on the same target area when studying the canopy BRDF effect, phenology, forest disturbance etc. Zhang's analysis shows that MODIS observations (MOD09GHK, MYD09GHK, MOD09A1, MYD09A1 and products based on them) may cover more than one 500 m x 500 m grid area when observing off nadir. Zhang used the Old Aspen site (OA) in Canada as an example. The 500 m x 500 m grid cells around the OA site are not homogeneous and the MODIS acquisitions with different view geometries cover targets with different characteristics. Zhang developed an algorithm to scale-up the MODIS observations that cover a 5x5 MODIS grid area (2.5 km x 2.5 km) and the

scaled-up super-grids cover almost the same area. The scaled-up super-grids were used to monitor phenology and interannual analysis and to calculate fraction of PAR absorbed by chlorophyll (fAPARchl). Combined with field flux measurements over the OA site, Zhang also analyzed the light use efficiency by chlorophyll for different years.

Description of Research

Two major objectives of this study are (1) how to get remote sensing information focusing on same target area; and (2) applications of the information. The first objective is related to a critical problem that has not been solved: the available remote sensing information is for different target areas that may have different characteristics. For example, AVHRR and MODIS off-nadir acquisitions do not often cover the same areas. When comparing signals that contain information for different areas from different times, the differences of the signals may come from both the spatial difference and the time difference. So it is essential to decouple the differences to get the true temporal variation. It is often assumed that remote sensing signals are from areas that have the same or similar characteristics when physical remote sensing models are inverted. It is important for model inversion to try to use signals from the same area or from different areas but with the same or similar properties.

Accomplishments during the Reporting Period

The importance of focusing on same target area is obvious to correctly interpret remote sensing signals of sub-areas that are not homogeneous. Zhang's study of the Old Aspen (OA) site in Canada revealed that the optics of the grid cells (500 m x 500 m) surrounding the OA site are not homogeneous. It explains why scientists could not get reasonable inverted results from their radiative transfer models and could not get reasonable empirical statistical results that they got for other sites where are homogeneous.

Zhang developed an innovative algorithm to scale up the MODIS acquisitions to cover a 2.5 km x 2.5 km area. Daily MODIS data (MOD09GHK, MODMGGAD, MODPTHKM, MOD09GST, MYD09GHK, MYDMGGAD, MYDPTHKM and MYD09GST) were used. If MOD09GST or MYD09GST shows that any acquisition is contaminated by snow, cloud, high amount aerosol, and residual clouds, etc., the acquisition will not be included in the assimilation procedure. If any acquisition covers area outside of the 2.5 km x 2.5 km area, the acquisition will not be included in the procedure, either. The acquisitions with similar sun-sensor-target geometries, *i.e.*, differences of geometry angles less than 5°, will be averaged and the cover percentage of all the acquisition to the 2.5 km x 2.5 km area is also recorded.

The algorithm was used to scale up MODIS daily acquisitions around the OA site for 2001–2004. When all daily observations that overlap the OA site are analyzed, a reasonable bi-directional reflectance distribution function (BRDF) effect could not be seen. When the assimilated observations with cover percentage greater than 72% were reviewed, the BRDF effect of all MODIS 7 land bands is obvious. It is easy to tell, using the assimilated observations, that year 2003 is a drought year over the OA site compared to the other 3 years because the SWIR1 (1.6µm) and SWIR2 (2.1µm) reflectance in 2003 is obviously higher than the reflectance in the other 3 years.

The assimilated observations are used to estimate the fraction of absorbed PAR by leaf chlorophyll (fAPARchl). Zhang linked the estimated fAPARchl and flux data [gross ecosystem productivity (GEP) and PPFD] and calculated the light use efficiency by leaf chlorophyll (LUEchl). The analysis shows that fAPARchl significantly contributes to seasonal and inter-annual cycles of GEP over the OA site. The average LUEchl over 2001 – 2004 is 0.023 µmol C µmol-1 PAR incident. The year still has significant effect on GEP [Zhang *et al.*, 2007].

Objectives for the Coming Year

Zhang's first objective is to extend applications of the MODIS assimilation algorithm, for example to the Harvard Forest site, the Bartlett Experimental Forest site, the Howland Forest site and other American-flux-net sites. Secondly, he plans to test his fAPARchl and LUEchl algorithm over more sites. MODIS has more

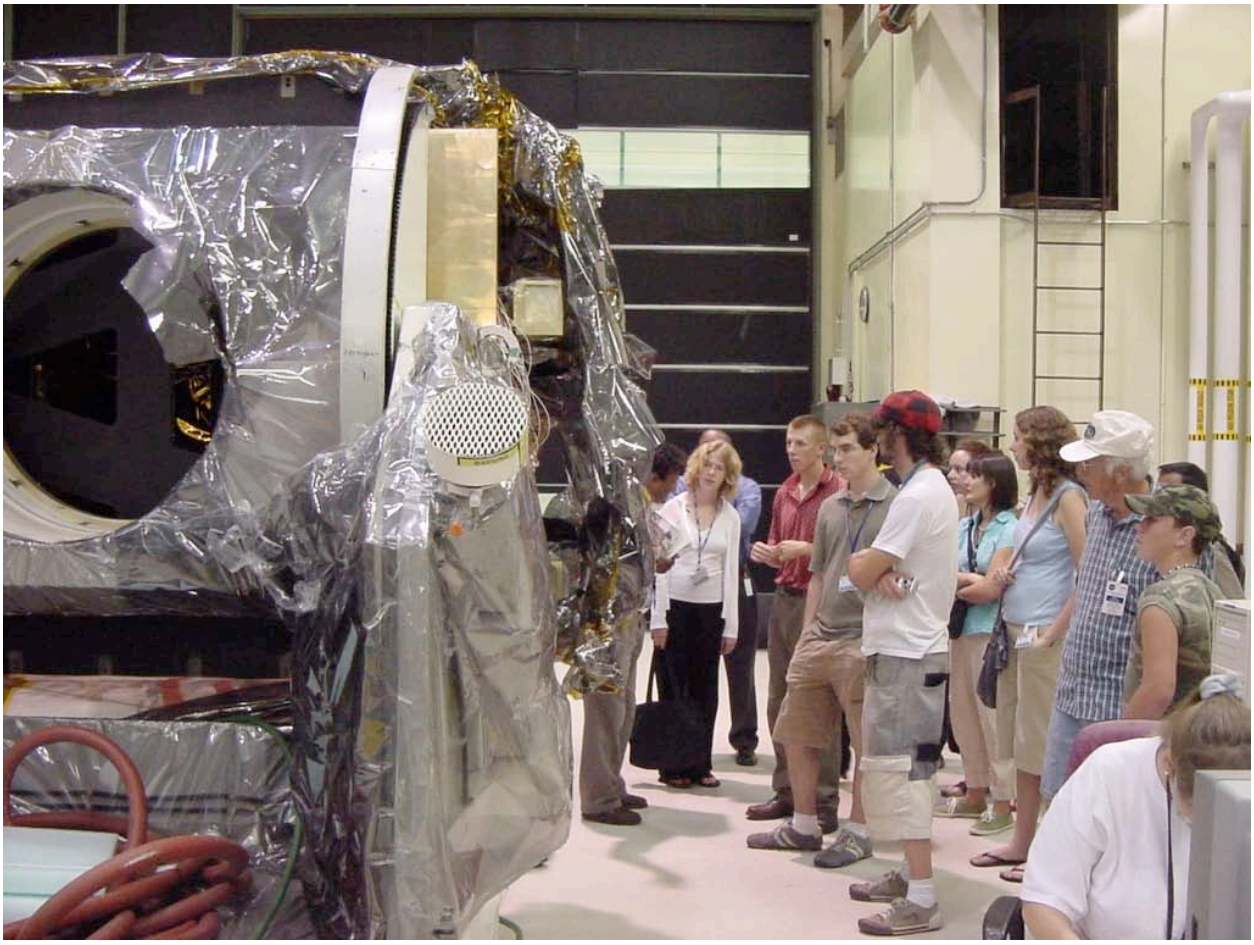
spectral bands designed for land remote sensing than AVHRR. The MODIS bands provide the opportunity to estimate fAPAR and LUE by leaf chlorophyll except by canopy.

This page intentionally left blank

Educational Programs

This page intentionally left blank

Educational Programs



GEST summer student interns touring NASA Goddard Space Flight Center's Flight facilities, August 2, 2006. [Figure courtesy of Valerie Casasanto.]

GSSP 2006 Final presentations attendees (GSFC mentors and students), NASA GSFC Visitor's Center, August 8, 2006. [Figure courtesy of Valerie Casasanto.]

Educational Programs

GEST has continued to be active in education and mentorship in 2006, with successful programs providing a "once in a lifetime" experience to a host of students.

Graduate Student Summer Program (GSSP)

The intent of the GSSP is to encourage graduate students in the Earth sciences to conduct genuine research at GSFC during a ten-week duration that can be incorporated into their graduate thesis. The program is open to students in a Master's or Ph.D. program. Each applicant must submit a proposal of the research they would like to carry out while at GSFC, and propose a GSFC mentor or research team they would like to work with. Students could be placed at any of the three Goddard institutions: GSFC, Goddard Institute for Space Studies (GISS) and Wallops Flight Facility (WFF). The GSSP 2006 summer program ran from June 5 to August 11, 2006.

Eleven students were selected to participate in GSSP 2006. The student population included nine doctoral students and two Master's students. The GSFC students were housed on-campus at the University of Maryland, College Park and were shuttled to GSFC daily. Three students were placed at GISS in New York City, while the remaining students were located at GSFC in Greenbelt, Maryland. Individual meetings were conducted with each student after two weeks into the program to monitor their progress, the mentor relationship and project comprehension. These meetings were followed up by visits to students at their workstations throughout the program. A weekly "brown bag" lunch was held for all students to get together and discuss their research. Each GISS student was reached by telephone and email to monitor progress.

A One Day Seminar series, "Earth in Flux: Geosystems in Change," was held in mid-July. A variety of GSFC, GEST, and JCET scientists were invited to speak on all disciplines of the Earth Sciences. The event was well attended by approximately 50 people including GSSP students, students from other summer programs, and GSFC scientists among others.

During the program a two-hour class was given by the Program Coordinator at GSFC's computer lab training facilities on the PC version of the GISS Global Climate Model. Also included in the software is a publication writing module which was useful for students to write their final reports. A variety of other educational and social events were held during the summer including a tour of NASA Goddard, a Saturday brunch, and a farewell dinner.

At the end of the program, students presented their work in a seminar with their peers and mentors. This year's format took place in the Goddard Visitor's Center. Each student gave a 10-15 minute seminar on the work completed this past summer. The students reported positive relationships with each other and their mentors. In particular, three students have extended their graduate research with their summer mentors, one of which will be returning as a self-directed intern during the summer of 2007. All students participated in research that will be utilized in their thesis.

The students' last requirement was to submit a paper to GEST, all of which are available for public review on the GEST website [http://gest.umbc.edu/student_opp/students.html].

Below is a list of the projects completed during GSSP 2006. Names marked with an asterisk indicate GEST faculty members.

2006 GSSP Alumni Project Reports

GSSP Students based at NASA Goddard Space Flight Center (GSFC), Greenbelt, MD

Comparisons of Carbon Monoxide Measurements using Aircraft and Model Data
Partha Sarathi Bhattacharjee
Mentor: Dr. Joanna Joiner, Laboratory for Atmospheres, GSFC

Barotropic Instability of the African Easterly Jet and its Potential for Development
Marangelly Fuentes
Mentor: Dr. Oreste Reale*, Laboratory for Atmospheres, GEST

Use of ICESat Altimeter Data for Ocean Monitoring: An Evaluation
Oscar Garcia
Mentor: Dr. Daniel Jacob*, Hydrospheric & Biospheric Sciences Laboratory, GEST

Improved Calibration of Electric Field Instrumentation Filter and Amplifier Characterization
Mauricio Garrido
Mentor: Dr. Robert Pfaff, Laboratory for Solar & Space Physics, GSFC

Simulation of Terrestrial Water Storage Dynamics in Illinois using the Community Land Model Augmented with a Model of an Unconfined Aquifer
Lindsey E. Gulden
Mentor: Dr. Matthew Rodell, Hydrological Sciences Branch, GSFC

Improving Simulations of the Convective Boundary Layer in and around Oklahoma City using the Coupled WRF-LIS System
Kodi L. Nemunaitis
Mentor: Dr. Christa Peters-Lidard, Hydrological Sciences Branch, GSFC

Estimating Carbonaceous Aerosol Emissions from Forest Fires in North American Boreal Forests in July 2004
Mariya (Shcherbyna) Petrenko
Mentor: Dr. Mian Chin, Laboratory for Atmospheres, GSFC

Investigating Gravity Wave Effects on Cirrus Clouds using a One Dimensional Cirrus Cloud
Tamara Singleton
Mentor: Dr. David O'C Starr, Mesoscale Atmospheric Processes Branch, GSFC

GSSP Students based at NASA Goddard Institute for Space Studies (GISS), New York, NY

The Effect of Solar Cycle Modulation on the Northern Hemisphere Sea Level Pressure Variability
Ambarish V. Karmalkar
Mentor: Dr. Drew D. Shindell, NASA GISS and Center for Climate Systems Research, Columbia University, New York

Investigating Climate Forcings Recorded in Tropical Ice Cores
Natalie Kehrwald
Mentor: Dr. Gavin Schmidt, NASA GISS

Climate Change Scenarios for the New York City Watershed
Andreea Ira
Mentor: Dr. Cynthia Rosenzweig, NASA GISS

GEST Student Summer Interns

GEST hosted six self-directed summer interns working with GSFC mentors on specific projects in the Earth Sciences. These interns performed actual science research and presented their results at the end of the Program. These students were housed along with the GSSP summer students and JCET summer interns.

GEST Graduate Fellowship

Samuel Trahan was awarded a one-year GEST Graduate Fellowship (August 2006-2007). Trahan is working on his Ph.D. in the Atmospherics Physics Department of UMBC. He has been working with his advisor, Dr. Lynn Sparling, on atmospheric numerical modeling. Trahan's current research is in numerical modeling of hurricanes, in particular to address some fundamental problems related to the air/sea interaction as represented in current mesoscale models.

During the fellowship, Trahan performed preparatory computational work and ported both Hurricane WRF and Advanced Research WRF to the UMBC Bluegrit cluster. He also helped the newly-formed UMBC High-Performance Computing group design a cluster for a $2 million NSF Major Research Infrastructure grant proposal.

Trahan has made significant progress in both his academic work and in preparation for his thesis research since the start of the GEST fellowship in August, 2006. He has overcome substantial challenges in the computational aspects of his research. He successfully defended his Ph.D. thesis proposal and is expected to be admitted to candidacy.

We are happy to report that a former GEST Graduate Fellow (in 2005-2006), Tetyana Vdovina, successfully defended her Ph.D. thesis in the Department of Applied Mathematics. Her advisor was Dr. Susan Minkoff.

Valerie Casasanto

This page intentionally left blank

Short-Term Visitors

This page intentionally left blank

Short-Term Visitors

GEST facilitates collaboration between scientists at GSFC and those at other research institutions to support science research and education at GSFC, WFF and GISS, field locations and external conferences. This program has hosted a wide variety of visitors, from graduate students to research support staff to senior researchers. Many of our visitors are invited speakers for established seminar series while the younger visitors are typically coming to GSFC for hands-on training or obtaining data for their own research at their home institution.

GEST facilitated the visits of approximately 85 short-term visiting scientists in the reporting period. During the past year, those scientists who visited GSFC under the auspices of GEST included:

Visitor's last name	Visitor's first name	Affiliation	Code Visited
Albrecht	Bruce	Univ. of Miami	613.2
Bauer	Peter	ECMWF	610.1
Blanc	Michel	Centre d'Etudes Spatiales des Rayonnements (CESR)	673
Boudreau	Jonathan	Fluxnet-Canada Rsch Network	614.4
Castanho	Andrea	MIT	613.2
Celis-Murillo	Antonio	NPP	614
Chen	Jhih-Ying	National Central Univ.	613.1
Cumbane	Juliao	Eduardo Mondlane Univ.	610
Deppe	Jill	NPP	614
Drolet	Guillaume	Fluxnet-Canada Research Network	614.4
Ellett	Kevin	Univ. of Melbourne	614.3
Fang	Ming	MIT	698
Freitas	Saulo	INPE	610.1
Gobakken	Terje	Agric Univ. of Norway	614.4
Goncalves	Luis Gustavo	ORAU	614.3
Gregoire	Tim	Yale Univ.	614.4
Groisman	Pavel	NOAA	610.6
Harshvardhan	Dr.	Purdue Univ.	613.2
Heymsfield	Andrew	National Center For Atmospheric Research	613.2
Huwig	Kathy	Case Western Reserve Univ.	699
Karnieli	Arnon	Ben Gurion Univ. (BGU) Inst. Desert Resrch	613.2
Kasibhatla	Prasad	Duke Univ.	613.3
Kaufman	Jean	Yoram J. Kaufman Memorial Session	613.3
Kelly	Richard	Univ. of Waterloo	614.6
Kim	Hyomin	Univ. of New Hampshire	670
Kostis	Helen-Nicole	Univ. of Chicago	130
Lakshmi	Venkat	Stanford Univ.	614.3
Lee	Lou-Chang	National Central Univ.	613.2
Liang	Qing	Univ. of Washington	613.3
Liu	Yinghui	Univ. of Wisconsin	613.2
Los	Alexander	KNMI	613.2
Lu	Jian	GFDL/NOAA	610.1
Luo	Yiyong	Univ. of Rhode Island	610.1

Visitor's last name	Visitor's first name	Affiliation	Code Visited
Ma	Po-Lun	Johns Hopkins Univ.	613.2
Margolis	Hank	Laval Univ.	614.4
Matrajt	Graciela	Univ. of Washington	699
Munchak	Joe	Penn State Univ.	613.1
Naesset	Erik	Univ. of Norway	614.4
Nenes	Anathasios	Georgia Institute of Technology	613.2
Niu	Guo-Yue	Univ. of Texas at Austin	610.1
Ohmura	Atsumu	Swiss Federal Institute of Technology	613.2
Panciera	Rocco	University of Melbourne, Australia	614.6
Pauliquevis	Theotonio	National Institute for Amazonion Research (INPA)	613.2
Perlwitz	Judith	NOAA	610.1
Petersen	Walt	UAH	610.1
Pincus	Robert	NOAA	613.2
Price	Colin	Tel Aviv Univ.	613.2
Prospero	Joseph	Univ. of Miami, CIMAS	613.2
Queface	Antonio	Eduardo Mondlane Univ.	613.2
Rasch	Phil	National Center for Atmospheric Research	613.2
Rosero	Enrique	Utah Water Research Lab	614.3
Rudich	Yinon	Weizmann Inst. Of Science	613.2
Samsonov	Andrey	St. Petersburg State Univ.	674
Sarantos	Menelaos	Univ. of Maryland, College Park	670
Schulz	Michael	Goddard Visiting Fellow	600
Shao	Hui	Florida State Univ.	610.1
Sofia	Sabatino	Yale Univ.	671
Stahl	Goran	Swedish Univ. of Agricultural Sciences	614.4
Tan	Qian	MIT	613.3
Tang	Youhua	Univ. of Iowa	613.3
Tripoli	Gregory	Univ. of Wisconsin	613.2
Wang	Jun	Harvard Univ.	610.1
Wanliss	James	Embry-Riddle Univ. Daytona	670
Waquet	Fabien	Univ. of Lille	613.2
Wu	Chiuan-Fang	Environmental Protection Administration of Taiwan	613.2
Wunch	Debra	Univ. of Toronto	613.3
Xiao	Yaping	Harvard Univ.	613.3
Yang	Yuekui	Univ. of Illinois at Urbana-Champaign	613.2
Yoshida	Yasuko	Georgia Tech	613.3
Zeng	Qin-Cun	Chinese Academy of Sciences	613.2
Zenitani	Seiji	JAXA	674

GEST's short-term visiting scientist program continues to grow and proves to be a needed service to the Earth Sciences and space communities.

Valerie Casasanto

APPENDICES

This page intentionally left blank

References

Anderson, T. L., R. J. Charlson, N. Bellouin, O. Boucher, M. Chin, S. A. Christopher, J. Haywood, Y. Kaufman, S. Kinne, J. A. Ogren, L. A. Remer, T. Takemura, D. Tanré, C. R. Trepte, B. A. Wielicki, D. M. Winker, and H. Yu (2005a), An 'A-Train' strategy for quantifying direct climate forcing by anthropogenic aerosols, *Bull. Amer. Meteo. Soc., 86*, 1795-1809.

Anderson, T. L., Y. Wu, D. A. Chu, B. Schmid, J. Redemann, and O. Dubovik (2005), Testing the MODIS satellite retrieval of aerosol fine-mode fraction, *J. Geophys. Res., 110*, doi:10.1029/2005JD005978.

Anyamba, A., J. P. Chretien, J. Small, C. J. Tucker, and K. J. Linthicum (2006), Developing climate anomalies suggest potential disease risks for 2006-2007, *International Journal of Health Geographics, 5*(60), doi: 10.1186/1476-072X-5-60, 2006. http://www.ij-healthgeographics.com/content/5/1/60/abstract

Arola, A., S. Kazadzis, N. Krotkov, A. Bias, J. Herman, and K. Lakkala (2005), Assessment of TOMS UV bias due to the absorbing aerosols, *J. Geophys. Res., 110*, D23211, doi:10.1029/2005JD005913.

Aydin, K., and T. M. Walsh (1999), Millimeter wave scattering from spatial and planar bullet rosettes, *IEEE Transactions on Geoscience and Remote Sensing, 37*, 1138-1150.

Baker, N. L., and R. Daley (2000), Observation and background adjoint sensitivity in the adaptive observation-targeting problem, *Quart. J. Roy. Meter. Soc., 126*, 1431-1454.

Beer, J., M. Vonmoos and R. Muscheler (2006), Solar variability over the past several millennia, *Space Science Reviews*, DOI: 10.1007/s11214-006-9047-4.

Benna, M., and P. Mahaffy (2006), 3-D MHD simulation of the solar wind interaction with comets, in *Advances in Geosciences Vol. 3*, Edited by W. Ip and A. Bhardwaj, 121-202, Word Scientific, Singapore.

Benna, M., and P. Mahaffy (2006), New multi-fluid model of comet 26P/Grigg-Skjellerup and extrapolation to comet 67P/Churyumo-Gerasimenko, *Geophys. Res. Lett., 33*(10), L10103.

Benna, M., and P. Mahaffy (2006), Multi-fluid model of comet 1P/Halley, *Planet. Space Sci.*, in press.

Benson, R. F., P. A. Webb, J. L. Green, L. Garica, and B. W. Reinisch (2004), Magnetospheric electron densities inferred from upper-hybrid band emissions, *Geophys. Res. Lett., 31*(20), L20803, doi 10.1029/2004GL020847.

Chandra, S., J. R. Ziemke, M. R. Schoeberl, L. Froidevaux, W. G. Read, P. F. Levelt, and P. K. Bhartia (2007), Effects of the 2004 El Nino on tropospheric ozone, *Geophys. Res. Lett.*, in press.

Charlson, R. J., J. Langner, H. Rodhe, C. B. Leovy, and S. G. Warren (1991), Perturbation of the Northern Hemisphere radiative balance by backscattering from anthropogenic sulfate aerosols, *Tellus, 43AB*, 152-163.

Chin, M., T. Diehl, T. Kucsera, M. Petrenko, L. Giglio, G. van der Werf, C. Ichoku, A. Soja, R. Levy, D. Giles, and R. Ferrare (2006), Use satellite data for modeling biomass burning emissions, Fifth AeroCom Workshop, Virginia Beach, VA, 17-19 October.

Chretien J. P., A. Anyamba, S. Bedno, R. Breiman, C. Njuguna, S. Sang, K. Sergon, A. Powers, M. Ball, C. Onyango, J. Small, C. J. Tucker, and K. J. Linthicum (2007), Drought-associated Chikungunya Emergence along Coast East Africa, *The American Journal of Tropical Medicine and Hygiene, 76*(3), 405–407.

Chu, D. A., L. A. Remer, Y. J. Kaufman, B. Schmid, J. Redemann, K. Knobelspiesse, J.-D. Chern, J. Livingston, P. Russell, X. Xiong, and W. Ridgway (2005), Evaluation of aerosol properties over ocean from Moderate Resolution Imaging Spectroradiometer (MODIS) during ACE-Asia, *J. Geophys. Res., 110*, doi:10.1029/2004JD005208, in press..

Chu, D. A., Y. J. Kaufman, C. Ichoku, L. A. Remer, D. Tanré, and B. Holben (2002), Validation of MODIS aerosol optical depth retrieval over land, *Geophys. Res. Lett., 29*(12), 10.1029/2001/GL013205.

Chung, C. E., V. Ramanathan, D. Kim, and I. A. Podgorny (2005), Global anthropogenic aerosol direct forcing derived from satellite and ground-based observations, *J. Geophys. Res., 110*, D24207, doi:10.1029/2005JD006356.

Coale, K. H., et al. (2004), Southern ocean iron enrichment experiment: Carbon cycling in high- and low-Si waters, *Science, 304*(5669), 408-414, 16 April.

Cooper, G. W., M. H. Thiemens, T. Jackson, and S. Chang (1997), Sulfur and hydrogen isotope anomalies in meteorite sulfonic acids, *Science, 277*, 1072-1074.

Crow, W. T., D. Entekhabi, R. Koster, and R. H. Reichle (2006), Synergy between planned NASA water cycle missions, *EOS, Transactions, American Geophysical Union, 87*(15), pp. 149,153.

De Lannoy, G. J. M., R. H. Reichle, P. R. Houser, V. R. N. Pauwels, and N. E. C. Verhoest (2007), Correcting for Forecast Bias in Soil Moisture Assimilation with the Ensemble Kalman Filter, *Water Resources Research*, in press.

de Santis, A, J. M. Torta, and L. R. Gaya-Piqué (2002), The first Antarctic geomagnetic Reference Model (ARM), *Geophys. Res. Lett., 29*, 33-1, DOI 10.1029/2002GL014675.

Diehl, T., and M. Chin (2006), A global emission inventory for aerosol simulations of the period 1980-2005, Fifth AeroCom Workshop, Virginia Beach, VA, 17-19 October.

Dong, J., D. L. Toll, P. R. Houser, C. Peter-Lidard, K. R. Arsenault, B. A. Cosgrove, and S. Kumar (2006), Evaluation of the factors and error propagation in the model energy flux estimates with Land Information System, AGU West Pacific Geophysical Meeting, Beijing, P.R.C., 24-27 July.

Dong, J., J. P. Walker, P. R. Houser, and C. Sun (2006), Scanning multichannel microwave radiometer snow water equivalent assimilation, *J. Geophys. Res.*, in press.

Dong, J., W. Ni-Meister and P. R. Houser (2006), Impacts of vegetation and cold season processes on soil moisture and climate relationships over Eurasia, *J. Geophys. Res.*, in press.

Duncan, B. N., S. E. Strahan, and Y. Yoshida (2007), Model study of cross-tropopause transport of biomass burning pollution, *Atmos. Chem. Phys. Disc., 7*, 2197-2248.

Duncan, B., J. Logan, et al. (2007b), The global budget of CO, 1988-1997: source estimates and validation with a global model, *J. Geophys. Res.*, submitted.

Duncan, B., S. Strahan, and Y. Yoshida (2007a), Model study of the cross-tropopause transport of biomass burning pollution, *Atmos. Chem. Phys. Disc.*, submitted.

Ehrendorfer, M., and R. M. Errico (2006), An intermediate-complexity model for data assimilation, Proceedings of the Second THORPEX International Science Symposium (STISS), Landshut, Germany, H. Volkert, Ed., WMO/TD No. 1355, WWRP/THORPEX No. 7, 58-59.

Ek, M., K. E. Mitchell, Y. Lin, E. Rogers, P. Grunmann, V. Koren, G. Gayno, and J. D. Tarpley (2003), Implementation of Noah land-surface model advances in the NCEP operational mesoscale Eta model, *J. Geophys. Res., 108*, D22.

Erickson, D. J. III et al. (2003), Atmospheric Iron Delivery and surface ocean biological activity in the Southern Ocean and Patagonia region, *Geo. Res. Let., 30*(12),1609, doi:10.1029/2003GL017242.

Farrell, W. M., G. T. Delory, and S. K. Atreya (2006), Martian dust storms as a possible sink of atmospheric methane, *Geophys. Res. Lett., 33*, L21203, doi:10.1029/ 2006GL027210.

Fensholt, R., A. Anyamba, S. Stisen, I. Sandholt, E. Pak, and J. Small (2007), Comparisons of compositing period length for vegetation index data from Polar-orbiting and Geostationary satellites for the Cloud-prone region of West Africa. Special Issue: Cloud-prone and Rainy areas Remote Sensing (CARRS), *Photogrammmetric Engineering and Remote Sensing, 73*(3), 297-310.

Formisano, V., S. Atreya, T. Encrenaz, N. Ignatiev, and M. Giuranna (2004), Detection of methane in the atmosphere of Mars, *Science, 306*, 1758-1761.

Foster, J., C. Sun, J. Walker, R. Kelly, A. Chang, J. Dong, and H. Powell (2005), Quantifying the uncertainty in passive microwave snow water equivalent observations, *Rem. Sens. Environ., 94*, 187-203.

Gaiero DM et al., (2003) Iron and other transition metals in Patagonian riverborne and windborne materials: Geochemical control and transport to the southern South Atlantic Ocean, *Geochim Cosmochim Acta 67*(19), 3603-3623.

Gaspari, V., et al. (2006), Atmospheric iron fluxes over the last deglaciation: Climatic implications, *Geophys. Res. Lett., 33*, L03704, doi:10.1029/2005GL024352.

Gaya-Pique, L. R., A. de Santis, and J. M. Torta (2005), Use of CHAMP magnetic data to improve the Antarctic geomagnetic Reference Model, in *Earth Observation with CHAMP: Results from Three Years in Orbit*, edited by C. Reigber, H. Lühr, P. Schwintzer and J. Wickert, Heidelberg, 287-292.

Grecu, M., and W. S. Olson (2007), Precipitating Snow Retrievals from Combined Airborne Cloud Radar and Millimeter Wave Radiometer Observations, *Journal of Applied Meteorology and Climatology*, submitted.

Gu, G., R. F. Adler, G. J. Huffman, and S. Curtis (2007), Tropical rainfall variability on interannual-to-interdecadal/longer-time scales derived from the GPCP monthly product, *Journal of Climate*, in press.

Hackam, R. (1969), Total secondary ionization coefficients and breakdown potentials of hydrogen, methane, ethylene, carbon monoxide, nitrogen, oxygen and carbon dioxide between mild steel coaxial cylinders, *J. Phys. B (Atom. Molec. Phys.), 2*, 216-233.

Heymsfield, A. J., and L. M. Miloshevich (2003), Parameterization for the cross-sectional area and extinction of cirrus and stratiform ice cloud particles, *J. Atmos. Sci., 60*, 936-956.

Higgins, W., D. Ahijevych, J. Amador, A. Barros, E. H. Berbery, E. Caetano, P. Ciesielski, R. Cifelli, M. Cortez-Vazquez, A. Douglas, M. Douglas, G. Emmanuel, C. Fairall, D. Gochis, D. Gutzler, R. Johnson, C. King, T. Lang, M.-I. Lee, D. Lettenmaier, R. Lobato, V. Magaña, J. Meitin, K. Mo, S. Nesbitt, E. Pytlak, P. Rogers, S. Rutledge, J. Schemm, S. Schubert, F. Torres, A. White, C. Williams, A. Wood, R. Zamora, and C. Zhang (2006), The NAME 2004 Field Campaign and Modeling Strategy, *Bull. Amer. Meteorol. Soc., 87*(1), 79–94.

Hsu, N. C, S. C. Tsay, M. D. King, et al. (2004), Aerosol properties over bright-reflecting source regions, *IEEE Trans. Geosci. Remote Sensing, 42*, 557-569.

Jacob, S. D., D. M. Le Vine, E. Dinnat, and P. de Matthaeis (2006), Forward Model Details, Aquarius Simulator Team Report.

Jickells, T. D. et al. (2005), Global iron connections between Desert, Ocean Biogeochemistry, and Climate. *Science, 308*, 67-71.

Kaufman, Y. J., D. Tanre, and O. Boucher (2002), A satellite view of aerosols in the climate system. Review, *Nature, 419*, 215-223.

Kaufman, Y. J., O. Boucher, D. Tanré, M. Chin, L. A. Remer, and T. Takemura (2005), Aerosol anthropogenic component estimated from satellite data, *Geophys. Res. Lett., 32*, L17804, doi:10/1029/2005GL023125.

Kiehl, J. T., and B. P. Briegleb (1993), The relative roles of sulfate aerosols and greenhouse gases in climate forcing, *Science, 260*, 311-314.

Krasnopolsky, V. A., J. P. Maillard, and T. C. Owen (2004), Detection of methane in the martian atmosphere: Evidence for life? *Icarus, 172*, 537–547.

Krotkov, N. A., P. K. Bhartia, J.Herman, J. Slusser, G. Scott, G. Labow, A. Vasilkov, T. Eck, O. Dubovik, and B. Holben (2005), Aerosol UV absorption experiment (2002- 04): 2. Absorption optical thickness, refractive index, and single scattering albedo, *Opt. Eng., 44*(4), 041005, doi:10.1117/1.1886819.

Kumar, S. V., C. D. Peters-Lidard, J. Eylander, R. Reichle, W. Crow, X. Zhan, P. Houser, R. Koster, M. Suarez, and J. Dong (2006), A Generic, Interoperable, Hydrologic Data Assimilation Framework using the Land Information System, H23E-1558, American Geophysical Union Fall Meeting, San Francisco, CA, December 11-15.

Kuo, K.-S., E. A. Smith, Z. S. Haddad, E. Im, T. Iguchi, and A. Mugnai (2004), Mathematical-physical framework for retrieval of rain DSD properties from dual-frequency Ku-Ka-band satellite radar, *J. Atmos. Sci.*, *61*(19), 2349-2369.

Lait, L. (1994), An alternative form for potential vorticity, *J. Atmos. Sci.*, *51*, 1754-1759.

Langel, R. A., T. J. Sabaka, R. T. Baldwin, and J. A. Conrad (1996), The near-Earth magnetic field from magnetospheric and quiet-day ionospheric sources and how it is modeled, *Phys. Earth Planet. Int.*, *98*, 235-267.

Langland, R. H., and N.L. Baker (2004), Estimation of observation impact using the NRL atmospheric variational data assimilation adjoint system, *Tellus*, *56A*, 189-201.

Lau, W. K. M., K.-M. Kim, and M.-I. Lee (2007), Characteristics of diurnal and seasonal cycles in global monsoon systems, *J. Meteorol. Soc. Japan*, *85*, Special Issue, 1-14.

Lawford, R. G., P. Arkin, D. Lettenmaier, and J. Roads (2007), Past and future GEWEX contributions to large-scale hydrometeorology, *Journal of Hydrometeorology*, in press.

Lawford, R., M. Bosilovich, S. Eden, S. Benedict, C. Brown, A. Gruber, P. Houser, K. Hou, J. Huang, W. Lau, T. Meyers, K. Mitchell, C. Peters-Lidard, J. Roads, M. Rodell, S. Sorooshian, D. Tarpley, and S. Williams (2006), U.S. Contributions to the CEOP, *BAMS*, *87*(7), 927-939.

Le Vine, D. M., S. D. Jacob, E. Dinnat, P. de Matthaeis, and S. Abraham (2007), The Influence of Antenna Pattern on Faraday Rotation in Remote Sensing at L-band, *IEEE Transactions on Geoscience and Remote Sensing*, submitted.

Lee, M.-I., S. D. Schubert, M. J. Suarez, A. Kumar, I. M. Held, H.-K. Kim, J. Ploshay, N.-C. Lau, and J. Schemm (2007), An analysis of the warm season diurnal cycle over the continental United States and northern Mexico in general circulation models, *J. Hydromet.*, in press.

Lee, M.-I., S. D. Schubert, M. J. Suarez, I. M. Held, A. Kumar, T. L. Bell, J.-K. E. Schemm, N.-C. Lau, J.-J. Ploshay, H.-K. Kim, J. J. Ploshay, and S.-H. Yoo (2007), Sensitivity to horizontal resolution in the AGCM Simulations of warm season diurnal cycle of precipitation over the United States and northern Mexico, *J. Clim.*, in press.

Levy, R. C., L. A. Remer, D. Tanré, Y. J. Kaufman, C. Ichoku, B. N. Holben, J. M. Livingston, P. B. Russell, and H. Maring (2003), Evaluation of the Moderate-Resolution Imaging Spectroradiometer (MODIS) retrievals of dust aerosol over the ocean during PRIDE, *J. Geophys. Res.*, *108*, (D19), 8594, doi:10.1029/2002JD002460.

Livingston, J. M., P. B. Russell, J. S. Reid, J. Redemann, B. Schmid, D. A. Allen, O. Torres, R. C. Levy, L. A. Remer, B. N. Holben, A. Smirnov, O. Dubovik, E. J. Welton, J. R. Campbell, J. Wang, and S. A. Christopher (2003), Airborne Sun photometer measurements of aerosol optical depth and columnar water vapor during the Puerto Rico Dust Experiment and comparison with land, aircraft, and satellite measurements, *J. Geophys. Res.*, *108*, (D19), 8588, doi:10.1029/2002JD002520.

Ljung, K., S. Björck, R. Muscheler, J. Beer, and P. W. Kubik (2007), Variable 10Be fluxes in lacustrine sediments from Tristan da Cunha, South Atlantic: a solar record?, *Quat. Sci. Rev.*, doi:10.1016/j.quascirev.2006.12.016, in press.

Lyapustin, A., and Wang, Y. (2005), Parameterized code Sharm-3D for radiative transfer over inhomogeneous surfaces, *Appl. Optics, 44*, 7602-7610.

Lyapustin, A., and Yu. Knyazikhin (2001), Green's function method in the radiative transfer problem. I: Homogeneous non-Lambertian surface, *Appl. Optics, 40*, 3495-3501.

Mahanama, S. P. P., R. D. Koster, R. H. Reichle, and M. J. Suarez (2007), Impact of Subsurface Temperature Variability on Meteorological Variability: An AGCM Study, *Journal of Hydrometeorology*, submitted.

Marinov, I., et al. (2006), The Southern Ocean biogeochemical divide, *Nature, 441*, 964-967, 22 June.

Maus, S, M. Rothe, K. Hemant, C. Stolle, H. Lühr, A. Kuvshinov and N. Olsen (2006), Earth's lithospheric magnetic field determined to spherical harmonic degree 90 from CHAMP satellite measurements, *Geophysical Journal International, 164*, 319-330.

Melnik O. and M. Parrot (1998), Electrostatic discharge in Marian dust storms, *J.Geophys. Res., 103*, 29107-29117.

Meng, C. J., K. Mitchell, C. Lu, H. Wei, J. Eastman, C. Peters-Lidard, P. Houser, and M. Rodell (2005), Optimal land initialization for the NCEP Global Forecast System using the NASA Land Information System, AMS Annual Meeting, San Diego, CA, January.

Mitchell, K., E., D. Lohmann, P. R. Houser, E. F. Wood, J. C. Schaake, A. Robock, B. A. Cosgrove, J. Sheffield, Q. Duan, L. Luo, R. W. Higgins, R. T. Pinker, J. D. Tarpley, D. P. Lettenmaier, C. H. Marshall, J. K. Entin, M. Pan, W. Shi, V. Koren, J. Meng, B. H. Ramsay, and A. A. Bailey (2004): The multi-institution North American Land Data Assimilation System (NLDAS), Utilizing multiple GCIP products and partners in a continental distributed hydrological modeling system, *J. Geophys. Res., 109*, D07S09.

Molnar, G. I., and J. Susskind (2006), Satellite Sounder-Based OLR-, Cloud- and Atmospheric Temperature Climatologies for Climate Analyses. Algorithms and Technologies for Multispectral, Hyperspectral and Ultraspectral Imagery XII, Proceedings of SPIE Vol. 6233, 62331D-1-62331D-10.

Molnar, G. I., and J. Susskind (2006), Assessment of the Usefulness of Atmospheric Satellite Sounder-Based Cloud Retrievals for Climate Studies. GEWEX Cloud Climatology Assessment Workshop, Madison, WI, 5-6 July.

Molnar, G. I., and J. Susskind (2007), Satellite Sounder-Based Atmospheric Parameter Climatologies: Tools for Monitoring/Assessing Short-, and Long-Term Climate Variabilities and Trends, 87th AMS Annual Meeting, San Antonio, TX, GA, 15-19 January.

Morris, G. A., S. Hersey, A. M. Thompson, S. Pawson, J. Eric Nielsen, P. R. Colarco, W. W. McMillan, A. Stohl, S. Turquety, J. Warner, B. J. Johnson, T. L. Kucsera, D. E. Larko, S. J. Oltmans, and J. C. Witte (2006), Alaskan and Canadian forest fires exacerbate ozone pollution over Houston, Texas, on 19 and 20 July 2004, *J. Geophys. Res., 111*, D24S03, doi:10.1029/2006JD007090.

Muscheler, R., and J. Beer (2006), Solar forced Dansgaard/Oeschger events?, *Geophys. Res. Lett., 33*, L20706, doi: 10.1029/2006GL026779.

Muscheler, R., F. Joos, J. Beer, S. A. Mueller, M. Vonmoos, and I. Snowball (2007), Solar activity during the last 1000 yr inferred from radionuclide records, *Quat. Sci. Rev.*, *26*, 82-97, doi:10.1016/j.quascirev.2006.07.012.

Nerger L., W. Hiller, and J. Schröter (2005), PDAF - The parallel data assimilation framework: Experiences with Kalman filtering, in *Use of High Performance Computing in Meteorology - Proceedings of the 11. ECMWF Workshop*, edited by W. Zwieflhofer and G. Mozdzynski, pp. 63-83, World Scientific, Singapore.

Nerger, L and W. W. Gregg (2007), Assimilation of SeaWiFS data into a global ocean-biogeochemical model using a local SEIK filter, *J. Mar. Syst.*, in press, doi:10.1016/j.jmarsys.2006.11.009.

Nerger, L., S. Danilov, W. Hiller and J. Schröter (2006), Using sea level data to constrain a finite-element primitive-equation ocean model with a local SEIK filter, *Ocean Dynamics*, *56*, 634-649.

Norris, P. M., and A. M. da Silva (2006), Assimilation of satellite cloud data into the GMAO Finite Volume Data Assimilation System using a parameter estimation method. Part I: Motivation and algorithm description, *Journal of the Atmospheric Sciences*, in press.

Pan, H. L., and L. Mahrt (1987), Interation between soil hydrology and boundary layer development, *Boundary Layer Meteor.*, *38*, 185-202.

Peters-Lidard, C. D., S. Kumar, and J. Dong (2006), Land information system assimilation enhancements, pp: 1-27, Omaha, NE, 12-14 September.

Petrenko, M., M. Chin, T. Diehl, T. Kucsera, and A. J. Soja (2007), Estimating carbonaceous aerosol emissions from fires in boreal forests of North America in July 2004, 87th AMS Annual Meeting, San Antonio, TX, 14-18 January.

Pizzarello, S., G. W. Cooper, and G. J. Flynn (2006), The Nature and Distribution of the Organic Material in *Carbonaceous Chondrites and Interplanetary Dust Particles in Meteorites and the Early Solar System II*, pp. 625-651, edited by D. S. Lauretta and H. Y. McSween Jr., University of Arizona Press, Tucson, AZ.

Prospero, J. M., et al. (2002), Environmental characterization of global sources of atmospheric soil dust identified with the Nimbus 7 Total Ozone Mapping Spectrometer (TOMS) absorbing aerosol product, *Rev. of Geophys.*. *40*, no.1: 2-1-31.

Pulkkinen, A., M. Hesse, M. Kuznetsova and Lutz Rastätter (2006), First-principles modeling of geomagnetically induced electromagnetic fields and currents from upstream solar wind to the surface of Earth, *Annales Geophysicae*, submitted.

Pulkkinen, A., R. Pirjola, and A. Viljanen (2007), Determination of ground conductivity and system parameters for optimal modeling of geomagnetically induced current flow in technological systems, *Earth, Planets and Space*, submitted.

Redemann, J., B. Schmid, J. A. Eilers, R. Kahn, R. C. Levy, P. B. Russell, J. M. Livingston, P. V. Hobbs, W. L. J. Smith, and B. N. Holben (2005), Suborbital measurements of spectral aerosol optical depth and its variability at subsatellite grid scales in support of CLAMS 2001, *J. Atmos. Sci.*, *62*, 993-1007.

Reichle, R. H., R. D. Koster, P. Liu, S. P. P. Mahanama, E. G. Njoku, and M. Owe (2006), Comparison and assimilation of global soil moisture retrievals from the Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E) and the Scanning Multichannel Microwave Radiometer (SMMR),, *J. Geophys. Res. – Atmos., 112,* D09108, doi:10.1029/2006JD008033.

Remer, L. A., Y. J. Kaufman, D. Tanré, S. Mattoo, D. A. Chu, J. V. Martins, R.-R. Li, C. Ichoku, R. Levy, R. G. Kleidman, T. F. Eck, E. Vermonte, and B. Holben (2005), The MODIS aerosol algorithm, products and validation, *J. Atmos. Sci., 62*, 947-973.

Renssen, H., H. Goosse, and R. Muscheler (2006), Coupled climate model simulation of Late Holocene cooling events: oceanic feedback amplifies solar forcing, *Climate of the Past, 2*, 79-90.

Ritter, P, H. Luhr, S. Maus, and A. Viljanen (2004), High-latitude ionospheric currents during very quiet times: their characteristics and predictability, *Ann. Geophys., 22*, 2001-2014.

Rodell, M., P. R. Houser, U. Jambor, J. Gottschalck, K. Mitchell, C. J. Meng, K. Arsenault, B. Cosgrove, J. Radakovich, M. Bosilovich, J. K. Entin, J. P. Walker, D. Lohmann, and D. Toll (2004), The Global Land Data Assimilation System, *Bull. Amer. Meteor. Soc., 85*(3), 381-394.

Sarmiento, J. L. and Toggweiler, J. R. (1984), A new model for the role of the oceans in determining atmospheric CO_2, *Nature, 308*, 620–624.

Schmid, B., J. Redemann, P. B. Russell, P. V. Hobbs, D. L. Hlavka, M. J. McGill, B. N. Holben, E. J. Welton, J. Campbell, O. Torres, R. A. Kahn, D. J. Diner, M. C. Helmlinger, D. A. Chu, C. Robles-Gonzalez, and G. de Leeuw (2003), Coordinated airborne, spaceborne, and ground-based measurements of massive, thick aerosol layers during the dry season in Southern Africa, *J. Geophys. Res., 108*, (D13), doi:10.1029/2002JD002297.

Schoeberl, M.R., and L.R. Lait (1992), Conservative-coordinate transformations for atmospheric measurements, Proc. Internat. School Phys. “Enrico Fermi'”, CXV Course, ed. J. C. Gille and G. Visconti, North-Holland, 419-431.

Shen, B.-W., R. Atlas, J.-D. Chern, O. Reale, S.-J. Lin, and T. Lee (2006), The 0.125 degree finite-volume General Circulation Model on the NASA Columbia supercomputer: preliminary simulations of mesoscale vortices, *Geophys. Res. Lett., 33*, L05801, doi:10.1029/2005GL024594.

Shen, B.-W., R. Atlas, O. Reale, S.-J. Lin, J.-D. Chern, J. Chang, C. Henze, and J.-L. Li (2006), Hurricane forecasts with a global mesoscale-resolving model: Preliminary results with Hurricane Katrina (2005), *Geophys. Res. Lett., 33*, L13813, doi:10.1029/2006GL026143.

Strahan, S. E., and B. C. Polansky (2006), Meteorological implementation issues in chemistry and transport models, *Atmos. Chem. Phys., 6*, 2895-2910.

Strahan, S. E., B. N. Duncan, and P. Hoor (2007), Observationally derived transport diagnostics for the lowermost stratosphere and their application to the GMI chemistry and transport model (2007), *Atmos. Chem. Phys. Disc., 7*, 1449-1477.

Sud, Y. C., G. Walker, Y. Zhou, and K.-M. Lau (2006), Influences of Local Sea-Surface Temperatures and Large-scale Dynamics on Monthly Precipitation Inferred from Two 10-year GCM-Simulations, in progress.

Sun, C., J. P. Walker, and P. R. Houser (2004), A methodology for snow data assimilation in a land surface model, *J. Geopyhs. Res.*, *109*, D08108, doi:10.1029/2003JD003765.

Taktashvili, A., M. Kuznetsova, M. Hesse, L. Rastätter, A. Chulaki, and A. Pulkkinen (2007), Metrics Analysis of the Coupled BATSRUS and Fok Ring Current Model Performance Based on a Case Study, *Space Weather*, submitted.

Tan, W., M. A. Geller, S. Pawson, and A. DaSilva (2004), A case study of excessive subtropical transport in the stratosphere of a data assimilation system, *J. Geophys. Res.*, *109*, D11102, doi:10.1029/2003JD004057.

Textor, C., M. Schulz, S. Guiber, S. Kinne, Y. Balkanski, S. Bauer, T. Berntsen, T. Berglen, O. Boucher, M. Chin, F. Dentener, T. Diehl, J. Feichter, D. Fillmore, P. Ginoux, S. Gong, A. Grini, J. Hendricks, L. Horowitz, P. Huang, I. S. A. Isaksen, T. Iversen, S. Kloster, D. Koch, A. Kirkevåg, J. E. Kristjansson, M. Krol, A. Lauer, J. F. Lamarque, X. Liu, V. Montanaro, G. Myhre, J. E. Penner, G. Pitari, S. Reddy, Ø. Seland, P. Stier, T. Takemura, and X. Tie (2007), The effect of harmonized emissions on aerosol properties in global models – an AeroCom experiment, *ACPD*, *7*, 1699-1723.

Tie, X., S. Chandra, J. R. Ziemke, C. Granier, and G. P. Brasseur (2006), Satellite Measurements of tropospheric column O_3 and NO_2 in eastern and southeastern asia: Comparison with a global model (MOZART-2), *J. Atmos. Chem.*, doi:10.1007/s10874-006-9045-7.

Toll, D. L., J. Dong, P. R. Houser, B. Cosgrove, C. Peters-Lidard, and S. Kumar (2006), Land surface water and energy flux evaluation from the North American Regional Reanalysis (NARR) and Land Data Assimilation Systems (LDAS) for water resources applications, *Eos Trans. AGU*, *87*(36), Jt. Assem. Suppl. Abstract A33D-02.

Toll, D., J. Dong, P. Houser, K. Arsenault, A. Pinherio, J. Basara, and J. Monroe (2006), Analysis of NOAA and NASA surface water and energy balance data for water resources applications, First Climate Prediction Program for the Americas (CPPA) PIs Meeting, Hilton El Conquistador Resort in Tucson, AZ, 14-16 August.

Torta, J. M., J. J. Curto, and P. Bencze (1997), Behavior of the quiet day ionospheric current system in the European region, *J. Geophys. Res.*, *102*, 2483–2494.

Turquety, S., J. A. Logan, D. J. Jacob, R. C. Hudman, F. Y. Leung, C. L. Heald, R. M. Yantosca, S. Wu, L. K. Emmons, D. P. Edwards, and G. W. Sachse (2007), Inventory of boreal fire emissions for North America in 2004: the importance of peat burning and pyro-convective injection, *J. Geophys. Res.*, in press.

Vermote, E. F, N. Z. El Saleous, and C. O. Justice (2002), Atmospheric correction of MODIS data in the visible to middle infrared: first results, *Rem. Sens. Environ.*, *83*, 97-111.

Vonmoos, M., J. Beer, and R. Muscheler (2006), Large variations in Holocene solar activity: Constraints from 10Be in the Greenland Ice Core Project ice core, *J. Geophys. Res.*, *111*, doi:10.1029/2005JA011500.

Webb, P. A., R. F. Benson, and J. M. Grebowsky (2006), Technique for determining midlatitude O+/H+ transition heights from topside ionograms, *Radio Sci.*, *41*, RS6S34, doi:10.1029/2005RS003391.

Weimer, D. R. (2001), Maps of ionospheric field-aligned currents as a function of the interplanetary magnetic field derived from Dynamics Explorer 2 data, *J. Geophys. Res.*, *106*(12), 889-12,902.

Wu, Y., J. Walker, C. Peters-Lidard, D. Schwede, R. Dennis, and W. Robarge (2006a), Modeling Bi-directional ammonia gas exchanges between the atmosphere and biosphere, I. Parameterization of ammonia compensation point, *Agricultural and Forest Meteorology*, submitted.

Wu, Y., J. Walker, C. Peters-Lidard, D. Schwede, R. Dennis, and W. Robarge (2006b), Role of leaf surface water in the bi-directional ammonia exchange between the atmosphere and terrestrial biosphere, Peer-reviewed Proceedings of the Workshop on Agricultural Air Quality: State of the Science, Bolger Conference Center, pp 1250-1253, Potomac, MD, 4-8 June.

Yu, H., Y. J. Kaufman, M. Chin, G. Feingold, L. A. Remer, T. L. Anderson, Y. Balkanski, N. Bellouin, O. Boucher, S. Christopher, P. DeCola, R. Kahn, D. Koch, N. Loeb, M. S. Reddy, M. Schulz, T. Takemura, and M. Zhou (2006), A review of measurement-based assessments of the aerosol direct radiative effect and forcing, *Atmos. Chem. Phys.*, *6*, 613-666, 2006. SRef-ID: 1680-7324/acp/2006-6-613.

Zaitchik, B. F., M. Rodell, and R. H. Reichle (2007), Assimilation of GRACE terrestrial water storage data into a land surface model: Results for the Mississippi River basin, *Journal of Hydrometeorology*, submitted.

Zhang, M. H., and J. L. Lin (1997), Constrained variational analysis of sounding data based on column-integrated budgets of mass, heat, moisture, and momentum: Approach and application to ARM measurements, *J. Atmos. Sci.*, *54*, 1503-1524.

Zhang, Q., F. Hall, E. Mittledon, and K., Hummerich (2007), Interannual comparison of spectral reflectance, vegetation indices, fAPARchl and LUEchl, *Remote Sens. Environ.*, submitted.

Zhou, Y. P., D. P. Kratz, A. C. Wilber, S. K. Gupta, and R. D. Cess (2006), An Improved Algorithm for Retrieving Surface Downwelling Longwave Radiation from Satellite Measurements, *J. Geophys. Res.*, submitted.

Zhou, Y. P., W.-K. Tao, A. Y. Hou, W. Olson, C.-L. Shie, K.-M. Lau, M.-D. Chou, X. Lin, and M. Grecu (2006), Use of High-Resolution Satellite Observations to Evaluate Cloud and Precipitation Statistics from Cloud-Resolving Model Simulations, Part I: South China Sea Monsoon Experiment, *J. Atmos. Sci.*, submitted.

Zhou, Y., S. C. Tsay, P. S. Yeh, and W. J. Wiscombe (2006), Physics-based Lossless Compression of Hyperspectral Data: How Much Improvement Can It Provide? *IEEE Trans. Geosci. Remote Sens.*, submitted.

Ziemke, J. R., S. Chandra, B. N. Duncan, L. Froidevaux, P. K. Bhartia, P. F. Levelt, and J. W. Waters (2006), Tropospheric ozone determined from Aura OMI and MLS: Evaluation of measurements and comparison with the Global Modeling Initiative's Chemical Transport Model, *J. Geophys. Res.*, *111*, D19303, doi:10.1029/2006JD007089.

Peer-Reviewed Publications

Abdou, W. A., S. H. Pilorz , M. C. Helmlinger, C. Bruegge, D. J. Diner, J. E. Conel,, J. V. Martonchik, C. K. Gatebe, M. D. King, and P.V. Hobbs (2006), Sua Pan Bidirectional Reflectance: A case study of the surface products of the Multi-angle Imaging SpectroRadiometer (MISR) 2000, *IEEE Trans. Geosci. Remote Sens.*, *44*(7), 1699-1706.

Alpert, P., D. Niyogi, R. A. Pielke Sr., J. L. Eastman, Y. K. Xue, and S. Raman (2006), Evidence for carbon dioxide and moisture interactions from the leaf cell up to global scales: Perspective on human-caused climate change, *Global and Planetary Change, Special Issue, 54*, 202-208.

Antón, M., V. E. Cachorro, J. M. Vilaplana, N. A. Krotkov, A. Serrano, C. Toledano, B. de la Morena, and J. R. Herman (2006), TOMS retrievals of erythemal UV irradiances and daily doses compared with Brewer ground-based measurements at El Arenosillo (Spain), *J. Geophys.Res.*, manuscript # 2006JD007254, in press.

Anyamba, A., J. P Chretien, P. Formenty, J. Small, C. J. Tucker, H. Bushra, V. Martin, and K. J. Linthicum (2006), Rift Valley fever potential, Arabian Peninsula, *Emerging Infectious Diseases, 12*, 518-520.

Anyamba, A., J. P. Chretien, J. Small, C. J. Tucker, and K. J. Linthicum(2006), Developing climate anomalies suggest potential disease risks for 2006-2007, *International Journal of Health Geographics, 5*(60), doi: 10.1186/1476-072X-5-60, 2006.

Arimoto, R., Y. J. Kim, Y. P. Kim, P. K. Quinn, T. S. Bates, T. L. Anderson, S. Gong, I. Uno, M. Chin, B. J. Huebert, A. D. Clarke, Y. Shinozuka, R. J. Weber, J. R. Anderson, S. A. Guazzotti, R. C. Sullivan, D. A. Sodeman, K. A. Prather, and I. Sokolik (2006), Characterization of Asian dust during ACE-Asia, *Global Planetary Change, 52*, 23-56, doi:10.1016/j.gloplacha.2006.02.013.

Asgharzadeh, M., R. R. B. von Frese, H. R. Kim, T. E. Leftwich, and J. W. Kim (2007), Spherical prism gravity effects by Gauss-Legendre quadrature integration, *Geophys. J. Int.*, in-press.

Atlas, R., S.-J. Lin, B.-W. Shen, O. Reale, and K.-S. Yeh (2007), Improving Hurricane Prediction through innovative global modeling, in *Extending the Horizons*, edited by E. K. Baker, A. Joseph, A. Mehrotra, and M. A. Trick, pp. 1-14, Springer, New York.

Atlas, R., S.-J. Lin, B.-W. Shen, O. Reale, and K.-S. Yeh (2007), Improving Hurricane Prediction through Innovative Global Modeling, in *Extending the Horizons: Advances in Computing, Optimization, and Decision Technologies*, p. 1-14, Springer, New York.

Bacmeister, J. T., M. J. Suarez, and F. Robertson (2006), Rain re-evaporation, Boundary layer convection interaction and Pacific rainfall patterns in an AGCM, *J. Atmos. Sci.*, *63*, 3383-3403, doi: 10.1175/JAS3791.1

Bates, T. S., T. L. Anderson, T. Bond, O. Boucher, G. Carmichael, A. Clarke, K. Duckenfield, C. Erlick, L. Horowitz, H. Maring, A. McComiskey, A. Middlebrook, K. Noone, J. Ogren, J. Penner, A. R. Ravishankara, D. L. Savoie, S. Schwartz, P. K. Quinn, and R. J. Weber (2006), Aerosol direct radiative forcing over the Northwest Atlantic, Northwest Pacific, and North Indian Oceans: Estimates based on in-situ chemical and optical measurements and chemical transport modeling, *Atmos. Chem. Phys.*, *6*, 175-362.

Beirle, S., N. Spichtinger, A. Stohl, K. Cummins, T. Turner, D. Boccippio, O. R. Cooper, M. Wenig, M. Grzegorski, U. Platt, and T. Wagner, Estimating the NOx produced by lightning from GOME and NLDN data: a case study in the Gulf of Mexico, *Atmos. Chem. Phys.*, *6*, 1075-1089.

Beirle, S., U. Platt, T. Wagner, J. Gleason, and M. Wenig (2007), Dioxide Pollution from Space, in *Glimpses of a Changing World*, pp. 74-77, Cambridge University Press, Boston, MA, in press.

Bélanger, S., H. Xie, N. Krotkov, P. Larouche, W. F. Vincent, and M. Babin (2006), Photomineralization of terrigenous dissolved organic matter in Arctic coastal waters from 1979 to 2003: Interannual variability and implications of climate change, *Global Biogeochem. Cycles*, *20*, GB4005, doi:10.1029/2006GB002708.

Benna, M., and P. Mahaffy (2006), 3-D MHD simulation of the solar wind interaction with comets, in *Advances in Geosciences Vol. 3*, Edited by W. Ip and A. Bhardwaj, 121-202, Word Scientific, Singapore.

Benna, M., and P. Mahaffy (2006), Multi-fluid model of comet 1P/Halley, *Planet. Space Sci.*, in press.

Benna, M., and P. Mahaffy (2006), New multi-fluid model of comet 26P/Grigg-Skjellerup and extrapolation to comet 67P/Churyumo-Gerasimenko, *Geophys. Res. Lett.*, *33*(10), L10103.

Benson, C. M., K. Drdla, G. E. Nedoluha, E. P. Shettle, J. Aflred, M. Fromm, and K. W. Hoppel (2006), Polar stratospheric clouds in the 1998-2003 Antarctic vortex: Microphysical modeling and Polar Ozone and Aerosol Measurement (POAM) III observations, *J. Geophys. Res.*, *111*, D18206, doi:10.1029/2005JD006948.

Benson, C. M., K. Drdla, G. E. Nedoluha, E. P. Shettle, K. W. Hoppel, and R. M. Bevilacqua (2006), Microphysical modeling of southern polar dehydration during the 1998 winter and comparison with POAM III observations, *J. Geophys. Res.*, *111*, D07201, doi:10.1029/2005JD006506.

Bian, H., S. R. Kawa, M. Chin, S. Pawson, Z. Zhu, P. Rasch, and L. Wu (2006), A Test of the representation of Convective Cloud Transport in a Model of CO_2 Transport, *Tellus*, *58*(5), 463-475.

Bosilovich, M. and J.-D. Chern (2006), Simulation of water sources and precipitation recycling for the MacKenzie, Mississippi and Amazon river basins, *J. Hydrometeorology*, *7*, 312-329.

Brasseur, G. P., M. Schultz, C. Granier, M. Saunois, T. Diehl, M. Botzet, E. Roeckner, and S. Walters (2006), Impact of Climate Change on the Future Chemical Composition of the Global Troposphere, *J. Clim.*, *19*, 3932-3951.

Braun, A., H. R. Kim, B. Csatho, and R. R. von Frese (2007), Gravity-inferred crustal thickness of Greenland, *Earth Planet. Sci. Lett.*, in press.

Braun, S. A., and L. Wu (2007), A numerical study of Hurricane Erin (2001), Part II: Shear and the organization of eyewall vertical motion, *Mon. Wea. Rev.*, in press.

Brinig, V. N., M. Thurai, K. Nakagawa, G. J. Huang, T. Kobayashi. A. Adachi, H. Hanado, and S. Sekizawa (2006), Rainfall Estimation from C-Band Polarimetric Radar in Okinawa, Japan: Comparison with 2D-Video Disdrometer and 400 MHz Wind Profiler, *Journal of Meteorological Society of Japan*, *84*(4), 705-724.

Bucsela, E. J., E. A. Celarier, J. F. Gleason, M. O. Wenig, J. P. Veefkind, K. F. Boersma, and E. Brinksma (2006), Algorithm for NO_2 vertical column retrieval from the Ozone Monitoring Instrument, *IEEE Trans. Geo. Rem. Sens.*, *44*(5), 1245-1258.

Carn, S. A., N. A. Krotkov, A. J. Krueger, K. Yang, and P. F. Levelt (2007), Sulfur dioxide emissions from Peruvian copper smelters detected by the Ozone Monitoring Instrument, *Geophys. Res. Lett.*, in press.

Carn, S. A., N. A. Krotkov, K. Yang, R. M. Hoff, A. J. Prata, A. J. Krueger, S. C. Loughlin, and P. F. Levelt (2007), Extended observations of volcanic SO_2 and sulfate aerosol in the stratosphere, *Atmos. Chem. Phys. Discuss.*, *7*, 2857-2871.

Cede, A., J. Herman, A. Ritcher, N. Krotkov, and J. Burrows (2006), Measurements of Nitrogen Dioxide Total Column Amounts at Goddard Space Flight Center Using a Brewer Spectrometer in Direct Sun Mode, *J. Geophys. Res.*, *111*, D05304, doi:10.1029/2005JD006585.

Chandra, S., J. R. Ziemke, M. R. Schoeberl, L. Froidevaux, W. G. Read, P. F. Levelt, and P. K. Bhartia (2007), Effects of the 2004 El Nino on tropospheric ozone, *Geophys. Res. Lett.*, in press.

Chretien J. P., A. Anyamba, S. Bedno, R. Breiman, C. Njuguna, S. Sang, K. Sergon, A. Powers, M. Ball, C. Onyango, J. Small, C. J. Tucker, and K. J. Linthicum (2007), Drought-associated Chikungunya Emergence along Coast East Africa, *The American Journal of Tropical Medicine and Hygiene*, *76*(3), 405–407.

Chu, D. A., and L. A. Remer (2006), MODIS observation of aerosols from EOS Terra and Aqua satellites, in *Earth Science Satellite Remote Sensing, Vol. 1: Science and Instruments*, edited by J. Qu, W. Gao, M. Kafatos, and V. V. Salomonson, pp. 93-109, ISBN10 3-540-35606-1, Springer, New York.

Cooper, O. R., A. Stohl, M. Trainer, A. Thompson, J. C. Witte, S. J. Oltmans, B. J. Johnson, J. Merrill, J. L. Moody, G. Morris, D. Trasick, G. Forbes, P. Nedelec, F. C. Fehsenfeld, J. Meagher, M. J. Newchurch, F. J. Schmidlin, S. Turquety, J. H. Crawford, K. E. Pickering, R. C. Cohen, T. Bertarm, P. Wooldrige, and W. H. Brune (2006), Large upper tropospheric ozone enhancement sabove mid-latitude North America during summer: In situ evidence from the IONS and MOZAIC ozone monitoring network, *J. Geophys. Res.*, *111*, D24S05, doi: 10.1029/2006JD007306.

Curtis, S., A. Salahuddin, R. Adler, G. Huffman, G. Gu, and Y. Hong (2007), Precipitation Extremes Estimated by GPCP and TRMM: ENSO Relationships, GEWEX special issue of the *J. Hydromet.*, in press.

Curtis, S., A. Salahuddin, R. F. Adler, G. J. Huffman, G. Gu, and Y. Hong (2007), Precipitation extremes estimated by GPCP and TRMM: ENSO relationships, *Journal of Hydrometeorology*, in press.

Curtis, S., R. F. Adler, G. J. Huffman, G. Gu, D. Bolvin, and E. Nelkin (2006), Comments on "El Niño: Catastrophe or opportunity," *Journal of Climate*, *19*, 6439-6442.

Dai, A., X. Lin, and K.-L. Hsu (2007), The Diurnal Cycle of Precipitation in Surface and Satellite Observations over Low- and Mid- latitudes, *Climate Dynamics*, in press.

de Goncalves, L. G. G., W. J. Shuttleworth, E. L. Burke, P. Houser, D. Toll, M. Rodell, and K. Arsenault (2006), Toward a South America Land Data Assimilation System: Aspects of land surface model spin-up using the Simplified Simple Biosphere, *J. Geophys. Res.*, *111*, D17110, doi:10.1029/2005JD006297.

Dentener, F., D. Stevenson, K. Ellingsen, T. van Noije, M. Schultz, M. Amann, C. Atherton, N. Bell, D. Bergmann, I. Bey, L. Bouwman, T. Butler, J. Cofala, B. Collins, J. Drevet, R. Doherty, B. Eickhout, H. Eskes, A. Fiore, M. Gauss, D. Hauglustaine, L. Horowitz, I. S. A. Isaksen, B. Josse, M. Lawrence, M. Krol, J. F. Lamarque, V. Montanaro, J. F. Müller, V. H. Peuch, G. Pitari, J. Pyle, S. Rast, J. Rodriguez, M. Sanderson, N. H. Savage, D. Shindell, S. Strahan, S. Szopa, K. Sudo, R. Van Dingenen, O. Wild, and G. Zeng (2006), The global atmospheric environment for the next generation, *Environ. Sci. Technol.*, *40*, 3586-3594.

Dentener, F., S. Kinne, T. Bond, O. Boucher, J. Cofala, S. Generoso, P. Ginoux, S. Gong, J. Hoelzemann, A. Ito, L. Marelli, J. Penner, J.-P. Putaud, C. Textor, M. Schulz, G. v. d. Werf, and J. Wilson (2006), Emissions of primary aerosol and precursor gases in the years 2000 and 1750 -prescribed data-sets for AeroCom, *Atmos. Chem. Phys.*, *6*, 4321-4344.

Dentener, F., S. Kinne, T. Bond, O. Boucher, J. Cofala, S. Generoso, P. Ginoux, S. Gong, J. Hoelzemann, A. Ito, L. Marelli, J. Penner, J.-P. Putaud, C. Textor, M. Schulz, G. v. d. Werf, and J. Wilson (2007), An AeroCom experiment, *Atmos. Chem. Phys. Discuss.*, *7*, 1699-1723.

Dong, J., J.P. Walker, P. R. Houser, and C. Sun (2006), Scanning multichannel microwave radiometer snow water equivalent assimilation, *J. Geophys. Res.*, in press.

Dong, J., W. Ni-Meister, and P. R. Houser (2006), Impacts of vegetation and cold season processes on soil moisture and climate relationships over Eurasia, *J. Geophys. Res.*, in press.

Douglass, A. R., R. S. Stolarski, S. E. Strahan, and B. C. Polansky (2006), Sensitivity of Arctic ozone loss to polar stratospheric cloud volume and chlorine and bromine loading in a chemistry and transport model, *Geophys. Res. Lett.*, *33*, L17809, doi:10.10.29/2006GL026492.

Dubovik, O., A. Sinyuk, T. Lapyonok, B. N. Holben, M. Mishchenko, P. Yang, T. F. Eck, H. Volten, O. Munoz, B. Veihelmann, W. J. van der Zande, J. F. Leon, M. Sorokin, and I. Slutsker (2006), Application of spheroid models to account for aerosol particle nonsphericity in remote sensing of desert dust, *J. Geophys. Res.*,*111*(D11), D11208.

Duncan, B. N., S. E. Strahan, and Y. Yoshida (2007), Model study of cross-tropopause transport of biomass burning pollution, *Atmos. Chem. Phys. Disc.*, *7*, 2197-2248.

Edwards, D. P., L. K. Emmons, J. C. Gille, D. A. Chu, J.-L. Attie, L. Giglio, S. W. Wood, J. Haywood, M. N. Deeter, S. T. Massie, D. C. Ziskin, and J. R. Drummond (2006), Satellite observed emission from southern hemisphere biomass burning, *J. Geophy. Res.*, *111*, D14312, doi:10.1029/2005JD006655.

Engel-Cox, J. A, R. M. Hoff, R. Rogers, F. Dimmick, A. C. Rush, J. J. Szykman, J. Al-Saadi, D. Allen Chu, and E. R. Zell (2006), Using particulate matter concentration and lidar and satellite optical depth to build a 3-Dimensional integrated air quality monitoring capability, *Atmos. Environ*., 40, 8056-8067.

Errico, R. M. (2007), Interpretations of an adjoint--derived observational impact measure, *Tellus*, in press.

Errico, R. M., J.-F. Mahfouf, and P. Bauer (2007), Issues regarding the assimilation of cloud and precipitation data, *J. Atmos. Sci.*, in press.

Eyring, V., D. S. Stevenson, A. Lauer, F. J. Dentener, T. Butler, W. J. Collins, K. Ellingsen, M. Gauss, D. A. Hauglustaine, I. S. A. Isaksen, M. G. Lawrence, A. Richter, J. M. Rodriguez, M. Sanderson, S. E. Strahan, K. Sudo, S. Szopa, T. P. C. van Noije, and O. Wild (2007), Multi-model simulations of the impact of international shipping on atmospheric chemistry and climate in 2000 and 2030, *Atmos. Chem. Phys.*, *7*, 757-780.

Fan, J., R. Zhang, G. Li, W.-K. Tao, and X. Li (2007), Simulations of cumulus clouds using a spectral microphysics cloud-resolving model, *J. Geophys. Res.*, *112*, D04201, doi:10.1029/2006JD007688.

Fensholt, R., A. Anyamba, S. Stisen, I. Sandholt, E. Pak, and J. Small (2007), Comparisons of compositing period length for vegetation index data from Polar-orbiting and Geostationary satellites for the Cloud-prone region of West Africa. Special Issue: Cloud-prone and Rainy areas Remote Sensing (CARRS), *Photogrammmetric Engineering and Remote Sensing*, *73*(3), 297-310.

Gao, S., X. Li, W.-K. Tao, C.-L. Shie, and S. Lang (2007), Convective and moist vorticity vectors associated with three-dimensional tropical oceanic convection during KWAJEX, *J. Geophys. Res.* *112*, D01105, doi:10.1029/2006JD007179.

Gassó, S., and A. F. Stein (2007), Does dust from Patagonia reach the sub-Antarctic Atlantic Ocean, *Geophys. Res. Lett.*, *34*, L01801, doi: 10.1029/2006GL027693.

Georgieva, E. M., E. L. Wilson, M. Miodek, and W. S. Heaps (2006), Total column oxygen detection using Fabry-Perot Interferometer, *Opt. Engin.*, *45*(11), 115001.

Gobbi, G. P., Y. J. Kaufman, I. Koren, and T. F. Eck (2007), Classification of aerosol properties derived from AERONET direct sun data, *Atmos. Chem. Phys*., 7: 453-458.

Golynsky, A. V., M. Chiappini, D. Damaske, F. Ferraccioli, C. Finn, M. Ghidella, T. Ishihara, H. R. Kim, L. Kovacs, V. Masolov, P. Morris, Y. Nogi, R. von Frese (2006), ADMAP – A Digital Magnetic Anomaly Map of the Antarctic, in *Antarctica: Contributions to global earth sciences*, edited by D. K. Futterer, D. Damaske, G. Gleinschmidt, H. Miller, and F. Tessensohn, Springer-Verlag, New York, 93-104.

Grecu, M., and W. S. Olson (2006), Bayesian Estimation of Precipitation from Satellite Passive Microwave Observations Using Combined Radar–Radiometer Retrievals, *J. Appl. Meteorol. Climatol.*, *45*, 416-433.

Green J. L., and S. Boardsen (2006), Kilometric Continuum Radiation, *Radio Science Bulletin*, *318* (September 2006), 34-42.

Green J. L., S. Boardsen, L. Garcia, S. F. Fung, and B. W. Reinisch (2006), Reply to Comment on On the origin of whistler mode radiation in the plasmasphere by Green et al., *J. Geophys. Res.*, *111*, A09211, doi:10.1029/2006JA011622.

Green, J. L. Green, S. Boardsen, S. Odenwald, J. Humble, and K. A. Pazamickas (2006), Eyewitness reports of the great auroral storm of 1859, *Adv. Sp. Res.*, *38*, 145–154.

Green, J. L., and S. Boardsen (2006), Duration and extent of the great auroral storm of 1859, *Adv. Sp. Res.*, *38*, 130–135.

Grim, J. A., R. M. Rauber, M. K. Ramamurthy, B. F. Jewett, and M. Han (2007), High-resolution observations of the trowal/warm-frontal regions of two continental winter cyclones, *Mon. Wea. Rev.*, in press.

Grzegorski, M., M. Wenig, U. Platt, P. Stammes, N. Fournier, and T. Wagner (2006), The Heidelberg iterative cloud retrieval utilities (HICRU) and its application to GOME data, *Atmos. Chem. Phys.*, *6*, 4461-4476.

Gu, G., R. F. Adler, G. J. Huffman, and S. Curtis (2007), Tropical rainfall variability on interannual-to-interdecadal/longer-time scales derived from the GPCP monthly product, *Journal of Climate*, in press.

Halekas, J. S., G. T. Delory, D. A. Brain, R. P. Lin, M. O. Fillingim, C. O. Lee, R. A. Mewaldt, T. J. Stubbs, W. M. Farrell, and M. K. Hudson (2007), Extreme lunar surface charging during space weather events, *Geophys. Res. Lett.*, *34*, L02111, doi:10.1029/2006GL028517.

Han, M., R. M. Rauber, M. K. Ramamurthy, B. F. Jewett, and J. A. Grim (2007), Mesoscale Dynamics of the Trowal and Warm-frontal Regions of Two Continental Winter Cyclones, *Mon. Wea. Rev.*, in press.

Heald C., D. Jacob,,R. J. Park, B. Alenander, T. Duncan, and D. A. Chu (2006), Transpacific transport of Asian Anthropogenic aerosols and impact on surface air quality in the United States, 111, D14310, doi:10.1029/2005JD006847.

Heaps, W. S., E. L.Wilson, and E. M.Georgieva (2007), Precision measurement of atmospheric trace constituents using a compact Fabry-Perot Radiometer, *Int. J. High Speed Electr. Sys.*, in press.

Higgins, W., D. Ahijevych, J. Amador, A. Barros, E. H. Berbery, E. Caetano, P. Ciesielski, R. Cifelli, M. Cortez-Vazquez, A. Douglas, M. Douglas, G. Emmanuel, C. Fairall, D. Gochis, D. Gutzler, R. Johnson, C. King, T. Lang, M.-I. Lee, D. Lettenmaier, R. Lobato, V. Magaña, J. Meitin, K. Mo, S. Nesbitt, E. Pytlak, P. Rogers, S. Rutledge, J. Schemm, S. Schubert, F. Torres, A. White, C. Williams, A. Wood, R. Zamora, and C. Zhang (2006), The NAME 2004 Field Campaign and Modeling Strategy, *Bull. Amer. Meteorol. Soc.*, *87*(1), 79–94.

Hong, Y., and R.F. Adler (2007), Estimate Global SCS Curve Numbers using Satellite Remote Sensing and Geospatial Datasets, *Int. J. Remote Sens.*, in press.

Hong, Y., and R.F. Adler (2007), Towards an Early Warning System for Global Landslides Triggered by Rainfall and Earthquakes, *Int. J. Remote Sens.*, in press.

Hong, Y., D. Gochis, J.T. Chen, K.L. Hsu, and S. Sorooshian (2007), Diurnal Variation and Evolution of Rainfall Observed by both Satellite and Gauge in the North American Monsoon region, *J. Hydromet.*, in press.

Hong, Y., K.-L. Hsu, H. Moradkhani, and S. Sorooshian (2006), Uncertainty quantification of satellite precipitation estimation and Monte Carlo assessment of the error propagation into hydrologic response, *Water Resour. Res.*, *42*(8), W08421, 10.1029/2005WR004398.

Hong, Y., R. Adler, and G. Huffman (2006), Evaluation of the Potential of NASA Multi-satellite Precipitation Analysis in Global Landslide Hazard Assessment, *Geophys. Res. Lett., 33*, L22402, doi:10.1029/2006GL028010.

Hong, Y., R. Adler, and G. Huffman (2006), Use of Satellite Remote Sensing Data in mapping of global shallow landslides Susceptibility, *J. Natural Hazards*, DOI: 10.1007/s11069-006-9104-z.

Hong, Y., R. F. Adler, A. Negri, and G. J. Huffman (2006), Flood and Landslide Applications of Near Real-time Satellite Rainfall Estimation, *J. Natural Hazards*, DOI: 10.1007/s11069-006-9106-x.

Hong, Y., R.F. Adler, and G.J. Huffman (2007), An Experimental Global Monitoring System for Rainfall-triggered Landslides using Satellite Remote Sensing Information, *IEEE Trans. Geosci. Remote Sens.*, in press.

Hong, Y., Y. Chiang, Y. Liu, K.-L. Hsu, and S. Sorooshian (2006), Satellite-based Precipitation Estimation using Watershed Segmentation and Growing Hierarchical Self-Organizing Feature Mapping Techniques, *Int. J. Remote Sens, 27*(23), p5165-5184, DOI: 10.1080/01431160600763428.

Hossain, F., Y. Hong, and A. Wolf (2006), The Emerging Role of Satellite Rainfall Data in Improving the Hydropolitical Situation of Flood Monitoring in the Under-developed Regions of the World, *J. Natural Hazards*, DOI: 10.1007/s11069-006-9094-x.

Howell, S. G., A. D. Clarke, Y. Shinozuka, V. Kapustin, C. S. McNaughton, B. J. Huebert, S. J. Doherty, and T. L. Anderson (2006), Influence of relative humidity upon pollution and dust during ACE-Asia: Size distributions and implications for optical properties, *J. Geophys. Res., 111*, D06205, doi:10.1029/2004JD005759.

Hua X.-M., J. Pan, D. Ouzounov, A. Lyapustin, Y. Wang, K. Tewar, G. Leptoukh, and B. Vollmer (2007), A spatial pre-screening technique for Earth observation data, *IEEE Geoscience and Remote Sensing Letters, 4*(1), 152-156.

Huffman, G., R. Adler, D. T. Bolvin, G. Gu, E. J. Nelkin, K. P. Bowman, Y. Hong, E. F. Stocker, and D. B. Wolff (2007), The TRMM Multi-satellite Precipitation Analysis: Quasi-Global, Multi-Year, Combined-Sensor Precipitation Estimates at Fine Scale, *J. Hydromet., 8*(1), 38-55

Jacob, S. D., and C. J. Koblinsky (2007), Effect of precipitation on the upper ocean heat and salt budget during a hurricane passage, *Mon. Wea. Rev.*, in press.

Jessen, C., M. Rundgren, S. Björck, and R. Muscheler (2007), Climate forced atmospheric CO_2 variability in the early Holocene: evidence from a stomatal frequency reconstruction, *Global Planetary Change*, doi:10.1016/j.gloplacha.2006.11.035, in press.

Joiner, J., A. Vasilkov, K. Yang, and P. K. Bhartia (2006), Observations over hurricanes from the Ozone Monitoring Instrument, *Geophys. Res. Lett., 33*, L06807, doi:10.1029/2005GL025592

Juang, H.-M., H., W.-K. Tao, X.-P. Zeng, C.-L. Shie, J. Simpson, and S. Lang (2007), Parallelization of a cloud-resolving model for massively parallel computing by using message passing interface, *TAO*, in press.

Juang, H.-M., W.-K. Tao, X. Zeng, C.-L. Shie and J. Simpson (2007), Implementation of a message passing interfacing into a cloud-resolving model for massive parallel computing, *TAO*, in press.

Kazantzidis A, A. F. Bais, J. Grobner, J. R. Herman, S. Kazadzis, N. A.Krotkov, E. Kyro, P. N. den Outer, K. Garane, P. Gorts, K. Lakkala, C. Meteli, H. Slaper, R. B. Tax, and T. Turunen (2006), Comparison of satellite-derived UV irradiances with ground-based measurements at four European stations, accepted, *J. Geophys.Res.*, in press.

Kim, H. R., R. R. B. von Frese, P. T. Taylor, A. V. Golynsky, and L. R. Gaya-Pique (2007), Improved magnetic anomalies of Antarctic lithosphere from satellite and near-sruface observations, *Geophys. Int.*, in press.

Kim, J. W., J. S. Hwang, R. R. B. von Frese, H. R. Kim, and S. H. Lee (2007), Geomagnetic Field Modeling from Satellite Attitude Control Magnetometer Measurements, *J. Geophys. Res.*, in-press.

Kim, M. K., K. M. Lau, M. Chin, K. M. Kim, Y. C. Sud, and G. Walker (2006), Atmospheric Teleconnection over Eurasia induced by aerosol radiative forcing during boreal spring, *J. Climate*, *19*, 4700-4718.

Kinne, S., M. Schulz, C. Textor, S. Guibert, Y. Balkanski, S. E. Bauer, T. Berntsen, T. F. Berglen, O. Boucher, M. Chin, W. Collins, F. Dentener, T. Diehl, R. Easter, J. Feichter, D. Fillmore, S. Ghan, P. Ginoux, S. Gong, A. Grini, J. Hendricks, M. Herzog, L. Horowitz, I. Isaksen, T. Iversen, A. Kirkevåg, S. Kloster, D. Koch, J. E. Kristjansson, M. Krol, A. Lauer, J. F. Lamarque, G. Lesins, X. Liu, U. Lohmann, V. Montanaro, G. Myhre, J. Penner, G. Pitari, S. Reddy, O. Seland, P. Stier, T. Takemura, and X. Tie (2006), An AeroCom initial assessment optical properties in aerosol component modules of global models, *Atmos. Chem. Phys.*, *6*, 1815-1834.

Kis, K., P. T. Taylor, S. Puszta, G. Wittmann, H. R. Kim, B. Toronyi, and T. Mayer-Gurr (2006), Intepretation of the CHAMP magnetic measurements over the Pannonian Basin (in Hungarian), *Mag. Geof.*, *47*(1), 21-27.

Kis, K., P. T. Taylor, S. Puszta, G. Wittmann, H. R. Kim, B. Toronyi, and T. Mayer-Gurr (2006), Intepretation of the CHAMP magnetic measurements over the Pannonian Basin (in Hungarian), *Mag. Geof.*, *47*, 21-27.

Köhler, P., R. Muscheler, and H. Fischer (2006), A model-based interpretation of low-frequency changes in the carbon cycle during the last 120,000 years and its implications for the reconstruction of atmospheric 14C, Geochemistry, *Geophysics, Geosystems*, *7*(11), Q11N06, doi:10.1029/2005GC001228.

Kraus, S., K. Degreif, N. Smoljar, M. Korniyenko, R. Kalkenings, T. Wagner, M. Wenig, B. Jähne, and U. Platt, Chapter 5: Spectroscopic Imaging, in *Image Sequence Analysis to Investigate Dynamic Processes*, *Lecture Notes in Computer Science*, Springer, New York, in press..

Krotkov, N. A., S. A. Carn, A. J. Krueger, P. K. Bhartia, and K. Yang (2006), Band Residual Difference algorithm for retrieval of SO_2 from the Aura Ozone Monitoring Instrument (OMI), *IEEE Trans. Geosci. Remote Sensing, AURA Special Issue*, *44*(5), 1259-1266, doi:10.1109/TGRS.2005.861932

Krueger, A., N. Krotkov, and S. Carn (2007), El Chichon: The genesis of volcanic sulfur dioxide monitoring from space, *Special issue of J.Volcanology and Geothermal Research on the 25th anniversary of the El Chichon eruption*, in press.

Kumar, N., D. Allen Chu, and A. Foster (2007), An empirical relationship between PM2.5 and aerosol optical depth in Delhi metropolitan, *Atmos. Environ.*, in press.

Kumar, S. V., C. D. Peters-Lidard, Y. Tian, P. R. Houser, J. Geiger, S. Olden, L. Lighty, J. L. Eastman, B. Doty, P. Dirmeyer, J. Adams, K. Mitchell, E. F. Wood, and J. Sheffield (2006), Land Information System – An Interoperable Framework for High Resolution Land Surface Modeling, *Environmental Modeling and Software, 21*, 1402-1415.

Kumar, S. V., T. A. Doby, J. W. Baugh Jr., E. D. Brill, and S. R. Ranjithan (2006), Genetic Algorithm-based design of water distribution networks using a cluster of workstations, *ASCE Journal of Water Resources Planning and Management, 132*(5), 378-384.

Kunhikrishnan, T., M. G. Lawrence, R. von Kuhlmann, M. O. Wenig, A. Richter and J. P. Burrows (2006), Regional NOx emission strength for the Indian subcontinent and the impact of emissions from India and neighboring countries on regional O_3 chemistry in light of seasonal meteorology, *J. Geophys. Res., 111*(D15), D15301.

Kuo, K.-S., E. A. Smith, R. Meneghini, and A. Mugnai (2007), Fundamental error source in radar remote sensing of precipitation: Pulse averaging requirements assuming fractal distribution of rain drops, *J. Atmos. Ocean. Tech.*, in press.

Lary, D. J., and A. Koratkar (2006), Data Assimilation and Objectively Optimized Earth Observation, Chapter 16, Advances in Science: Earth Science, Imperial College Press.

Lary, D. J., and L. R. Lait (2006), Using probability distribution functions for satellite validation, *IEEE Trans. On Geoscience and Remote Sensing, 44*(5), 1359-1366.

Lau, K. M., and K. M. Kim (2006), Observational relationships between aerosol and Asian monsoon rainfall, and circulation, *Geophys. Res. Lett., 33*, L21810, doi:10.1029/2006GL027546.

Lau, K. M., S. S. P. Shen, K.-M. Kim, and H Wang (2006), A multimodel study of the twentieth-century simulations of Sahel drought from the 1970s to 1990s, *J. Geophys. Res., 111*, D07111, doi:101029/2005JD006281.

Lau, K.-M., and K.-M. Kim (2007), Does aerosol weaken or strengthen the Asian monsoon? *Mountains: Witnesses of Global Changes-Research in the Himalaya and Karakoram*, edited by R. Baudo, G. Tartari, and E. Vuillermoz, Elsevier Science, in press.

Lau, K.-M., K.-M. Kim, and M.-I. Lee (2007), Characteristics of diurnal and seasonal cycles in global monsoon systems, *J. Meteor. Soc. Japan*, n press.

Lau, K.-M., M.-K. Kim, and K.-M. Kim (2006), Asian summer monsoon anomalies induced by aerosol direct forcing: the role of the Tibetan Plateau, *Climate Dynamics, 26*(7-8), 855-864, doi:10.1007/s00382-006-0114-z.

Lau, K.-M., S. Shen, K.-M. Lau, and H. Wang (2006), A multi-model study of the 20th century simulations of Sahel drought from the 1970s to 1990s, *J. Geophys. Res.*, *111*, D0711, doi:10.1029/2005JD006281.

Lau, W. K. M., K.-M. Kim, and M.-I. Lee (2007), Characteristics of diurnal and seasonal cycles in global monsoon systems, *J. Meteorol. Soc. Japan*, *85*, Special Issue, 1-14.

Lavraud, B., M. F. Thomsen, B. Lefebvre, S. J. Schwartz, K. Seki, T. D. Phan, P. J. Cargill, Y. Wang, A. Fazakerley, H. Reme, and A. Balogh (2006), Evidence for newly closed magnetosheath field lines at the dayside magnetopause under northward IMF, *J. Geophys. Res.*, *111*, A05211, doi:10.1029/2005JA011266.

Lawford, R. G., P. Arkin, D. Lettenmaier, and J. Roads (2007), Past and future GEWEX contributions to large-scale hydrometeorology, *J. Hydromet.*, in press.

Lawford, R., M. Bosilovich, S. Eden, S. Benedict, C. Brown, A. Gruber, P. Houser, K. Hou, J. Huang, W. Lau, T. Meyers, K. Mitchell, C. Peters-Lidard, J. Roads, M. Rodell, S. Sorooshian, D. Tarpley, and S. Williams (2006), U.S. Contributions to the CEOP, *BAMS*, *87*(7), 927-939.

Le Vine, D. M., S. D. Jacob, E. Dinnat and P. deMattaeis (2007), The Influence of Antenna Pattern on Faraday Rotation in Remote Sensing of Sea Surface Salinity at L-band, *IEEE Trans. Geoscience and Remote Sensing*, in press.

Lee, M.-I., S. D. Schubert, M. J. Suarez, A. Kumar, I. M. Held, H.-K. Kim, J. Ploshay, N.-C. Lau, and J. Schemm (2007a), An analysis of the warm season diurnal cycle over the continental United States and northern Mexico in general circulation models, *J. Hydromet.*, in press.

Lee, M.-I., S. D. Schubert, M. J. Suarez, I. M. Held, A. Kumar, T. L. Bell, J.-K. E. Schemm, N.-C. Lau, J.-J. Ploshay, H.-K. Kim, J. J. Ploshay, and S.-H. Yoo (2007b), Sensitivity to horizontal resolution in the AGCM Simulations of warm season diurnal cycle of precipitation over the United States and northern Mexico, *J. Clim.*, in press.

Lettenmaier, D. P., A. de Roo, and R. Lawford (2006), Toward a capability for global flood forecasting, *WMO Bulletin*, *55*(3), 185–190.

Lin, J. L., B. E. Mapes, K. M. Weickmann, G. N. Kiladis, S. D. Schubert, M. J. Suarez, J. T. Bacmeister, and M.-I. Lee (2007), North American monsoon and associated intraseasonal variability simulated by IPCC AR4 coupled GCMs, *J. Climate*, in press.

Lin, J. L., K. M. Weickmann, G. N. Kiladis, B. E. Mapes, S. D. Schubert, M. J. Suarez, J. T. Bacmeister, and M.-I. Lee (2007), Intraseasonal variability associated with Asian summer monsoon simulated by 14 IPCC AR4 coupled GCMs, *J. Climate*, in press.

Lin, X., J.-L. F. Li, M. J. Suarez, A. M. Tompkins, D. E. Waliser, M. M. Rienecker, J. Bacmeister, J. H. Jiang, C. M. Tassone, J.-D. Chern, B. Chen, and H. Su (2006), A view of hurricane Katrina with early 21st century technology, *Eos.*, *87*, 433, 440.

Lin, X., S. Q. Zhang, and A. Y. Hou (2006) Variational assimilation of global microwave rainfall retrievals: Physical and dynamical impacts on GEOS analyses, American Meteorological Society, *Mon. Wea. Rev.*, in press.

Linthicum, K. J., A. Anyamba, S. C. Britch, J.-P. Chretien, R. L. Erickson, J. Small , C. J. Tucker, K. Bennett, R. Mayer, E. Schmidtman , T. G. Andreadis, J. F. Anderson, W. Wilson, J. Freier, A. James, R. Miller, B. S. Drolet, S. Miller, C. Tedrow, C. Bailey, D. Strickman, D. R. Barnard, G. G. Clark, and L. Zou (2007), A Rift Valley fever risk surveillance system for Africa using remotely sensed data: Potential for use on other continents, *Veternaria Italiano*, in press.

Liu, A. K., Y. Zhao, and M. K. Hsu (2006), Ocean surface drift revealed by synthetic aperture radar images, *Eos, Trans., AGU, 87*(24), 233 & 239.

Liu, H., J. H. Crawford, R. B. Pierce, P. Norris, S. E. Platnick, G. Chen, J. A. Logan, R. M. Yantosca, M. J. Evans, C. Kittaka, Y. Feng and X. Tie (2006), Radiative effect of clouds on tropospheric chemistry in a global three-dimensional chemical transport model, *J. Geophys. Res., 111*, D20303, doi:10.1029/2005JD006403.

Loughner, C. P., D. J. Lary, L. C. Sparling, R. C. Cohen, P. DeCola, and W. R. Stockwell (2006), A Method to Determine the Spatial Resolution Required to Observe Air Quality from Space, *IEEE Transactions on Geoscience and Remote Sensing, 45*(5), 1308-1314.

Lundstedt, H., L. Liszka, R. Lundin, and R, Muscheler (2006), Long-term solar activity explored with wavelet methods, *Annales Geophysicae, 24*, 1-9.

Luo, C., C. Zender, H. Bian, and S. Metzger (2007), Role of ammonia chemistry and coarse mode aerosols in global climatological inorganic aerosol distributions, *Atmospheric Enivronment*, in press.

Lyapustin, A., Y. Wang, J. Martonchik, J. L. Privette, B. Holben, I. Slutsker, A. Sinyuk, A. Smirnov (2006), Local analysis of MISR surface BRF and albedo over GSFC and Mongu AERONET sites, *IEEE Trans. Geosci. Rem. Sens., 44*, 1707-1718.

Lyapustin, A., Y. Wang, J. Martonchik, J. Privette, B. Holben, I. Slutsker, A. Sinyuk, and A. Smirnov (2006), Local analysis of MISR surface BRF and albedo over GSFC and Mongu AERONET sites, *IEEE Trans. Geosci. Remote Sens., 44*, 1707-1718.

Lyapustin, A., Y. Wang, R. Kahn, J. Xiong, A. Ignatov, R. Wolfe, A. Wu, B. Holben, and C. Bruegge (2007), Analysis of MODIS-MISR calibration differences using surface albedo around AERONET sites and cloud reflectance, *Rem. Sens. Environment, 107*, 12-21.

Lyapustin, A., Y. Wang, R. Kahn, J. Xiong, A. Ignatov, R. Wolfe, A. Wu, and C. Bruegge (2006), Analysis of calibration difference between MODIS and MISR. Proceedings of SPIE - Remote Sensing and Modeling of Ecosystems for Sustainability III, Vol. 6298, 62980X (Sep. 27, 2006) - doi: 10.1117/12.680896.

Marshak, A., S. Platnick, T. Varnai, G. Wen, and R. F. Cahalan (2006), Impact of three-dimensional radiative effects on satellite retrievals of cloud droplet sizes, *J. Geophys. Res., 111*, D09207, doi:10.1029/2005JD006686.

Martin, R. V., B. Sauvage, I. Folkins, C. E. Sioris, C. Boone, P. Bernath, and J. R. Ziemke (2007), Space-based constraints on the production of nitric oxide by lightning, *J. Geophys. Res.*, in press.

Meneghini, R., and L. Liao (2007), On the Equivalence of Dual-Wavelength and Dual-Polarization Equations for Estimation of the Raindrop Size Distribution, *J. Atmos. Oceanic Technol.*, in press.

Merka, J., D. Merkova, and D. Odstrcil (2007), A step toward data assimilation in solar wind research, *J. of Atmospheric and Solar-Terrestrial Physics*, *69*(1-2), 170-178, doi: 10.1016/j.jastp.2006.07.012.

Moradkhani, H., K. Hsu, Y. Hong, and S. Sorooshian (2006), Investigating the impact of remotely sensed precipitation and hydrologic model uncertainties on the ensemble streamflow forecasting, *Geophys. Res. Let.*, *33*(12), L12107, 10.1029/2006GL026855.

Morris, G. A., L. Branum-Martin, N. Harshman, S. D. Baker, E. Mazur, S. Dutta, T. Mzoughi, and V. McCauley (2006), Testing the test: Item response curves and test quality, *Am. J. Phys.*, *74*, 449 – 453.

Morris, G. A., S. Hersey, A. M. Thompson, S. Pawson, J. Eric Nielsen, P. R. Colarco, W. W. McMillan, A. Stohl, S. Turquety, J. Warner, B. J. Johnson, T. L. Kucsera, D. E. Larko, S. J. Oltmans, and J. C. Witte (2006), Alaskan and Canadian forest fires exacerbate ozone pollution over Houston, Texas, on 19 and 20 July 2004, *J. Geophys. Res.*, *111*, D24S03, doi:10.1029/2006JD007090.

Mussa, H., D. Lary, and R. Glen (2006), Building Structure-Property Predictive Models Using Data Assimilation, *Lectures in Computer Science*, *4216*, 64-73.

Nedoluha, G. E., C. M. Benson, K. W. Hoppel, J. Alfred, R. M. Bevilacqua, and K. Drdla (2007), Antarctic dehydration 1998-2003: POAM measurements and IMPACT results with four meteorological models, *J. Geophys. Res.*, *112*, doi:10.1029/2006JD007414, in press.

Nerger, L and W. W. Gregg (2007), Assimilation of SeaWiFS data into a global ocean-biogeochemical model using a local SEIK filter, *J. Mar. Syst.*, in press, doi:10.1016/j.jmarsys.2006.11.009

Nerger, L., S. Danilov, G. Kivman, W. Hiller, and J. Schröter (2007), Data assimilation with the Ensemble Kalman Filter and the SEIK filter applied to a finite element model of the North Atlantic, *J. Mar. Syst.*, *65*, 288-298

Nerger, L., S. Danilov, W. Hiller and J. Schröter (2006), Using sea level data to constrain a finite-element primitive-equation ocean model with a local SEIK filter, *Ocean Dynamics*, *56*, 634-649.

Norris, P. M., and A. M. da Silva (2006), Assimilation of satellite cloud data into the GMAO Finite Volume Data Assimilation System using a parameter estimation method. Part I: Motivation and algorithm description, *J. Atmos. Sci.*, in press.

Olsen, M. A., A. R. Douglass, R. S. Stolarski, and M. R. Schoeberl (2006), On detecting a trend in the residual circulation from observations of column HCl, *Geophys. Res. Lett.*, *33*, L14815, doi:10.1029/2006GL026214.

Pielke Sr., R. A., T. Matsui, G. Leoncini, T. Nobis, U. Nair, E. Lu, J. Eastman, S. Kumar, C. Peters-Lidard, Y. Tian, and R. Walko (2006), A new paradigm for parameterizations in numerical weather prediction and other atmospheric models, *National Weather Digest*, *30*, 93-99.

Pieterse, G., A. Bleeker, A. T. Vermeulen, Y. Wu, and J.W. Erisman (2006), High resolution modeling of atmosphere-canopy exchange of acidifying and eutrophying components and carbon dioxide for European forests, *Tellus-B*, TeB-06-04-0065.R, in press.

Pulkkinen, A (2007), Spatiotemporal characteristics of the ground electromagnetic field fluctuations in the auroral region and implications on the predictability of geomagnetically induced currents, in *Space Weather, Research towards Applications in Europe, Series: Astrophysics and Space Science Library*, edited by J. Lilensten, Vol. 344, 2007, XII, 332 p., Springer, New York.

Pulkkinen, A., A. Klimas, D. Vassiliadis, and V. Uritsky (2006), The role of stochastic fluctuations in the magnetosphere-ionosphere system: a stochastic model for the AE-index variations, *J.Geophys. Res., 111*, A10218, doi:10.1029/2006JA011661.

Pulkkinen, A., A. Klimas, D. Vassiliadis, V. Uritsky, and E. Tanskanen (2006), Spatiotemporal scaling properties of the ground geomagnetic field variations, *J.Geophys. Res., 111*, A03305, doi:10.1029/2005JA011294.

Pulkkinen, A., A. Viljanen, and R. Pirjola (2006), Estimation of geomagnetically induced current levels from different input data, *Space Weather, 4*, S08005, doi:10.1029/2006SW000229.

Pulkkinen, A., and R. Kataoka (2006), S-transform view of geomagnetically induced currents during geomagnetic superstorms, *Geophys. Res. Lett., 33*, L12108, doi:10.1029/2006GL025822.

Reichle, R. H., R. D. Koster, P. Liu, S. P. P. Mahanama, E. G. Njoku, and M. Owe (2006), Comparison and assimilation of global soil moisture retrievals from the Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E) and the Scanning Multichannel Microwave Radiometer (SMMR),, *J. Geophys. Res. – Atmos., 112*, D09108, doi:10.1029/2006JD008033.

Riishojgaard, L. P., R. Atlas, and G. D. Emmitt (2006), Reply (to comment by Stoffelen *et al.*), *J. Appl. Meteorol., 45*, 887-888.

Russell, P. B., J. Livingston, J. Redemann, B. Schmid, S. Ramirez, J. Eilers, R. Kahn, D. A. Chu, L. A. Remer, P. Quinn, M. J. Rood, and W. Wang (2007), Multi-Grid-Cell validation of satellite aerosol property retrieval in INTEX/ITCT/ICARTT, *J. Geophys. Res.*, in press.

Sakerin, S. M., D. M. Kabanov, A. V. Smirnov, B. N. Holben, I. Slutsker, D. Giles, and O. V. Kopelevich (2006), Variability of aerosol optical layer of the atmosphere in South Atlantic, in *Basic Researches of Oceans and Seas*, p. 127-145, edited by N.P. Laverov, Book 1, Nauka, Moscow, Russia.

Sauvage, B., R. V. Martin, A. van Donkelaar, and J. R. Ziemke (2007), Quantification of the factors controlling tropical tropospheric ozone and the South Atlantic maximum, *J. Geophys. Res.*, in press.

Schmid, B., R. Ferrare, C. Flynn, R. Elleman, D. Covert, A. Strawa, E. Welton, D. Turner, H. Jonsson, J. Redemann, J. Eilers, K. Ricci, A. G. Hallar, M. Clayton, J. Michalsky, A. Smirnov, B. Holben, and J.Barnard (2006), How well do state-of-the-art techniques measuring the vertical profile of tropospheric aerosol extinction compare?, *J.Geophys.Res., 111*, D05S07, doi: 10.1029/2005JD005837.

Schmidt, H., G. P. Brasseur, M. Charron, E. Manzini, M. A. Giorgetta, T. Diehl, V. I. Fomichev, D. Kinnison, D. Marsh, and S. Walters (2006), The HAMMONIA Chemistry Climate Model: Sensitivity of the Mesopause Region to the 11-year Solar Cycle and CO_2 Doubling, *J. Clim., 19*, 3903-3931.

Schoeberl, M. R., B. N. Duncan, A. R. Douglass, J. Waters, N. Livesey, W. Read, and M. Filipiak (2006), The carbon monoxide tape recorder, *Geophys. Res. Lett., 33*, L12811, doi:10.1029/2006GL026178.

Schoeberl, M. R., S. R. Kawa, A. R. Douglass, T. McGee, E. V. Browell, J. Waters, N. Livesey, W. Read, L. Froidevaux, M. L. Santee, H. C. Pumphrey, L. R. Lait, and L. Twigg (2006), Chemical observations of a polar vortex intrusion, *J. Geophys. Res., 111*(D20), D20306, doi:10.1029/2006JD007134.

Schubert, S. D., Y. Chang, M. J. Suarez, and P. J. Pegion (2007), ENSO and Wintertime Extreme Precipitation Events Over the Contiguous United States, *J. Climate*, in press.

Schulz, M., C. Textor, S. Kinne, Y. Balkanski, S. Bauer, T. Berntsen, T. Berglen, O. Boucher, F. Dentener, A. Grini, S. Guibert, T. Iversen, D. Koch, A. Kirkeveg, X. Liu, V. Montanaro, G. Myhre, J. Penner, G. Pitari, S. Reddy, X. Seland, P. Stier, and T. Takemura (2006), Radiative forcing by aerosols as derived from the AeroCom present-day and pre-industrial simulations, *Atmos. Chem. Phys., 6*, 5225-5246 .

Shay, L. K. and S. D. Jacob (2006), Relationship Between Oceanic Energy Fluxes and Surface Winds During Tropical Cyclone Passage. in *Atmosphere-Ocean Interactions Volume II Special Issue of Advances in Fluid Mechanics*, edited by W. Perrie, pp. 115-137, WIT Press, Ashurst, UK.

Shen, B.-W., R. Atlas, J.-D. Chern, O. Reale, S.-J. Lin, and T. Lee (2006), The 0.125 degree finite-volume General Circulation Model on the NASA Columbia supercomputer: preliminary simulations of mesoscale vortices, *Geophys. Res. Lett., 33*, L05801, doi:10.1029/2005GL024594.

Shen, B.-W., R. Atlas, O. Reale, S.-J. Lin, J.-D. Chern, J. Chang, C. Henze, and J.-L. Li (2006), Hurricane forecasts with a global mesoscale-resolving model: Preliminary results with Hurricane Katrina (2005). *Geophys. Res. Lett., 33*, L13813, doi:10.1029/2006GL026143.

Shige, S., Y. N. Takayabu, W.-K. Tao, and C.-L. Shie (2007), Spectral retrieval of latent heating profiles from TRMM PR data, Part II: Comparisons of lookup tables from TOGA-COARE, GATE, SCSMEX and KWAJEX simulations, *J. Appl. Meteor. Climatol.*, in press.

Shindell, D. T., G. Faluvegi, D. S. Stevenson, M. C. Krol, L. K. Emmons,J.-F. Lamarque, G. Pe´tron, F. J. Dentener, K. Ellingsen, M. G. Schultz, O. Wild, M. Amann, C. S. Atherton, D. J. Bergmann, I. Bey, T. Butler, J. Cofala,W. J. Collins, R. G. Derwent, R. M. Doherty, J. Drevet, H. J. Eskes, A. M. Fiore, M. Gauss, D. A. Hauglustaine, L. W. Horowitz, I. S. A. Isaksen, M. G. Lawrence, V. Montanaro, J.-F. Müller, G. Pitari, M. J. Prather, J. A. Pyle, S. Rast, J. M. Rodriguez, M. G. Sanderson, N. H. Savage, S. E. Strahan, K. Sudo, S. Szopa, N. Unger, T. P. C. van Noije, and G. Zeng (2006), Multimodel simulations of carbon monoxide: Comparison with observations and projected near-future changes, *J. Geophys. Res., 111*, D19306, doi:10.1029/2006JD007100.

Shiobara, M., M. Yabuki, R. Neuber, J. D. Spinhirne, E. J. Welton, J. R. Campbell, W. D. Hart, and T. A. Berkoff (2007), Arctic experiment for the ICESat/GLAS ground validation with a Micro-Pulse Lidar at Ny-Alesund, Svalbard, *Polar Meteorol. Glaciology, 20*, 28-39.

Smirnov, A., B. N. Holben, S. M. Sakerin, D. M. Kabanov, I. Slutsker, M. Chin, T. L. Diehl, L. A. Remer, R. Kahn, A. Ignatov, L. Liu, M. Mishchenko, T. F. Eck, T. L. Kucsera, D. Giles, and O. V. Kopelevich (2006), Ship-based aerosol optical depth measurements in the Atlantic Ocean, comparison with satellite retrievals and GOCART model, *Geophys. Res. Lett., 33*, L14817, doi: 10.1029/2006GL026051.

Strahan, S. E., and B. C. Polansky, Meteorological implementation issues in chemistry and transport models, *Atmos. Chem. Phys.*, *6*, 2895-2910, 2006.

Strahan, S. E., B. N. Duncan, and P. Hoor (2007), Observationally derived transport diagnostics for the lowermost stratosphere and their application to the GMI chemistry and transport model (2007), *Atmos. Chem. Phys. Disc.*, *7*, 1449-1477.

Stubbs, T. J., J. S. Halekas, W. M. Farrell, and R. R. Vondrak (2007), Lunar surface charging: A global perspective using Lunar Prospector data, in *Dust in Planetary Systems (Workshop, September 26–30 2005, Kauai, HI)*, edited by H. Krüger and A.L. Graps, ESA Publications, SP-643, pp. 181–184.

Stubbs, T. J., R. R. Vondrak, and W. M. Farrell (2006), A dynamic fountain model for lunar dust, *Adv. Space Res.*, *37*(1), 59–66.

Stubbs, T. J., R. R. Vondrak, and W. M. Farrell (2007), A dynamic fountain model for dust in the lunar exosphere, in *Dust in Planetary Systems (Workshop, September 26–30 2005, Kauai, HI)*, edited by H. Krüger and A.L. Graps, ESA Publications, SP-643, pp. 185–190.

Stubbs, T. J., R. R. Vondrak, and W. M. Farrell (2007), Impact of dust on lunar exploration, in *Dust in Planetary Systems (Workshop, September 26–30 2005, Kauai, HI)*, edited by H. Krüger and A.L. Graps, ESA Publications, SP-643, pp. 239–244.

Sun, C., M. M. Rienecker, A. Rosati, M. Harrison, A. Wittenberg, C L. Keppenne, J. P. Jacob, and R. M. Kovach (2007), Comparison and sensitivity of ODASI ocean analyses in the tropical Pacific, *Mon. Wea. Rev.*, in press.

Sun, J., X. Xiong, W. Barnes, and B. Guenther (2007), MODIS Reflective Solar Bands On-orbit Lunar Calibration, *IEEE Transactions on Geoscience and Remote Sensing*, in press.

Sun, W. Y., and J.-D. Chern (2006), Numerical study of the influence of Central Mountain Ranges in Taiwan on a cold front, *J. Meteor. Soc. Japan*, *84*, 27-46.

Susskind J., C. D. Barnet, J. M. Blaisdell, L. Iredell, F. Keita, L. Kouvaris, G. Molnar, and M. Chahine (2006), Accuracy of Geophysical Parameters Derived from AIRS/AMSU as a Function of Fractional Cloud Cover, *J. Geophys. Res.*, *111*(D9), doi:10.1029/2005JD006272.

Svensson, A., K. K. Andersen, M. Bigler, H. B. Clausen, D. Dahl-Jensen, S. M. Davies, S. J. Johnsen, R. Muscheler, S. O. Rasmussen, R. Röthlisberger, J. P. Steffensen, and B. M. Vinther (2006), The Greenland Ice Core Chronology 2005, 15-42 ka. Part 2: comparison to other records, *Quat. Sci. Rev.*, *25*, 3258-3267, doi:10.1016/j.quascirev.2006.08.003.

Tanskanen, A., N. Krotkov, J. R. Herman, P. K. Bhartia, and A. Arola (2006), Surface UV Irradiance from OMI, *IEEE Transactions on Geoscience and Remote Sensing, AURA special issue*, *44*(5), 1267-1271, doi:10.1109/TGRS.2005.861932, 2006.

Tedesco, M. (2007), Snowmelt detection over the Greenland ice sheet from SSM/I brightness temperature daily variations, *Geophys. Res. Lett.*, *34*, pp 16-22.

Tedesco, M., and A. Kokhanovsky (2007), The semi-analytical snow retrieval algorithm and its application to MODIS data, *Rem. Sen. Environ.*, in press.

Tedesco, M., and E. J. Kim (2006), A study on the retrieval of dry snow parameters from radiometric data using a Dense Medium model and Genetic Algorithms, *IEEE Transactions on Geoscicence and Remote Sensing, 44*, pp: 2143-2151.

Tedesco, M., and E. J. Kim (2006), Inter-comparison of electromagnetic models for passive microwave remote sensing of snow, *IEEE Transactions on Geoscience and Remote Sensing,, 44*, 2654-2666.

Tedesco, M., and J. Miller (2007), Combining active and passive microwave space-borne data for snow depth retrieval at large spatial scale, *Rem. Sens. Environ.*, in press.

Tedesco, M., and J. Miller (2007), Northern Hemisphere snow covered area mapping: optical vs. active and passive microwave data, *IEEE Geoscience Remote Sensing Letters*, in press.

Tedesco, M., and J. R. Wang (2006), Atmospheric correction of AMSR-E brightness temperatures for dry snow cover mapping, *IEEE Geoscience and Remote Sensing Letters, 3*, 320-324.

Tedesco, M., E. J Kim, A. W. England, R. de Roo, and J. P. Hardy (2006), Observations and modeling of snow melting/refreezing cycles using a multi-layer dense medium theory-based model, *IEEE Transactions on Geoscience and Remote Sensing, 44*, pp 3100-3112.

Ten Kate, I. L., J.R.C.Garry, Z.Peeters, B. Foing, and P. Ehrenfreund (2006), The effects of Martian near surface conditions on the photochemistry of amino acids, *PSS, 54*, 296-302, doi: 10.1016/j.pss.2005.12.002.

Textor, C., M. Schulz, S. Guiber, S. Kinne, Y. Balkanski, S. Bauer, T. Berntsen, T. Berglen, O. Boucher, M. Chin, F. Dentener, T. Diehl, J. Feichter, D. Fillmore, P. Ginoux, S. Gong, A. Grini, J. Hendricks, L. Horowitz, P. Huang, I. S. A. Isaksen, T. Iversen, S. Kloster, D. Koch, A. Kirkevåg, J. E. Kristjansson, M. Krol, A. Lauer, J. F. Lamarque, X. Liu, V. Montanaro, G. Myhre, J. E. Penner, G. Pitari, S. Reddy, Ø. Seland, P. Stier, T. Takemura, and X. Tie (2007), The effect of harmonized emissions on aerosol properties in global models – an AeroCom experiment, *Atmos. Chem. Phys., 7*, 1699-1723.

Textor, C., M. Schulz, S. Guibert, S. Kinne, Y. Balkanski, S. Bauer, T. Berntsen, T. Berglen, O. Boucher, M. Chin, F. Dentener, T. Diehl, R. Easter, H. Feichter, D. Fillmore, S. Ghan, P. Ginoux, S. Gong, A. Grini, J. Hendricks, L. Horowitz, P. Huang, I. Isaksen, T. Iversen, S. Kloster, D. Koch, A. Kirkevåg, J. E. Kristjansson, M. Krol, A. Lauer, J. F. Lamarque, X. Liu, V. Montanaro, G. Myhre, J. Penner, G. Pitari, S. Reddy, Ø. Seland, P. Stier, T. Takemura, and X. Tie (2006), Analysis and quantification of the diversities of aerosol life cycles within AeroCom, *Atmos. Chem. Phys., 6*, 1777-1813.

Tian L., G. M. Heymsfield, L. Li, and R. C. Srivastava (2007), Properties of Light Stratiform Rain Derived from 10 and 94 GHz Airborne Doppler Radars Measurements, *J. Geophys. Res.*, in press.

Tie, X., S. Chandra, J. R. Ziemke, C. Granier, and G. P. Brasseur (2006), Satellite Measurements of tropospheric column O_3 and NO_2 in eastern and southeastern Asia: Comparison with a global model (MOZART-2), *J. Atmos. Chem.*, doi:10.1007/s10874-006-9045-7.

Ting, M., and H. Wang (2006), The role of the North American topography on the maintenance of the Great Plains summer low-level jet, *Journal of the Atmospheric Sciences, 63*(3), 1056–1068.

Tischler, M., M. Garcia, C. Peters-Lidard, M. S. Moran, S. Miller, D. Thomas, S. V. Kumar, and J. Geiger (2006), A GIS framework for surface-layer soil moisture estimation combining satellite radar measurements and land surface modeling with soil physical property estimation, *Environmental Modelling & Software, 22*, 891-898, doi:10.1016/j.envsoft.2006.05.022.

Vallina, S., R. Simo, and S. Gassó (2006), What controls CCN seasonality in the Southern Ocean?: A statistical analysis based on satellite-derived chlorophyll and CCN model-estimated OH radical and rainfall, *Global Biogeochemical Cycles, 20*, GB1014, doi: 10.1029/2005GB002597.

Van Noije, T. P. C., H. J. Eskes, F. J. Dentener, D. S. Stevenson, K. Ellingsen, M. G. Schultz, O. Wild, M. Amann, C. S. Atherton, D. J. Bergmann, I. Bey, K. F. Boersma1, T. Butler, J. Cofala, J. Drevet,A. M. Fiore, M. Gauss, D. A. Hauglustaine, L. W. Horowitz, I. S. A. Isaksen, M. C. Krol, J.-F. Lamarque,M. G. Lawrence, R. V. Martin, V. Montanaro, J.-F. Müller, G. Pitari, M. J. Prather, J. A. Pyle, A. Richter, J. M. Rodriguez, N. H. Savage, S. E. Strahan, K. Sudo, S. Szopa, and M. van Roozendael (2006), Multi-model ensemble simulations of tropospheric NO_2 compared with GOME retrievals for the year 2000, Atmos. Chem. Phys., 6, 2943-2979.

Vassiliadis, D., A. Pulkkinen and A. Klimas (2007), Predicting the Multifractal Geomagnetic Field, in 20 Years of Nonlinear Dynamics in the Geosciences, Springer Verlag, in press.

Viljanen, A., A. Pulkkinen, R. Pirjola, K. Pajunpaa, P. Posio, and A. Koistinen (2006), Recordings of geomagnetically induced currents and a nowcasting service of the Finnish natural gas pipeline system, *Space Weather, 4*, S10004, doi:10.1029/2006SW000234.

Viljanen, A., E. Tanskanen, and A. Pulkkinen (2006), Relation between substorm characteristics and rapid temporal variations of the ground magnetic field, *Annales Geophysicae, 24*, 725-733.

Walker, J., W. P. Robarge, Y. Wu, and T. Meyers (2006), Measurement of bi-directional ammonia fluxes over soybean using the modified Bowen-ratio technique, *Agricultural and Forest Meteorology, 138*, 54-68.

Wang, H. and K.-M. Lau (2006), Atmospheric hydrological cycle in the tropics in twentieth century coupled climate simulations, *International Journal of Climatology, 26*, 655-678.

Wang, J. R., and M. Tedesco (2006), The Atmospheric Corrections on the Estimation of Snow Water Equivalent from AMSR-E Measurements, *Rem. Sens. Environ.*, in press.

Wang, J.-J., X. F. Li, and L. Carey (2007), Evolution, structure, cloud microphysical and surface rainfall processes of monsoon convection during the South China Sea Monsoon Experiment, *J. Atmos. Sci., 64*, 360-380.

Wang, Y., R. C. Elphic, B. Lavraud, M. G. G. T. Taylor, J. Birn, C. T. Russell, J. Raeder, H. Kawano, and X. X. Zhang (2006), The dependence of flux transfer events on solar wind conditions from three years of Cluster observations, *J. Geophys. Res., 111*, A04224, doi:10.1029/2005JA011342.

Webb, P. A., R. F. Benson, and J. M. Grebowsky (2006), Altitude variations of middle-latitude topside ionospheric electron-density profiles, *Adv. Space Res., 37*(5), doi 10.1016/j.asr.2005.05.130, 951-957.

Webb, P. A., R. F. Benson, and J. M. Grebowsky (2006), Technique for determining midlatitude O+/H+ transition heights from topside ionograms, *Radio Sci., 41*, RS6S34, doi:10.1029/2005RS003391.

Wen, G., A. Marshack, R. F. Cahalan, L. A. Remer, and R. G. Kleidman (2007), 3D Aerosol-Cloud Radiative Interaction Observed in Collocated MODIS and ASTER Images of Cumulus Cloud Fields, *J. Geophys. Res.*, in press.

Wenig, M., C. Leue, S. Kraus, T. Wagner, U. Platt, and B. Jähne (2007), Chapter 15: Emission, Transport, and Fate of Tropospheric Trace Gases, in *Image Sequence Analysis to Investigate Dynamic Processes, Lecture Notes in Computer Science*, Springer, New York, in press.

Wilmouth, D. M., R. M. Stimpfle, J. G. Anderson, J. W. Elkins, D. F. Hurst, R. J. Salawitch, and L. R. Lait (2006), Evolution of inorganic chlorine partitioning in the Arctic polar vortex, *J. Geophys. Res., 111*(D20), D16308, doi:10.1029/2005JD006951.

Wilson, E. L., E. M. Georgieva, and W. S. Heaps (2007), Development of a Fabry-Perot interferometer for ultra-precise measurements of column CO_2, *Meas. Sci. Tech.*, in press.

Wu, L. Q. Zhang, and Z. Jiang (2006), Three Gorges Dam affects regional precipitation. *Geophys. Res. Lett., 33*, L13806. doi:10.1029/2006GL026780.

Wu, L., S. A. Braun, J. Halverson, and G. Heymsfield (2006), A numerical study of hurricane Erin (2001), Part I: Model verification and storm Evolution, *J. Atmos. Sci., 63*, 65-86.

Wu, L., S. A. Braun, J. J. Qu, and X. Hao (2006), Simulating the formation of Hurricane Isabel (2003) with AIRS data, *Geophys. Res. Lett., 33*, L04804, doi:10.1029/2005GL024665.

Wu, Y., J. Walker, C. Peters-Lidard, D. Schwede, R. Dennis, and W. Robarge (2006), Role of leaf surface water in the bi-directional ammonia exchange between the atmosphere and terrestrial biosphere, peer-reviewed *Proceedings of the Workshop on Agricultural Air Quality: State of the Science, Bolger Conference Center*, pp 1250-1253, Potomac, MD, 5-8 June.

Wyant, M. E., C. S. Bretherton, J. T. Bacmeister, J. T. Kiehl, I. M. Held, M. Zhao, S. A. Klein, and B. A. Soden (2006), A comparison of tropical cloud properties and responses in GCMs using mid-tropospheric vertical velocity, *Climate Dynamics, 27*, 261–279, doi: 10.1007/s00382-006-0138-4

Xia, X. A., H. B. Chen, P. C. Wang, W. X. Zhang, P. Goloub, B. Chatenet, T. F. Eck, and B. N. Holben (2006), Variation of column-integrated aerosol properties in a Chinese urban region, *J. Geophys. Res., 111*(D5), D05204.

Xiao, X., S. Hagen, Q. Zhang, M. Keller, and B. Moore (2006), Detecting leaf phenology of seasonally moist tropical forests in South America with multi-temporal MODIS images, *Rem. Sens. Environ., 103*, 465-473.

Xiong, X., J. Sun, W. Barnes, V. Salomonson, J. Esposito, H. Erives, and B. Guenther (2007), Multi-year On-orbit Calibration and Performance of Terra MODIS Reflective Solar Bands, *IEEE Transactions on Geoscience and Remote Sensing*, in press.

Yamasoe, M. A., C. von Randow, A. O. Manzi, J. S. Schafer, and T. F. Eck (2006), Source Effect of smoke and clouds on the transmissivity of photosynthetically active radiation inside the canopy, *Atmos. Chem. Phys., 6*, 1645-1656.

Yang, R., J. Guo, and L. P. Riishojgaard (2006), Application of an error statistics estimation method to PSAS forecast error covariance model, *Advances in Atmospheric Sciences, 23*, 33-44.

Yeh, K.-S. (2007), The Streamline Subgrid Integration Method: I. Quasi-Monotonic Second-Order Transport Schemes, *Journal of Computational Physics*, doi:10.1016/j.jcp.2007.02.033.

Young, L.-H., J. C. Wilson, D. R. Benson, W. M. Montanaro, S.-H. Lee, L. L. Pan, D. C. Rogers, J. Jensen, J. Stith, C. A. Davis, T. L. Campos, K. P. Bowman, W. A. Cooper, and L. R. Lait (2007), Enhanced New Particle Formation Observed in the Northern Midlatitude Tropopause Region, *J. Geophys.Res.*, in press.

Yu, J., A. K. Liu, and Y. Zhao (2006), Sea ice motion and deformation in the marginal ice zone through SAR, in *Advances in Geosciences, Vol. 5*, edited by W-H. Ip, pp. 41-47, World Scientific, Hackensack, NJ.

Yurchak, B.S. (2007), Description of cloud-rain bands in a tropical cyclone by a hyperbolic-logarithmic spiral, *Meteorology and Hydrology, 1*, 15-29.

Zeng, X., W.-K. Tao, M. Zhang, C. Peters-Lidard, S. Lang, J. Simpson, S. Kumar, S. Xie, J. L. Eastman, C.-L. Shie, and J. V. Geiger (2007), Evaluating clouds in long-term cloud-resolving model simulations with observational data, *J. Atmos. Sci.*, in press.

Zhang, C., P. Woodworth, and G. Gu (2006), The seasonal cycle in the lower troposphere over West Africa from sounding observations, *Quarterly Journal of the Royal Meteorological Society, 132*, 2559-2582.

Zhang, Q, X. Xiao, B. Braswell, E. Linder, S. Ollinger, M. L. Smith, J.P. Jenkins, F. Baret, A. D. Richardson, B. Moore, and R. Minocha (2006), Characterization of seasonal variation of forest canopy in a temperate deciduous broadleaf forest using daily MODIS data, *Rem. Sens. Environ., 105*, 189-203.

Zhao, Y., and A. K. Liu (2006), Arctic sea-ice motion and its relation to pressure field, *Journal of Oceanography*, in press.

Zhou, Y. P., W. -K. Tao, A. Hou, W. S. Olson, C.-L. Shie, K.-M. Lau, M. D. Chou, X. Lin, and M. Grecu (2007), Use of high-resolution satellite observations to evaluate cloud and precipitation statistics from cloud-resolving model simulations, Part I: South China Sea Monsoon Experiment, *J. Atmos. Sci.*, in press.

Ziemke, J. R., S. Chandra, B. N. Duncan, L. Froidevaux, P. K. Bhartia, P. F. Levelt, and J. W. Waters (2006), Tropospheric ozone determined from Aura OMI and MLS: Evaluation of measurements and comparison with the Global Modeling Initiative's Chemical Transport Model, *J. Geophys. Res., 111*, D19303, doi:10.1029/2006JD007089.

This page intentionally left blank

Other Publications

Anyamba, A., C. J. Tucker, and J. Small (2006), Monitoring and Mapping eco-climatic conditions associated with RVF Outbreaks. Annual Report to DoD /GEIS Walter Reed Army Institute for Research.

Anyamba, A., J. Small, C. J. Tucker, K. J. Linthicum, and J. P. Chretien (2006), Possible RVF Activity in the Horn of Africa. Food and Agricultural Organization of the United Nations (FAO-UN) Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases (EMPRES WATCH) http://www.fao.org/docs/eims/upload/217874/EW_hornafrica_nov06_rvf.pdf

Bais, A. F., D. Lubin, A. Arola, G. Bernhard, M. Blumthaler, N. Chubarova, C. Erlick, H. P. Gies, N. Krotkov, K. Lantz, B. Mayer, R. L. McKenzie, R. Piacentini, G. Seckmeyer, J. R. Slusser, and C. S. Zerefos (2006), Surface UV radiation: Past, Present and Future, Chapter 7, WMO ozone assessment update.

Clark, P. E., J. W. Keller, W. M. Farrell, T. J. Stubbs, J. A. Nuth, and S. A. Curtis (2006), Electrostatic dust control and collection on planetary surfaces, Lunar Planet. Sci. Conf. XXXVII, 1128.

Crider, D. H., and T. J. Stubbs (2007), History of the inner Solar System according to the lunar cold traps, invited white paper for the Workshop on Science Associated with the Lunar Exploration Architecture, NASA Advisory Council, Tempe, AZ, 26 February – 2 March.

Curran, Robert J. (editor), Our Changing Planet: The U.S. Climate Change Science Program for FY 2007.

Delaney, M. P. (2006) Name the ISS Node 2 Challenge Educator Guide. http://esc.nasa.gov.

Delaney, M. P., and A. Owens (2006) Design a Lunar Base Challenge Educator Guide. http://esc.nasa.gov.

Delaney, M. P., and A. Owens (2006) Fuel Your Imagination! Challenge Educator Guide. http//:esc.ansa.gov.

Delaney, M. P., and J. Entwistle (2006) Lights, Camera, Action! Challenge Educator Guide. http://esc.nasa.gov.

Farrell, W. M., J. S. Halekas, T. J. Stubbs, R. R. Vondrak, G. T. Delory, S. D. Bale, and R. P. Lin (2007), The lunar wake as a unique plasma physics laboratory, contributed white paper for the Workshop on Science Associated with the Lunar Exploration Architecture, NASA Advisory Council, Tempe, AZ, 26 February – 2 March.

Ferrare, R. A., E. V. Browell, J. W. Hair, S. Ismail, D. D. Turner, M. Clayton, C. F. Butler, V. G. Brackett, M. A. Fenn, A. Notari, S. A. Kooi, M. Chin, S. Guibert, M. Schulz, C. Chuang, M. Krol, S. E. Bauer, X. Liu, G. Myhre, X. Seland, D. Fillmore, S. Ghan, S. Gong, P. Ginoux, and T. Takemura (2006), The Vertical Distribution of Aerosols: Lidar Measurements vs. Model Simulations, in *23rd International Laser Radar Conference*, edited by N.S. Chikao, Nagasawa, Nara, Japan, 24-28 July.

Halekas, J. S., G. T. Delory, T. J. Stubbs, W. M. Farrell, R. R. Vondrak, and M. R. Collier (2006), Lunar electric fields and dust: Implications for in situ resource utilization, Space Resources Roundtable VIII, 1006.

Holben, B. N., T. F. Eck, I. Slutsker, A. Smirnov, A. Sinyuk, J. Schafer, D. Giles, and O. Dubovik (2006), AERONET's Version 2.0 quality assurance criteria, in *Remote Sensing of the Atmospheres and Clouds*, edited by Si-Chee Tsay, Teruyuki Nakajima, R.P. Singh, and R, Sridharan, Proc. of SPIE Vol. 64080Q, (2006), doi:10.1117/12.706524.

Hsu, K. L., Y. Hong, and S. Sorooshian (2007), Rainfall Estimation using A Cloud Patch Classification Map, in *Measuring Precipitation from Space EURAINSAT and the Future Series: Advances in Global Change Research, Vol. 28*, edited by L. Vincenzo, P. Bauer, and J. Turk, ISBN: 978-1-4020-5834-9, pp. 329-343, Springer Publisher.

Jacob, S. D. (2006), On the Surface Density from Brightness Temperature Relationship, Aquarius Simulator Team Report.

Jacob, S. D., D. M. Le Vine, E. Dinnat and P. deMattaeis (2006), Forward Model Details, Aquarius Simulator Team Report.

Jacob, S. D., D. M. Le Vine, E. Dinnat, and P. de Matthaeis (2006), Forward Model Details, Aquarius Simulator Team Report.

Justice, C., A. Anyamba, M. Hansen, and M. B. Sullivan (2006), Support of Application of NASA EOS MODIS Data by USDA Global Agriculture Monitoring Project: A Joint Project between NASA/GSFC, USDA/FAS, and University of Maryland, NAG 5134000, 2006 Annual Report.

Lawford, R. (2006), GEWEX data sets for climate assessment activities, *GEWEX Newsletter, 16*(3), 2.

Lawford, R. (2006), GEWEX, AMMA and capacity building in Africa, *GEWEX Newsletter, 16*(1), 2.

Lawford, R. (2006), GWSP SSC meeting, *GEWEX Newsletter, 16*(2), 18.

Lawford, R. (2006), Highlights of the GEWEX Roadmap, *GEWEX Newsletter, 16*(4), 10-12.

Lawford, R. (2006), Second IGWCO workshop and CEOP science meeting, *GEWEX Newsletter, 16*(2), 15.

Lawford, R. (2006), World Water Forum IV, *GEWEX Newsletter, 16*(2), 17.

Lawford, R. G. (2006), GEWEX Project Overview, JSC Meeting, Pune, India, March.

Lawford, R. G. (2006), Report on the activities of the international GEWEX Project Office, prepared for the pan-GEWEX meeting, Frascati, Italy.

Lawford, R., and C. Ishida (2006), IGWCO/JAXA/GEO capacity building workshop, *GEWEX Newsletter, 16*(4), 18-19.

Lawford, R., D. Erlich, W. Rossow, J. Roads, C. Jakob, and S. Benedict (2006), First Pan-GEWEXmeeting a great success, *GEWEX Newsletter, 16*(4), 8-10.

Lawford, R.G. (2006), Report of the NEESPI Steering and Coordinating Committee, Vienna, Austria, February.

Lawford, R.G. (2007), Changes in the water cycle associated with global change, paper accepted for publication in the proceedings of the RIHN Conference, Kyoto, Japan.

Roads, J., S. Benedict, T. Koike, R. Lawford, and S. Sorooshian (2006), On the transition of GHP to CEOP, paper prepared for the GEWEX SSG meeting to support a major reorganization in GEWEX.

Roper, M., K. Howell, and D. Laughlin (2007), NASA eEducation Strategic Research Roadmap, a white paper for NASA published by the Federation of American Scientists.

Schiffer, Robert (2006), Report of the National Research Council - Board on Atmospheric Sciences and Climate - Planning Retreat Report: Summary of Ideas for Possible Future Activities, August.

Schiffer, Robert [Principle Editor] (2007), NASA Energy and water Cycle Study Implementation Plan (NEWS) Executive Summary, January.

Sorooshian, S., K.-L. Hsu, B. Imam, and Y. Hong (2007), Global Precipitation Estimation from Satellite Imagery using Artificial Neural Networks, in *Hydrological modeling in arid and semi-arid areas*, UNESCO, in press.

Stubbs, T. J. (2007), Characterizing the near lunar plasma environment, invited white paper for the Workshop on Science Associated with the Lunar Exploration Architecture, NASA Advisory Council, Tempe, AZ, 26 February – 2 March.

Stubbs, T. J. (2007), Characterizing the near lunar plasma environment, invited white paper for the Workshop on Science Associated with the Lunar Exploration Architecture, NASA Advisory Council, Tempe, AZ, 26 February – 2 March.

Stubbs, T. J., J. S. Halekas, W. M. Farrell, R. R. Vondrak, and G.T. Delory (2006), Global modeling of the electrostatic lunar surface potential, Lunar Planet. Sci. Conf. XXXVII, 2217.

Stubbs, T. J., W. M. Farrell, and R. R. Vondrak (2006), Predictions of dust concentrations in the lunar exosphere, Proc. 8th ILEWG International Conference on Exploration and Utilization of the Moon, in press.

This page intentionally left blank

Presentations and Conference Publications

Adler, R. F., Y. Hong, and G. J. Huffman (2007), An Experimental Global Landslide Prediction System, International Panel on Landslide Risk Analysis and Sustainable Disaster Management Symposium, Tokyo, Japan, 22-25 January.

Anatharaj, V., C. D. Peters-Lidard, P. Houser, G. Mostovoy, T. Haupt, R. Moorhead, and S. V. Kumar (2006), Integration of the NASA Land Information System as an Application Framework into the MRC Rapid Prototyping Capabilities Infrastructure, American Geophysical Union Fall meeting, San Francisco, CA, 11-15 December.

Anderson, T. L. (2006), A review of aerosol measurements: Extending to the global scale, invited presentation at International European Fleet for Airborne Research (EUFAR) Workshop: Combining Upcoming Satellite Missions and Aircraft Activities: Future Challenges for the EUFAR Fleet, Paris, 13-15 September.

Anderson, T. L. (2006), Discussion concerning surface in-situ measurements to validate and interpret CALIPSO extinction profiles with examples from TexAQS/GoMACCS, paper presented at CALIPSO Science Team Meeting, Annapolis, MD, 3-5 October.

Anderson, T. L. (2006), 'Stay the Course' or 'Cut and Run'? Strategic Considerations Regarding the Quantification of Climate Forcing by Anthropogenic Aerosols, paper presented at weekly AeroCenter seminar, Bldg 33, NASA/GSFC, Greenbelt, MD, 7 November.

Anderson, T. L. (2007), CALIPSO and the A-Train: Spaceborne lidar for global aerosol/climate assessment, paper presented at the weekly Climate and Radiation seminar, Department of Atmospheric Sciences, University of Washington, Seattle, WA, 5 February.

Anderson, T. L. (2007), 'Stay the Course' or 'Cut and Run'? Strategic Considerations Regarding the Quantification of Climate Forcing by Anthropogenic Aerosols, invited presentation at Environmental Sciences Friday Seminar, Brookhaven National Laboratory, Brookhaven, NY, 26 January.

Anderson, T. L., R. J. Charlson, L. V. Leahy, B. A. Wielicki, and N. G. Loeb (2006), Empirical assessment of a lidar-derived proxy for local, planetary albedo, poster A51E-0110, presented at American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December.

Anyamba, A. (2006), Monitoring and Mapping Eco-Climatic Conditions associated with outbreaks of Rift Valley Fever and other Arboviruses. Joint WHO Inter-Country Workshop on Crimean-Congo Haemorrhagic Fever, CCHF. Istanbul, Turkey, 6-8 November.

Anyamba, A., J. Chretien, S. Yingst, J. Small, K. J. Linthicum, and C. Tucker (2006), Satellite-based Rift Valley fever forecasts predict a large yellow fever epidemic in Sudan, 2005, presented at the International Conference on Emerging Infectious Diseases 2006, Atlanta, GA, 19-22 March.

Anyamba, A., J. Small, C. J. Tucker, K. J. Linthicum, and J. P. Chretien (2007), Rift Valley Fever Monitoring Update, FEWS Science Meeting, 27 November.

Anyamba, A., K. J. Linthicum, J. Small, J. P. Chretien, and C. J. Tucker (2006), Rift Valley Fever: Overview and Monitoring. USDA RVF Working Group Fall Meeting, Fort Collins, CO, 5-7 December..

Arsenault, K. R., R. Stodt, A. Pinheiro, P. Houser (2006), Improving Water Demand Forecasting in the Middle Rio Grande River Basin, poster presented at the NOAA CPPA Annual Meeting, Tucson, AZ, 14-16 August.

Arsenault, K. R., R. Stodt, D. Frevert, S. Hunter, and A. Brower (2006), Water Management Applications with the US Bureau of Reclamation, presented at NASA Water Management Program Workshop, College Park, MD, 14-15 June.

Asgharzadeh M. F., R. R. B. von Frese, and H. R. Kim (2006), Evaluating spherical Earth magnetic gradients from Swarm by Gauss-Legendre quadrature integration, abstract, First Swarm Intl. Sci. Meeting, Nante, France, 3-5 May.

Asgharzadeh, M, R. R. B. von Frese, and H. R. Kim (2006), Spherical earth analysis of SWARM magnetic anomalies, *Eos Trans. AGU, 87*(36), Jt. Assem. Suppl., Abstract GP41A-01.

Bacmeister, J. T. (2006), Cloud Related Physics Parameterizations for the GEOS-5 AGCM, NASA/CMAI Meeting, New York NY, 20 April.

Bacmeister, J. T. (2007), Examining the relationship between Tropical precipitation and convergence in Atmospheric General Circulation Model simulations, invited talk in the NCAR/CGD Seminar Series, Boulder, CO, 30 January.

Bacmeister, J. T., L. Takacs, and M. J. Suarez (2006), First Look at cloud fields in the GEOS-5 data assimilation system, NCAR CCSM Workshop, Breckenridge, CO, 20 June.

Bacmeister, J. T., M. J. Suarez, and F. R. Robertson (2006), Rain Re-evaporation and Pacific Rainfall Patterns in an AGCM, EGS Annual Meeting, Vienna, Austria, 6 April.

Bale, S. D., G. T. Delory, R. P. Lin, J. W. Hines, B. Yost, W. M. Farrell, J. S. Halekas, T. J. Stubbs, T. Zurbuchen, J. W. Keller, M. R. Collier, A. J. Ricco, J. Bonnell, V. Angelopoulos, R. R. Vondrak (2006), The Lunar Explorer for Elements and Hazards (LEEAH) mission: Characterizing lunar-heliospheric interactions for both science and exploration, AGU Fall Meeting, San Francisco, CA, 11–15 December.

Barnes, W., X. Xiong, X. Xie, A. Wu, K. Chiang, J. Sun, V. Salomonson, and B. Guenther (2006), Four Years of Aqua MODIS On-orbit Radiometric Calibration, *Proceedings of SPIE - Sensors, Systems, and Next Generation of Satellites X, 6361*, 63610R, doi:10.1117/12.687160.

Bell, T. L., D. Rosenfeld, K.-M. Kim, and M. Hahnenberger (2006), “Weekend-effect” evidence for intensification of storms by pollution over US, European Geosciences Union General Assembly 2006, Vienna, Austria, 2-7 April.

Bell, T. L., D. Rosenfeld, K.-M. Kim, and M. Hahnenberger (2006), The "Weekend Effect" in summertime U.S. rainfall: evidence for midweek intensification of storms by pollution, *Eos Trans. AGU, 87*(36), Jt. Assem. Suppl., Abstract H52B-07.

Bell, T. L., K.-M. Kim, D. Rosenfeld, J.-M. Yoo, M.-I. Lee, and M. Hahnenberger (2007), “Weekend effect" for precipitation over eastern U.S.: Evidence for midweek intensification by pollution and historical evolution, paper presented at the 87th Annual AMS Meeting, San Antonio, Texas, 14-18 January.

Benna, M., and J. Barriot (2006), Characterization of the internal structure of comet 67P/Churyumov-Geraimenko using the CONSERT experiment data, paper presented at the Workshop on Spacecraft Reconnaissance of Asteroid and Comet interiors, LPI, Santa Cruz, CA, 5-6 October.

Benna, M., and P. Mahaffy (2006), 3-D multi-fluid modeling of comet 1P/Halley and 26P/Grigg-Skjellerup and comparison with the Giotto data, paper presented at the 36th COSPAR Scientific Assembly, Beijing, China, 16-23 July.

Benna, M., and P. Mahaffy (2006), 3-D multi-fluid modeling of comet 26P/Grigg-Skjellerup: Extrapolation to comet 67P/Churyumo-Gerasimenko, paper presented at the 3rd AOGS Annual Meeting, Singapore, 10-14 July.

Benna, M., and P. Mahaffy (2006), Multi-fluid modeling of comet 1P/Halley and comparison with the 1986 Giotto data, paper presented at the 207th Meeting of the AAS, Washington, DC, 8-12 January.

Benna, M., and W. Kasprzak (2006), 3-D multi-fluid modeling of Enceladus' interaction with the magnetosphere of Saturn, paper presented at the 36th COSPAR Scientific Assembly, Beijing, China, 16-23 July.

Benna, M., and W. Kasprzak (2006), Advanced MHD modeling of Enceladus' interaction with the magnetosphere of Saturn, paper presented at the 2006 AGU fall meeting, San Francisco, CA, 11-15 December.

Benna, M., and W. Kasprzak (2006), Multi-fluid modeling of the atmosphere of Enceladus, paper presented at the 3rd AOGS Annual Meeting, Singapore, 10-14 July.

Benson, C., R. Kawa, E. Nielsen, and S. Pawson (2006), Simulations of atmospheric composition using GEOS-4: Evaluation with EOS-Aura data, Aura Science Meeting, Boulder, CO, 11-15 September.

Benson, R. F., V. A. Osherovich, J. Fainberg, J. L. Green, S. A. Boardsen, L. N. Garcia, N. Tsyganenko, and B. W. Reinisch (2006), RPI/IMAGE Plasma and Magnetic Signatures of Solar-Wind/Magnetosphere Interactions, AGU 2006 Joint Assembly, Baltimore, MD, U.S.A., 23–26 May.

Berkoff, T. A., E. Welton, and J. Spinhirne (2006), Can Micro-Pulse Lidar Measure Raman Nitrogen Signals From the Atmosphere?, Proceedings, Twenty-third International Laser Radar Conference (ILRC23) 2P-33, pp.1-4. Japan

Berkoff, T. A., L. Belcher, J. Campbell, J. Spinhirne, and E. J. Welton (2007), Satellite to Ground-Based Lidar Comparisons Using MPLNET Data Products, Proceedings, American Meteorological Society, 87th Annual Meeting, Third Symposium on Lidar Atmopsheric Applications, P1.2, pp. 1-4.

Berkoff, T. A., L. Belcher, J. Campbell, J. Spinhirne, and E. J. Welton (2007), Satellite to Ground-Based Lidar Comparisons Using MPLNET Data Products, AMS 87th Annual Meeting, Third Symposium on Lidar Atmospheric Applications, San Antonio, TX, 14-18 January.

Berkoff, T. A., R. Rogers, K. McCann, K. Evans, W. McMillan, R. Hoff, R. Alverz, R. Richter, J. Intrieri, and W. Eberhard (2006), Initial Results Using a Depolarization and Backscatter Unattended Lidar

(DABUL2) Systems Operating at the University of Maryland Baltimore County (UMBC), Poster presentation, American Geophysical Union, *EOS Trans.*, *87*(36), Jt. Assem. Suppl., Abstract A43A-07.

Bian, H., and M. Chin (2006), Improve dust and sea salt simulation in GMI, GMI workshop, Greenbelt, MD, 11-13 October.

Bian, H., M. Chin, T. Diehl, X. Liu, J. Penner, M. Wang, J. Rodriguez, B. Duncan, and S. Strahan (2006), Comparisons of global aerosol simulations from GOCART and GMI, AGU Joint Assembly, Baltimore, MD, 23-26 May.

Bian, H., M. Chin, X. Liu, J. Penner, M. Wang, T. Diehl, J. Rodriguez, and S. Strahan (2006), Investigation of uncertainties in aerosol simulation using GMI: A complementary approach to AEROCOM, Virginia Beach, VA, 17-19 October.

Bian, H., R. Kawa, and M. Chin (2007), Online CO_2 simulation using GEOS-4, Carbon Data Analysis meeting, Annapolis, MD, 29-30 January.

Boardsen, S. A., and J. A. Slavin (2006), Examination of MARINER-10 Magnetic Field Data for Heavy Ion Signatures During the Mercury I and III Encounters by Mariner-10, *Eos Trans. AGU, 87*(52), Fall Meet. Suppl., Abstract SM23A-0309

Boardsen, S. A., J. L. Green, K. Hashimoto, H. Matsumoto, D. L. Gallagher, and P. A. Webb (2006), Is the Linear Mode Conversion Theory viable for generating Kilometric Continuum?, *Eos Trans. AGU, 87*(36), AGU 2006 Joint Assembly, Baltimore, MD, U.S.A., 23–26 May.

Bojkov, B. (2006), AVDC Update, invited presentation to the Aura Science Team Meeting, Boulder CO, 11-15 September.

Bojkov, B. (2006), Hosted the SAUNA Workshop, Tenerife, Spain, 8-11 November.

Bojkov, B. (2006), SAUNA - Sodankylä Total Ozone Intercomparison and Validation Campaign, Aura Science Team Meeting, Boulder CO, 11-15 September.

Bojkov, B. (2006), The Aura Validation Data Center, invited presentation to the Calypso Science Team Meeting, Annapolis, MD, 3-5 October.

Bosilovich, M. G., C. P. Lidard, M. Rodell, R. H. Reichle, G. Compo, P. Dirmeyer, and P. Houser (2006), Land Data Reanalyses, Meeting of the National Research Council's Climate Research Committee, Washington, DC, 22-23 March.

Braun, A., R. R. B. von Frese, B. Csatho, H. R. Kim, and C. K. Shum (2006), Solid earth – cryosphere interactions in Greenland, CGU Annual scientific meeting, Banff, Canada, 14-17 May.

Bucsela, E. J., E. A. Celarier, J. F. Gleason, M. O. Wenig, T. H. Bertram, R. C. Cohen, A. E. Perring, P. J. Wooldrige, and K. F. Boersma (2006), Validation of the OMI tropospheric NO_2 standard product using measurements from INTEX-B, Fall 2006 Meeting, American Geophysical Union, San Francisco, CA, 11-15 December.

Cahalan R. F., G. Wen, A. Marshak, L. Remer, and R. Kleidman (2006), SPIE Meeting, Cloud-aerosol three-dimensionalk interactions, SPIE, Asia-Pacifi Remote Sensing, Fifth International Symposium, Panaji, Goa, India, 13-17 November.

Carn, S. A, N. A. Krotkov, A. J. Krueger, K. Yang, and A. J. Prata (2006), New insights into volcanic degassing from OMI and the A-Train, AURA ST meeting, PLENARY SESSION, 11-15 September.

Carn, S. A., N. A. Krotkov, A. J. Krueger, and K. Yang (2006), The first daily measurements of passive volcanic degassing from space, AGU Fall Meeting, V32, San Francisco, CA, 11-15 December.

Carn, S. A., N. A. Krotkov, A. J. Krueger, and T. P Kurosu (2006), Monitoring Global Volcanic Degassing with the Ozone Monitoring Instrument (OMI), presentation at Cities on Volcanoes 4 meeting in Quito, Ecuador, February.

Carn, S. A., N. A. Krotkov, A. J. Krueger, K. Yang, and A. J. Prata (2006), New insights into volcanic degassing from OMI and the A-Train, AURA ST meeting, PLENARY SESSION, 11-15 September.

Chang, Y., S. Schubert, and M. Suarez (2006), The Evolution of the Subsurface Thermal Structure in the Equatorial Pacific Ocean and its Relationship to ENSO, paper presented at the NOAA's 31th Annual Climate Diagnostics and Prediction Workshop, Boulder, CO, 23-27 October.

Charlson, R. J. and T. L. Anderson, Integral Earth-system properties viewed from space: Introducing the 'lidar reflectivity' (2006), poster A51E-0109, presented at American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December.

Chekalyuk, A. M. (2006), Fluorescence Analysis of Phytoplankton Pigments, Group, and Physiological Variability, NASA Ocean Color Research Team meeting, Newport, RI, 11-13 April.

Chekalyuk, A. M., and M.A. Hafez (2006), Laser Fluorescence Monitoring in Coastal and Estuarine Aquatic Environments, Ocean Optics XVIII, Montreal, Quebec, 9-13 October.

Chern, J.-D., W.-K. Tao, and X. Lin (2006), Applications of the Goddard Multi-scale Modeling Framework in climate simulation, AGU 2006 Joint Assembly, Baltimore, MD, 23-26 May.

Chern, J.-D., W.-K. Tao, and X. Lin (2006), Diurnal variations of the water cycle in the Goddard Multi-scale Modeling Framework, submitted to the AMS 27th Conference on Hurricanes and Tropical Meteorology, Monterey, CA, 24-28 April.

Chern, J.-D., W.-K. Tao, C. Peters-Lidard, and B.-W. Shen (2006), Use of a couple, global cloud-scale and land surface modeling system to study the impact of land surface processes on energy and water cycle, NASA Energy and Water Cycle Study (NEWS) PI Meeting, Adelphi, MD, 26-28 September.

Chern, J.-D., W.-K. Tao, S. Lang, Z. Luo, and G. L. Stephens (2007), Evaluation and Improvements of cloud microphysics in multi-scale modeling system, The Center for Multi-scale Modeling of Atmospheric Processes (CMMAP) team meeting, Princeville, HI, 20-22 February.

Chin, M., H. Yu, and T. Diehl (2006), Near-term to Long-term Aerosol Trends from Combined Use of Global Model and Satellite Data, First Workshop on the GEWEX Global Aerosol Products Assessment, College Park, MD, 14-15 September.

Chin, M., P. Ginoux, and T. Diehl (2006), Intercontinental Transport of Aerosols: Implications for Regional Air Quality, Joint IGAC/CACGP/WMO Symposium "Atmospheric Chemistry at the Interfaces," Cape Town, South Africa, 17-23 September.

Chin, M., P. Ginoux, and T. Diehl (2006), Intercontinental Transport of Aerosols: Implications for Regional Air Quality, Fifth AeroCom Workshop, Virginia Beach, VA, 17-19 October.

Chin, M., T. Diehl, A. Chu, S. Palm, J. Spinhirne, H. Yu, and T. Kucsera (2006), Using Models and Satellite Data for Air Quality Studies, AGU Joint Assembly, Baltimore, MD, 23-26 May.

Chin, M., T. Diehl, and A. Chu (2006), Using Models and Satellite Data for Air Quality Studies, USDA Air Quality Workshop, Potomac, MD, 6-8 June.

Chin, M., T. Diehl, H. Yu, and P. Ginoux (2006), Impact of Asian dust on global surface air quality, AGU Western Pacific Geophysics Meeting, Beijing, China, 24-27 July.

Chin, M., T. Diehl, L. Remer, R. Levy, R. Kahn, D. Giles, B. Holben, H. Yu, and H. Bian (2006), Multi-year global aerosol distributions from MODIS (and MISR) and GOCART, MODIS Science Team Meeting, Adelphi, MD, 31 October 31 – 2 November.

Chin, M., T. Diehl, P. Ginoux, and B. Holben (2006), Regional and global aspects of aerosols in western Africa: From air quality to climate, Joint IGAC/CACGP/WMO Symposium "Atmospheric Chemistry at the Interfaces," Cape Town, South Africa, 17-23 September.

Chin, M., T. Diehl, T. Kucsera, M. Petrenko, L. Giglio, G. van der Werf, C. Ichoku, A. Soja, R. Levy, D. Giles, and R. Ferrare (2006), Use satellite data for modeling biomass burning emissions, Fifth AeroCom Workshop, Virginia Beach, VA, 17-19 October.

Chin, M., T. L. Diehl, D. A. Chu, S. P. Palm, J. D. Spinhirne, and H. Yu (2006), Using global model and satellite data for air quality studies, *Eos Trans. AGU, 87*(36), Jt. Assem. Suppl., Abstract A33E-03.

Chretien, J., S. Bedno, A. Anyamba, R. Breiman, C. Njuguna, R. Sang, K. Sergon, A. Powers, C. Onyango, J. Small, K.J. Linthicum, and C. Tucker (2006), Eco-climatic precursors to large Chikungunya outbreaks in Kenya and Comoros, 2004-2005, presented at the International Conference on Emerging Infectious Diseases 2006, Atlanta, GA, 19-22 March.

Chu, D. A. (2006), Analysis of the relationship between MODIS aerosol optical depth and PM2.5 in the summertime US, Proc. of SPIE, Vol. 6299, 629903, SPIE Annual Meeting, San Diego, CA, 13-17 August.

Clark, P. E., J. W. Keller, S. A. Curtis, J. A. Nuth, T. J. Stubbs, and W. M. Farrell (2006), SPARCLE: Space Plasma Alleviation of Regolith Concentrations in the Lunar Environment, AGU Joint Assembly, Baltimore, MD, 23-26 May.

Clark, P. E., J. W. Keller, W. M. Farrell, T. J. Stubbs, J. A. Nuth, and S. A. Curtis (2006), Electrostatic dust control and collection on planetary surfaces, Lunar Planet. Sci. Conf. XXXVII, League City, TX, 13-17 March.

Comstock, J. M., R.-F. Lin, D. O. Starr, and S. A. McFarlane (2006), Use of lidar and radar data for cirrus cloud model initialization and validation, The 23rd International Laser Radar Conference. Nara City, Japan, 24-28 July.

Comstock, J., R.-F. Lin, D. O'C. Starr, and P. Yang (2006), Simulations of cirrus clouds using an explicit cloud model: integrating ARM water vapor and forcing data for analysis of cirrus microphysical properties, The 12th Conference on Cloud Physics, Madison, Wisconsin, 10-14 July.

Comstock, J., R.-F. Lin, D. O'C. Starr, and P. Yang (2006), Simulations of cirrus clouds using an explicit cloud model: integrating ARM water vapor and forcing data for analysis of cirrus formation and evolution, The 16th Atmospheric Radiation Measurement (ARM) Science Team Meeting, Albuquerque, NM, 27-31 March.

Crider, D. H., T. J. Stubbs, and R. R. Vondrak (2006), History of the inner solar system according to the lunar cold traps, *Eos Trans. AGU, 87*(52), Fall Meet. Suppl., Abstract SM43A-1478.

Crow, W. T., D. Entekhabi, R. Koster, and R. H. Reichle (2006), Synergy between planned NASA water cycle missions, *EOS, Transactions, American Geophysical Union, 87*(15), pp 149,153.

Csatho, B., C. J. van der Veen, R. R. B. von Frese, J. Kiss, H. R. Kim, T. Leftwich, and A. Braun (2006), Subglacial controls on glacier flow in Northern Greenland, Abstract, Int. Symp. Earth. Planet. Ice-Volcano Interact., sponsored by IGC, Reykjavik, Iceland, 19-23 June.

De Lannoy, G. J., R. H. Reichle, P. R. Houser, V. R. Pauwels, and N. E. Verhoest (2006), Ensemble Kalman Filtering of Soil Moisture Observations With Model Bias Correction, AGU Fall Meeting, San Francisco, CA, 11-15 December.

de Matthaeis, P. , and R. H. Lang (2006), Scattering by a Vertical Tree Trunk Over a Flat Ground: A Comparison Between Analytical and Numerical Approach, paper presented at PIERS 2006, Cambridge, MA, 26-29 March.

Delaney, M. P., and S. Hoban (2006), Challenging 21st century students to take the step-by-step approach to a scientific investigation by incorporating interactive multimedia events with a real scientist, presented at 2006 American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December.

Delaney, M. P., and S. Hoban (2007), Moon Math: Challenging students to use measurement in a lunar investigation, presented at 2007 Space Exploration Educators Conference, Houston, TX, 8-10 February.

DeSouza-Machado, S., D. A. Chu, N. R. Nalli, L. L. Strow, S. E. Hannon, H. E. Motteler, and P. J. Minnett, Estimation of dust loading and height using MODIS, AIRS, and MAERI data, Proc. of SPIE, Vol. 6299, 62990D, SPIE Annual Meeting, San Diego, CA, 13-17 August.

DeYoung, R., J. Szykman, K. Severance, D. A. Chu, R. Rosen, and J. Al-Saddi (2006), Aerosol lidar and MODIS satellite comparison for future aerosol loading forecast, Proc. of SPIE, Vol. 6299, 629905, SPIE Annual Meeting, San Diego, CA, 13-17 August.

Diehl, T. L., M. Chin, T. C. Bond, S. A. Carn, B. N. Duncan, N. A. Krotkov, and D. G. Streets (2006), Compilation of a Global Emission Inventory from 1980 to 2000 for Global Model Simulations of the Long-term Trend of Tropospheric Aerosols, AGU Joint Assembly, Baltimore, MD, 23-26 May.

Diehl, T. L., M. Chin, T. C. Bond, S. A. Carn, B. N. Duncan, N. A. Krotkov, and D. G .Streets (2006), Compilation of a Global Emission Inventory from 1980 to 2005 for Global Model Simulations of the Long-term Trend of Tropospheric Aerosols, Aerosol Workshop on Climate Prediction Uncertainties, Santa Fe, NM, 20-21 July.

Diehl, T., and M. Chin (2006), A global emission inventory for aerosol simulations of the period 1980-2005, Fifth AeroCom Workshop, Virginia Beach, VA, 17-19 October.

Dinnat, E. P., P. de Matthaeis, and D. M. Le Vine (2006), The Sun as a Source of Error for Sea Surface Salinity Retrieval by Means of Passive Microwave Remote Sensing at L-band, *Eos Trans. AGU, 87*(52), Fall Meet. Suppl., San Francisco, CA, 11-15 December.

Dong, J., D. L. Toll, P. R. Houser, C. Peter-Lidard, K. R. Arsenault, B. A. Cosgrove, and S. Kumar (2006c), Evaluation of the factors and error propagation in the model energy flux estimates with Land Information System, AGU West Pacific Geophysical Meeting, Beijing, P.R.C., 24-27 July.

Eastman, J. L., C. D. Peters-Lidard, S. V. Kumar, and Y. Tian (2006), Evaluation of land surface spin-up and their impacts on hi-resolution convective modeling, Goddard Earth Sciences and Technology (GEST) Seminar, University of Maryland Baltimore County, GEST Center, Baltimore, MD, 5 April.

Eastman, J. L., C. Peters-Lidard, W.-K. Tao, S. Kumar, S. Lang, Y. Tian, and X. Zeng (2006), The Impact of Forcing Resolution on Data Assimilation and High Resolution Atmospheric Modeling, AGU Conference, Baltimore, MD, 23–26 May.

Eastman, J. L., C. Peters-Lidard, W.-K. Tao, S. Kumar, X. Zeng, and S. Lang (2006), Recent Accomplishments in Coupling High Resolution Earth System Models Using Advanced Computational Technologies, NASA's Sixth Annual Earth Science Technology Conference, College Park, MD, 27-29 June.

Eck, T. F., B. N. Holben, E. J. Hyer, J. S. Reid, N. C. Hsu, J. R. Van de Castle, F. S. Chapin, N. T. O'Neill, A. Sinyuk, O. Dubovik, and A. Smirnov (2006), Optical properties of biomass burning aerosols in Alaska and transport of smoke to remote Arctic regions, AGU Fall Meeting, San Francisco, CA, 11-15 December, (*Eos Trans. AGU, 87*(52), Fall Meet. Suppl., Abstract A53D-0215).

Eck, T. F., B. N. Holben, J. Boonjawat, A. X. Nguyen, L. A. Remer, J. S. Reid, O. Dubovik, A. Sinyuk, J. Schafer, and A. Smirnov (2006), Aerosol optical properties in Southeast Asia from AERONET observations and computation of clear sky direct radiative forcing, 2006 Western Pacific Geophysics Meeting, Beijing, China, 24-27 July, (*Eos Trans. AGU, 87*(36), West. Pac. Geophys. Meet. Suppl., Abstract A14A-0024).

Ehrendorfer, M., and R. M. Errico (2006), An intermediate-complexity model for data assimilation, Proceedings of the Second THORPEX International Science Symposium (STISS), Landshut, Germany, H. Volkert, Ed., WMO/TD No. 1355, WWRP/THORPEX No. 7, 58-59.

Ehrenfreund, P., J. Garry, I. L. Ten Kate, P. Nørnberg, and K. van Sluis, (2006), Mars simulations relevant to planetary protection, 36th COSPAR Scientific Assembly, Beijing, China, 16-23 July, p. 583.

Errico, R. M. (2006), Consideration of representativeness error in an OSSE framework, seminar presented at the National Centers for Environmental Prediction, Camp Springs, MD, 16 November.

Errico, R. M. (2006), Interpretations of an adjoint-derived observational impact measure, poster presented at the 7th International Workshop on Adjoint Applications in Dynamic Meteorology, Obergurgl, Austria, 10 October.

Errico, R. M. (2006), Some fundamentals of ensemble Kalman filters, seminar presented at the Global Modeling and Assimilation Office, Goddard Space Flight Center, Greenbelt, MD, 7 September.

Errico, R. M. (2006), Some issues concerning ensemble Kalman filters and their interpretations, seminar presented at the Global Modeling and Assimilation Office, Goddard Space Flight Center, Greenbelt, MD, 14 September.

Errico, R. M. (2006), The development and applications of adjoint models in dynamic meteorology, keynote presentation at the 7th International Workshop on Adjoint Applications in Dynamic Meteorology, Obergurgl, Austria, 9 October.

Errico, R. M., R. Yang, M. Masutani, and J. Woollen (2006), The use of an OSSE to estimate characteristics of analysis error, seminar presented at the National Centers for Environmental Prediction, Camp Springs, MD, 5 September.

Errico, R. M., R. Yang, M. Masutani, and J. Woollen (2006), The use of an OSSE to estimate characteristics of analysis error, seminar presented at the Global Modeling and Assimilation Office, Goddard Space Flight Center, Greenbelt, MD, 15 September.

Errico, R.M. (2007), Some issues concerning the use of weather forecasts, invited presentation at the Workshop on Doing Something about the Weather, Naval Postgraduate School, Monterey, CA, 3 January.

Eylander, J. B., S. V. Kumar, and C. D. Peters-Lidard (2007), The Land Information System- A new common infrastructure for land data assimilation at NASA and AFWA, 21th Conference on Hydrology, 87th American Meteorological Society Annual Meeting, San Antonio, TX, 13-18 January.

Farrell, W. M., G. T. Delory, T. J. Stubbs, M. Collier, J. Keller, J. S. Halekas, and R. R. Vondrak (2006), Lunar Emissions, Electrons, and Dust (LEED): An instrument for assessment of the hazards of the dusty-plasma surface environment, AGU Fall Meeting, San Francisco, CA, 11–15 December.

Farrell, W. M., J. S. Halekas, T. J. Stubbs, R. R. Vondrak, G. T. Delory, S. D. Bale, and R. P. Lin (2007), The lunar wake as a unique plasma physics laboratory, contributed presentation at the Workshop on Science Associated with the Lunar Exploration Architecture, NASA Advisory Council, Tempe, AZ, 26 February – 2 March.

Fu, R., H. Yu, and Y. Zhang (2006), Influence of biomass burning aerosols on land-atmosphere coupling over South America, invited presentation to West Pacific AGU meeting, Beijing, China, 22-26 July.

Garcia, L. N., S. A. Boardsen, G. Le, Y. Wang, J. B. Sigwarth, J.A. Slavin, and R. J. Strangeway (2006), A Comparison of ST5 Derived Field Aligned Currents with Auroral Images by the Polar Spacecraft and a Comparison of Magnetic Conjunctions of the ST5 Spacecraft with Other Spacecraft, AGU Fall Meeting, San Francisco, CA, 11–15 December.

Garcia, L. N., S. A. Boardsen, G. Le, Y. Wang, J. B. Sigwarth, J. A. Slavin, and R. J. Strangeway (2006), A Comparison of ST5 Derived Field Aligned Currents with Auroral Images by the Polar Spacecraft and a Comparison of Magnetic Conjunctions of the ST5 Spacecraft with Other Spacecraft, 2006 AGU Fall Meeting, San Francisco, CA, U.S.A., 11–15 December.

Garcia, M., C. D. Peters-Lidard, and D. Goodrich (2006), Spatial interpolation of precipitation in a dense gauge network for monsoon storm events in southeastern Arizona, *Eos Trans. AGU, 87*(36), Jt. Assem. Suppl., Abstract H21C-04.

Garcia, M., S. Kumar, D. Gochis, D. Yates, J. McHenry, T. Burnet, C. Coats, and J. Condrey (2006), Distributed application of the Unified Noah LSM with hydrologic flow routing on an Appalachian headwater basin, *Eos Trans. AGU, 87*(36), Jt. Assem. Suppl., Abstract H23D-20 (poster).

Garcia, M., S. V. Kumar, D. J. Gochis, D. N. Yates, J. McHenry, T. Burnet, C. J. Coats, and J. Condrey (2007), Test Applicaton of a distributed hydrologic LSM with subsurface and overland flow routing for a tropical storm event in an Appalachian headwater basin, 21th Conference on Hydrology, 87th American Meteorological Society Annual Meeting, San Antonio, TX, 13-18 January.

Garcia, M., Y. Tian, C. D. Peters-Lidard, J. B. Eylander, C. Daly, R. Joyce, and J. Janowiak (2007), Spatial downscaling and evaluation of CMORPH and TRMM 3B42V6 analyses over the continental U. S., paper presented at the 87th AMS Annual Meeting, San Antonio, TX, 16 January.

Garcia, V., S. Kondragunta, D. Holland, F. Dimmick, B. Boothe, J. Szykman, and A. Chu (2006), Integration of Satellite, Modeled, and Ground Based Aerosol Data for use in Air Quality and Public Health Applications, *Eos Trans. AGU, 87*(36), Jt. Assem. Suppl., Abstract A33E-06.

Gasso, S. (2006), Long Range Transport of Dust from the Patagonia desert into the SW Atlantic, American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December.

Gassó, S. (2006), Long Range Transport of Dust from the Patagonia desert into the SW Atlantic, AGU Fall Meeting, San Francisco, CA 11-15 December.

Gasso, S. (2006), Satellite - Based Studies of Smoke - Cloud Interactions in the Atlantic Ocean off the coast of South America, American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December.

Gassó, S. (2006), Satellite - Based Studies of Smoke - Cloud Interactions in the Atlantic Ocean off the coast of South America, AGU Fall Meeting, San Francisco, CA 11-15 December.

Gasso, S. (2006), Volcanic Plumes in the South Atlantic Ocean: A Natural Laboratory for the Study of Aerosol - Cloud Interactions, American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December.

Gassó, S. (2006), Volcanic Plumes in the South Atlantic Ocean: A Natural Laboratory for the Study of Aerosol - Cloud Interactions, AGU Fall Meeting, San Francisco, CA 11-15 December.

Gatebe, C. K., G. T. Georgiev, J. J. Butler and M. D. King (2006), Insights from Laboratory and Airborne BRDF Measurements for Satellite Remote Sensing, the 4th International Workshop of Multiangular Measurements and Models (IWMMM-4), Sydney, Australia, 20-25 March.

Gatebe, C. K., G. T. Georgiev, J. J. Butler and M. D. King (2006), Insights from Laboratory and Airborne BRDF Measurements for Satellite Remote Sensing, AMS 12th Conference on Atmospheric Radiation, Madison, WI, 10-14 July.

Gatebe, C. K., M. D. King, and G. T. Arnold (2006), Airborne Spectral and Angular Measurements of Surface-Atmosphere Anisotropy for Several Surfaces and Ecosystems, the 4th International Workshop in Multiangular Measurements and Models (IWMMM-4), Sydney, Australia, 20-25 March.

Gatebe, C. K., M. D. King, and G. T. Arnold (2006), Airborne Spectral Measurements of Surface-Atmosphere Anisotropy over Different Surfaces in Mexico, the First MILAGRO Science Meeting, Boulder, CO, 23-25 October.

Gazis, P. R., J. D. Scargle, N. Lal, S. Hoban, and M. J. Way (2006), The AISRP Code and Algorithm Library, presented at American Astronomical Society 208th Meeting, Calgary, Canada, 4-8 June.

Gazis, P. R., N. Lal, S. Hoban, and M. Way (2006), The AISRP Code and Algorithm Library, presented at 2006 American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December.

Georgiev, G. T., C. K. Gatebe, J. M. Butler, and M. D. King (2006), Comparison between laboratory and airborne BRDF measurements for remote sensing, in *Proc. SPIE, Optics and Photonics, Remote and In Situ Sensing-Earth and Remote Systems XI*, edited by James J. Butler and Jack Xiong, 6296 (629603-8), San Diego, CA, 13-17 August.

Georgieva, E. M., E. L. Wilson, and W. S. Heaps (2006), Precise measurement of CO_2 from space using Fabry-Perot based optical setup: current status and development, Proc. SPIE Earth Observing Systems XI, vol.6296, 62961G.

Giles, D. M., B. N. Holben, I. Slutsker, E. J. Welton, M. Chin, J. Schmaltz, T. Kucsera, and T. Diehl (2006), A New Web-based Tool for Aerosol Data Analysis: the AERONET Data Synergy Tool, AGU Fall Meeting, San Francisco, CA, 11-15 December.

Grecu, M. (2006), Passive-Microwave Precipitation Estimation over Land using a Physical Mode, AGU Joint Assembly, Baltimore, MD, 23-26 May.

Grecu, M. (2006), Snowfall estimation from space-borne active and passive microwave observations, AGU Fall Meeting, San-Francisco, CA, 11-15 December.

Grecu, M., W. S. Olson, D. S. Walliser, C. L. Shie, and W. K. Tao (2006), Estimating Global Latent-Heating Distributions Using a PR-TMI trained algorithm, NASA Energy and Water Study Science Meeting, College Park, MD, 23 September.

Grecu, M., W.S. Olson, C.-L. Shie, and W.K. Tao (2006), Estimating global latent heating distributions using a PR/TMI-Trained Radiometer Algorithm, 2nd NASA Energy and Water cycle Study NEWS PI Meeting, UMICC, College Park, MD, 26-28 September.

Gu, G., and R, F. Adler (2006), Subseasonal rainfall variability in the tropical eastern Atlantic-West African region, paper presented at 27th Conference on Hurricane and Tropical Meteorology, Monterey, CA, 25 April.

Gu, G., R. F. Adler, G. J. Huffman, and S. Curtis (2006), Interannual-to-interdecadal/ong-term tropical rainfall variability/change in the GPCP monthly precipitation product, paper presented at 2006 Western Pacific Geophysics, Beijing, China, 26 July.

Guenther, B., F. DeLuccia, G. Grimm, E. Johnson, J. Young, and X. Xiong (2006), NPOESS VIIRS Calibration Activities, AMS Annual Meeting, Atlanta, GA, 29 January – 2 February.

H. Bian, M.Chin, R. Kawa, B. Duncan, P. Kasibhatla, and A.Arellano (2006), Effect of biomass burning emissions on global and Asia CO simulations, Western Pacific Geophysical Meeting, Beijing China, 24-27 July.

Halekas, G. T. Delory, T. J. Stubbs, W. M. Farrell, and R. R. Vondrak (2006), Lunar electric fields: Observations and implications, AGU Fall Meeting, San Francisco, CA, U.S.A., 11–15 December.

Halekas, J. S., G. T. Delory, D. A. Brain, R. P. Lin, M. O. Fillingim, C. O. Lee, R. A. Mewaldt, T. J. Stubbs, W. M. Farrell, and M. K. Hudson (2006), Lunar surface charging during solar energetic particle events, American Astronomical Society, Division of Planetary Sciences meeting 38, Pasadena, CA, 9-13 October.

Halekas, J. S., G. T. Delory, T. J. Stubbs, W. M. Farrell, R. R. Vondrak, and M. R. Collier (2006), Lunar electric fields and dust: Implications for in situ resource utilization, Space Resources Roundtable VIII, Colorado School of Mines, Golden, CO, 31 October 31 – 2 November.

Heaps, W. S., E. L. Wilson, and E. M. Georgieva (2006), Considerations on validation of space-based CO_2 measurement, NASA Carbon Cycle and Ecosystems Joint Workshop on NASA Biodiversity, Terrestrial Ecology and Related Applied Sciences, College Park, MD, 24-26 August.

Heaps, W. S., E. L. Wilson, and E. M. Georgieva (2006), Fabry-Perot based differential radiometers for precise determination of atmospheric column, AGU 2006 Fall Meeting, San Francisco, CA, 11-15 December.

Hernandez, O., R. R. B. von Frese, and H. R. Kim (2006), Tectonic analysis of Northwestern South America from integrated satellite, airborne and surface potential field anomalies, Backbone of the Americas GSA topical meeting, Mendoza, Argentina, 3-7 April.

Heymsfield, G. M., L. Belcher, J. Halverson, L. Tian, and L. Li (2006), Intense Convective Burst Observed From Hurricane Emily (2005) During TCSP, AMS 27th Conference on Hurricanes and Tropical Meteorology, Monterey, CA, 24-28 April.

Hoff, R., A. Chu, A. Prados, C. Wayland, F. Dimmick, et al. (2006), 3D-AQS, *Eos Trans. AGU, 87*(36), Jt. Assem. Suppl., Abstract A43A-01, 2006.

Hoff, R., J. A. Engel-Cox, F. Dimmick, J. J. Szykman, B. Johns, S. Kondragunta, R. Rogers, K. McCann, D. A. Chu, O. Torres, A. Prados, J. Al-Saddi, C. Kittaka, V. Boothe, S. Ackerman, and A. Wimmers (2006), 3D-AQS, a three-dimensional air quality system, Proc. of SPIE, Vol. 6299, 629901, SPIE Annual Meeting, San Diego, CA, 13-17 August.

Holben, B. N., T. F. Eck, A. Smirnov, A. Siniuk, W. W. Newcomb, I. Slutsker, D. Giles, J. Schafer, M. Sorokin, A. Scully, and O. Dubovik (2006), The AERONET makeover, GEWEX Aerosol Working Group Workshop, College Park, MD, 14-15 September.

Holben, B. N., T. F. Eck, A. Smirnov, D. Giles, W. W. Newcomb, M. Sorokin, A. Ho, A. Sinyuk, J. Schafer, A. Scully, and I. Slutsker (2006), AERONET overview – principles and applications, AERONET Training Workshop, Chung-Li, Taiwan, 7 April

Hong, Y., R. Adler, A. Negri, G. Huffman, and M. Pando (2006), Towards a Quasi-global precipitation-induced Landslide Detection System using Remote Sensing Information, EOS Transaction, AGU, Baltimore, MD, 23-27 May.

Hong, Y., R. Adler, and G. Huffman (2006), A Conceptual Framework for Space-borne Flood Detection/Monitoring System, EOS Transaction, AGU Spring, Baltimore, MD, May 23-27.

Hong, Y., R. F. Adler, and G. J. Huffman (2006), An Operational Monitoring System for Global Rainfall-induced Landslide Hazards, EOS Transaction, AGU Fall, SF, CA, USA, 11- 15 December.

Hong, Y., R. F. Adler, and G. J. Huffman (2006), Evaluation of the Potential of NASA TRMM-based Precipitation Analysis in Global Landslide Hazard Assessment, ICL/UNESCO, Paris, France, 23-24 November.

Hong, Y., R. F. Adler, and G. J. Huffman (2006), From Space-borne Rainfall Map to Flood Potential Map, EOS Transaction, Western Pacific Geophysical Meeting, Beijing, China, 24-27 July.

Hong, Y., R. F. Adler, and G. J. Huffman (2007), Mapping Global Landslide Susceptibility, International Panel on Landslide Risk Analysis and Sustainable Disaster Management Symposium, Tokyo, Japan, 22-25 January.

Hong, Y., R. F. Adler, R. Brakenridge, and G. J. Huffman (2007), Global Flood Watch: from Satellite Precipitation Data to a Flood Inundation Map, 87th AMS Annual Conference, San Antonio, TX, 14-18 January.

Hsu, M. K., A. K. Liu, and Y. Zhao (2006), SAR data collection plan during SCS'07, presented at ONR SCS FY07 Field Planning Meeting, Kaoshiung, Taiwan, 13-19 November.

Jacob, S. D., D. M. Le Vine, and G. S. E. Lagerloef (2006), Sensitivity of Sea Surface Salinity to Surface Forcing and Mixing, paper presented at the 3rd Aquarius Science Team meeting, Woods Hole, MA, 10-12 May.

Jacob, S. D., D. M. Le Vine, and G. S. E. Lagerloef (2006), Variability Scales of Sea Surface Salinity, paper presented at the CLIVAR Salinity Working Group meeting, Woods Hole, MA, 8-10 May.

Jacob, S. D., L. K. Shay, and G. R. Halliwell (2006), Upper Ocean Response during Extreme Forcing Events, paper presented at the 13th Layered Ocean Modeling Conference, Miami, FL, 8-10 February.

Kataoka, A., and A. Pulkkinen (2006), S-transform analysis of geomagnetically induced currents during intense geomagnetic storms, paper presented at Fall AGU meeting, San Francisco, CA, 11-15 December.

Kawa, S. R., P. A. Newnan, P. Colarco, H. Bian, A. da Silva, M. Chin, M. Loewenstein, C. Webster, S. Wofsy, and N. Livesey (2006), Goddard 3D Chemistry/Transport Modeling for CR-AVE, CR-AVE Science Team Meeting, Greenbelt, MD, 14-17 November.

Kawa, S. R., P. A. Newnan, P. Colarco, H. Bian, A. da Silva, M. Chin, M. Loewenstein, C. Webster, J. Elkins, S. Wofsy, and J. Waters (2006), Goddard 3D Chemistry/Transport Modeling for CR-AVE, AURA science meeting, Boulder, CO, September.

Kelly, R. E. J., M. Tedesco, E. J. Kim, and J. L. Foster (2006), Does the spatial resolution of passive microwave measurements of snow matter? Some observations from the NASA Cold Land Processes Experiment, IGARSS'06, Denver, CO, 26 July – 3 August.

Kim, E. J., and M. Tedesco (2006), An integrated snow radiance and snow physics modeling framework for cold land surface modeling, MicroRad 2006, Puerto Rico, 28 February - 3 March.

Kim, E. J., and M. Tedesco (2006), Snow Spatial Scaling Analyses Using In Situ Measurements, Radiances, and Retrievals from CLPX-1, 63rd Eastern Snow Conference, Newark, DE, 4-7 June.

Kim, E. J., and M. Tedesco (2006), Spatial Scaling Behavior of Brightness Temperatures During CLPX and Appropriate Satellite Sensor Resolution, invited presentation at Progress in Electromagnetic Research Symposium, Cambridge, MA, 26-29 March.

Kim, E. J., M. Tedesco, and J. P. Walker (2006), Observed Scaling Behavior of Snow and Soil Moisture Signatures from the CLPX and NAFE Campaigns, MicroRad 2006, Puerto Rico, 28 February - 3 March.

Kim, E., M. Tedesco, B. Choudhury, J. Foster, and D.Hall (2006), The Goddard snow radiance assimilation project: an integrated snow radiance and snow physics modeling framework for snow/cold land surface modeling, AGU Fall meeting, San Francisco, CA, 11-15 December.

Kim, E., M. Tedesco, R. H. Reichle, B. Choudhury, J. Foster, D. Hall, C. Peters-Lidard, and G. Riggs (2006), The Goddard Snow Radiance Assimilation Project: an Integrated Snow Radiance and Snow Physics Modeling Framework for Snow/Cold Land Surface Modeling, AGU Fall Meeting, San Francisco, CA, 11-15 December.

Kim, H. R., P. T. Taylor, R. R. B. von Frese, A. V. Golynsky, and L. R. Gaya-Pique (2006), Antarctic lithospheric magnetic anomalies from ADMAP, CHAMP and Ørsted data, abstract, First Swarm Intl. Sci. Meeting, Nante, France, 3-5 May.

Kim, H. R., P. T. Taylor, R. R. B. von Frese, A. V. Golynsky, L. R. Gaya-Pique, and J. W. Kim (2006), Antarctic lithospheric magnetic anomalies from ADMAP, CHAMP and Orsted data, *Eos Trans. AGU, 87*(36), Jt. Assem. Suppl., Abstract GP41A-02.

Kim, K.-M. and K.-M. Lau (2007), The impacts of aerosols on Asian summer monsoon rainfall and circulation, AMS Annual Meeting, San Antonio, TX, 14-18 January.

King, T., R. Walker, J. Merka, and S. Joy (2007), Virtual Magnetospheric Observatory, THEMIS Pre-Launch Science Meeting, Cape Canaveral, Florida, 13-14 February.

Kittaka, C., R. B. Pierce, J. J. Szykman, J. A. Al-Saadi, T. K. Schaack, G. J. Tripoli, A. Chu, and A. J. Soja (2006), Improvement of Aerosol Modeling Using a MODIS AOD Assimilation, *Eos Trans. AGU, 87*(36), Jt. Assem. Suppl., Abstract A32A-06.

Koster, R. D., and R. H. Reichle (2007), Current Capabilities and Future Directions for Land Surface Data Assimilation, Invited presentation at the 87th AMS Annual Meeting, San Antonio, TX, 13-18 January.

Koster, R. D., M. J. Suarez, S. D. Schubert, R. H. Reichle (2006), Using Observed Spatial Correlation Structures of Rainfall and Temperature to Improve the Skill of Subseasonal Forecasts Relying on Land Surface Moisture Initialization, AGU Spring Meeting, Baltimore, MD, 23-26 May.

Koster, R., P. Liu, and S. Mahanama (2006), Impact of Soil Moisture on Precipitation: A Sensitivity Study with the GEOS5 AGCM, NOAA's 31st Climate Diagnostics and Prediction Workshop (CDPW), Boulder, CO, 23-27 October.

Krotkov, N. A, P. K. Bhartia, K. Yang, S. Carn, and A. Krueger (2006), SO_2 detection with OMI, 11th OMI Science Team Meeting, De Bilt, The Netherlands, 19-22 June.

Krotkov, N. A., P. K. Bhartia, K. Yang, S. Carn, A. Krueger, R. R. Dickerson, J. C. Hains, C. Li, Z. Li, L. T. Marufu, J. W. Stehr and P. Levelt (2006), SO_2 over China detected with OMI, AGU Fall Meeting, A16, San Francisco, CA, 11-15 December.

Krotkov, N. A., P. K. Bhartia, K. Yang, S. Carn, A. Krueger, R. R. Dickerson, J. C. Hains, C. Li, Z. Li, L. T. Marufu, J. W. Stehr, and P. Levelt (2006), SO_2 over China detected with OMI, Fall AGU, A16, 11-15 December.

Krotkov, N. A., P. K. Bhartia, K. Yang, S. Carn, and A. Krueger (2006), SO_2 detection with OMI, OMI ST meeting, SO_2 working Group, De Bilt, Netherlands, 19-22 June.

Krotkov, N. A., S. A. Carn, A. J. Krueger, P. K. Bhartia, and K. Yang (2006), OMI Measurements of Volcanic and Anthropogenic SO_2, EGU meeting, Vienna, Austria, 3-6 April.

Krueger, A. J., N. A. Krotkov, S. A. Carn, K. Yang, P. Levelt, G. Serafino, G. Stephens, M. Guffanti, D. Schneider, G. Hufford, and C. Kessinger (2006), NASA research satellite data for volcanic aviation hazards, SACS Aviation Hazard Meeting, Brussels, 3 October.

Kumar, S. V., C. D. Peters-Lidard, J. Eylander, R. Reichle, W. Crow, X. Zhan, P. Houser, R. Koster, M. Suarez, and J. Dong (2006), A Generic, Interoperable, Hydrologic Data Assimilation Framework using the Land Information System, H23E-1558, American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December.

Kumar, S. V., C. D. Peters-Lidard, J. L. Eastman, and W-K. Tao (2007), Evaluation of the influence of fine scale land surface representation on convective processes using the coupled LIS-WRF system, 21th Conference on Hydrology, 87th American Meteorological Society Annual Meeting, San Antonio, TX, 13-18 January.

Kumar, S. V., C. Peters-Lidard, J. Eastman, and W.-K. Tao (2007), Evaluation of the influence of fine scale land surface representation on convective processes using the coupled LIS-WRF system. 21st Conference on Hydrology, 87th American Meteorological Society Annual Meeting, Atlanta, GA, 29 January - 2 February.

Lait, L. R., P. Newman, and P. Bui (2006), A persistent westerly tropical jet encountered during CRAVE, paper presented at the CRAVE Science Team Meeting, Lanham-Seabrook, MD, 14-17 November.

Lang, S., W.-K. Tao, X. Zeng, C. Peters-Lidard, S. Kumar, and J. L. Eastman (2006), High-Resolution CRM Simulations from IHOP: Cloud-Radiation Interactions, AGU Conference, Baltimore, MD, 23-26 May.

Lary, D., and L.R. Lait (2006), Using Probability Distribution Functions for Satellite Validation,poster presented at the 2006 Joint Assembly or AGU and EGU, Baltimore, MD, 23-26 May.

Lau, K. M., and K. M. Kim (2007), How nature foiled the 2006 hurricane forecasts, *EOS Trans. AGU, 88*(9), 27 February 2007.

Lau, K-M, and K.-M. Kim (2006), Modeling the effects of Sahara Dust on the climate and water cycle of the Tropical Atlantic/Caribbean region, *Eos Trans. AGU, 87*(52), Fall Meet. Suppl., Abstract A32C-02.

Lau, K-M, M-K Kim, and K.-M. Kim (2006), Hydroclimate feedback induced by aerosols over the Asian monsoon regions - the elevated-heat-pump hypothesis, *Eos Trans. AGU, 87*(36), Jt. Assem. Suppl., Abstract A23E-03.

Lawford, R. G. (2006), A Pot Pourri of international programs dealing with drought, Saskatchewan Research Center workshop on climate change and drought, Saskatoon, Saskatchewan, Canada, 28-29 November.

Lawford, R. G. (2006), A summary of GEWEX and its possible links to the International Polar Year (IPY), NAS Interagency Meeting, Washington, DC, 3 February.

Lawford, R. G. (2006), An introduction to some international hydrometeorological activities, Seminar at the National Water Research Institute, Saskatoon, Saskatchewan, Canada, 30 November.

Lawford, R. G. (2006), Background for the capacity building working group discussions, IGWCO/GEO Asian Capacity Building Workshop, Bangkok, Thailand, 25-27 September.

Lawford, R. G. (2006), Changes in the water cycle associated with climate changes, invited presentation at Research Institute for Humanity and Nature Symposium, Kyoto, Japan, 6-7 November.

Lawford, R. G. (2006), CLIVAR, GEWEX and monsoons at the upcoming JSC meeting, GEWEX SSG Meeting, Dakar, Senegal, 9-13 January.

Lawford, R. G. (2006), Contributions of the Global Energy and Water Cycle Experiment (GEWEX) to climate science, Western Pacific Geophysical Union Meeting, Beijing, China, 24-27 July.

Lawford, R. G. (2006), Contributions of the Global Energy and Water Cycle Experiment (GEWEX) to climate science, Chinese Meteorological Administration, Beijing, China, 28 July.

Lawford, R. G. (2006), Developing global water cycle observations and science to address the world's water issues, Western Pacific Geophysical Union Meeting, Beijing, China, 24-27 July.

Lawford, R. G. (2006), Energy and water cycle research from the global scale to drought anomalies on the Canadian prairies, Seminar at the University of Manitoba, Winnipeg, Manitoba, 1 November.

Lawford, R. G. (2006), Future of IGWCO, Second IGWCO Planning Meeting, Paris, France, 27 March – 2 April.

Lawford, R. G. (2006), GEWEX (and Water Cycle) considerations for AMMA, U.S. AMMA workshop, Silver Spring, MD, 4-5 May.

Lawford, R. G. (2006), GEWEX and its links with IGWCO, Second IGWCO Planning Meeting, Paris, France, 27 March – 2 April.

Lawford, R. G. (2006), GEWEX Roadmap (under construction), Pan-GEWEX Meeting, Frascati, Italy, 9-13 October.

Lawford, R. G. (2006), GEWEX thoughts about WCRP monsoon plans, JSC Meeting, Pune, India, 6-11 March.

Lawford, R. G. (2006), Global Water Cycle observational and research contributions to reducing the societal impacts of unusual weather and climate, invited presentation at EGU Conference, Vienna, Austria, 3-7 April.

Lawford, R. G. (2006), Global Water System initiatives, overview of water cycle research, Conference at the International Institute of Sustainable Development, Winnipeg, Manitoba, 31 May - 1 June.

Lawford, R. G. (2006), Goals and structure of the first Pan-GEWEX meeting, Pan-GEWEX Meeting, Frascati, Italy, 9-13 October.

Lawford, R. G. (2006), IGWCO and its links to GWSP, Science Committee Meeting of the Global Water System Project (GWSP), Oxaca, Mexico, 22-24 March.

Lawford, R. G. (2006), Integrated Global Water Cycle Observation (IGWCO) theme update, Second IGWCO Planning Meeting, Paris, France, 27 March – 2 April.

Lawford, R. G. (2006), Integrated Global Water Cycle Observation (IGWCO) theme and its connections to CEOP, Fifth CEOP Science Meeting, Paris, France, 27 March – April 2.

Lawford, R. G. (2006), International programs contributing to the development of integrated Earth Observations Systems, EGU Conference, Vienna, Austria, 3-7 April.

Lawford, R. G. (2006), Introduction to a quest for a capacity building program for Latin America, Capacity Building Workshop, Buenos Aires, Argentina, 16-17 November

Lawford, R. G. (2006), Introduction to capacity building, Second IGWCO Planning Meeting, Paris, France, 27 March – 2 April.

Lawford, R. G. (2006), Introduction to GEWEX and its contribution to water management, Reservoir Workshop, Beijing, China, 28 July.

Lawford, R. G. (2006), Introduction to IGWCO and its capacity building goals. IGWCO/GEO Asian Capacity Building Workshop, Bangkok, Thailand, 25-27 September.

Lawford, R. G. (2006), Linkages between GEWEX and GWSP, Science Committee Meeting of the Global Water System Project (GWSP), Oxaca, Mexico, 22-24 March.

Lawford, R. G. (2006), NEESPI in transition, Vienna, Austria, 22-24 February.

Lawford, R. G. (2006), Observing surface waters for global change applications, Global Change Symposium, Madrid, Spain, 24-26 April.

Lawford, R. G. (2006), On the road to the GEWEX Roadmap, GEWEX SSG Meeting, Dakar, Senegal, 9-13 January.

Lawford, R. G. (2006), Pan-GEWEX meeting summary, Pan-GEWEX Meeting, Frascati, Italy, 9-13 October.

Lawford, R. G. (2006), Planetary water cycle science and observations for decision making in the water sector, ESSP Conference, Beijing, China, 9-12 November.

Lawford, R. G. (2006), Potential areas for research contributions to GEWEX and related programs, Seminar at Howard University, Washington DC, 12 April.

Lawford, R. G. (2006), Potential NEESPI linkages with IGWCO and GEWEX, Vienna, Austria, 22-24 February.

Lawford, R. G. (2006), Report by the NEESPI Steering and Coordinating Committee, Vienna, Austria, 22-24 February.

Lawford, R. G. (2006), Roadmap construction and project office reconstruction, JSC Meeting, Pune, India, 6-11 March.

Lawford, R. G. (2006), Summary of the findings of the Second IGWCO workshop, Second IGWCO Planning Meeting, Paris, France, 27 March – 2 April.

Lawford, R. G. (2006), Towards a global water cycle Community of Practice, GEO Users Interface Committee (UIC), Ottawa, Ontario, Canada, 5-7 September.

Lawford, R. G. (2006), Update on the activities and plans of the International GEWEX Project Office (IGPO), GEWEX SSG Meeting, Dakar, Senegal, 9-13 January.

Lawford, R. G. (2006), Update on the IGWCO theme, GEWEX SSG Meeting, Dakar, Senegal, 9-13 January.

Lawford, R. G. (2006), Update on the Integrated Global Water Cycle Observations (IGWCO) theme, JSC Meeting, Pune, India, 6-11 March.

Lawford, R. G. (2006), Update on the Integrated Global Water Cycle Observations (IGWCO) theme of IGOS-P, WOAP Meeting, Ispra, Italy, 2-4 October.

Lawford, R. G. (2006), Updates on GEO water tasks, GEO Users Interface Committee, Ottawa, Ontario, Canada, 5-7 September.

Lawford, R. G. (2006), Water Cycle Observations and opportunities for capacity building in Africa, World Bank, Washington, DC, 16 June.

Lawford, R. G. (2006), Water Cycle Observations for water management globally and in South America, CEOS Teacher's Workshop, CONAE, Buenos Aires, Argentina, 17 November.

Lawford, R. G., and C. Ishida (2006), Update on the IGOS Water Cycle theme, IGOSBis meeting, Buenos Aires, Argentina, 13 November.

Lawford, R. G., and P. Groisman (2006), NEESPI and a WCRP Perspective, (Northern Eurasia Earth Science Partnership Initiative), JSC Meeting, Pune, India, 6-11 March.

Lawford, R. G., and S. Greb (2006), Moving from global information to local scale decisions: Making an example from Wisconsin, World Water Forum IV, Mexico City, Mexico, 16-21 March.

Lawford, R. G., and W. Grabs (2006), WMO and capacity building for water management in Asia, IGWCO/GEO Asian Capacity Building Workshop, Bangkok, Thailand, 25-27 September.

Lawford, R. G., and W. Grabs, GEO and IGOS-P Updates, Pan-GEWEX Meeting, Frascati, Italy, 9-13 October.

Le, G., Y. Wang, J. A. Slavin, and R. J. Strangeway (2006), Space Technology 5 measurements of field-aligned currents: Separating spatial and temporal variations, AGU Fall Meeting, San Francisco, CA, 11–15 December.

Lee, M.-I. (2006), An analysis of the mid-latitude wintertime subseasonal variability in the coupled GCMs, Invited lecture, APEC Climate Center, Busan, Korea, 23 October.

Lee, M.-I. (2006), Madden-Julian Oscillation: Observations and Modeling, Invited lecture, APEC Climate Center, Busan, Korea, 20 October.

Lee, M.-I. (2006), Modeling the warm season diurnal cycle of precipitation in global climate models, Invited lecture, APEC Climate Center, Busan, Korea, 19 October.

Lee, M.-I., D. Kim, M. J. Suarez, and I. M. Held (2006), Simulations of tropical sub-seasonal variability in the idealized aqua-planet AGCMs, paper presented at the 2006 AGU Joint Assembly, Baltimore, MD, 23-26 May.

Lee, M.-I., S. D. Schubert, M. J. Suarez, and T. L. Bell (2006), An examination of the diurnal cycle of precipitation simulation in the NASA/GMAO atmospheric GCM, paper presented at the Korea-Japan-China Second Joint Conference on Meteorology, Seoul, Korea, 11-13 October.

Lee, M.-I., S. D. Schubert, M. J. Suarez, I. M. Held, A. Kumar, J.-K. E. Schemm, N.-C. Lau, J. J. Ploshay, H.-K. Kim, T. L. Bell, S.-H. Yoo, H.-L. Pan, and J. Han (2007), Simulations of warm season diurnal cycle of precipitation over the continental United States and northern Mexico in general circulation models, paper presented at the 87th Annual AMS Meeting, San Antonio, TX, 14-18 January.

Lee, M.-I., S. D. Schubert, M. J. Suarez, J. Schemm, S.-H. Yoo, H.-L. Pan, and J. Han (2006), Diurnal cycle over the Great Plains in NCEP/GFS, Invited talk at NOAA's 31st Climate Diagnostics and Prediction Workshop, Boulder, CO, 23-27 October.

Lepping, R. P., T. W. Narock, and C.-C. Wu (2006), A Scheme for Finding the Front Boundary of an Interplanetary Magnetic Cloud and its Role in Geomagnetic Storm Prediction, American Geophysical Union Fall Conference, San Francisco, CA, 11-15 December.

Li, J.-L., D. E. Waliser, J. H. Jiang, A. M. Tompkins, J.-D. Chern, W.-K. Tao, and M. F. Khairoutdinov (2006), Comparisons of EOS MLS cloud ice measurements with ECMWF analyses and multi-scale-modeling simulations, AGU 2006 Joint Assembly, Baltimore, MD, 23-26 May.

Li, L., Z. Wang, G. M. Heymsfield, and A. J. Heymsfield (2006), Study Optically Thick Ice Clouds with Airborne Dual-wavelength Radar Measurements, AGU Fall Meeting, San Francisco, CA, 11-15 December.

Li, X., W.-K. Tao, A. Khain, and J. Simpson (2006) Aerosol indirect effect on a mesoscale convective system: A modeling study, AMS 12th Conference on Cloud Physics, Madison, WI, 10-14 July.

Li, X., W.-K. Tao, A. Khain, and J. Simpson (2006), Aerosol impact on deep precipitation processes: A modeling study, ESSIC Seminar, Earth System Science Interdisciplinary Center, University of Maryland, College Park, College Park, MD, 13 March.

Li, X., W.-K. Tao, A. Khain, and J. Simpson (2006), Aerosol indirect effects on mesoscale convective systems: A cloud-resolving model study, 2nd International Conference on Global Warming and Aerosol Workshop, Santa Fe, NM, 17-21 July.

Liao, L., and R. Meneghini (2006), Retrieval of Microphysical Properties of Hydrometeors by Airborne Radar, IGARSS'06, Denver, CO, 31 July-4 August.

Liao, L., and R. Meneghini (2006), Validation of TRMM Precipitation Radar Products through 8-Year Measurements over Central Florida, WPGM'06, Beijing, China, 24-27 July.

Lin, R.-F., D. O'C. Starr, A. Lare, B. Demoz, and T. Rickenbach (2006), On cirrus anvil dissipation simulated by a mesoscale model with bulk microphysics, The 12th Conference on Cloud Physics, Madison, WI, 10-14 July.

Lin, X., A. Hou, C. Shie, W. Tao, and Y. Zhou (2006), Observational evaluation of long-term 3-D cloud simulations forced by the NASA GEOS analyses, AGU Joint Assembly, Baltimore, MD, 23-26 May.

Lin, X., A. Hou, C.-L. Shie, W.-K. Tao, and Y. Zhou (2006), Observational evaluation of long-term 3-D cloud simulations forced by GEOS reanalysis: Statistics of rainfall and cloud over the CRYSTAL-FACE region, AGU 1006 Joint Assembly, Baltimore, MD, 23-26 May.

Lin, X., and A. Y. Hou (2006), Evaluation of AMSU-B rain rates against TMI/SSMI/AMSR-E estimates using TRMM PR and ground measurements as references, The 3rd Workshop of the International Precipitation Working Group, Melbourne, Australia, 23-27 October.

Linthicum, K. J., A. Anyamba, and J-P Chretien (2006), Near real-time surveillance for Rift Valley fever in Africa and the Arabian Peninsula, presented at the 72nd Annual Meeting of the American Mosquito Control Association, Detroit, MI, 25 February – 2 March.

Linthicum, K. J., A. Anyamba, J. Chretien, P.B. Formenty, J. Small, C. J. Tucker, J. L. Malone, H. El Bushra, and V. Martins (2006), Potential for Rift Valley fever activity on the Arabian Peninsula:

detection of suitable eco-climatic conditions, presented at the International Conference on Emerging Infectious Diseases 2006, Atlanta, GA, 19-22 March.

Linthicum., K. J., A. Anyamba, J.-P. Chretien, R. L. Erickson, J. Small, C. J. Tucker, S. C. Britch, K. Bennett, R. Mayer, E. Schmidtman, T. G. Andreadis, J. F. Anderson, W. Wilson, J. Freier, A. James, R. Miller, B. Drolet, S. Miller, C. Tedrow, D. Strickman, D. R. Barnard, G. G. Clark, and L. Zou (2006), A Rift Valley fever risk surveillance system in Africa using remotely sensed data in a GIS: Potential for use on other continents, presented at the 1st OIE International Conference, Use of GIS in Veterinary Activities, Silvi Marina, Abruzzo, Italy, 8-11 October.

Liu, A. K., Y. Zhao, and M. K. Hsu (2006), Ocean surface drift by wavelet tracking of SAR images, presented at International Symposium of Remote Sensing and The international Pan Ocean Remote Sensing Conference (PORSEC) Association, Busan, Korea, 2-4 November.

Livingston, J., J. Redemann, P. Russell, S. Ramirez, Q. Zhang, O. Torres, E. Browell, J. Hair, Y. Shinozuka, C. McNaughton, A. Clarke, A. Smirnov, and B. Holben (2006), Aerosol optical depths from airborne sunphotometry in INTEX-B/MILAGRO as a validation tool for the Ozone Monitoring Instrument (OMI) on Aura, the Aura Science and Validation Team Meeting, Boulder, CO, 11-15 September.

Livingston, J., P. Russell, J. Redemann, S. Ramirez, Q. Zhang, O. Torres, A. Smirnov, B. Holben, E. Browell, J. Hair, C. McNaughton, A. Clarke, and Y. Shinozuka (2006), Aerosol optical depths from airborne sunphotometry in INTEX-B/MILAGRO as a validation tool for the ozone monitoring instrument (OMI) on Aura, MILAGRO/INTEX-B Science Team Meeting, Boulder, CO, 23-25 October.

Lyapustin, A. (2006), A new generic aerosol retrieval – atmospheric correction algorithm for MODIS, AEROCENTER Seminar, NASA GSFC, Greenbelt, MD, 14 November.

Lyapustin, A. (2006), Analysis of calibration difference between MODIS and MISR, Invited talk, SPIE, San Diego, CA, 16-18 August.

Lyapustin, A. (2006), Near-Constant Contrast (NCC) Method of atmospheric correction over land, AGU Spring Meeting, Baltimore, MD, 24 May.

Lyapustin, A. (2007), A generic aerosol retrieval – atmospheric correction algorithm for MODIS, NOAA/NESDIS/ORA Seminar, 25 January.

Lyapustin, A. (2007), MAIAC – Multi-Angle Implementation of Atmospheric Correction MODIS, Laboratory for Atmospheres Special Seminar, NASA GSFC, Greenbelt, MD, 26 February.

Lyapustin, A., and Y. Wang (2007), A generic aerosol retrieval – atmospheric correction algorithm for MODIS, AEROCENTER annual Poster Session, Greenbelt, MD, 9 January.

Lyapustin, A., Y. Wang, B. Holben, D. Diner, and J. Martonchik (2007), AERONET-based Surface Reflectance Validation Network – ASRVN, IWMMM-4 conference, Sydney, Australia, 21-24 March.

Mahaffy, P., and I. L. Ten Kate (2006), Mitigation of the impact of terrestrial contamination on organic measurements from the Mars Science Laboratory, *Eos Trans. AGU, 87*(52), Fall Meet. Suppl. Abstract P53A-02.

Mahanama, S. P. P., R. D. Koster, and P. Liu (2006), Impact of Subsurface Temperature Variability on Meteorological Variability: An AGCM Study, AGU Joint Assembly, Baltimore, MD, 23-26 May.

Mahanama, S., R. D. Koster, J. T. Bacmeister, P. Liu, M. J. Suarez, and R. H. Reichle (2007), Single column model analysis of land-atmosphere coupling strength, 21th Conference of Hydrology at 87th AMS Annual Meeting, San Antonio, TX, 15-19 January.

Mannino, A., M.E. Russ, and S.B. Hooker (2006), Satellite-derived distribution of DOC and CDOM in the Southern Middle Atlantic Bight, poster presented at the MODIS Science Team Meeting in College Park, MD, 31 October - 2 November.

Marshak, A., G. Wen, T. Varnai, and R. F. Cahalan (2007), How 3D science can help to correctly interpret satellite data on aerosol-cloud interaction, The 87th AMS Annual Meeting, San Antonio, TX, 14-18 January.

Marshak, A., R. F. Cahalan, T. Varnai, G. Wen, B. Vant-Hull (2006), How 3D science can help to correctly interpret MODIS data for better understanding of aerosol-cloud interactions, MODIS Science Meeting, Adelphi, MD, 1 November.

Marshak, A., T. Varnai, S. Platnick, G. Wen, and R. F. Cahalan (2006), Impact of 3D cloud structure on satellite retrievals of cloud droplet size, Madison, WI, 9-14 July.

Martin, V., P. Formenty, A. Anyamba, S. N'diaye, M. Thomson, and Y. Thiongane (2006), Perspectives on using seasonal climate forecasts for climate-related zoonotic diseases with focus on Rift Valley Fever, International Symposium on Veterinary Epidemiology and Economics, Cairns, Australia, 6-11 August.

McMillan, W., J. Warner, D. Wicks, C. Barnet, G. Sachse, D. A. Chu, and L. Sparling (2006), AIRS Views of Anthropogenic and Biomass Burning CO: INTEX-B/MILAGRO and TEXAQS/GoMACCS, *Eos Trans. AGU, 87*(52), Fall Meet. Suppl., A31A-0838.

McMillan, W., J. Warner, M. M. Comer, C. Barnet, W. Wolf, A. Chu, G. Sachse, and G. Diskin (2006), Tropospheric Carbon Monoxide Observations from AIRS During INTEX- B/MILAGRO, *Eos Trans. AGU, 87*(36), Spring Jt. Assem. Suppl., Abstract A42B-02.

Meneghini, R., and L. Liao (2006), Methods of Attenuation Correction for Dual-Wavelength and Dual-Polarization Weather Radar Data, IGARSS'06, Denver, CO, 31 July-4 August.

Meng, C. J., K. Mitchell, and H. Wei (2006), Monitoring the global soil moisture climatology using GLDAS/LIS, AGU 2006 Joint Assembly, Baltimore, MD, 23-26 May.

Meng, C. J., K. Mitchell, H. Wei, D. Tarpley, and I. Laszlo (2006), Comparison of Land Surface Skin Temperature derived from Operational NWP modeling and data assimilation systems, LDAS, satellite retrieval, and ground observations, 1st Workshop on Remote Sensing and Modeling of Surface Properties, Paris, France, 20-22 June.

Meng, C. J., K. Mitchell, H. Wei, J. Derber, G. Gayno, and M. Liu (2007), Improving the assimilation of land-surface sensitive satellite channels in NCEP's Global Data Assimilation System (GDAS) by improving land-surface emission in the Community Radiative Transfer Model (CRTM), AMS Annual Meeting, San Antonio, TX, 14-18 January.

Meng, C. J., K. Mitchell, M. Ek, and H. Wei (2006), The NOAA/NCEP Global Land Data Assimilation System, 1st Workshop on Remote Sensing and Modeling of Surface Properties, Paris, France, 20-22 June.

Meng, C. J., K. Mitchell, R. Yang, J. Gottschalk, and C. Peters-Lidard (2006), Applying Noah LSM in NASA-NCEP LIS to Provide a Realtime and 25-year Retrospective Global Land Data Base for Climate Model Impact Studies in NOAA CTB, 31st Climate Diagnostic and Prediction Workshop, Boulder, CO, 23-27 October.

Meng, C. J., K. Mitchell, R. Yang, J. Gottschalk, and C. Peters-Lidard (2006), 26-year global land climatology for the NOAA Climate Test Bed, The First Climate Prediction Program for the Americas (CPPA) PIs Meeting, Tucson, AZ, 14-16 August.

Merka, J. (2006), The Virtual Magnetospheric Observatory VMO, The Evolving Heliophysics Data Environment: VxO Kickoff Meeting, Baltimore, MD, 22 May.

Merka, J. (2007), Current status of the Virtual Magnetospheric Observatory, THEMIS Pre-Launch Science Meeting, Cape Canaveral, Florida, , 13-14 February.

Merka, J., A. Szabo, and T. Narock (2006), How to effectively discover and search heliospheric/magnetospheric data sets? The VHO and VMO goals explained, *Eos Trans. AGU, 87*(52), Fall Meet. Suppl., Abstract SM21A-0248.

Merka, J., D. Merkova, and D. Odstrcil (2006), On near-Earth MHD solar wind model and data assimilation, *Eos Trans. AGU, 87*(36), Jt. Assem. Suppl., Abstract SH53A-02.

Merka, J., T. Narock, and A. Szabo (2006), VHO/VMO experience with implementing SPASE 1.1.0, SPASE Meeting, UCLA, California, 8-10 November.

Mocko, D. M., C. D. Peters-Lidard, M. A. Tischler, Y. Wu, M. E. Garcia, and J. A. Santanello, Jr. (2006), The relative roles of soil, land cover, and precipitation uncertainty for watershed-scale soil moisture prediction in a semi-arid environment, AGU 2006 Joint Assembly, Baltimore, MD, 23-26 May.

Mocko, D. M., C. D. Peters-Lidard, M. A. Tischler, Y. Wu, M. Garcia, and J. A. Santanello (2006), The relative roles of soil, land cover, and precipitation uncertainty for watershed-scale soil moisture prediction in a semi-arid environment, *Eos Trans. AGU, 87*(36), Jt. Assem. Suppl., Abstract H43B-07 (poster).

Mohammed, P., J. Knuble, and J. Piepmeier (2006), Analog radio-frequency interference (RFI) suppression system for microwave radiometers, *EOS Trans. AGU, 87*(52), Fall Meet. Suppl., Abstract IN21A-1189.

Molnar, G. I., and J. Susskind (2006), Assessment of the Usefulness of Atmospheric Satellite Sounder-Based Cloud Retrievals for Climate Studies. GEWEX Cloud Climatology Assessment Workshop, Madison, WI, 5-6 July.

Molnar, G. I., and J. Susskind (2006), Satellite Sounder-Based OLR-, Cloud- and Atmospheric Temperature Climatologies for Climate Analyses. Algorithms and Technologies for Multispectral, Hyperspectral and Ultraspectral Imagery XII, Proceedings of SPIE Vol. 6233, 62331D-1-62331D-10.

Molnar, G. I., and J. Susskind (2007), Satellite Sounder-Based Atmospheric Parameter Climatologies: Tools for Monitoring/Assessing Short-, and Long-Term Climate Variabilities and Trends, 87th AMS Annual Meeting, San Antonio, TX, GA, 15-19 January.

Morris, G. A, B. Bojkov, M. Schoeberl, A. Wozniak, J. Ziemke, S. Chandra, J. Fishman, and I. Stajner (2006), Comparison of tropospheric ozone columns calculated from MLS, OMI, and ozonesonde data, Aura validation meeting, Boulder, CO, 17 September.

Mubenga, K., R. Hoff, K. McCann, A. Chu, and A. Prados (2006), Comparing MODIS-Terra and GOES surface albedo for New York City NY, Baltimore MD and Washington DC for 2005, *Eos Trans. AGU, 87*(36), Jt. Assem. Suppl., Abstract A43A-03.

Muscheler, R. (2007), The implications of the GICC05 time scale for the interpretation of the 10Be record during the last ice age, Second Carlsberg Dating Conference, Copenhagen Denmark, 15-17 November.

Muscheler, R. (2007), Uncertainties in 10Be-14C dating and the implications of the GICC05 time scale, Second Carlsberg Dating Conference, Copenhagen Denmark, 15-17 November.

Muscheler, R., F. Joos, and J. Beer (2007), The solar cycle during the last 500 years inferred from Radiocarbon, AGU fall meeting, San Francisco, CA, 11-15 December.

Muscheler, R., P. Koehler, A. Svensson, and J. Beer (2007), Production-related 14C variations - Can they explain the main changes in the atmospheric 14C concentration during the last 50 kyr?, AGU fall meeting, San Francisco, CA, 11-15 December.

Nakagawa, K., H. Hanado, N. Takahashi, S. Satoh, K. Fukutani, and T. Iguchi (2006), Development of a C-band polarimetric and pulse compression radar in Okinawa, Japan, paper presented at the 2006 IGARSS, Denver, CO, 31 July-4 August.

Narock, T. W., A. Szabo, and J. Merka (2006), Connecting Virtual Observatories with Grid Enabled Services, American Geophysical Union Spring Conference, San Antonio, TX, 13-18 January.

Narock, T. W., A. Szabo, and J. Merka (2006), Extending the Space Science Data Environment through Semantics and Knowledge Representation, American Geophysical Union Fall Conference, San Francisco, CA, 11-15 December.

Narock, T. W., A. Szabo, J. Merka, and K. Rash (2006), VHO and VMO Primer: Interactive Demonstration and Example Use Cases, American Geophysical Union Fall Conference, San Francisco, CA, 11-15 December.

Narock, T., A. Szabo, and J. Merka (2006), Extending the space science data environment through semantics and knowledge representation, *Eos Trans. AGU, 87*(52), Fall Meet. Suppl., Abstract IN43D-03.

Nerger, L. (2006), Assimilation of SeaWiFS Ocean Chlorophyll data with a simplified local SEIK filter. Seminar at GMAO, NASA/GSFC, Greenbelt, MD, 2 May.

Nerger, L. (2006), Assimilation with the Ensemble Kalman Filter and the SEIK filter in the North Atlantic, Seminar at Johns Hopkins University, Department of Earth and Planetary Sciences, Baltimore, MD, 12 April.

Nerger, L. (2007), Data assimilation into ocean-biogeochemical models. Symposium on the cluster of excellence “The Future Ocean,” Kiel, Germany, 1 February.

Nerger, L. and W. W. Gregg (2006), Multivariate Assimilation of satellite ocean chlorophyll data into a global model – prospects and challenges. AGU fall meeting, San Francisco, CA, 10-15 December.

Norris, P. M. (2006), Cloud data assimilation, CloudSat Science Team Meeting, Kona, Hawaii, 16-20 October.

Novakovskaia, E., R. Gelaro, R. M. Errico, and S. Pawson (2006), Examinations of stratospheric dynamics using adjoint sensitivity and SV analysis, talk presented at the 7th International Workshop on Adjoint Applications in Dynamic Meteorology, Obergurgl, Austria, 9 October.

O’Halloran, T., J. D. Fuentes, D. R. Collins, X. Li, and W.-K. Tao (2007), Cloud microphysical impacts of biogenic aerosols, Gordon Conference on Gaseous Ions: Structures, Energetics and Reactions, Ventura Beach, CA, 26 February – 2 March.

O’Halloran, T., J. D. Fuentes, W.-K. Tao, and X. Li (2006), The influence of biogenic aerosols on cloud microphysics, AGU Fall meeting, San Francisco, CA, 11-15 December.

Olsen, M. A., M. R. Schoeberl, and J. R. Ziemke (2006), Estimate of Stratosphere-Troposphere Exchange of Ozone Derived From MLS Observations, Aura Validation Meeting, Boulder, CO, 17 September.

Olsen, M. A., M. R. Schoeberl, and J. R. Ziemke (2006), Investigations of Stratosphere-Troposphere Exchange of Ozone Derived From MLS Observations, American Geophysical Union (AGU) Fall Meeting, San Francisco, CA, 11-15 December.

Olson, W. S., M. Grecu, C.-L. Shie, and S. A. Braun (2006), Estimation of precipitation and latent heating distributions in tropical convection from a combined analysis of passive microwave and spaceborne radar observations, the AMS 27th Conference on Hurricanes and Tropical Meteorology, Monterey, CA, 24-28 April.

Panchenko, M. V., S. M. Sakerin, D. M. Kabanov, V. V. Belov, S. V. Afonin, B. N. Holben, A. V. Smirnov, S. A. Beresnev, S. Y. Gorda, G. I. Kornienko, S. V. Nikolashkin, V. A. Poddubnyi, and M. A. Taschilin (2006), AEROSIBNET, 12 International Joint Seminar on the Regional Deposition Processes in the Atmosphere, Beijing, China, 13-15 November.

Pap, J. (2006) Project report on irradiance variations (2006), paper presented at the NSF Workshop in Tatranska Lomnica, Slovakia, September.

Pap, J. (2006) Solar Irradiance Variations Over Solar Cycles 21 to 23, paper presented at the AGU Fall Meeting, San Francisco, CA, December.

Pap, J., D. McMullin, and L. Flouyd, EUV Irradiance Variations (2006), paper presented at the ISROSES meeting, Varna, Bulgaria, September.

Pap, J., G. Thuillier, and S.T. Wu (2006), CAWSES Theme 4 (Space Climatology) Report, invited paper presented at the STP-12 meeting, Rio de Janiero, Brazil, March.

Peters-Lidard, C. D., J. A. Santanello Jr. , S. V. Kumar, and J. L. Eastman (2006), Land Atmosphere Coupling: Soil Moisture, Vegetation and Boundary Layer, American Geophysical Union Fall meeting, San Francisco, CA, 11-15 December.

Peters-Lidard, C. D., S. Kumar, and J. Dong (2006), Land information system assimilation enhancements, pp: 1-27, AFWA internal report, Omaha, NE, 12-14 September.

Petrenko, M., M. Chin, T. Diehl, T. Kucsera, and A. J. Soja (2007), Estimating carbonaceous aerosol emissions from fires in boreal forests of North America in July 2004, 87th AMS Annual Meeting, San Antonio, TX, 14-18 January.

Pfaff, R. F., T. J. Stubbs, J. K. Burchill, C. Liebrecht, and K. R. Bromund (2006), A statistical survey of cusp plasma characteristics using FAST data, AGU Fall Meeting, San Francisco, CA, U.S.A., 11–15 December.

Pinheiro, A. C., R. H. Reichle, S. Kumar, K. Arsenault, J. L. Privette, and Y. Yu (2006), Determining the required accuracy of LST products for estimating surface energy fluxes, AGU Fall Meeting, San Francisco, CA, 11-15 December.

Pinheiro, A. T. C., S. Kumar, R. Reichle, K. Arsenault, and D. Toll (2007), Toward the Assimilation of Remotely Sensed Land Surface Temperature into the Land Information System, seminar at the Hydrological Sciences Branch, NASA GSFC, Greenbelt, MD, 30 January.

Pinheiro, A., S. Kumar, R. Reichle, J. L. Privette, Y. Yu, and K. Arsenault (2006), Determining the required accuracy of LST products for estimating surface energy fluxes, poster presented at the 2nd International Symoposium on Recent Advances in Quantitative Remote Sensing, Valencia, Spain, 25-29 September.

Potts, L, L. R. Gaya-Piqué , H. R. Kim, R. R. B. von Frese, and C. K. Shum (2006), Comparison of Altimetry-derived Ionosphere Electron Counts and CHAMP-measured External Field Variability over the Polar Regions, Geophysical Research Abstract, 8, 05010, European Geosciences Union.

Potts, L., M. Schmidt, C. K. Shum, R. R. B. von Frese, C. Zeilhofer, and H. R. Kim (2006),Multi-resolution ionospheric electron density and external field over Antarctica from altimetry and CHAMP magnetic observations, Geophysical Research Abstract, 8, 05525, European Geosciences Union.

Potts, L., R. R. B. von Frese, H. R. Kim, L. R. Gaya-Pique, and C. K. Shum (2006),Altimetry-derived Ionsphere Electron Counts and CHAMP External Magnetic Fields over the Polar Regions, *Eos Trans. AGU, 87*(36), Jt. Assem. Suppl., Abstract SA31B-03.

Pulkkinen, A. (2006), Ground effects of space weather: science, societal impacts and mitigation, invited paper presented at IGARSS 2006, Denver, CO, 31 July – 4 August.

Pulkkinen, A., A. Viljanen, and R. Pirjola (2006), Estimation of geomagnetically induced current levels from different input data, invited paper presented at Space Weather Week, Boulder, CO, 25-28 April.

Pulkkinen, A., A. Viljanen, and R. Pirjola (2006), Estimation of geomagnetically induced current levels from different input data, paper presented at COSPAR 2006, Beijing, China, 6-23 July.

Pulkkinen, A., and R. Kataoka (2006), S-transform view of geomagnetically induced currents during geomagnetic superstorms, paper presented at COSPAR 2006, Beijing, China, 6-23 July.

Pulkkinen, A., M. Hesse, M. Kuznetsova, and L. Rastaetter (2006), First-principles modeling of geomagnetically induced currents from the upstream solar wind to the surface of the Earth, invited paper presented at SUNBURST 2006, Washington, DC, 8 September.

Pulkkinen, A., M. Hesse, M. Kuznetsova, and L. Rastaetter (2006), First-principles modeling of geomagnetically induced currents from the upstream solar wind to the surface of the Earth, paper presented at 2006 Fall AGU meeting, San Francisco, CA, 11-15 December.

Pulkkinen, A., S. Lindahl, A. Viljanen, and R. Pirjola (2006), October 29-31, 2003 geomagnetic storm: geomagnetically induced currents and their relation to problems in the Swedish high-voltage power transmission system, paper presented at Space Weather Week, Boulder, CO, 25-28 April.

Rash, K., T. Narock, A. Szabo, and J. Merka (2006), VHO and VMO primer: Interactive demonstration and example use cases, *Eos Trans. AGU, 87*(52), Fall Meet. Suppl., Abstract SM21A-0249.

Reale, O., R. Rosenberg, E. Brin, J. Terry, L. P. Riishojgaard, J. C. Jusem, J. Susskind, M. Suarez, L. Takacs, and R. Todling (2006), Impact of AIRS retrievals on Forecast Skill using the GEOS-5 DAS, AIRS Science Team Meeting, Greenbelt, MD, 25-27 September (presented by R. Rosenberg).

Reichardt, J., S. Reichardt, R.-F. Lin, M. Hess, D. O'C. Starr (2006), Optical-microphysical modeling. The 23rd International Laser Radar Conference. Nara City, Japan, 24-28 July.

Reichle, R. H. (2006), Assimilating retrievals of surface soil moisture and land surface temperature into a land surface model, Invited presentation at the IEEE International Geoscience and Remote Sensing Symposium, Denver, CO, 31 July - 4 August.

Reichle, R. H. (2006), Biases and scaling in soil moisture and temperature data assimilation, presentation at the Annual Meeting of the Joint Center for Satellite Data Assimilation, Greenbelt, MD, 31 May.

Reichle, R. H. (2006), Land Data Assimilation and Application to Seasonal Climate Prediction, seminar at the Earth System Science Interdisciplinary Center, University of Maryland, College Park, MD, 8 December.

Reichle, R. H. (2006), Land data assimilation and application to seasonal climate prediction, seminar at the Department of Civil and Environmental Engineering, University of Connecticut, Storrs, CT, 12 May.

Reichle, R. H. (2006), Land data assimilation and seasonal climate prediction, seminar at the Center for Urban Environmental Research and Eduation, University of Maryland, Baltimore County, Baltimore, MD, 22 October.

Reichle, R. H. (2006), Soil moisture and soil temperature assimilation with the Ensemble Kalman filter, Invited Presentation at the Workshop on Predictability, Observations, and Uncertainties in Geosciences, School of Computational Science, Florida State University, Tallahassee, FL, 13-15 March.

Reichle, R. H. (2006), Soil moisture and soil temperature data assimilation in the NASA/GMAO system, seminar at the European Centre for Medium-Range Weather Forecasting (ECMWF), Reading, UK, 14 November.

Reichle, R. H., R. D. Koster, and S. P. P. Mahanama (2007), The Catchment Land Surface Model in GEOS-5, NASA/MAP Carbon Data Analysis project meeting, Annapolis, MD, 29 January.

Reichle, R. H., R. D. Koster, M. G. Bosilovich, and S. P. P. Mahanama (2006), Biases and scaling in soil moisture and temperature data assimilation, AGU Joint Assembly, Baltimore, MD, 23-26 May.

Reichle, R. H., R. Koster, S. Mahanama, and P. Liu (2006), Data assimilation of AMSR-E soil moisture and comparison with SMMR results, AMSR-E Science Team Meeting, La Jolla, CA, 6-8 September.

Reichle, R. H., W. T. Crow, R. D. Koster, H. Sharif, and S. Mahanama (2007), Assessment of uncertainty and utility of soil moisture retrievals in a data assimilation experiment, 21th Conference of Hydrology at 87th AMS Annual Meeting, San Antonio, TX, 15-19 January.

Reichle, R. H.,, W. Crow, R. D. Koster, H. Sharif, and S. Mahanama (2006), Assessing the impact of errors in soil moisture retrievals on their utility in a data assimilation system, AGU Fall Meeting, San Francisco, CA, 11-15 December.

Reid, J., J. Zhang, J. N. Porter, S. Raman, R. A. Kahn, and T. F. Eck (2006), Observations of sudden changes in aerosol properties along the coast: Separating artifact from physics in the littoral zone, AGU Fall Meeting, San Francisco, CA, 11-15 December.

Rienecker, M. M., M. J. Suarez, R. D. Koster, R. H. Reichle, C. Keppenne, D. Adamec and S. D. Schubert (2006), Improving Short-term Climate Forecasts with Satellite Observations, IEEE International Geoscience and Remote Sensing Symposium, Denver, CO, 31 July - 4 August.

Riishojgaard, L. P. (2006), An update on the Molniya Orbit Imager, in *Proceedings of the 8th International Winds Workshop in Beijing*, April, EUMETSAT.

Riishojgaard, L. P. (2006), invited presentation on Observing Systems Simulated Environment, NASA Rapid Prototyping Capability Workshop; Hampton VA, April.

Riishojgaard, L. P. (2006), invited presentation on Observing System Simulation Experiments, Climate Change Science Program Observations Working Group Workshop, Washington, DC, June.

Riishojgaard, L. P. (2006), invited presentation on The Molniya Orbit Imager; a high-latitude imaging complement to GOES/Meteosat, Finnish National Remote Sensing Days, Helsinki, Finland, October.

Riishojgaard, L. P. (2006), keynote address on Space Based Observing Systems: Needs, challenges, optimum utilization, Second THORPEX International Science Symposium, Landshut, December.

Riishojgaard, L. P. (2006), Observation System Simulation Experiments at the Goddard Space Flight Center. A white paper submitted to NASA Headquarters, December.

Riishojgaard, L. P. (2006), The Molniya Orbit Imager; a high-latitude quasi-geostationary mission concept, in *Proceedings of the 2006 EUMETSAT Meteorological Satellite Conference*, EUMETSAT.

Riishojgaard, L. P. M. Sienkiewicz and G. P. Lou (2006), The impact on forecast skill of water vapor and window channel winds from MODIS, in *Proceedings of the 8th International Winds Workshop*, EUMETSAT.

Robertson, F. R., J. T. Bacmeister, and T. Miller (2007), Relationships Between Model Tropical Oceanic Precipitation Biases, PBL Convergence, and Energy Fluxes (presented with F. R. Robertson), WGNE/PCMDI Meeting on Model Biases, San Francisco, CA, 15 February.

Rodell, M., R. H. Reichle, K. Ellett, J. Walker, F. Lemoine, and H. Kato (2006), Land Surface Model Assimilation of Data from GRACE and Other Satellites, Invited presentation, AGU Spring Meeting, Baltimore, MD, 23-26 May.

Rosen, R., D. A. Chu, J. J. Szykman, R. DeYoung, J. A. Al-Saddi, A. Kaduwela, and C. Bohnenkamp (2006), Application of satellite data for three-dimensional monitoring of PM2.5 formation and transport in San Joaquin Valley, California, Proc. of SPIE, Vol. 6299, 629904, SPIE Annual Meeting, San Diego, CA, 13-17 August.

Russ, M.E., and A. Mannino (2006), Microbial lability of dissolved organic carbon in the Chesapeake Bay and Mid-Atlantic Bight, poster presented at the IDS Team Meeting in Providence, RI, 29-31 March.

Russ, M.E., and A. Mannino (2006), Microbial lability of dissolved organic carbon in the Chesapeake Bay and Mid-Atlantic Bight, poster presented at the Ocean Color Team Meeting in Providence, RI, 10-13 April.

Russ, M.E., and A. Mannino (2007), Evaluating the fate of DOC and CDOM at the Chesapeake Bay mouth to the coastal Mid-Atlantic Bight though microbial degradation and photo-oxidation experiments, talk presented at the ASLO Aquatic Sciences Meeting, Santa Fe, NM, 4-7 April.

Russell D. Y., J. Szykman, K. Severance, and D. A. Chu (2006), Comparison of MODIS Satellite and Airborne Lidar Aerosol Profiles,7th International Symposium on Tropospheric Profiling: Needs and Technologies, Boulder, CO, 11-17 June.

Sakerin, S. M., A. Smirnov, D. M. Kabanov, Yu. S. Turchinovich, B. N. Holben, V. F. Radionov, and I. Slutsker (2006), Ship-based aerosol optical depth measurements near Antarctica, AGU Fall Meeting, San Francisco, CA, 11-15 December, (*Eos Trans. AGU, 87*(52), Fall Meet. Suppl., Abstract A53C-0202).

Santanello, J. A., C. D. Peters-Lidard, M. Garcia, and D. Mocko (2006), Using remotely-sensed estimates of soil moisture to infer spatially distributed soil hydraulic properties. Eos Trans. AGU, 87 (36), Jt. Assem. Suppl., Abstract H22A-04.

Schafer, J., B. Holben, T. Eck, and P. Artaxo (2006), Characterization of the optical properties of the atmospheric aerosol in Amazônia from long-term distributed sunphotometry [1993-95; 1999-2004], AGU Fall Meeting, San Francisco, CA, 11-15 December.

Schoeberl, M. R., J. R. Ziemke, and M. A. Olsen (2006), Improved Tropospheric Ozone from OMI-MLS Differences, OMI Science Team Meeting, De Bilt, The Netherlands, June.

Schubert, S., M. Suarez, P. Pegion, M.-I. Lee, Y. Chang, M.-L. Wu, R. Koster, and J. Bacmeister (2007), The impact of large-scale climate variability on weather, Invited talk at the 87th Annual AMS Meeting, San Antonio, TX, 14-18 January.

Schubert, S., M. Suarez, P. Pegion, M.-I. Lee, Y. Chang, M.-L. Wu, R. Koster, and J. Bacmeister (2007), The impact of large-scale climate variability on weather, paper presented at the 87th AMS Annual Meeting, San Antonio, TX, 13-18 January.

Schubert, S., M. Suarez, R. Koster, P. Pegion, and Y. Chang (2006), Overview of Climate Predictability at SI Time Scales, paper presented at the First CPPA PI meeting, Flagstaff, AZ, 14-18 August.

Schubert, S., M. Suarez, R. Koster, P. Pegion, and Y. Chang (2006), The predictability of drought and pluvial conditions over the Americas: The role of the oceans and land, paper presented at 2006 Fall AGU Meeting, San Francisco, CA, 11-15 December.

Schulz, M. (2006), Analysing aerosol model diversity using AeroCom results, presentation at Climate Brunch meeting, GSFC, Greenbelt, MD, 6 September.

Schulz, M. (2006), Analysing aerosol model diversity using AeroCom results, presentation during GMI annual meeting, GSFC, Greenbelt, MD, 13 October.

Schulz, M. (2006), Forcing diversity using AeroCom results, presentation during AeroCom workshop, Virginia Beach, VA, 18 October.

Schulz, M. (2006), INCA aerosol model development and the link to the AeroCom model intercomparison framework, invited presentation to NCEP/EMC/NOAA Science Center, Camp Springs, MD, 15 August.

Schulz, M. (2006), Invited talk at GEWEX aerosol assessment workshop, University of Maryland, College Park, MD, 14 September.

Schulz, M. (2006), Invited talk at UMBC Physics department, Baltimore, MD, 13 September.

Schulz, M. (2006), Lessons from AeroCom and future perspective, invited presentation to IGAC/WCRP Atmospheric Chemistry and Climate planning meeting, NCAR, Boulder, CO, 7 August.

Schulz, M. (2006), Quality and diversity of modelled aerosol radiative forcing as derived from AeroCom simulations, invited talk at GFDL, Princeton University, 2 October.

Shen, B.-W., W.-K. Tao, R. Atlas, J.-D. Chern, and S.-J. Lin (2007), Multiscale simulations of a Mei-Yu front accompanied by a drifting meso-cyclone with a global mesoscale model, The Center for Multi-scale Modeling of Atmospheric Processes (CMMAP) team meeting, Princeville, HI, 20-22 February.

Shie, C., W. Tao, A. Hou, X. Zeng, X. Lin, Y. Zhou, W. Olson, and H. Juang (2006), Simulated long-term cloud systems using a cloud resolving model, AGU Joint Assembly, Baltimore, MD, 23-26 May.

Shie, C.-L., et al. (2006a), Various Applications on Tropical Convective Systems Using a Cloud Resolving Model, invited talk to Central Weather Bureau, Taipei, Taiwan. (invited talk), 29 November.

Shie, C.-L., et al. (2006b), Simulated Long-term Cloud Systems Using a Cloud Resolving Model: Impact of Large-scale Temperature and Moisture Forcing Using Observations and GEOS-3 Reanalysis, invited talk to Central Weather Bureau, Taipei, Taiwan, 28 November.

Shie, C.-L., W.-K. Tao, A. Hou, and X. Lin (2006d), Simulated convective systems using a cloud resolving model: Impact of large-scale temperature and moisture forcing using observations and GEOS-3 reanalysis, the AMS 27th Conference on Hurricanes and Tropical Meteorology, Monterey, CA, 24-28 April.

Shie, C.-L., W.-K. Tao, A. Hou, X. Zeng, X. Lin, Y. Zhou, W. Olson, and H. Juang (2006c), Simulated long-term cloud systems using a cloud resolving model, AGU 1006 Joint Assembly, Baltimore, MD, 23-26 May.

Shige, S., Y. N. Takayabu, W.-K. Tao, and C.-L. Shie (2006), Spectral retrieval of latent heating profiles from TRMM PR data: Algorithm improvement and heating estimates over tropical ocean regions, the AMS 27th Conference on Hurricanes and Tropical Meteorology, Monterey, CA, 24-28 April.

Shusse, Y., K. Nakagawa, N. Takahashi, S. Satoh, and T. Iguchi (2006), Characteristics of polarimetric radar variables and their precipitation type dependence on a highly humid oceanic region, paper presented at the Fourth European Conference on Radar in Meteorology and Hydrology, Barcelona, Spain, September 18-22.

Sipes, T. B., H. Karimabadi, J. Driscoll, Y. Wang, B. Lavraud, and J. A. Slavin (2006), Automated Detection and Predictive Modeling of Flux Transfer Events using CLUSTER Data, AGU Fall Meeting, San Francisco, CA, 11–15 December.

Smirnov, A., B. N. Holben, C. R. McClain, and K. D. Knobelspiesse (2006), Oceanic Aerosol Network: from SIMBIOS to AERONET, Ocean Optics 2006 Meeting, Montreal, PQ, Canada, 8-13 October.

Smirnov, A., B. N. Holben, C. R. McClain, and K. D. Knobelspiesse (2006), AERONET and upcoming measurements over the oceans, NASA Workshop “Supporting in-situ and space-based measurements”, Montreal, PQ, Canada, 6-7 October.

Smirnov, A., B. N. Holben, K. D. Knobelspiesse, C. R. McClain, and T. F. Eck (2006), Ship-based aerosol optical depth measurements over the oceans: current status and prospective, AGU Fall Meeting, San Francisco, CA, 11-15 December.

Smirnov, A., B. N. Holben, K. D. Knobelspiesse, C. R. McClain, and T. F. Eck (2006), Ship-based aerosol optical depth measurements over the oceans: current status and prospective, AGU Fall Meeting, San Francisco, CA, 11-15 December, (*Eos Trans. AGU, 87*(52), Fall Meet. Suppl., Abstract A51F-03).

Smirnov, A., B. N. Holben, M. V. Panchenko, S. M. Sakerin, A. A. Aculinin, N. Y. Chubarova, O. Karner, A. P. Chaikovsky, A. I. Sukhinin, V. Y. Pavlov, O. V. Kopelevich, V. F. Radionov, G. K. Korotayev (2006), Aerosol Robotic Network activity in Russia, Moldova, Estonia, Belarus, and Ukraine - as an example of the mutually beneficial collaborative effort - results and prospective,

International Symposium on Atmospheric Radiation (MCAP-2006), St.Petersburg, Russia, 27 June - 30 June.

Smirnov, A., B. N. Holben, T. F. Eck, and I.Slutsker (2006), AERONET cloud screening: Two philosophies–implementation and implications, AeroCenter Seminar, Goddard Space Flight Center, Greenbelt, MD, 14 March.

Smirnov, A., B. N. Holben, T. F. Eck, I. Slutsker, P. Goloub, B. Chatenet, I. Sano, J. E. Kim, P. H. Lin, T. H. Lin, and H. Khudulmur (2006), Aerosol optical depth diurnal variability in East Asia, 2006 Western Pacific Geophysics Meeting, Beijing, China, 24-27 July, (*Eos Trans. AGU, 87*(36), West. Pac. Geophys. Meet. Suppl., Abstract A14A-0021).

Smirnov, A., B. N. Holben, T. F. Eck, I. Slutsker, P. Goloub, B. Chatenet, I. Sano, J. Kim, P. Lin, and T. Lin (2006), Aerosol optical depth diurnal variability in East Asia, 2006 Western Pacific Geophysics Meeting, Beijing, 24-27 July.

Sorooshian, S., T. Koike, and R. G. Lawford (2006), GEWEX Report to JSC 27th Session, Pune, India, 6–11 March.

Stajner, I., C. Benson, H. Liu, S. Pawson, L. Chang, and L. P. Riishojgaard (2006), Detection of ice polar stratospheric clouds from assimilation of atmospheric infrared sounder data, American Geophysical Union 2006 Fall Meeting, San Francisco, CA, 11-15 December.

Starr, D. O., R.-F. Lin, A. Lare, B. Demoz, and T. Rickenbach (2006), On cirrus anvil dissipation simulated by a mesoscale model with bulk microphysics, AGU 2006 Fall Meeting, San Francisco, CA, 11-15 December.

Strahan, S. E. (2006), Fidelity of stratospheric and upper tropospheric processes in CTM simulations using GCM and assimilated meteorological products, invited presentation to Data Assimilation Working Group for Stratospheric Processes and their Role in Climate (SPARC), Noordwijk, Netherlands, 2 October.

Strahan, S. E. (2006), How model transport differences influence the prediction of polar ozone recovery, American Geophysical Union Spring Meeting, Baltimore, MD, 24 May.

Strahan, S. E. (2006), Seasonal transport into the tropical upper troposphere in the Global Modeling Initiative CTM, American Geophysical Union Fall Meeting, San Francisco, CA, 11 December.

Strangeway, R. J., G. Le, J. A. Slavin, and S. A. Boardsen (2006), Comparison of Field-Aligned Current Signatures Observed by ST5 and FAST, 2006 AGU Fall Meeting, San Francisco, CA, U.S.A., 11–15 December.

Stroud, D. B., and K. Elinich (2006), Unique Approaches to Interactive Content for K20, paper presented at 10th Annual Member Meeting, Internet2, Chicago, IL, 4-7 December.

Stubbs, T. J. (2006), Surface charging and field-aligned current “closure” at Mercury (2006), AGU Fall Meeting, San Francisco, CA, 11–15 December.

Stubbs, T. J., J. Bosqued, M. W. Dunlop, M. Lockwood, P. J. Cargill, C. J. Owen, M. G. Taylor, and M. Goldstein (2006), Multiscale observations of the structure and motion of field-aligned cusp currents, 36th COSPAR Scientific Assembly, Beijing, China, 16-23 July.

Stubbs, T. J., J. Bosqued, M. W. Dunlop, M. Lockwood, P. J. Cargill, C. J. Owen, M. G. Taylor, and M. Goldstein (2006), Multiscale observations of plasma transport through the cusp region, AGU Joint Assembly, Baltimore, MD, 23-26 May.

Stubbs, T. J., J. S. Halekas, W. M. Farrell, R. R. Vondrak, and G.T. Delory (2006), Global modeling of the electrostatic lunar surface potential, Lunar Planet. Sci. Conf. XXXVII, League City, TX, 13-17 March.

Stubbs, T. J., R. R. Vondrak, W. M. Farrell, J. S. Halekas, and G. T. Delory (2007), Characterizing the near lunar plasma environment, invited presentation at the Workshop on Science Associated with the Lunar Exploration Architecture, NASA Advisory Council, Tempe, AZ, 26 February – 2 March.

Stubbs, T. J., R. R. Vondrak, W. M. Farrell, J. S. Halekas, and G. T. Delory (2006), The lunar dust-plasma environment: Implications for exploration, presented to the 3rd Lunar Airborne Dust Toxicity Advisory Group meeting, South Shore Harbor Resort, League City, TX, 7-8 December.

Stubbs, T. J., R. R. Vondrak, W. M. Farrell, J. S. Halekas, and G. T. Delory (2006), The lunar dust-plasma environment: Implications for exploration systems, invited presentation to the Mechanical Systems SPRT Lunar Dust Assessment Group, NASA Engineering and Safety Center, Houston, TX, 6-8 October.

Stubbs, T. J., R. R. Vondrak, W. M. Farrell, J. S. Halekas, and G. T. Delory (2006), The lunar dust-plasma environment, invited presentation to the Committee on the Scientific Context for the Exploration of the Moon, Space Studies Board, National Research Council, Santa Fe, NM, 25-27 October.

Stubbs, T. J., R. R. Vondrak, W. M. Farrell, M. R. Collier, J. S. Halekas, and G. T. Delory (2007), The lunar dust-plasma environment: Implications for exploration, presented at the NESC Lunar Dust Workshop, NASA Ames Research Center, Moffett Field, CA, 30 January 30 – 1 February.

Stubbs, T. J., R. R. Vondrak, W. M. Farrell, M. R. Collier, J. S. Halekas, and G. T. Delory (2007), The lunar dust-plasma environment: Implications for science and exploration, invited Science Lecture, National Institute of Aerospace, Hampton, VA, 24 January.

Stubbs, T. J., W. M. Farrell, and R. R. Vondrak (2006), Lunar electrostatic dust dynamics in the solar wind and geospace environments, 36th COSPAR Scientific Assembly, Beijing, China, 16-23 July.

Stubbs, T. J., W. M. Farrell, and R. R. Vondrak (2006), Predictions of dust concentrations in the lunar exosphere, 8th ILEWG International Conference on Exploration and Utilization of the Moon, Beijing, China, 23-27 July.

Stubbs, T. J., W. M. Farrell, and R. R. Vondrak (2006), The impact of space weather on the lunar electrostatic environment, 36th COSPAR Scientific Assembly, Beijing, China, 16-23 July.

Stubbs, T. J., W. M. Farrell, R. R. Vondrak, and J. S. Halekas (2006), Lunar surface charging and dust transport, invited seminar at University of Maryland, College Park, MD, 18 May.

Sun, C. (2006), Impact of Argo Salinity Observations on Ocean Analyses, presentation at 2006 Aquarius/SAC-D Science Workshop, Woods Hole, MA, 10-12 May.

Sun, C. (2006), Impact of Argo Salinity Observations on Ocean Analyses, poster at the CLIVAR Salinity Workshop, Woods Hole, MA, 8-10 May.

Sun, C., M. Rienecker, C. Keppenne, J. Jacob, R. Kovach, and N. Kurkowski (2006), Sensitivity of Salinity Assimilation Implementations on Global Ocean Analysis, 2006 Ocean Sciences Meeting, Honolulu, Hawaii, 20-24 February.

Susskind J., and G. Molnar, "Trends" of Four years of Monthly Mean Version 4.0 AIRS Products, AIRS Science Team Meeting, Greenbelt, MD, 25-27 September.

Tao, W.-K., A. Khain, X. Li, and J. Simpson (2007), The role of aerosols on precipitation processes, 17th ARM Science Team Meeting, Monterey, CA, 26-30 March.

Tao, W.-K., X. Li, A. Khain and J. Simpson (2006), The role of aerosols on precipitation processes. AGU 2006 Joint Assembly, Baltimore, MD, 23-26 May.

Tassone, C. M., J. T. Bacmeister, and L. Takacs (2007), The impact of the boundary layer parameterization on the weather and climate of the GEOS-5 model, 19th AMS Conf. on Climate Variability and Change, San Antonio, TX, 15 January.

Taylor, P. T., H. R. Kim, and J. Kutina (2006), Geohazard assessment from satellite magnetic data modeling, abstract, International Symposium of Remote Sensing, Pan Ocean Remote Sensing Conference, Busan, Korea, 2 November.

Taylor, P. T., H. R. Kim, and T. Mayer-Gurr (2006), Tectonic interpretation of CHAMP geopotential data over the Northern Adriatic Sea, *Eos Trans. AGU, 87*(36), Jt. Assem. Suppl., Abstract GP41A-03.

Tedesco, M. and E. J. Kim (2006), Electromagnetic models for passive microwave remote sensing of snow and application to experimental data, invited presentation at Progress in Electromagnetics Research Symposium, Cambridge, MA, 26-29 March.

Tedesco, M., A. Kokhanovsky, and E. Zege (2006), Retrieval of snow grain size and impurities from remotely sensed data, European Geophysical Union Society EGU meeting, Vienna, Austria, 2-7 April.

Tedesco, M., and E. J. Kim (2006), Analysis of spatial scaling behavior during CLPX-I: snow observations, radiometric data and microwave emission modeling, IGARSS'06, Denver, CO, 26 July – 3 August.

Tedesco, M., and E. J. Kim (2006), Application of Artificial Neural Networks and Genetic Algorithms to the retrieval of snow parameters from passive microwave remote sensing data, invited presentation to Progress in Electromagnetic Research Symposium, Cambridge, MA, 26-29 March.

Tedesco, M., and E. J. Kim (2006), Spatial behavior of snow observations, radiometric data and microwave emission modeling, European Geophysical Union Society EGU meeting, Vienna, Austria, 2-7 April.

Tedesco, M., and E. J. Kim (2006), Validation, inter-comparison and development of electromagnetic models for passive microwave remote sensing of snow, 63rd Eastern Snow Conference, Newark, DE, 4-7 June.

Tedesco, M., and J. Miller (2006), Combining active and passive microwave spaceborne data for remote sensing of snow at global scale, AGU Fall meeting, San Francisco, CA, 11-15 December.

Tedesco, M., and J. Miller (2006), Combining space-borne active and passive microwave data for remote sensing of snow at global scale, invited presentation at IGARSS'06, Denver, CO, 26 July – 3 August.

Tedesco, M., and J. Miller (2006), Global multi-sensor active and passive microwave retrieval of snow parameters, European Geophysical Union Society EGU meeting, Vienna, Austria, 2-7 April.

Ten Kate, I. L., C.A. van Sluis, F. Selch, J. R. C. Garry, H. Stan-Lotter, M. van Loosdrecht, and P. Ehrenfreund (2006), UV resistance of a halophilic archaeon in simulated martian conditions, European Planetary Science Congress, Berlin, Germany, 18-22 September, p.112.

Ten Kate, I. L., J. R. C. Garry, Z. Peeters, B. H. Foing, and P. Ehrenfreund, (2006), Amino acid destruction in the Martian surface environment, 37th Annual Lunar and Planetary Science Conference, abstract no.2397, League City, TX, 13-17 March.

Tian, L., G. Heymsfield, L. Li, and X. Li (2006), Observations of stratiform rain by mm- and cm-Wavelength Radars, AMS 12th Conference on Cloud Physics, Madison, WI, 10-14 July.

Tian, L., G. Heymsfield, L. Li, and X. Li (2006), Observations of stratiform rain by mm- and cm-Wavelength Radars, AMS 12th Conference on Cloud Physics, Madison, WI, 10-14 July.

Tian, Y., C. D. Peters-Lidard, M. Garcia, and S. Kumar (2006), Evaluation of TRMM-based precipitation products in the southeast U. S. and their impact on hydrological modeling, *Eos Trans. AGU, 87*(36), Jt. Assem. Suppl., Abstract H23A-03.

Tian, Y., C. D. Peters-Lidard, M. Garcia, and S. V. Kumar (2006), Evaluation of TRMM-based precipitation products in the Southeast U.S. and their impact on hydrological modeling, *Eos Trans. AGU, 87*(36), Jt. Assem. Suppl., Abstract H23A-03 (poster).

Toll, D. L., J. Dong, P. R. Houser, B. Cosgrove, C. Peters-Lidard, and S. Kumar (2006), Land surface water and energy flux evaluation from the North American Regional Reanalysis (NARR) and Land Data Assimilation Systems (LDAS) for water resources applications, *Eos Trans. AGU, 87*(36), Jt. Assem. Suppl. Abstract A33D-02.

Toll, D., J. Dong, P. Houser, K. Arsenault, A. Pinheiro, J. Basara, and J. Monroe (2006), Analysis of NOAA and NASA Surface Water and Energy Balance for Water Resources Applications, poster presented at the NOAA CPPA Annual Meeting, Tucson, AZ, 14-16 August.

Toll, D., J. Dong, P. Houser, K. Arsenault, A. Pinherio, J. Basara, and J. Monroe (2006), Analysis of NOAA and NASA surface water and energy balance data for water resources applications, First Climate Prediction Program for the Americas (CPPA) PIs Meeting, Hilton El Conquistador Resort in Tucson, AZ, 14-16 August.

Toll, D., J. Dong, P. Houser, K. Arsenault, and B. Cosgrove (2006), Land Surface Water and Energy Flux Evaluation from the North American Regional Reanalysis (NARR) and Land Data Assimilation Systems (LDAS) for Water Resources Applications, poster presented at the American Geophysical Union Spring Meeting, Baltimore, MD, 23–26 May.

Toll, D., K. Arsenault, E. Engman, L. Friedl, C. Peters-Lidard, A. Pinheiro, and J. Nigro (2006), Protect and Monitor Water Resources 2006, paper presented at the IGARRS Annual Meeting, Denver, CO, 31 July – 6 August.

Turchinovich, Yu. S., D. M. Kabanov, S. M. Sakerin, A. V. Smirnov, B. N. Holben, and I. A. Slutsker (2006), Results of investigation of the aerosol optical thickness of the atmosphere in 24th cruise of research vessel "Akademik Fedorov", XII Joint International Symposium Atmospheric and Ocean Optics, Atmospheric physics, Tomsk, Russia, 2-7 July.

Uritsky, V., A. Klimas, and A. Pulkkinen, Robust Measures of Dynamical Complexity for Magnetospheric Research, invited paper presented at 2006 Fall AGU meeting, San Francisco, CA, 11-15 December.

von Frese, R. R. B., M. F. Asgharzadeh, O. Hernandez, H. R. Kim, and J. W. Kim (2006), Assessing intraplate earthquake hazards from satellite geopotential field observations, abstract, International Symposium of Remote Sensing, Pan Ocean Remote Sensing Conference, Busan, Korea, 2 November.

von Frese, R. R. B., S. Wells, L. R. Gaya-Pique, A. V. Golynsky, O. Hernandez, J. W. Kim, H. R. Kim, and J. S. Hwang (2006), Permian-Triassic mascon in Antarctica, *Eos Trans. AGU, 87*(36), Jt. Assem. Suppl., Abstract T41A-08.

Vondrak, R. R., T. J. Stubbs, W. M. Farrell, J. S. Halekas, and G. T. Delory (2006), Impact of space weather on the lunar electrodynamic environment, AGU Fall Meeting, San Francisco, CA, 11–15 December.

Wang, H. and K.-M. Lau (2006), Atmospheric hydrological cycle in the tropics in the twentieth century coupled climate simulations, paper presented at the 2006 American Geophysical Union (AGU) Joint Assembly, Baltimore, MD, 23-26 May.

Wang, H., S. Siegfried, J. Chen, M. Suarez, A. Kumar, and M. Hoerling (2006), Understanding surface temperature trends over Asia and North America during 1950-2000, paper presented at the NOAA's 31st Annual Climate Diagnostics and Prediction Workshop, Boulder, CO, 23-27 October.

Wang, H., S. Siegfried, M. Suarez, J. Chen, M. Hoerling, and A. Kumar (2007), Attribution of seasonality and regionality of the U.S. climate trends during 1950-2000, paper presented at the NASA MAP Science Team Meeting, College Park, MD, 7-9 March.

Wang, H., S. Siegfried, M. Suarez, P. Pegion, J. Chen, M. Hoerling, and A. Kumar (2007), Understanding seasonality and regionality of climate trends over the U.S. during 1950-2000, paper presented at the Seventh Workshop on Decadal Climate Variability, Kona, HI, 30 April – 3 May.

Wang, Y, G. Le, S. A. Boardsen, J. A. Slavin, and R. J. Strangeway (2006), The Dependence of Field-Aligned Currents on Solar Wind and Geomagnetic Conditions From ST5 Multiple Spacecraft Observations, AGU Fall Meeting, San Francisco, CA, 11–15 December.

Wang, Y., G. Le, B. Lavraud, R. C. Elphic, H. Kawano, X. Zhang, and J. Slavin (2006), Geophysical Control of FTE Solar Wind Dependence and Its Implications from Three Years of Cluster Observations, 36th COSPAR Scientific Assembly, Beijing, China, 16–23 July.

Wang, Y., G. Le, B. Lavraud, R. C. Elphic, H. Kawano, X. Zhang, and J. A. Slavin (2006), Geophysical Control of FTE Solar Wind Dependence, AGU Joint Assembly, Baltimore, MD, 23–26 May.

Wang, Y., G. Le, J. Raeder, R. C. Elphic, J. Birn, and B. Lavraud (2006), Understanding FTE structure and dynamics from Cluster Multi-Spacecraft Observations and Global MHD Simulations, Western Pacific Geophysical Meeting, Beijing, China, 24–27 July.

Wang, Y., G. Le, S. A. Boardsen, J. A. Slavin, and R. J. Strangeway (2006), The Dependence of Field-Aligned Currents on Solar Wind and Geomagnetic Conditions From ST5 Multiple Spacecraft Observations, 2006 AGU Fall Meeting, San Francisco, CA, U.S.A., 11–15 December.

Wang, Y., J. Birn, J. Raeder, and M. Hesse (2006), Magnetotail Bubble Dynamics from MHD Simulations and Observations, 36th COSPAR Scientific Assembly, Beijing, China, 16–23 July.

Wang, Y., J. Birn, J. Raeder, and M. Hesse (2006), Magnetotail Bubble Dynamics from MHD Simulations and Observations, AGU Joint Assembly, Baltimore, MD, 23–26 May.

Wang, Y., R. C. Elphic, B. Lavraud, J. Birn, R. Friedel, M. G. G. T. Taylor, J. Raeder C. T. Russell, H. Kawano, Q. G. Zong, H. Zhang, X. X. Zhang, and G. Le (2006), FTE Dependence on Geophysical Parameters and Solar Wind Conditions from Cluster Observations and Global MHD Simulations, GEM meeting, Snowmass, CO, June.

Warner, J. X., J. M. Grossmann, D. A. Chu, K. F. Huemmrich, and R. A. Warner (2006), Airborne hyperspectral data collection with UMBC VNIR sensor, Proc. of SPIE, Vol. 6299, 629910, SPIE Annual Meeting, San Diego, CA, 13-17 August.

Weaver, C. (2006), Simultaneous retrieval of Aerosol and Chlorophyll form MODIS Aqua radiances, presented at MODIS Science Team Meeting, College Park, November.

Webb, P. A. (2006), Assembling a Plasmaspheric Electron Density Database from IMAGE RPI Dynamic Spectra, Laboratory for Solar and Space Physics Seminar Series, NASA Goddard Space Flight Center, Greenbelt, MD, 5 May.

Webb, P. A. (2006), Deriving plasmaspheric electron densities from IMAGE RPI dynamic spectra, Institute of Geophysics and Planetary Physics Space Science Seminar, UCLA, Los Angeles, CA, 10 March.

Webb, P. A., R. A. Goldberg, W. D. Pesnell, M. N. P. Assis, and H. D. Voss (2006), Refinement of the DROPPS polar summer mesosphere particle data, 36th COSPAR Scientific Assembly, Beijing, China, 16–23 July.

Webb, P. A., R. F. Benson, and J. M. Grebowsky (2006), Determining mid-latitude O+/H+ transition altitudes from topside ionograms, 2006 AGU Joint Assembly, Baltimore, MD, 23–26 May.

Webb, P. A., R. F. Benson, J. M. Grebowsky, D. Bilitza, and X. Huang (2006), ISIS Data Preservation and Transformation, NASA Applied Information Systems Research Program Principal Investigators Meeting, College Park, MD, October 3-5.

Webb, P. A., R. F. Benson, J. M. Grebowsky, D. Bilitza, and X. Huang (2006), Variations in Ionosphere-Plasmasphere O+/H+ Transition Heights Determined from Satellite Topside Sounders, Department of Physics Plasma Physics Seminars, Dartmouth College, NH, 7 November.

Webb, P. A., R. F. Benson, J. M. Grebowsky, D. Bilitza, and X. Huang (2006), Determination of Ionosphere-Plasmasphere O+/H+ Transition Heights from Satellite Topside Sounders, Department of Physics Seminar, The University of Auckland, New Zealand, 21 November.

Webb, P. A., R. F. Benson, J. M. Grebowsky, D. Bilitza, and X. Huang (2006), Solar-Cycle and Short-Term Variations of Topside Ionospheric Electron-Density Profiles, 2006 AGU Fall Meeting, San Francisco, CA, 11–15 December.

Webb, P. A., R. F. Benson, J. M. Grebowsky, D. Bilitza, and X. Huang (2007), O+/H+ Transition Height Variations Determined from Topside Ionospheric Electron-Density Profiles, Chapman Conference on Mid-latitude Ionospheric Dynamics and Disturbances, Yosemite National Park, CA, 3–6 January.

Wen, G., A. Marshack, and R. F. Cahalan, L. A. Remer, and R. G. Kleidman (2006), 3D Aerosol-Cloud Radiative Interaction in a Cumulus Field in Brazil, 12th Conference on Atmospheric Radiation, Madison, WI, 9-14 July.

Wen, G., A. Marshak, R. F. Cahalan, and W. Wiscombe (2006), Analyses of MODIS retrieved cloud properties of cumulus clouds in Brazil, Madison, WI, 9-14 July.

Wen, G., H. Miyahara, R. F. Cahalan (2006), Deriving Historical TSI Variations from Lunar Borehole Profiles, the SORCE Science Meeting, San Juan Island, WA, 20-22 September.

Wenig, M. (2006), 10 Years of Satellite Measurements of Global NO_2 Emissions, Institute for Terrestrial and Planetary Atmospheres (ITPA) of the Marine Sciences Research Center (MSRC), Stony Brook University, Stony Brook, NY, March.

Wenig, M. (2006), Satellite Measurements of Global NO_2 Emissions, Remote Sensing Seminar, Ecoles Polytechniques Fédérales de Lausanne (EPFL), February.

Wenig, M. (2006), Validation Study of Two Years of OMI NO_2 Data, 6th International Symposium on advanced Environmental Monitoring, Heidelberg, Germany, June.

Wilson, E. L., E. M. Georgieva, and W. S. Heaps (2006), Progress on a Fabry-Perot Instrument for column measurements of CO_2, O_2, H_2O, and CH_4, AGU 2006 Fall Meeting, San Francisco, CA, 11-15 December.

Wu, L. (2006), Changes in tropical cyclone intensity over the past 30 years, invited talk to Mesoscale Atmospheric Branch, GSFC/NASA, Greenbelt, MD, April.

Wu, L. (2006), The possible influence of the Three-Gorges Dam on regional climate: Satellite data analysis and numerical simulation, invited talk to National Climate Center, China Meteorological Administration, Beijing, China, August.

Wu, L., and S. A. Braun (2006), Influence of the Saharan Air Layer on the formation and intensification of Hurricane Isabel (2003): Analysis of AIRS data and numerical simulation, The AGU 2006 Fall Meeting, San Francisco, CA, 10-15 December.

Wu, L., B. Wang, and S. A. Braun (2006), Changes in tropical cyclone intensity over the past 30 years, The 2006 Western Pacific Geophysics Meeting, Beijing, China, 24-28 July.

Wu, L., S. A. Braun, and J. Qu (2006), Simulating the influence of the Sahara Air Layer on the formation of Hurricane Isabel (2003) using AIRS data, 27th Conference on Hurricanes and Tropical Meteorology, Monterey, CA, 24-28 April.

Wu, Y., and C. Peters-Lidard (2006), Application of satellite data to estimating land-air ammonia exchanges, invited presentation at IGARSS, Denver, CO, 31 July – 4 August.

Xiaowen Li, W.-K. Tao, A. Khain, C. Kummerow, and J. Simpson (2006), Detecting aerosol indirect effect on deep convective precipitation systems: A modeling study, AGU 2006 Joint Assembly, Baltimore, MD, 23-26 May.

Xiong, X., J. Butler, W. Barnes, and B. Guenther (2006), Using Spacecraft Maneuvers for Sensor Calibration and Characterization, Proceedings of CALCON 2006.

Xiong, X., J. Sun, K. Chiang, W. Barnes, and B. Guenther (2006), Using the Moon for Sensors On-orbit Calibration and Characterization, Western Pacific Geophysics Meeting, Beijing, China, 24-27 July.

Xiong, X., J. Sun, K. Chiang, W. Barnes, and B. Guenther (2006), Lunar Observations Used for MODIS Sensor Calibration and Characterization," invited presentation at Pre-workshop, Proceedings of CALCON 2006.

Xiong, X., K. Chiang, N. Chen, S. Xiong, W.L. Barnes, and B. Guenther (2006), Results and Lessons from MODIS Thermal Emissive Bands Calibration: Pre-launch to On-orbit, *Proceedings of SPIE – Earth Observing Systems XI, 6296*, 62960A, doi:10.1117/12.680992.

Xiong, X., N. Che, C. Pan, X. Xie, J. Sun, W. L. Barnes, and B. Guenther (2006), Results and Lessons from MODIS Reflective Solar Bands Calibration: Pre-launch to On-orbit, *Proceedings of SPIE – Earth Observing Systems XI, 6296*, 629607, doi:10.1117/12.679144.

Xiong, X., N. Che, Y. Xie, D. Moyer, W. Barnes, B. Guenther, and V. Salomonson (2006), Four-years On-orbit Spectral Characterization Results for Aqua MODIS Reflective Solar Bands, *Proceedings of SPIE - Sensors, Systems, and Next Generation of Satellites X, 6361*, 63610S, doi:10.1117/12.687163.

Xiong, X., V. Salomonson, K. Chiang, N. Chen, S. Xiong, W. Barnes, and B. Guenther (2006), Summary of Terra MODIS Thermal Emissive Bands On-orbit Calibration, Proceedings of IGARSS 2006.

Xiong, X., V. Salomonson, W. Barnes, B. Guenther, K. Chiang, and J. Sun (2006), NASA EOS Terra and Aqua MODIS On-orbit Performance, COSPAR 2006, Beijing, China, 16-23 July.

Xiong, X., V. Salomonson, W. Barnes, B. Guenther, X. Xie, and J. Sun (2006), An Overview of Terra MODIS Reflective Solar Bands On-orbit Calibration, Proceedings of IGARSS 2006.

Yang, K., N. A. Krotkov, A. J. Krueger, S. A. Carn, and P. K. Bhartia (2006), Spectral Fitting Technique for OMI SO_2, 11th OMI Science Team Meeting, De Bilt, The Netherlands, 19-22 June.

Yang, K., N. A. Krotkov, S. A. Carn, A. J. Krueger, P. K. Bhartia, and P. F. Levelt (2006), A Fast Algorithm for Retrieval of Volcanic Sulfur Dioxide With OMI, AGU Fall Meeting, V32, San Francisco, CA, 11-15 December.

Yang, K., N. Krotkov, S. Carn, A. Krueger, and P. Levelt (2006), Fast Algorithm for Retrieval of Volcanic Sulfur Dioxide With OMI, Fall AGU, V32, 11-15 December.

Yang, R., R. M. Errico, M. Masutani, and J. Woollen (2006), The use of an OSSE to estimate characteristics of analysis error, poster presented at the 7th International Workshop on Adjoint Applications in Dynamic Meteorology, Obergurgl, Austria, 10 October.

Yang, S., E. A. Smith, and K.-S. Kuo (2006), Diurnal variability of precipitation from TRMM measurements, *Proc. of SPIE, 6404*(640401), doi:10.1117/12.696275.

Yoshida, Y., E. Bucsela, M. Wenig, B. Duncan, J. Rodriguez, and J. Gleason (2006), What does OMI NO_2 tell us about emission source strengths?, poster presented at the 2006 AGU Fall Meeting, San Francisco, CA, 13 December.

Yu, H. (2006), Satellite-based study of aerosol impacts on climate and air quality, invited presentation to Department of Atmospheric Sciences, Nanjing University, Nanjing, China, 15 November.

Yu, H., L. Remer, and M. Chin (2007), Satellite-based estimates of transpacific transport of pollution aerosol, Goddard Aerosol Update 2007, Greenbelt, MD, 22 February.

Yu, H., M. Chin, and L. Remer (2006), Assessing capabilities of satellite remote sensing for quantifying the aerosol direct climate forcing, Earth System Science Partnership (ESSP) Open Science Conference (OSC), Beijing, China, 8-12 November.

Yu, H., Y. Kaufman, M. Chin, and L. Remer (2006), An assessment of satellite-based estimates of the aerosol direct radiative forcing, AGU Spring Joint Assembly, Baltimore, MD, 23-26 May.

Yurchak, B.S. (2006), SAR Signature Characterization Studies of a Forest-Tundra Fire Scar in winter, AGU Fall meeting, San Francisco, CA, 11-15 December.

Zaitchik, B. F., M. Rodell, R. H. Reichle, and F. G. Lemoine (2006), Assimilating GRACE observations into the Catchment LSM: results for the Mississippi basin, AGU Fall Meeting, San Francisco, CA, 11-15 December.

Zeng, X., W.-K. Tao, C. Peters-Lidard, S. Lang, J. Simpson, S. Kumar, J. L. Eastman, C.-L. Shie, and J. V. Geiger (2006), Long-term numerical simulations of clouds in contrast to ARM observational data, AGU 1006 Joint Assembly, Baltimore, MD, 23-26 May.

Zeng, X., W.-K. Tao, M. Zhang, C. Peters-Lidard, S. Lang, J. Simpson, S. Kumar, S. Xie, J. L. Eastman, C.-L. Shie, and J. V. Geiger (2006), Long-Term Numerical Simulations of Clouds in Contrast to ARM Observational Data, The 2006 Joint Assembly, Baltimore, MD, 23-26 May.

Zeng, X., W.-K. Tao, M. Zhang, C. Peters-Lidard, S. Lang, J. Simpson, S. Kumar, S. Xie, J. L. Eastman, C.-L. Shie, and J. V. Geiger (2006), Evaluation of Long-Term Cloud-Resolving Modeling with ARM Data. The 16th Atmospheric Radiation Measurement (ARM) Program Science Team Meeting, Alquerque, NM, 26 March-1 April.

Zeng, X., W-K Tao, M. Zhang, C. Peters-Lidard, S. Lang, J. Simpson, S. Kumar, S. Xie, J. L. Eastman, C.-L. Shie, and J. V. Geiger (2006), Long-Term Numerical Simulations of Clouds in Contrast to ARM Observational Data, AGU Conference, Baltimore, MD, 23-26 May.

Zeng, X., X. Li, and W.-K. Tao (2006), The sensitivity of model dimensionality and microphysics on Arctic clouds, The 2006 ARM Cloud Modeling Meeting, San Francisco, CA, 29 October-1 November.

Zenitani, S., and M. Hoshino (2006), Magnetic reconnection in relativistic current sheets of pair plasmas, paper presented at the 2006 AGU fall meeting, San Francisco, CA, 11-15 December.

Zenitani, S., and M. Hoshino (2006), Particle acceleration by relativistic magnetic reconnection, paper presented at the reconnection workshop, Nagoya, Japan, October.

Zenitani, S., M. Hoshino, and M. Hesse (2007), Relativistic magnetic reconnection with a guide magnetic field, paper presented at the 8th International School/Symposium for Space Simulations, Kauai, Hawaii, February.

Zhan, X., W. Crow, S. V. Kumar, P. R. Houser, C. D. Peters-Lidard, and T. J. Jackson (2007), Impact of Observational Data preprocessing on their assimilation in NASA's Land Information System using the kalman filters, 21th Conference on Hydrology, 87th American Meteorological Society Annual Meeting, San Antonio, TX, 13-18 January.

Zhang, Q., X. Xiao, B. Braswell, E. Linder, and B. Moore (2006), Are seasonal MODIS spectral variations of two temperate deciduous broadleaf forest canopies during plant growing season only due to vegetation anisotropic nature?, AGU 2006 Fall Meeting, San Francisco, CA, 11-15 December.

Zhao, Y., A. K. Liu, and M. K. Hsu (2006), Ocean surface drift derived by feature tracking between ERS-2 and ENVISAT SAR images, presented at AGU Western Pacific Geophysics Meeting, Beijing, China, 24-27 July.

Zhou, Y. P., A. Hou, W. Lau, C.-L. Shie, W. -K. Tao, W. Olson, M. D. Chou, M. Grecu, and X. Lin (2006), Using high-resolution satellite observations for evaluation of cloud and precipitation statistics from cloud-resolving model simulations, Part I: South China Sea Monsoon Experiment, AGU 1006 Joint Assembly, Baltimore, MD, 23-26 May.

Zhou, Y. P., A. Hou, W. Lau, C.-L. Shie, W. -K. Tao, W. Olson, M. D. Chou, M. Grecu, and X. Lin (2006), Using high-resolution satellite observations for evaluation of cloud and precipitation statistics from cloud-resolving model simulations, Part I: South China Sea Monsoon Experiment, AGU 1006 Joint Assembly, Baltimore, MD, 23-26 May.

Zhou, Y. P., W.-K. Tao, A.Y. Hou, K.-M. Lau, and C. –L. Shie (2006), Cloud and precipitation simulations from cloud-resolving model when evaluated by satellite observations: missing microphysics? Western Pacific Geophysics Meeting, Beijing, China, 24-27 July.

Zhou, Y., A. Hou, W. K. Lau, C. Shie, W. Tao, X. Lin, M. Chou, W. S. Olson, and M. Grecu (2006), Using high-resolution satellite observations for evaluation of cloud and precipitation statistics from cloud-resolving model simulations, Part I: South China Sea Monsoon Experiment, AGU Joint Assembly, Baltimore, MD, 23-26 May.

Zhou, Y., D. P. Kratz, A. C. Wilber, S. K. Gupta, and R. D. Cess (2006) Retrieving surface downwelling longwave radiation from satellite measurements: Improvement of the Zhou-Cess algorithm, 12th Conference on Atmospheric Radiation, Madison, WI, 10-14 July.

Ziemke, J. R., E. V. Browell, G. J. Labow, and S. Chandra (2006), A cross-evaluation of tropospheric ozone from Aura OMI/MLS and DIAL lidar measurements during INTEX-B, Aura validation meeting, Boulder, CO, 17 September.

Ziemke, J. R., R. Chandra, W. G. Read, L. Froidevaux, and P. K. Bhartia (2006), Aura OMI/MLS measurements of tropospheric O_3 from MJO to El Nino timescales: Comparisons with MLS tropospheric H2O, Aura validation meeting, Boulder, CO, 17 September.

Zinner, T., A. Marshak, X. Li, S. Lang, and W.-K. Tao (2007), Remote sensing of cloud side of deep convective clouds, 17th ARM Science Team Meeting, Monterey, CA, 26-30 March.

Zubair, L., S. Mahanama, J. Chandimala, and N. Ward (2006), Hydroclimatological Simulation over Sri Lanka Using Global Reanalyses, AGU Fall Meeting, San Francisco, CA, 11-15 December.

Grant Proposals and Status

(sorted by funding agency, proposal title)

Proposal Title	Funding Agency	PI	Co-I(s)	Status
Design and Evaluation of the AFWA Weather Research and Forecast (WRF) model coupling with the AFWA/NASA Land Information System	AFWA	Christa Peters-Lidard (GSFC, Code 614.3)	Sujay Kumar (GEST)	Funded
DoD-GEIS utilization of remotely sensed satellite data to monitor and forecast Rift Valley fever and other vector-borne disease outbreaks	DoD – Walter Reed Army Institute for Research	Assaf Anyamba (GEST), Compton J. Tucker (GSFC, Code 614.0)	J. P. Chretien (WRAIR/GEIS), J. Richardson (USAMRU-GEIS, Kenya), Kenneth Linthicum (USDA/ CMVE)	Funded
Advances in 3-dimensional atmospheric radiation: I3RC toolbox, interactive aerosol retrieval, and cloud inhomogeneity parameterization	DOE ARM	Robert F. Cahalan (GSFC, Code 613.2)	Guoyong Wen (GEST), Lazaros Oreopoulos (JCET)	Funded
CRS and EDOP in Support of the DOE CLASIC Field Compaign	DOE ARM	Gerry Heymsfield (GSFC, Code 613.1)	Lihua Li (GEST)	Funded
Identification and Detection of Coastal HAB species and other Conditions Favoring the Outbreaks by Remote Sensing	EPA	Juying Warner (JCET)	Allen Chu (GEST), Timothy Berkoff (GEST)	Pending
Evaluation of Antarctic and Tropical Forest sites for Calibration and Cross-Calibration of Spaceborne L-band Radiometers. Submitted to ESA	ESA	Ed Kim (GSFC, Code 614)	Jeffrey Walker (Univ. of Melbourne), Marco Tedesco (GEST), David Le Vine (GSFC, Code 614.6), Bob Bindschadler (GSFC, Code 614)	Funded
Rift Valley Fever in West Africa	FAO	P. Ceccato (IRI/Columbia Univ.)	Assaf Anyamba (GEST)	Funded
Lunar Dust: Characterization and Mitigation	GSFC/ IRAD	William Farrell (GSFC, Code 695)	Timothy Stubbs (GEST), Steven Curtis (GSFC, Code 695), Michael Collier (GSFC, Code 673), Keller (GSFC, Code 691), Snook (GSFC, Code 693), Peters (GSFC, Code 546), Straka (GSFC, Code 546), Minetto (GSFC, Code 695), Cardiff (GSFC, Code 597), Clark (Catholic Univ. of America)	Funded

Proposal Title	Funding Agency	PI	Co-I(s)	Status
Great Lakes Regional Ozonesonde Network Demonstration	Indiana Space Grant Consortium	Gary A. Morris (GEST)		Pending
3D Ion Composition for Planetary Missions: Minor Ion Detection	NASA	Ed Sittler (GSFC, Code 673)	Paschalidis (NASA JPL), Richard Hartle (GSFC, Code 613), Hasso Niemann (GSFC, Code 699), Mehdi Benna (GEST), Dennis Chornay (GSFC, Code 673)	Pending
A Data Delivery System for Atmospheric Science	NASA	Leslie R. Lait (GEST)	Paul Newman (GSFC, Code 613.3)	Pending
A Flexible and Multi-faceted Land Surface Data Assimilation System	NASA	Randal Koster (GSFC, Code 610.1)	Christa Peters-Lidard (GSFC, Code 614.3) , Max Suarez (GSFC, Code 610.1), Rolf Reichle (GEST), Sarith Mahanama (GEST)	Not funded
A General Framework and System Prototype for the Self-Adaptive Earth Predictive Systems (SEPS)—Dynamically Coupling Sensor Web with Earth System Models	NASA	Liping Di (GSFC, Code 610.2)	James Smith (GSFC, Code 614.0), David Lary (GEST)	Funded
A global model study of emissions and long-range transport of aerosols and trace gases using Terra and Aqua satellite data	NASA	Mian Chin (GSFC, Code 613.3)	Huisheng Bian (GEST), D. Allen Chu (GEST), Thomas Diehl (GEST), Tom Kucsera (GEST), Wallace McMillan (UMBC), Loraine Remer (GSFC, Code 613.2), Amber Soja (NIA/NASA Langley), Hongbin Yu (GEST), Chris Barnet (NOAA NESDIS), David Edwards (NCAR), Louis Giglio (SSAI), Ralph Kahn (JPL)	Pending
A Global Modeling Initiative (GMI) Study of the Long-Range Transport of Pollution using Fused Carbon Monoxide Measurements from EOS	NASA	Bryan Duncan (GEST)	Yasuko Yoshida (GEST), Joanna Joiner (GSFC, Code 613.3), Arlindo da Silva (GSFC, Code 610.1), Michael Buchwitz (Univ. of Bremen), Louisa Emmons (NCAR), Qing Liang (NASA), Mark Schoeberl (GSFC, Code 613.3)	Pending
A Global Modeling Initiative (GMI) Study of the Sensitivity of Transport to Meteorological Fields	NASA	Bryan Duncan (GEST)	Mian Chin (GSFC, Code 613.3), Loretta Mickley (Harvard Univ.), Mark Olsen (GEST)	Funded

Proposal Title	Funding Agency	PI	Co-I(s)	Status
A long-term AVHRR and MODIS record of land vegetation properties mediating surface-atmosphere carbon, water and energy exchange	NASA	Forrest Hall (JCET)	Qingyuan Zhang (GEST), Karl Hummerich (JCET), Alex Lyapustin (GEST), Yujie Wang (GEST)	Pending
A multi-decadal sulfur dioxide climatology from UV satellite instruments	NASA	Nickolay Krotkov (GEST)	Kai Yang (GEST), Arlin J. Krueger (JCET), Simon A. Carn (JCET), Curt Tilmes (GSFC, Code 614.5)	Pending
A Prototype Land Information System Sensor Web	NASA	Paul Houser (George Mason Univ.)	Sujay Kumar (GEST), Yudong Tian (GEST), James Geiger (GSFC, Code 587.0)	Funded
A remote sensing technique for estimating absorbing aerosols and grain size in Greenland snow: field data collection, algorithm development and validation	NASA	Marco Tedesco (GEST)	Konrad Steffen (Univ. of Colorado), Knut Stamnes (Stevens Tech.), Michael Bergin (Georgia Tech.)	Pending
A study of Winter Precipitation Systems Using TRMM and Numerical Simulations	NASA	Scott Braun (GSFC, Code 613.1)	Mei Han (GEST)	Funded
Advanced MHD Modeling of the Magnetosphere of Mercury to Support the Messenger Mission	NASA	Mehdi Benna (GEST)		Pending
Advances studies in Aqua ocean data assimilation	NASA	Watson W. Gregg (GSFC, Code 610.1)	Lars Nerger (GEST)	Pending
Aerosol algorithm development support for GOES-R	NASA	Alexei Lyapustin (GEST)	Yujie Wang (GEST)	Funded
Aerosol and Cloud Classification Using Synthesized CALIPSO and MODIS Measurements	NASA	Ali Omar (NASA LaRC)	D. Allen Chu (GEST), and 5 others	Pending
Air Quality Monitoring and Source Strength Estimation using OMI Image Sequence Analysis	NASA	James Gleason (GSFC, Code 613.3)	Mark Wenig (GEST)	Not funded
Algorithm Development for the Dual-wavelength Precipitation Radar	NASA	Robert Meneghini (GSFC, Code 614.6)	Liang Liao (GEST)	Funded
An A-train cloud retrieval that accounts for aerosol properties	NASA	Clark Weaver (GEST)		Pending
An integrated study of 3-D distributions of aerosols and their direct radiative effects	NASA	Hongbin Yu (GEST)	Mian Chin (GSFC, 613.3), Lorraine Remer (GSFC, 613.2)	Pending

Proposal Title	Funding Agency	PI	Co-I(s)	Status
An interactive approach to improve the qualities of CALIPSO data and global aerosol transport model for climate and air quality studies	NASA	Mian Chin (GSFC, Code 613.3)	Oleg Dubovik (GSFC, 614.4), Richard Ferrare (NASA Langley), Ralph Kahn (NASA JPL), Orga Kalashnikova (NASA JPL), Ali Omar (NASA Langley), Jim Spinhirne (GSFC, 613.1), David Winker (NASA Langley), Hongbin Yu (GEST)	Pending
An NACP Thematic Data Center for Modeling and Synthesis	NASA	J. Ranson (GSFC, Code 614.4)	Joseph Eastman (GEST), Lin Tian (GEST), Jeff Morisette (GSFC, Code 614.5), Hall (GSFC, Code 614.4), Masek (GSFC, Code 614.4), Bounoua (GSFC, Code 614.4), Collatz (GSFC, Code 614.4), Wolfe (GSFC, Code 614.4)	Not funded
An Objectively Optimized Sensor Web	NASA	David Lary (GEST)	Robert Connerton (GSFC, Code 610), Michael Seablom (GSFC, 610.3), Mark Schoeberl (GSFC, Code 613.3), Stephen Talabac (GSFC, Code 586), Michael Tornetta (AGI)	Funded
Analyses of Magnetosheath Plasma Entry and Energization in the Dayside Magnetosphere	NASA	Timothy Stubbs (GEST)	Scudder (Univ. of Iowa), Sibeck (GSFC, Code 674), Scott Boardsen (GEST)	Not funded
Analysis and Simulation of the Influence of the Saharan Air Layer on Tropical Cyclogenesis Using Data from NAMMA-06 and A-Train Satellite	NASA	Liguang Wu (GEST)		Funded
Antarctic microwave observations and modeling supporting Icesat, SMOS, and Aquarius science	NASA	Ed Kim (GSFC, Code 614)	Marco Tedesco (GEST), Jeffrey Walker (Univ. of Mebourne), Mary Albert (CRREL)	Pending
Application of Artificial Neural Networks to Integrate Remote Sensing Data into the National Fire Danger Rating System	NASA	Scott Goodrick (USDA)	David Lary (GEST)	Not funded
Application of Multi-Scale Modeling Systems in Studies of Clouds and Convective Systems and their Associated Rainfall, Latent Heating and Moistening Structures for the Tropical Rainfall Measuring Mission and Global Precipitation Mission	NASA	Wei-Kuo Tao (GSFC, Code 613.1)	Joanne Simpson (GSFC, Code 613.1), Xiaowen Li (GEST), Stephen Lang (SSAI)	Funded

Proposal Title	Funding Agency	PI	Co-I(s)	Status
Aquarius: Global Modeling of Sea Surface Salinity	NASA	S. Daniel Jacob (GEST)	David Le Vine (GSFC, Code 614.6)	Funded
Arctic Climate Study Using Sea Ice Motion Derived from QuikSCAT, Midori-2 SeaWinds, and Other Satellite Data	NASA	Antony Liu (GSFC, Code 614.2)	Yunhe Zhao (GEST)	Not funded
Assessing current and future passive microwave water and energy cycle observational capabilities through multi-satellite resampling	NASA	Ed Kim (GSFC, Code 614)	Marco Tedesco (GEST), Richard Armstrong (NSIDC), Mary Brodzik (NSIDC)	Not funded
Assessment of Aqua, Aura and IASI Water Vapor, Temperature and Ozone profiles using dedicated field measurements from Beltsville, MD	NASA	D. N. Whiteman (NASA)	Belay Demoz (GSFC, Code 613.1), Bojan Bojkov (GEST), Everette Joseph (Howard Univ.), Mariana Adam (Howard Univ.), Larry Miloshevich (NCAR), Holger Vomel (Univ. of Colorado), Iliana Restrepo (Trinity Univ.)	Pending
Assimilation of Cloud/Precipitation Information from CloudSat and A-Train in a Cloud-Resolving Model for Improving Global Forecast and Climate Systems	NASA	Arthur Hou (GSFC, Code 610.1)	Wei-Kuo Tao (GSFC, Code 613.1), Peter Norris (GEST), Derek Posselt (CSU)	Pending
Assimilation of Constituents for Evaluation and Intercomparison of Aura Observations (ACEi-Aura)	NASA	David Lary (GEST)		Funded
Automating Electron Density Determinations from Magnetospheric Dynamic Spectra	NASA	Phillip Webb (GEST)	Robert Benson (GSFC, Code 673), James Green (NASA HQ)	Funded
Bayesian Classification of Multidimensional NSO Magnetograms for Comparison with Solar Irradiance and Study of the Solar Cycle	NASA	Judit Pap (GEST)		Funded
Building an Integrated View of Terra, Aqua, and Aura Tropospheric Trace Gas Products: Global Modeling and Detailed Case Study Investigations	NASA	Wallace McMillan (UMBC)	D. Allen Chu (GEST), Huisheng Bian (GEST), and 3 others	Pending
CALIPSO Impacts on the Determination of Transport of Lower Tropospheric Aerosols	NASA	Raymond Hoff (JCET)	D. Allen Chu (GEST), and 3 others	Pending

Proposal Title	Funding Agency	PI	Co-I(s)	Status
CALIPSO RFI 1-117: Coupling CALIPSO to In Situ Measurements for Estimation of Direct Aerosol Radiative Forcing, 1-year extension	NASA	Robert J. Charlson (Univ. of Washington)	Theodore L. Anderson (GEST)	Pending
Characterization of Aerosols and Bidirectional Reflectance Distribution Function from Airborne Radiation Measurements	NASA	Charles Gatebe (GEST)	Michael King (GSFC, Code 610), James Butler (GSFC, Code 614.4)	Pending
Characterization of Volcanic Clouds from Top to Bottom with the A – Train	NASA	Simon Carn (JCET)	Nickolay Krotkov (GEST), Arlin Krueger (JCET)	Pending
Characterizing the Composition of Large Mid - latitude Topside Ionospheric /Plasmaspheric Gradients	NASA	Robert Benson (GSFC, Code 673)	Phillip Webb (GEST), Dieter Biltza (Raytheon IIS, GSFC, Code 672), Joseph Grebowsky (GSFC, Code 695)	Pending
Chemistry-Climate Studies Using General Circulation Models	NASA	Richard Stolarski (GSFC, Code 613.3)	Julio Bacmeister (GEST)	Funded
Cirrus and Convective Structure Using EDOP and CRS	NASA	Gerry Heymsfield (GSFC, Code 613.1)	Lihua Li (GEST), Lin Tian (GEST)	Funded
Climate Change Science Program through Intergovernmental Personnel Act appointment	NASA	Robert J. Curran (GEST)		Funded
Cluster Cusp Studies	NASA	Timothy Stubbs (GEST)		Funded
Combined Radar/Radiometer Estimates of Precipitation and Latent Heating Profiles for Training Spaceborne Passive Microwave Radiometer Algorithms	NASA	William S. Olson (JCET)	Mircea Grecu (GEST), Liang Liao (GEST)	Funded
Comparisons of TRMM and GPM Products to Ground-Based Measurements: An Approach to Improve the Validation of Satellite Precipitation Products	NASA	Liang Liao (GEST)	Robert Meneghini (GSFC, Code 614.6)	Funded
Computing resources for the assimilation of AMSR-E soil moisture retrievals	NASA	Rolf Reichle (GEST)	Randal Koster (GSFC, Code 610.1)	Funded
Continuation of the Stratospheric General Circulation with Chemistry Project	NASA	Anne R. Douglass (GSFC, Code 613.3)	Mark A. Olsen, Randy Kawa (GSFC, Code 613.3)	Funded

Proposal Title	Funding Agency	PI	Co-I(s)	Status
Cryospheric Experimental Synthetic Aperture Radiometer (CESAR): A UAV-mounted synthetic aperture radiometer for cryospheric applications	NASA	Thorsten Markus (GSFC, Code 614)	Robert Bindschadler (GSFC, Code 614), Geoffrey Bland (GSFC, Code 614), Peter Hildebrand (GSFC, Code 614), Lawrence Hilliard (GSFC, Code 500),Richard Kelly (UMBC),Wes Lawrence (GSFC, Code 500), David Le Vine (GSFC, Code 614.6), Christopher Ruf (GSFC, Code 500), Christopher Shuman (GSFC, Code 614)	Not funded
Demonstrating NASA Snow Observations and Modeling in Operational Decision Support	NASA	Paul Houser (George Mason Univ.)	D. Cline (NOHRSC), Kristi Arsenault (GEST), L. Rundquist, (RFC), D. Luna (RFC)	Not funded
Deriving Daytime and Nighttime Dust Optical Depth and Height from MODIS/AIRS to Study Diurnal Radiative Forcing and Effects Over Ocean	NASA	D. Allen Chu (GEST)	William Ridgway (SSAI), Emily Huichun Liu (SAIC), Sergio DeSouza-Machado (JCET), Kyu-Myong Kim (GEST), Ellsworth Welton (GSFC, Code 613.1), Belay Demoz (GSFC, Code 613.1), Mian Chin (GSFC, Code 613.3)	Pending
Detecting Aerosol-Cloud-Precipitation Interactions in Mixed-Phase Cloud Systems from the Space: A Modeling Guided Data Analysis	NASA	Xiaowen Li (GEST)		Not Funded
Detection of Sunspots and Weak Magnetic Fields from the High Resolution MDI Images	NASA	Judit Pap (GEST)		Pending
Development and evaluation of a generalized framework to assimilate observed microwave radiances emerging from raining areas into a global circulation model Development and evaluation of a generalized framework to assimilate observed microwave radiances emerging from raining areas into a global circulation model	NASA	Mircea Grecu (GEST)	Sara Q. Zhang (SSAIC)	Funded
Development of small, precise sensors for composition measurements of the Martian Atmosphere	NASA	William Heaps (GSFC, Code 550.0)	Emily Wilson (GSFC, Code 554), John Pearl (GSFC, Code 693), Elena Georgieva (GEST)	Pending

Proposal Title	Funding Agency	PI	Co-I(s)	Status
Development, Validation, and Scientific Evaluation of a Multi-year Sounder Based Climate Data Set Using Products Derived from AIRS/AMSU and TOVS Observations	NASA	Joel Susskind (GSFC, Code 613.5)	Gyula Molnar (GEST)	Pending
Effect of soil moisture initialization uncertainty on subseasonal rainfall and temperature prediction	NASA	Randal Koster (GSFC, Code 610.1)	Rolf Reichle (GEST), Max Suarez (GSFC, Code 610.1), Shepherd (GSFC, Code 610.1)	Not funded
Electrostatically-Based Dust Control, Containment, and Characterization for Planetary Surfaces	NASA	Clark (Catholic Univ. of America)	Timothy Stubbs (GEST), Keller (GSFC, Code 691), Nuth (GSFC, Code 691), Farrell (GSFC, Code 695), Curtis (GSFC, Code 695), Minetto (GSFC, Code 695), Calle (NASA KSC), Carrier (Lunar Geotechnical Inst.), Berg (unaffiliated)	Pending
Electrostatically-Based Toolkit for Characterization of Dust/Plasma Interaction on the Lunar Surface	NASA	Steven Curtis (GSFC, Code 695)	Timothy Stubbs (GEST), Clark (Catholic University of America). Keller (GSFC, Code 691), Farrell (GSFC, Code 695), Minetto (GSFC, Code 695), Calle (NASA KSC)	Pending
Enhanced Baseline Measurements on Antarctica Cloud Cover for IPY and their Application	NASA	James Spinhirne (GSFC, Code 613.1)	Timothy Berkoff (GEST), Stephen Palm (SSAI), James Campbell (Univ. of Alaska), Bruno Tremblay (Columbia Univ.), Robert Stone (NOAA)	Pending
Enhanced Ionospheric Topside-Sounder Science Return from Existing and Future Data	NASA	Robert Benson (GSFC, Code 673)	Phillip Webb (GEST), Xueqin Huang (Univ. of Massachusetts Lowell), Bodo W. Reinisch, (Univ. of Massachusetts Lowell)	Pending
Enhancement of USDA SCAN using NASA LIS and AMSR-E	NASA	V. Anatharaj (MSU), Christa Peters-Lidard (GSFC, Code 614.3)	Sujay Kumar (GEST), Paul Houser (George Mason Univ.)	Funded
Enhancing the Department of Defense Global Emerging Infections Surveillance & Response System (DoD-GEIS) through Integration of NASA Earth-Sun System Research Results	NASA	J. P. Chretien (WRAIR/GEIS)	Assaf Anyamba (GEST), K. J. Linthicum (USDA/ CMAVE), Compton Tucker (GSFC, Code 614.0)	Not funded
EOS and NPP satellite data fusion to develop a long term record on aerosol absorption	NASA	Omar Torres (JCET)	Santiago Gassó (GEST)	Pending

Proposal Title	Funding Agency	PI	Co-I(s)	Status
Establishing a long term record of biomass-burning carbon emissions by combining satellite data with modeling	NASA	Charles Ichoku (ESSIC)	Eric Vermote (UMCP), Mian Chin (GSFC 613.3), Louis Giglio (SSAI), Martin Wooster (Kings College), Tatsiana Lapionak (SSAI), Oleg Doubovik (Univ. of Lille), David Roy (South Dakota State Univ.), Thomas Diehl (GEST)	Pending
Estimates of Sea Surface Roughness from GLAS	NASA	S. Daniel Jacob (GEST)	Beckley (SGT), Luthcke (GSFC), Le Vine (GSFC), Ray (GSFC)	Not funded
Evaluation of multi-scale microwave forward models and hydrological retrievals for the North Slope of Alaska and forested snow-covered areas	NASA	Ed Kim (GSFC, Code 614)	Marco Tedesco (GEST)	Not funded
Exploiting satellite and surface measurements to improve global modeling of black carbon absorption	NASA	Greg Schuster (NASA/LaRC)	Hongbin Yu (GEST), and others	Pending
Flood and Landslide Early Warning Products for USAID Disaster Management Requirements	NASA	Robert F. Adler (GSFC, Code 613.1)	Yang Hong (GEST)	Funded
Flux Transfer Events: Structures, Dynamics, and Their Geophysical and Solar Wind Control from Cluster Multiple-Spacecraft Observations and Global Magnetohydrodynamic Simulations	NASA	Yongli Wang (GEST)	Le (GSFC, Code 674)	Not funded
Forecast and Analysis of Aerosol Distribution and Transport Using MODIS Near Real Time and Geostationary Satellite Measurements and Trajectory Model for INTEX-B	NASA	D. Allen Chu (GEST)	Lorraine Remer (GSFC, Code 613.2)	Funded
Forecasting Vector-borne Diseases for Public Health using Earth-Sun Science	NASA	G. Gregory (John Hopkins Univ.)	Assaf Anyamba (GEST)	Not funded
GEWEX/IGPO	NASA	Robert Schiffer (GEST)	Rick Lawford (GEST)	Funded
Global multi-sensor active and passive microwave retrieval of snow parameters	NASA	Marco Tedesco (GEST)	Ed Kim (NASA GSFC, Code 614), Richard Kelly (UMBC), Glenn Liston (Univ. of Colorado)	Pending

Proposal Title	Funding Agency	PI	Co-I(s)	Status
Global Precipitation Analysis for Climate and Weather Studies	NASA	Robert F. Adler (GSFC, Code 613.1)	George Huffman (SSAI), Guojun Gu (GEST), Scott Curtis (ECU)	Funded
Ground validation activities at mid-latitude coastal site	NASA	Jian-Jian Wang (GEST)		Not funded
Ground water sustainability and management in the Magrheb Region of North Africa	NASA	Jasinski (NASA)	T. Engman (SSAI), C. Voss (USGS), F. Lemoine (GSFC), Kristi Arsenault (GEST), M. Roddell (GSFC), I. Verstraeten (USGS)	Not funded
Heads-Up! Health, Environment and National Assessment Decision Support Systems for Urban Pollution	NASA	David Lary (GEST)	Neff (UMBC), Boothe (CDC), Stephanie Davis (CDC), Zonderman (NIH), Evans (NIH), Round (MA Env. Agency), Sattler (UM Baltimore), Baier-Anderson (Univ. of Maryland, Baltimore), Squibb (Univ. of Maryland, Baltimore), Jessica Kelley-Moore (UMBC)	Not funded
High-altitude Imaging Wind and Rain Airborne Profiler (HIWRAP)	NASA	Gerry Heymsfield (GSFC, Code 613.1)	Lihua Li (GEST), James Careswell (Remote Sensing Solution Inc.), Daniel Schaubert (Univ. of Mass. at Amherst)	Funded
I3RC workshop and 3D community tools applied to assessments and improvements of cloud retrievals from Terra, Aqua, and THOR offbeam data	NASA	Robert F. Cahalan (GSFC, Code 613.2), Alexander Marshak (GSFC, Code 613.2)	Frank Evans (Univ. of Colorado), Lazaros Oreopoulos (JCET), Tamas Varnai (JCET), Guoyong Wen (GEST)	Funded
Improved clouds and radiation in GEOS-5 from global analysis, parameterization and assimilation of A-Train cloud retrievals	NASA	Lazaros Oreopoulos (JCET)	Peter Norris (GEST), Julio Bacmeister (GEST), Steven Platnick (GSFC, Code 613.2), Arlindo da Silva (GSFC, Code 610.1)	Pending
Improved derivation of snowfall in polar and sub polar regions through synergistic multi-sensor satellite analysis	NASA	James Foster (GSFC, Code 614.3)	Skofronick-Jackson (NASA), J. Wang (GSFC), Bindschadler (GSFC), Ed Kim (GSFC), Bliven (GSFC), Marco Tedesco (GEST), Min-Jeong Kim (GEST)	Not funded
Improved estimates of CO_2 fluxes using CO_2/CO correlations: An integration approach through observations and simulations	NASA	Huisheng Bian (GEST)		Not funded

Proposal Title	Funding Agency	PI	Co-I(s)	Status
Improved passive microwave retrieval of overland precipitation rates by coupled land surface and radiative transfer modeling	NASA	Matthew Garcia (GEST)	Christa D. Peters-Lidard (GSFC, Code 614.3), Chris Kummerow (Colorado State Univ.), John Eylander (AFWA), Sujay Kumar (GEST)	Not funded
Improved polar precipitating snow/snow depth maps through the synergistic analysis of satellite multi-sensor physically-consistent atmospheric and surface retrievals	NASA	James Foster (GSFC, Code 614.3)	Thorsten Markus (GSFC, Code 614), G. Jackson (GSFC, Code 614), Marco Tedesco (GEST), M.-J. Kim (GEST), J. Wang (GEST), R. Bindschadler, L. Bliven (GSFC, Code 614)	Not funded
Improving smoke characterization in chemical transport models by introducing satellite measurements of fire radiative energy	NASA	Charles Ichoku (ESSIC)	Thomas Diehl (GEST), Martin Wooster (Kings College), Mian Chin (GSFC, Code 613.3), Louis Giglio (SSAI)	Pending
Improving Water Supply and Demand Forecasting Using NASA Earth Science Data with USBR Decision Support Systems	NASA	Boyle (U. Nevada/DRI)	David Toll (GSFC, Code 614.3), Kristi Arsenault (GEST), R. Allen (U. Idaho), Steve Bowser (USBR), D. Frevert (USBR), R. Stodt (USBR), D.Clark (USBR)	Not funded
Integrated forecasting system for mitigating adverse space weather effects on the Northern American high-voltage power transmission system	NASA	Michael Hesse (GSFC, Code 674)	Antti Pulkkinen (GEST), Policelli (GSFC, Code 610), van Der Zel (EPRI)	Funded
Investigating the magnetization and density of the middle and lower crust in selected tectonic regions using long-wavelength satellite geopotential data	NASA	Patrick Taylor (GSFC, Code 698.0)	Hyung Rae Kim (GEST), and 5 others	Pending
Investigation of Relationships between Observed Aerosol Concentrations, Sources, and Effects on Convective Storm Characteristics and Precipitation	NASA	Kenneth E. Pickering (GSFC, Code 613.3)	Wei-Kuo Tao (GSFC, Code 613.1), Mian Chin (GSFC, Code 613.3), Dale Allen (Univ. Of Maryland), Xiaowen Li (GEST)	Not Funded
Ion Injection and Transport in the High-latitude Magnetosphere	NASA	Timothy Stubbs (GEST)	Sibeck, Fok, Scott Boardsen (GEST), Trattner, Moore	Not funded
Land data assimilation development and implementation for NASA Water and Energy Cycle Studies	NASA	Rolf Reichle (GEST)		Not funded

Proposal Title	Funding Agency	PI	Co-I(s)	Status
Lunar Emissions, Electrons, and Dust (LEED): Science and Hazard Assessment of the Dusty-Plasma Environment	NASA	William M. Farrell (GSFC, Code 695.0)	Timothy Stubbs (GEST), Keller (GSFC, Code 691), Vondrak (GSFC, Code 690), Michael Collier (GSFC, Code 673), Peters (GSFC, Code 546), Delory (UC Berkeley), Jasper Halekas (UC Berkeley)	Pending
Lunar Surface Charging and Dust Transport During Extreme Space Weather Events	NASA	Jasper Halekas (UC, Berkeley)	Timothy Stubbs (GEST), Brain (UC Berkeley), Fillingim (UC Berkeley)	Pending
Lunar-Based Soft X-ray Science	NASA	Michael Collier (GSFC, Code 673)	Timothy Stubbs (GEST), Porter (GSFC, Code 662), Snowden (GSFC, Code 662), Hills (QSS Group, Inc.), Kuntz (JHU), Cravens (Kansas Univ.), Robertson (Kansas Univ.), Travnicek (Inst. Atmos. Phys.)	Pending
Magnetospheric Currents, Surface Charging and Dust Transport at Mercury	NASA	Timothy Stubbs (GEST)		Pending
Magnetospheric Electron Density	NASA	Richard Denton (Dartmouth College)	Phillip Webb (GEST), Jerry Goldstein (Southwest Research Institute), Roger Anderson (Univ. of Iowa)	Not funded
Maintenance and refinement of the AMSR-E SWE algorithm	NASA	Marco Tedesco (GEST)	Ed Kim (GSFC, Code 614), James Foster (GSFC, Code 614), Jim Wang (GSFC, Code 614), Jeff Miller (SSAI)	Pending
Mapping SO_2 emissions with NASA AURA Ozone Monitoring Instrument (OMI) and GOCART model for air quality and climate science	NASA	Nickolay Krotkov (GEST)	Arlin Krueger (JCET), Simon Carn (JCET), R. Dickerson (Univ. of Maryland)	Funded
Mars Observations for Surface, Atmosphere, and Ice change (MOSAIC)	NASA	Jim Garvin (GSFC, Code 600.0)	Gregory Neumann (GSFC, Code 698.0), Bryan Blair (GSFC, Code 694.0), John.C. Pearl (GSFC, Code 693.0), Peter G. Ford (MIT), Keith Raney (APL/JHU), Emily Wilson (GSFC, Code 554.0), Elena Georgieva (GEST)	Not funded
Measurement of the aerosol interaction with clouds and forcing of climate	NASA	Lorraine Remer (GSFC, Code 613.2)	Hongbin Yu (GEST), Mian Chin (GSFC, Code 613.3), Ilan Koren (JCET), Norman Loeb (LaRC), Mark Jacobson (Stanford Univ.)	Funded

Proposal Title	Funding Agency	PI	Co-I(s)	Status
Measurement-based assessment of intercontinental transport of aerosols through a synergy of A-Train data	NASA	Hongbin Yu (GEST)	Lorraine Remer (GSFC, 613.2), Mian Chin (GSFC, 613.3)	Pending
Measuring and modeling bi-directional exchanges of ammonia between the atmosphere and biosphere in the south eastern U.S.	NASA	Yihua Wu (GEST)	John Walker (EPA), Robarge (NCSU), Juying Warner (JCET), Christa Peters-Lidard (GSFC, Code 614.3), Donna Schwede (EPA), Drew Pilant (EPA)	Not funded
Meteorological support for the tropical composition, cloud, and climate coupling experiment (TC4) experiment	NASA	Paul Newman (GSFC, Code 613.3)	Leslie R. Lait (GEST), S. Randolf Kawa (GSFC, Code 613.3), Steven Platnick (GSFC, Code 613.2), Mark R. Schoeberl (GSFC, Code, 613.3), Peter Colarco (GSFC, Code 613.3), Arlindo da Silva (GSFC, Code 610.1), Kenneth Pickering (GSFC, Code 613.3)	Funded
MHD - Chemistry Modeling of High-energy Cometary Emissions	NASA	Mehdi Benna (GEST)	Rodgers (SETI/NASA-Ames), Charnley (SETI/NASA-Ames), Dalgarno (Harvard Univ.), Millar (Queen's Univ. Belfast)	Not funded
Model Investigations of Upper-Tropopshere/Lower-Stratosphere Water Vapor and Transport into the Stratosphere	NASA	Mark A. Olsen (GEST)	William Gallus, Jr. (Iowa State Univ.)	Funded
Multi-decadal aerosol trends and effects on surface radiation and air quality	NASA	Mian Chin (GSFC, Code 613.3)	Peter Colarco (GSFC, Code 613.3), Thomas Diehl (GEST), Tom Kucsera (GEST), Yun Qian (PNNL), Streets (ANL), Hongbin Yu (GEST), Arlindo da Silva (GSFC, Code 610.1), Rachel Pinker (UMCP), Paul Stackhouse (NASA Langley), Martin Wild (ETH)	Pending
Multi-fluid Modeling of the Atmosphere of Enceladus and Interaction with Saturn's Magnetosphere	NASA	Mehdi Benna (GEST)	Kasprzak (GSFC, Code 699), Olson (Drexel Univ.)	Not funded
Multiple factors affecting the African Easterly Jet (AEJ) and cyclone development over the tropical Atlantic	NASA	William Lau (GSFC, Code 613)	Oreste Reale (GEST), Arlindo da Silva (GSFC, Code 610.1), Eric Wilcox (GSFC, Code 613.2)	Funded
Multiscale Modeling of Aerosol Impacts on Clouds and Precipitation	NASA	Steve Ghan (DOE/PNL)	Richard Easter, Mikhail Ovtchinnikov, Xiaohong Liu, Yun Qian (DOE/PNL), Vince Larson (Univ. Wisconsin Madison), Hongbin Yu (GEST)	Funded

Proposal Title	Funding Agency	PI	Co-I(s)	Status
Multi-scale Modeling Studies of Cloud and Precipitation Processes Using ARM Data	NASA	Wei-Kuo Tao (GSFC, Code 613.1)	Jiun-Dar Chern (GEST), Christa Peters-Lidard (GSFC, Code 614.3)	Not funded
Multi-Sensor, Multi-Parameter Radiance-Based Assimilation for Snow and Cold Lands	NASA	Ed Kim (GSFC, Code 614)	Marco Tedesco (GEST), J. Foster, D. Hall, R. Kelly (UMBC) J. Walker (Univ. of Melbourne)	Pending
Multi-spacecraft Study of Escaping Non-thermal Continuum	NASA	Scott Boardsen (GEST)	Green (NASA HQ)	Funded
New Operational Mode for Space-Borne Quadrupole Mass-Spectrometers	NASA	Zurbuchen (Univ. of Michigan)	Paul Mahaffy (GSFC, Code 699), Mehdi Benna (GEST), Block (Univ. of Michigan), Rubin (Univ. of Michigan)	Pending
Observational and Theoretical Constraints on Lunar Surface and Dust Charging Processes	NASA	Delory (UC, Berkeley)	Jasper Halekas (UC, Berkeley), Timothy Stubbs (GEST)	Pending
Obtaining a 30 year aerosol record from satellite radiances	NASA	Clark Weaver (GEST)		Funded
Ocean Color Calibration and Validation Data in the Southern Ocean with Application to the Influence of Ocean Biology on Atmospheric CO_2 Uptake	NASA	M. E. Russ (GEST)	Stan Hooker (GSFC, Code 614.8), Davide D'Alimonte (JCET)	Pending
Open-source Peer-to-Peer (P2P) Environment to Enable Sensor Web Architecture	NASA	Holland (GSFC, Code 673)	Antti Pulkkinen (GEST)	Funded
Polar magnetic properties and mass dynamics from Ørsted and CHAMP satellite geopotential observations – extended	NASA	Hyung Rae Kim (GEST)		Funded
Polar Studies Using a Hyperspectral Imager on UAV	NASA	Juying Warner (JCET)	Fred Huemmrich (JCET), D. Allen Chu (GEST), Timothy Berkoff (GEST), Thorsten Markus (GSFC, Code 614.6)	Pending
Pollutant Source Strength Analysis by Applying Inversion Techniques to OMI Data using a Set of Modeled Localized Sources as Basis Functions	NASA	Mark Wenig (GEST)	Kenneth Pickering (GSFC, Code 613.3), Jeff Stehr (Univ. of Maryland), Dale Allen (Univ. of Maryland), Bryan Duncan (GEST), Peter Colarco (GSFC, Code 613.3), Nickolay Krotkov (GEST), James Gleason (GSFC, Code 613.3), Simon Carn (JCET)	Pending

Proposal Title	Funding Agency	PI	Co-I(s)	Status
Precise Measurement of Total Atmospheric Column Employing Fabry-Perot Interferometer	NASA	William Heaps (GSFC, Code 550.0)	Emily Wilson (GSFC, Code 554), Randy Kawa (GSFC, Code 613), Elena Georgieva (GEST)	Not funded
Project Lead the Way STEM Enhancement Pilot	NASA	Niel Tebbano (Project Lead the Way)	Susan Hoban (GEST)	Funded
Proposal to the National Aeronautics and Space Administration under Research Opportunities in Space and Earth Sciences – 2006	NASA	Paul Newman (GSFC, Code 613.3)	Huisheng Bian (GEST)	Funded
Rapid development of a focused Virtual Magnetospheric Observatory and its integration with VxOs for S3C data	NASA	Jan Merka (GEST)	Sibeck (GSFC, Code 674), Roberts (GSFC, Code 672), Le (NASA, Code 674), Paterson (Hampton Univ.), Karimabadi (SciberQuest), Fritz (Boston Univ.), Faden (Cottage Systems), Angelopolous (UC, Berkeley)	Funded
Remote sensing measurements of aerosol absorption and its effect on climate forcing	NASA	Vanderlei Martins (UMBC)	Lorraine Remer (GSFC, 613.2), Hongbin Yu (GEST), Charles Ichoku (ESSIC)	Pending
Reprocessing of Goddard Satellite-based Surface Turbulent Fluxes (GSSTF) Data Set for Global Water and Energy Cycle Research	NASA	Chung-Lin Shie (GEST)	Long S. Chiu (George Mason Univ.), Robert F. Adler (GSFC, Code 613.1)	Pending
Retrievals of Precipitating Snow and Light Rain Using Synergistic Multi-Sensor Active and Passive Observations	NASA	Gail Skofronick Jackson (NASA)	William S. Olson (JCET), M.-J. Kim (GEST), Mircea Grecu (GEST), J. Wang (NASA), Ben Johnson (JCET)	Pending
Satellite-based assessments of the aerosol direct forcing	NASA	Yoram Kaufman (GSFC, Code 613.2), Hongbin Yu (GEST)	Mian Chin (GSFC, Code 613.3)	Funded
SAUNA-2: validation of satellite profile and total column ozone measurements at very large solar zenith angles using LIDAR and ozonesondes	NASA	Bojan Bojkov (GEST)	T. McGee (GSFC, Code 613.3), P. K. Bhartia (GSFC, Code 613.3), R. D. McPeters (GSFC, Code 613.3)	Funded
Sea Ice Drift from Multiple Satellite Sensors	NASA	Antony A. Liu (GSFC, Code 614.2)	Yunhe Zhao (GEST), Donald J. Cavalieri (GSFC, Code 614.1), Thorsten Markus (GSFC, Code 614.6)	Pending

Proposal Title	Funding Agency	PI	Co-I(s)	Status
SENsor Web System for EarthQuake Early Warning, "SENEQA"	NASA	Shahid Habib (GSFC, Code 604.0)	Dimitar Ozounov (GSFC, Code 610.2), S. Pulinets (GSFC), G. Cervone (GSFC), David Lary (GEST), P. Taylor (GSFC), F. Policelli (GSFC), S. Talabac (GSFC)	Not funded
Simultaneous retrivals of chlorophyll and absorbing aerosol optical depth from MODIS and VIIRS	NASA	Clark Weaver (GEST)		Pending
Small Ultra-sensitive Detector for Methane and Water on Mars	NASA	William Heaps (GSFC, Code 550.0)	Emily Wilson (GSFC, Code 554), Elena Georgieva (GEST)	Funded
Solar Variability: Results from SOHO and SDO	NASA	Judit Pap (GEST)		Funded
Solar Wind Input into the Magnetosphere: Assimilation of Multispacecraft Data	NASA	Jan Merka (GEST)		Funded
Studies of Tropical Cyclone Genesis and Tropical Cirrus Using ER-2 Radars	NASA	Gerry Heymsfield (GSFC, Code 613.1)	Lihua Li (GEST), Paul Racette (GSFC, Code 555.0), Lin Tian (GEST)	Funded
Study of the Effect of Dust Radiative and Microphysical Properties on Precipitation and Enerty Budget Using a A-Train Setellite Measurements and Cloud-Resolving Model	NASA	D. Allen Chu (GEST)	Sergio DeSouza-Machado (JCET), Omar Torres (JCET), Chung-Lin Shie, Ruei-Fong Lin (GEST), Belay Demoz (JCET), Ellsworth Welton (GSFC, Code 613.1), Xiaowen Li (GEST)	Funded
Study of the Influence of the Saharan Air Layer on Tropical Cyclone Intensity Using Data from Aqua Multi-Sensors and other "A-Train" Satellites	NASA	Liguang Wu (GEST), Scott Braun (GSFC, Code 613.1)	Chung-Lin Shie (GEST)	Pending
Support for the NEWS Science Integration Team	NASA	Paul Houser (George Mason Univ.)	Robert Schiffer (GEST), Rossow (CUNY), Schlosser (MIT), Njoku (JPL), Lin (NASA LaRC), and Lapenta (NASA MSFC)	Funded
Surface Variability and Subsurface Structure of North Pacific	NASA	S. Daniel Jacob (GEST)		Not funded
Survey of Simultaneous Observations of the Auroral Ovals in Both Hemispheres	NASA	Timothy Stubbs (GEST)		Funded

Proposal Title	Funding Agency	PI	Co-I(s)	Status
Synoptic to Seasonal Variability of Temperature, Humidity, Aerosol, and Precipitation over West Africa and Tropical Atlantic Ocean	NASA	Guojun Gu (GEST)	Robert Adler (GSFC, Code 613.1), Chidong Zhang (Univ. of Miami)	Pending
The Impact of emissions and long-range transport on regional air quality: An analysis with a global-regional atmospheric modeling system	NASA	Mian Chin (GSFC, Code 613.3)	Dale Allen (Univ. of Maryland), Huisheng Bian (GEST), Thomas Diehl (GEST), Bryan Duncan (GEST), George Grell (NOAA FSL), D. Allen Chu (GEST), Tom Kucsera (GEST), Hongbin Yu (GEST)	Funded
The NASA Micro-Pulse Lidar Network (MPLNET): A proposal to renew operations and continue scientific investigations	NASA	Ellsworth Welton (GSFC, Code 613.1)	Timothy Berkoff (GEST), James Campbell (SSAI), James Spinhirne (GSFC, Code 613.1), Si-Chee Tsay (GSFC, Code 613.2)	Funded
The Swift Neurological Acceleration of Atmospheric Photochemistry and Aerosol Calculations [SNAPA]: Development and Application to Atmospheric Chemistry and Aerosol Simulations with a Focus on UT/LS Ozone	NASA	David Lary (GEST)	Dale Allen (Univ. of Maryland), Anne Douglass (GSFC, Code 613.3), Bryan Duncan (GEST), Michael Herzog (Princeton Univ.)	Funded
Three-Dimensional Air Quality System (3D-AQS)	NASA	Raymond Hoff (JCET)	D. Allen Chu (GEST), and 10 others	Funded
Towards improved weather and sub-seasonal climate forecasts through assimilation of NASA EOS land surface products into the NASA GMAO seasonal forecasting and weather prediction systems	NASA	Rolf Reichle (GEST)	Marco Tedesco (GEST), Michael Bosilovich (GSFC, Code 610.1), Randal Koster (GSFC, Code 610.1)	Pending
Understanding the Carbon Cycle in the Southern Hemisphere: Dust Transport into the South Atlantic Ocean and Possible Effects on Biological Activity	NASA	Santiago Gassó (GEST)	N. Meskhidze (NCSU)	Not funded
Unified Data Access Services for Virtual Observatories	NASA	Vandegriff (JHU/APL)	Morrison (JHU/APL), Thieman (GSFC, Code 690), Thomas Narock (GEST), Candey (GSFC, Code 672)	Pending
Use of a coupled, global cloud-scale and land surface modeling system to study the impact of land surface processes on energy and water cycles	NASA	Wei-Kuo Tao (GSFC, Code 613.1)	Robert Atlas (NOAA), Christa Peters-Lidard (GSFC, Code 614.3), Jiun-Dar Chern (GEST), William Lau (GSFC, Code 613.0)	Funded

Proposal Title	Funding Agency	PI	Co-I(s)	Status
Use of atmospheric vertically-resolved GLAS/ICESat aerosol data to evaluate GOCART aerosol and underlying Goddard GEOS-DAS models	NASA	Mohan Gupta (FAA)	Julio Bacmeister (GEST), Mian Chin (GSFC, Code 613.3), Peter Colarco (GSFC, Code 613.3), Arlindo da Silva (GSFC, Code 610.1), Thomas Diehl (GEST), Charles Ichoku (ESSIC), Stephen Palm (SSAI), James Spinhirne (GSFC, Code 613.1)	Pending
Use of Neural Network Techniques in the Physics Parameterizations of Atmospheric General Circulation Models	NASA	Max Suarez (GSFC, Code 610.1)	David Lary (GEST)	Funded
Using Fast HPLC Technologies to Improve the Quantitation of Marine Pigments	NASA	M. E. Russ (GEST)	L. Van Heukelum (Horn Point Laboratory/ UMCES), C. Thomas (Horn Point Laboratory/ UMCES), S.B. Hooker (GSFC, Code 614.8)	Pending
Using GLAS/ICESat Measurements of Aerosol and Cloud Profiles to Constrain the Assessment of Aerosol Radiative Forcing and Influences on Tropospheric Chemistry	NASA	Hongbin Yu (GEST)	Huisheng Bian (GEST), Mian Chin (GSFC, Code 613.3), Thomas Diehl (GEST), Bryan Duncan, Stephen Palm (SSAI)	Not funded
Using Infrared Satellite Data for Assimilation and Model Evaluation	NASA	Joanna Joiner (GSFC, Code 613.3)	Robert Atlas (NOAA), Bryan Duncan (GEST), Clark Weaver (GEST), Kevin Bowman (JPL)	Funded
Using integrated CALIPSO and A-Train observations to study direct climate forcing by anthropogenic aerosols	NASA	Theodore L. Anderson (GEST)	Robert J. Charlson (Univ. of Washington)	Pending
Utilization of Space Based Lidar Data in Numerical Aerosol Models to Study Dust Outbreak Phenomenology	NASA	Jeffrey Reid (NRL)	Santiago Gassó (GEST), Douglas Westphal (NRL)	Pending
Validation of Global Circulation Model Cloud Parameterization using GLAS Atmospheric Channel Measurements	NASA	Stephen Palm (SSAI)	Peter Norris (GEST), Lazaros Oreopoulos (JCET), David Randall (CSU), William Hart (SSAI)	Not funded
Validation of Non-Coincident Trace Species Measured by AURA Using Trajectory Mapping and Statistical Analysis	NASA	Gary Morris (GEST)	Lynn Sparling (UMBC), David Lary (GEST), Mark R. Schoeberl (GSFC, Code 613.3)	Funded

Proposal Title	Funding Agency	PI	Co-I(s)	Status
Validation of OMI Tropospheric NO_2 Column Amounts in Regions Dominated by Lightning NOx Production	NASA	Kenneth Pickering (GSFC, Code 613.3)	Dale Allen (Univ. of Maryland), Eric Bucsela (GEST), M. Barth, W. Skamarock, E. Atlas, P. K. Bhartia (GSFC, Code 613.3), R. Blakeslee, R. Cohen, M. Loewenstein, Wei-Kuo Tao (GSFC, Code 613.1)	Funded
Virtual Cosmic Ray Observatory	NASA	John Cooper (GSFC, Code 672)	McGuire (GSFC, Code 672), Lal (GSFC, Code 672), Hill (JHU/APL), Armstrong (Fundamental Technologies), McKibben (UNH), Thomas Narock (GEST)	Pending
Virtual Heliospheric Observatory – a VxO for S3C Data	NASA	Adam Szabo (GSFC, Code 672)	Roberts (GSFC, Code 672), Ho (JHU/APL), Kasper (MIT), Thomas Narock (GEST), Schroeder (UC Berkeley), Davis (Cal Tech Univ.), Vandergriff (JHU/APL), Raines (Univ. Michigan)	Funded
WaterNet: The NASA Water Cycle Solutions Network	NASA	Paul Houser (George Mason Univ.)	Bisher Imam (UC, Irvine), Dave Matthews (unaffiliated), C. Schlosser (MIT), Charles Vorosmarty (Univ. of New Hampshire), Richard Lawford (GEST), Deborah Belvedere (Inst. Global Environ. Studies), Hoshin Gupta (Univ. of Arizona), Robert Schiffer (GEST), Claire Welty (CUERE)	Funded
Wavelength and time dependence of solar forcing of Earth's atmosphere-ocean system	NASA	Robert F. Cahalan (GSFC, Code 613.2)	Guoyong Wen (GEST), Peter Pilewskie (LASP/Univ. of Colorado)	Funded
What is the role of dust deposition in phytoplankton productivity?	NASA	Santiago Gassó (GEST)	N. Meskhidze (NCSU), Watson Gregg (GSFC, Code 610.1), Peter Colarco (GSFC, Code 613.3)	Pending
Transitioning NASA's Land Information System as the Support Infrastructure for JCSDA Land Data Assimilation	NASA and NOAA	Christa D Peters-Lidard (GSFC, Code 614.3)	Sujay Kumar (GEST)	Funded
Global Warming discussions at DC Metro Schools	NASA Educational Outreach	Clark Weaver (GEST)		Pending
Investigation of Lunar Dust Transport	NASA ETDP	William Farrell (GSFC, Code 695)	Timothy Stubbs (GEST)	Funded

Proposal Title	Funding Agency	PI	Co-I(s)	Status
Developing an improved early warning system for Africa using a new generation of Earth Observation data	National Danish Research Council	R. Fensholt (Univ. of Copenhagen, Denmark)	Assaf Anyamba (GEST), C. A. Shisanya (Kenyatta Univ., Kenya)	Funded
Air Toxins and Respiratory Health: New Method for Integrating Environmental and Social Science	NIH	Jessica Kelley-Moore (UMBC)	David Lary (GEST)	Pending
AERONET-based Surface Reflectance Validation Network (ASRVN): Centralized Support of the Government's Calibration-Validation Plan for the VIIRS Instrument	NOAA	Alexei Lyapustin (GEST)	Yujie Wang (GEST)	Not funded
Demonstrate application of NASA Land Information System (LIS) to NCEP weather prediction models	NOAA	Jesse Meng (GEST)	Mitchell (NOAA)	Funded
Developing Aerosol Height Index Algorithm for GOES-R	NOAA	D. Allen Chu (GEST)		Funded
NASA Land Information System Development, Application and Validation for Improving Ensemble Hydrologic Prediction in Support of NOAA NWSRFS	NOAA	David Toll (GSFC, Code 614.3)	Paul Houser (George Mason Univ.), Jiarui Dong (GEST), Brian Cosgrove (NASA-SAIC), Christa Peters-Lidard (GSFC, Code 614.3)	Pending
Potential response to the drought phenomenon at the basin and local scales: A tale of two countries	NOAA	Rick Lawford (GEST), John Wiener	Terry Rolfe	Not funded
Sensitivity of the EMC Coupled Hurricane Prediction System to the Ocean Component Representation and its Validation	NOAA	S. Daniel Jacob (GEST)	Scott Braun (GSFC, Code 613.1), Chung-Lin Shie (GEST), George R. Halliwell (Univ. of Miami)	Not Funded
A global water cycle observatory cyberinfrastructure demonstration	NSF	Paul Houser (George Mason Univ.)	B. Doty (COLA), P. Cornillon (URI), Sujay Kumar (GEST)	Not funded
A two-pronged attack on the problem of aerosol climate forcing	NSF	Theodore L. Anderson (GEST)	Robert J. Charlson (Univ. of Washington)	Funded
Advanced MHD-Chemistry Cometary Atmosphere Simulator	NSF	Mehdi Benna (GEST)	Paul Mahaffy (GSFC, Code 699), MacNeice (Drexel Univ.), Olson (Drexel Univ.), Bhardwaj (VSSC, India)	Not funded
Collaborative Research: Advanced Laser Fluorometer (ALF) for in vivo Characterization of Phytoplankton Pigments, Physiology and Community Structure	NSF	Alexander Chekalyuk (GEST)		Funded

Proposal Title	Funding Agency	PI	Co-I(s)	Status
Development and validation of a combined algorithm for falling snow and snow on the ground	NSF	Marco Tedesco (GEST)	M.J. Kim (UMBC), Daqing Yang (UAF)	Pending
Development of a combined model to estimate falling snow and snow on the ground	NSF	Marco Tedesco (GEST)	Min-Jeong Kim (GEST), Daqing Yang (Univ. of Alaska)	Not funded
Ion Injection and Transport in the High-latitude Magnetosphere	NSF	Timothy Stubbs (GEST)	Sibeck, Fok, Scott Boardsen (GEST), Trattner, Moore	Not funded
Magnetospheric Electron Density	NSF	Richard Denton (Dartmouth College)	Phillip Webb (GEST), Jerry Goldstein (Southwest Research Institute), Roger Anderson (Univ. of Iowa)	Pending
Multi-scale Analysis of Vegetation Dynamics and Land Cover Land Use Change Patterns in the Mt. Kilimanjaro region using satellite data (1970s - 2000s)	NSF	Assaf Anyamba (GEST)	S. Youngsinn (UMBC)	Not funded
Patagonian Dust Deposition and Biological Productivity in the South Atlantic Ocean: Implications for the Present-day and Future Regional Carbon Cycle	NSF	Santiago Gassó (GEST)	Nicholas Meskhidze (Georgia Tech. Inst.), A. Nenes (Georgia Tech. Inst.)	Not funded
Tessellation-Based Analysis and Modeling of In Situ and Remote Observations of Space Weather Events	NSF	Vassiliadis (GSFC, Code 673)	Antti Pulkkinen (GEST), Karakos (JHU), Priebe (JHU), Tsonis (Univ. of Wisconsin-Milwaukee)	Pending
Integrating MODIS and NPP VIIRS Observations into the USDA FAS Decision System	USDA/ FAS and NASA	C. O. Justice (Univ. of Maryland)	M. Hansen (San Diego State Univ.), Descloitres (SSAI), C. Reynolds (USDA/FAS), Assaf Anyamba (GEST), Compton Tucker (GSFC, Code 614.0), Ed Masuoka (GSFC, Code 614.5), D. Tarpley (NOAA)	Funded
Development of an early warning system to detect conditions for elevated populations of potential vectors of Rift Valley Fever (RVF) and other mosquito-borne emerging virus threats in the United States	USDA/CM AVE	Assaf Anyamba (GEST)	Compton Tucker (GSFC, Code 614.0)	Funded

This page intentionally left blank

Biographies

Dr. Theodore L. Anderson received a Ph.D. in atmospheric sciences from the University of Washington (UW), Seattle, in 1992. His dissertation research involved optimizing a cloud droplet sampler for investigation of aerosol-cloud interactions. He spent one year as a post-doc at Stockholm University, helping to develop an airborne version of this device for studying pollution effects on cirrus clouds. He then returned to the Washington where he is now a research faculty member of the Department of Atmospheric Sciences. From 1994-2003 his work concentrated on improving in situ methods for measuring optical properties of atmospheric aerosols. From 2003 to the present he has increasingly focused on the coupling of satellite and in situ methods for global-scale assessment of aerosol climatic effects. He has participated in the Science Team for the CALIPSO satellite mission from 1996 to the present. CALIPSO was launched in April, 2006 and is expected to gather vertically resolved information on aerosols and clouds for three years as part of the A-Train constellation of satellites. In 2005, Dr. Anderson led a team of scientists in articulating an "A-Train strategy" for quantification of direct climate forcing by anthropogenic aerosols, published in the Bulletin of the American Meteorological Society. He is the author or co-author of more than 60 peer-reviewed papers. His current interests include refining the ability of satellites to assess the global burden of anthropogenic aerosols and the use of satellite-borne Lidar to assess the global frequency of tenuous, boundary-layer clouds, which are hypothesized to be highly sensitive to perturbation by aerosols.

Dr. Assaf Anyamba is an associate research scientist with the Goddard Earth Sciences Technology Center/University of Maryland-Baltimore County (GEST/UMBC) at NASA's Goddard Space Flight Center. He received his undergraduate degree from Kenyatta University, Nairobi, Kenya in Geography and Economics (1989) and a Masters degree in Geography from Ohio University, Athens (1992). He received his Ph.D. (1997) in Geography with focus on Remote Sensing of Land Surface Patterns of ENSO from Clark University, Worcester, MA. His research interests are in the extraction of interannual climate variability signals from remotely sensed vegetation measurements, drought pattern analysis, applications of remotely sensed data in agricultural monitoring, drought & famine early warning and the links between climate and disease outbreaks. His current work supports research and development for USDA/FAS-PECAD and USAID/FEWNET, DoD-GEIS and USDA/CMAVE Programs.

Dr. Kristi R. Arsenault received a Bachelor’s of Science degree in geography and climatology from Arizona State University in May of 1997. While at Arizona State, she interned at the NASA Mars Global Surveyor TES Laboratory for two years, working on the interplay between dust storms and the northern polar ice cap of Mars. After graduating, Ms. Arsenault attended The Ohio State University in Columbus, Ohio, where she pursued a Master’s of Science degree in atmospheric sciences. Her graduate work involved investigating the role of air-sea interactions over the North Atlantic Ocean and their effects farther downstream over the Eurasian continent. Ms. Arsenault began working at NASA Goddard Space Flight Center full-time in early January of 2001. Her main research at NASA Goddard has focused mainly on applying the latest research at NASA to water resource related issues. Her focus has been on how satellite and land surface models can be enhanced and integrated to improve energy and moisture budget estimations to help benefit other government agencies, like the Bureau of Reclamation. In conjunction with her work at GSFC, she is pursuing her Ph.D. degree in Climate Dynamics at George Mason University in Fairfax, VA.

Dr. Julio T. Bacmeister received his Ph.D. in Geophysical Fluid Dynamics from Princeton University in 1987 where his research concentrated on numerical simulation of stratified flow around obstacles. From 1987 until 1992 he worked as a post-doctoral fellow in the Atmospheric Chemistry and Dynamics Branch at NASA’s Goddard Space Flight Center. He joined the Middle Atmospheric Chemistry and Dynamics Branch at the Naval Research Laboratory in Washington DC in 1992 where he led the development of a

two-dimensional chemical transport model, as well as establishing a research effort in Atmospheric Gravity Wave Dynamics. In 1998, Dr. Bacmeister joined the NASA Seasonal-to-Interannual Prediction Project as a Visiting Scientist, where he led efforts in atmospheric model development. In 2003, Dr. Bacmeister joined the Global Modeling and Assimilation Office (GMAO) at Goddard Space Flight Center, where he leads physics parameterization development for the GMAO's global atmospheric model. His current interests include cloud and convection parameterization, as well as parameterization of orographic effects for tropospheric climate models. He has published over 35 refereed papers in the fields of gravity wave dynamics, atmospheric transport, and parameterization development for climate models.

Dr. Hamed Bekerat received a B.S. in physics from Birzeit University (Palestine) and a Ph.D. in physics from Utah State University (USU) in 2006. During the course of his PhD, he worked as a research assistant in the Center for Atmospheric and Space Sciences (CASS) at USU from 1999 to 2006. The main focus of his research is the high-latitude ionosphere. He has worked with large data sets, and different statistical and numerical models for the high-latitude ionosphere. He has extensive experience in how to handle and work with large data sets and in statistical modeling using large data sets. His work with numerical ionospheric models helped him gain a wide-ranging understanding for numerical modeling of the high-latitude ionosphere using the appropriate transport equations as well as understanding the various chemical, transport, radiative processes that operate to define the state of the ionosphere.

Mr. Larry Belcher received his MS in Atmospheric Science (2000) from Colorado State University, Fort Collins, CO, and a BS in Physics from Colorado State University (1997). His MS thesis is on the intercomparison of radar, profiler, and disdrometer observations of tropical convection during the NASA TRMM-LBA field program. He worked at NASA/GSFC for Science Systems and Applications Inc. (SSAI) for two years as a research scientist. He worked as a research associate at the North Carolina State University investigating airborne radar observations of mixed-phase altocumulus clouds. He then rejoined SSAI in 2004 at NASA/GSFC continuing his work on tropical precipitation processes. In 2005, he joined the Goddard Earth Sciences Technology Center at the University of Maryland, Baltimore County as a member of the scientific research staff. His current work has recently taken a new direction working with Lidar data processing and analysis from the NASA Micro-pulse Lidar Network.

Dr. Benita Bell received her doctoral degree in nutrition and chemistry from Howard University. Her bachelors and masters degrees are also in chemistry from UNC Chapel Hill and North Carolina A&T State University, respectively. Dr. Bell has taught chemistry at Howard University in the School of Allied Health Sciences, North Carolina Central University and Bennett College where she was an Associate Professor of Chemistry and the Director of the Science, Technology, Engineering and Mathematics (STEM) Program. Dr. Bell was awarded a NASA Administrator's Fellowship position where she served as a NASA Fellow in the Office of Biological and Physical Research at NASA Headquarters in Washington, DC. There she developed a pilot clinical research study on soy isoflavones and their role in immunity and heart disease. Dr. Bell has also had corporate experience working with Johnson and Johnson and Smithkline in the medical and pharmaceutical sales industry. She has received numerous honors and awards, a few of which include the recipient of the Board of Trustees Faculty Teaching Excellence Award and the Division of Higher Education Exemplary Teacher of the Year Award. Dr. Bell is currently working at NASA Goddard Space Flight Center with the Minority University Space Interdisciplinary Network (MUSPIN) in the area of Astrobiology. She is the Co-Director of the Minority Institution Astrobiology Collaborative (MIAC). Her research interests are in the areas of astrobiology, science education and women's health.

Dr. Mehdi Benna received his degree in Electrical Engineering from the Engineering School of Tunis (ENIT) in 1999. After obtaining a M.Sc. in Radio-wave Telecommunication from the University of Tunis in 2000, he received in 2002 a Ph.D. in Space Science from the University of Toulouse in France. From 2002 to 2003, Dr. Benna was an associate scientist at the Planetary and Terrestrial Geophysics Laboratory

(CNRS) in France. In 2003, he came to NASA's Goddard Space Flight Center as an NRC postdoctoral fellow where he remained for three years. In 2006, he joined the Goddard Earth Science and Technology Center as an assistant research scientist. Dr. Benna's main research interest is the numerical modeling of planetary magnetospheres. He also uses his engineering experience in supporting the development of several space-borne instruments (Rosetta-CONSERT, MSL-SAM, NIGMS). His publications include papers on MHD modeling of comets and icy moons of the solar system, radio tomography techniques, and ill-posed inverse problems.

Dr. Craig Benson received a Ph.D. in Physical Chemistry (2002) from The George Washington University in Washington, DC, following a BA in Chemistry (1997) from Brandeis University in Waltham, MA. His doctoral dissertation concerns simulations of water droplet behavior in extreme conditions. Subsequent to his Ph.D. studies, Craig worked for three years as a National Research Council Postdoctoral Research Associate at the Naval Research Laboratory Remote Sensing Department in Washington, DC. During this time, Craig investigated numerical modeling of PSC formation mechanisms while a member of the POAM science team. Craig joined the Goddard Earth Sciences and Technology Center at the University of Maryland, Baltimore County, as a research faculty member in 2006. He continues to study polar stratospheric clouds using NASA's GEOS-4 and GEOS-5 global climate models.

Mr. Timothy Berkoff is a research engineer with the University of Maryland's Goddard Earth Science and Technology Center. He has more than 15 years of experience in optical instrumentation and measurement analysis, and currently serves at the instrument manager for NASA's Micro-Pulse Lidar Network (MPLNET), a global network of Lidar systems to provide long-term observations of aerosols and clouds. His background includes Lidar, fiber-optic sensing techniques, interferometry, spectroscopic gas detection, tunable diode lasers, optical design, opto-electronics, and optical diagnostics. He has more than 15 peer reviewed publications, numerous conference proceedings, and is an inventor on two patents in the field of optical sensing. Mr. Berkoff obtained a B.S. in Optics from the University of Rochester in 1988.

Dr. Huisheng Bian received a B.S. in atmospheric science from Nanjing University in 1985, a M.S. in 1988, and a Ph.D. from University of California, Irvine in 2001. From 1988 to 1995, she worked in Chinese Meteorological Academy as an assistant researcher, where her research interest was regional air quality modeling. Her Ph.D. work focused on improving, validating, and applying UCI global chemistry transport model for tropospheric ozone simulation, as well as on developing a module (Fast-J2) to accurately simulate stratospheric photolysis in global chemistry models. Upon graduation, Dr. Bian became interested in atmospheric aerosols, their distribution and their photolytic and heterogeneous impacts on tropospheric chemistry. Her current major research interest involves improving and applying multiple CTMs to the atmospheric chemistry studies and providing mission planning and mission support.

Dr. Scott A Boardsen is currently a research associate at GEST. He received his B.S. in Physics in 1981, his M. S. in Physics in 1984, and his Ph.D. in Physics in 1988, all from the University of Iowa. His master thesis research was in laboratory plasma physics were he studied methods for improving the efficiency of ion propulsion engines. His Ph. D. research was in space plasma physics were he studied electrostatic ion cyclotron waves generated along the auroral field lines. Throughout his career he has worked on various topics in magnetospheric physics including studies of equatorial fast magnetosonic waves and their interaction with unstable ion distributions, auroral kilometric radiation, kilometric continuum radiation, plasmaspheric hiss and its relation to lightning, high latitude magnetic reconnection, and magnetopause modeling.

Dr. Bojan R. Bojkov received B.A.Sc. (1990), M.A.Sc. (1992) and Ph.D. (1994) from the University of Toronto for research in numerical analysis, algorithm design and optimization and optimal control. In 1995, he moved to Oslo, Norway joining the University of Oslo and the Norwegian Institute for Air

Research (NILU) working in various atmospheric chemistry areas, including in-situ instrumentation, satellite validation and models. He joined NASA, Goddard Space Flight Center, in 2001 where he worked on applications of satellite data, and the development of ground-based UV validation and retrieval studies. He is currently an associate research scientist with GEST.

Dr. Eric Bucsela is an Associate Research Scientist at GEST. Dr. Bucsela received a B.S. in physics from Emory University in 1983, a M.S. in electrical science from the Department of Electrical Engineering at the University of Michigan in 1986 and a Ph.D. in physics from the University of Michigan in 1994. At Michigan, he conducted research in aeronomy of the dayglow and developed instrumentation for in situ measurements and remote sensing of the atmosphere. He completed a postdoctoral fellowship at the Naval Research Laboratory in 1997. At NRL he developed models to investigate atomic and molecular excitation processes in the thermosphere. He also participated in the Defense Missile Satellite Program by playing a pivotal role in the calibration of the far-ultraviolet SSULI spectrometer. Additional research and publications have involved studies of thunderstorm electrification processes. Such processes create sprites and other visible emissions above thunderstorms. In addition to his work at NRL, Dr. Bucsela has been active in research at NASA Goddard Space Flight Center through affiliations with Raytheon, SSAI and most recently, UMBC. His work at NASA has led to key insights about how observations of Raman scattering in the atmosphere can be used to infer cloud-top heights from space. Current research involves retrievals of critical trace-gas constituents from satellite measurements and the development of algorithms to extract total column and profile information for air pollutants. These algorithms are now being used to retrieve NO_2 amounts from the Ozone Monitoring Instrument (OMI) on board the EOS-AURA satellite. OMI is part of an international venture between NASA and the Royal Dutch Meteorological Institute (KNMI).

Dr. Sushil Chandra is a Senior Research Scientist in the Goddard Earth Science and Technology Center (GEST) at University of Maryland, Baltimore County, Md. Prior to GEST appointment, he was a senior scientist at NASA Goddard Space Flight Center (GSFC) where he conducted research in the fields of aeronomy, ionosphere, and many other aspects of atmospheric science. He has over 100 publications, most all of which are in refereed journals and most of those as first author. Sushil Chandra was involved in the development of the first interactive ionosphere-atmosphere model. This coupled model played a major role in the interpretation of data obtained from several NASA satellites including OGO-4, OGO-6, Explorer 31, ISIS, AE, AEROS-A and AEROS-B. As a principal investigator for the RPA (Retarding Potential Analyzer) on OGO-4, Sushil Chandra initiated several correlative studies using ionospheric and airglow data from a number of instruments on OGO-4. As a member of the AEROS Science Team, he initiated several collaborative studies of the thermospheric density and temperature involving US and German scientists. Later, Sushil Chandra moved to stratospheric ozone research and made significant contributions to understanding the variability of ozone and temperature on different time scales ranging from 27-day solar rotation periods to long term trends. Currently, Sushil Chandra is involved in developing new methods for deriving tropospheric ozone from satellite data. This work has produced a unique ~25-year record of tropospheric column ozone in the tropics and has helped in the understanding of the seasonal and long term changes in the tropical troposphere including intra-seasonal, inter-annual, and decadal changes associated with the Madden Julian Oscillation, QBO, El Nino, La Nina, and solar cycle. Chandra is PI and Co-I for several NASA funded proposals. He was a Co-I for the WINDII (Wind Imaging Interferometer) experiment on the UARS and was a member of the UARS Science Team from the very beginning of the UARS program. Dr. Chandra is currently an active science team member for EOS Aura OMI.

Dr. Yehui Chang received a BS in Physics from ECNU in 1982, and a Ph.D., in Geophysical Fluid Dynamics from the Florida State University in 1994. He took a lectureship in Physics in the Nanjing College of Economics from 1982 to 1987. From 1994 to 2001, he served as senior scientist in SAIC studying climate and its variability and predictability, the variability and predictability of the Madden-

Julian Oscillation, extreme weather events, short term climate and dynamical seasonal forecasting. His specific interest is in developing and applying mathematical, numerical and statistical methods to diagnose and characterize the complex climate systems and the system responses. Such methods are important not only in the detection and estimation of forced signals but provide a clue as to natural variability of a climate system and the accuracy of the data assimilation system. Dr. Chang's publications deal with EOF modeling, diagnostics of climate and the data assimilation system, dynamical seasonal prediction, the impact of ENSO on extratropical low frequency noise in seasonal forecasts and extreme weather events. Dr. Chang joined GEST in September 2001, as Associate Research Scientist at UMBC.

Dr. Alexander M. Chekalyuk received a B.S. in physics, from Moscow State University (MSU), in 1977, and a Ph.D. in physics, from MSU, in 1982. He conducted laboratory research on new technologies for phytoplankton taxonomic analysis (2001-present, NASA/GSFC Wallops Flight Facility), airborne LIDAR technique for remote monitoring of aquatic photosynthesis (1998 – present, NASA/GSFC Wallops Flight Facility), submersible multispectral camera with laser illumination for small-scale structure studies (1997, Scripps Institution of Oceanography, CA), pump-during-probe technique and instrumentation for measurement of photosynthetic characteristics of phytoplankton cells with micro-fluorometry and flow cytometry (1994-97, Woods Hole Oceanographic Institution, MA), pump-and-probe LIDAR prototype for remote monitoring of photosynthetic activity of phytoplankton and terrestrial vegetation (1990-93, MSU), pulsed saturation fluorometry for retrieving quantitative characteristics of complex organic molecules in liquid media (1975-89, MSU), nonlinear laser spectrometer and its application for quantitative measurements in two-component liquid media (1979-81, MSU), LIDAR applications in biological oceanography and environmental monitoring in the sea (1977-91, MSU), shipboard LIDAR system for remote monitoring of phytoplankton and dissolved organic matter in the sea water (1976-89, MSU), new technique and instrumentation for measurement of concentration of fluorescent organic substances in liquid Raman-active solutions (1975-76, MSU). Dr. Chekalyuk served as research scientist at the Department of Physics, MSU, in 1977-94. He was a visiting scientist at Woods Hole Oceanographic Institution, MA, in 1994-1997. He served as a project scientist at Scripps Institution of Oceanography in 1997-1998. He was a National Research Council Senior Research Associate with NASA/GSFC/WFF in 1998-2001.

Dr. Jiun-Dar Chern received a BS from National Taiwan University in 1984 and a Ph. D. in Atmospheric Sciences in 1994 from Purdue University where he has developed the Purdue Mesoscale Model (PMM) and applied the model to study lee vortices, and winter cyclogenesis over the western United Stated. Form1995-2000, he worked as a Research Associate at Purdue University to develop the Purdue Regional Climate Model (PRCM) and snowpack and sea-ice model. The model has been applied to study the 1988 US drought, 1993 Midwestern flood, and 1998 flood in Eastern Asia. In 2000 he joined UMBC/GEST and worked at the DAO, NASA/GSFC to improve the physical parameterizations of the fvGCM and the interface between the fvGCM and GEOS4 data assimilation system. In 2004 he joined the modeling group at Mesoscale Atmospheric Processes Branch to develop the Multi-scale Modeling Framework or superparameterization based on the fvGCM and 2D GCE models.

Dr. D. Allen Chu received a BS in Atmospheric Sciences from the National Taiwan University in 1982 and a Ph.D. in Atmospheric Sciences from Georgia Institute of Technology. In 1989, he joined in ISAMS (Improved Stratospheric and Mesospheric Sounder) team at NASA Langley Research Center where he worked on the ozone and nitric acid retrievals using ISAMS measurements as well as radiance simulations using line-by-line/broadband radiative transfer models. In 1996, he joined MODIS (Moderate Resolution Imaging Spectroradiometer) aerosol team at NASA Goddard Space Flight Center to work on MODIS aerosol retrieval and also lead quality assurance for the MODIS atmosphere products. In 2004, he joined the JCET of UMBC as a Associate Research Scientist. Since then, he has been involved in various projects including the application of MODIS AOD to air quality, Aura validation using simultaneous MODIS, OMI, and CALIPSO observations, evaluation of aerosol radiative forcing in the INTEX-A and

INTEX-B field campaigns, study of dust direct and indirect effects over the tropical Atlantic Ocean, and intercomparison of model (e.g., GOCART, GEOS-CHEM, and CMAQ) and MODIS and MISR-derived aerosol properties. In 2007, he joined the GEST to continue his researches. He currently serves as science team member for INTEX-A, INTEX-B, NAMMA, and GOES-R projects.

Dr. Amelia Colarco obtained her M.S. in 1999, and her Ph.D. in 2003, from the Astrophysical and Atmospheric Science Department at the University of Colorado, Boulder with a focus on in situ measurements of carbon dioxide in the upper troposphere and lower stratosphere. She worked for two years as a NASA contractor setting up a local boundary layer measurement using similar instrumentation for comparison with an on-going CO_2 LIDAR effort at GSFC. After completion of her degree, Amelia was awarded a two-year NRC Research Associate Fellowship under Dr. John Burris, GSFC Code 613.3, to study the requirements and potential benefits of a ground-based profiling CO_2 LIDAR. At the completion of this fellowship, Amelia began working under Arlindo da Silva on satellite data assimilation in the spring of 2006.

Ms. Laurie Cook is an Instructional Design Specialist at GEST. She is currently working on her Doctoral Degree in Science Education at Morgan State University, with anticipated completion in 2008. She received an MEd. in Science Education from Salisbury State University in 1986, and an MS in Conservation Biology and Sustainable Development from the University of Maryland in 1996. Cook taught high school science in the public school system for 9 years. She taught developmental mathematics at Baltimore City Community College and environmental science at the Community College of Baltimore County. In October of 2005, Ms. Cook joined the GEST Information Science and Educational Technology Faculty Group to work on the educational implementation of a map sonification tool to allow NASA Earth science data to be accessible to blind learners. Her current research area is improving education for blind students and minority students through the use of advanced technologies.

Dr. Robert J. Curran has served as senior staff scientist in the Climate Change Science Program Office in Washington, DC since August 2005. He is seconded to this position from UMBC through an Intergovernmental Personnel Act (IPA) agreement funded by NASA Headquarters. In that position his responsibilities include: 1) development of Our Changing Planet, which is the CCSP annual report to Congress as required by statute, and 2) coordination of the CCSP Atmospheric Composition interagency working group. Prior to joining the CCSPO, Dr. Curran was Director of the Goddard Earth Sciences and Technology Center (GEST) at the University of Maryland, Baltimore County. Dr. Curran has over 12 years experience as a science program manager in the Earth sciences at NASA Headquarters. He also has 12 years experience as a research scientist at the Goddard Space Flight Center. His main research interests are in understanding the radiation properties of clouds and aerosols and their role in climate. In addition to his experience within NASA, Dr. Curran has 6 years experience in industry, part of which was as project scientist with the Hughes Aircraft Corporation in its development of the Earth Observing System Data and Information System. His undergraduate degree (BS) major was in Physics from Creighton University. His graduate degrees (MS and PhD) were also in Physics with specialization in Atmospheric Physics and were from the University of Arizona.

Dr. Paolo de Matthaeis was born in Rome, Italy. He received the Laurea degree (Summa cum Laude) in Electrical Engineering from the University of Rome "Tor Vergata", Italy, in 1991. In 1993-1994 he was with the European Space Agency at ESTEC in The Netherlands under the Young Graduate Trainee program. In 1994-1995, he received a grant from the Italian Space Agency (ASI) to carry out research in the SIR-C/X-SAR data at the Remote Sensing Laboratory at the University of Rome "Tor Vergata". He earned the Doctor of Science degree in Electrical Engineering from The George Washington University in Washington, DC in 2005. He is currently working at the NASA Goddard Space Flight Center in Greenbelt, MD, as a Research Associate with the Goddard Earth Sciences and Technology Center (GEST) of the University of Maryland Baltimore County. His research work includes active and passive

microwave remote sensing, with special interest in electromagnetic modeling of vegetation and sea surface. He is part of the Science Algorithms team for the AQUARIUS instrument.

Dr. Marci P. Delaney is a Research Associate at GEST. Marci received her B.S. in Marine Biology with a concentration in Physics at the University of North Carolina in Wilmington in 1994. She earned her M.Sc. and Ph.D. in Biological Oceanography at Memorial University of Newfoundland in St. John's, Newfoundland. Her graduate research for both degrees focused on the effects of small-scale turbulence on the marine microbial food web of a cold-ocean environment. She also continues to consult as a science content specialist to companies that produce educational materials for grades K-12. Dr. Delaney is currently the project coordinator for the NASA Exploring Space Challenges (NASA ESC). This initiative from NASA Education brings together new and traditional academic competitions for students in grades K-12. The NASA ESC covers all disciplines, from science and math to language and creative arts.

Dr. Thomas Diehl received a M.S. in physics from the State University of New York at Stony Brook in 1990 while being on a fellowship, and a diploma in physics from the University of Tübingen, Germany, in 1992. From 1993 to 1994 he was a research fellow at the High Performance Systems Division at the Hewlett-Packard Company in Richardson, Texas. He received his Ph.D. in computational astrophysics from the Department of Astrophysics and Computational Physics at the University of Tübingen in 1996, where he was also a postdoctoral fellow from 1996 until 1997. During his time in Tübingen, he conducted research in the field of scalable parallel algorithms for the solution of elliptical PDE's and developed a model to investigate the magnetosphere of radio pulsars. He then spent four years at the German Climate Computing Center in Hamburg implementing efficient parallel versions of regional and global atmospheric climate models and developed a benchmark suite for the procurement of a high performance computing server. From 2001 to 2003, he was a research scientist at the Max Planck Institute for Meteorology in Hamburg, where he coupled chemistry modules to an AGCM. He used the coupled model to investigate the climate-forcing impact of a global hydrogen economy, the impact of climate change on the chemical composition of the troposphere, and contributed to the development of a coupled model covering altitudes up to 250km. Dr. Diehl has been working at GSFC since 2004, first through an affiliation with SSAI, and since February 2005 with GEST. His current research focuses on aerosol modeling with the GOCART model and comparing model results with AERONET and satellite data.

Dr. Jiarui Dong received a B.S. in meteorology from Beijing Institute of Meteorology in 1989, a M.S. in computational mathematics in 1992 from Chinese Academy of Sciences (CAS), and a Ph.D. in atmospheric sciences in 1997 from CAS, where he developed a coupled model for simulating drought and regional flood disasters. In addition, he earned another Ph.D. in remote sensing in 2002 from Boston University. Dr. Dong's major accomplishments include remote sensing estimates of northern boreal and temperate forest woody biomass: carbon pools, sinks and sources, improving the precision of simulated hydrologic fluxes in land surface models, developing and analyzing vegetation data sets from NOAA global data, and evaluating the utility of satellite-based vegetation parameters for climate simulation. Dr. Dong joined the GEST center at the Hydrological Science Branch at GSFC in 2002, working on assimilating the global land surface remote sensing products into land surface models to generate optimal global land products and improving the capability of land data assimilation system.

Dr. Bryan Duncan received a B.S. in Chemistry in 1991 and a Ph.D. in Earth and Atmospheric Sciences in 1997 from the Georgia Institute of Technology. He was a postdoctoral fellow and research assistant from 1997 to 2001 in the Department of Earth and Planetary Sciences at Harvard University where he helped to develop the GEOS-CHEM 3-D model of transport and chemistry and conducted a model study of the seasonal and interannual variations of carbon monoxide. He then spent two years at the Swiss Federal Institute of Technology as a research scientist performing model studies of the export of pollution from Europe and from wildfires in Indonesia. Now as an Associate Research Scientist, he contributes to the model development and validation for the NASA GMI.

Dr. Joseph L. Eastman a Ph.D. in ecology/atmospheric science from Colorado State University, Ft. Collins, CO. in 1999. Prior to that, he received a B.A. in physics from the University of Minnesota in 1987 and a M.S. in atmospheric science focusing on the development of a Lagrangian Particle Dispersion model. He was the first to couple a carbon and stomatal control model to mesoscale atmospheric model leading to a dissertation detailing the effects of carbon dioxide and land use change on regional scale climate. His post-doctoral appointment in 1999 was under the guidance of Dr. Robert Waide, national director of the Long Term Ecological Research program and examined the implementation of high performance computing in ecological and atmospheric models. He served as a research associate from 2001-2002, working with Dr. Roger Pielke Sr. researching regional climate using coupled ecological and atmospheric models. He joined the Goddard Earth Science Technology Center at the University of Maryland, Baltimore County, in 2002 as a member of the research faculty. His research interests include mesoscale meteorological modeling, tropical cyclone modeling, regional climate change, dispersion modeling, and coupled earth system process models.

Mr. Thomas F. Eck received a BS in meteorology from Rutgers University in 1977 and an MS in meteorology from the University of Maryland (College Park) in 1982 where his major interests were in micrometeorology and atmospheric radiation. In 1981 be began work at Goddard Space Flight Center (GSFC) and has continued working at GSFC (in association with the Biospheric Sciences Branch, Code 614.4) for more than 25 years, through to the present. During his career he was involved in algorithm development and data analysis for the Nimbus-7 cloud climatology project. He was also active in instrument calibration, field instrument deployment, and data analysis for the PARABOLA instrument project (plant canopy bi-directional reflectance), and analysis of AVHRR satellite data for water vapor retrievals. Beginning in 1992 he has carried out instrument calibration and deployment, field experimentation, data analysis, and scientific research within the global Aerosol Robotic Network (AERONET) project. He has authored and co-authored over 80 refereed papers with recent emphasis on studies of the optical properties of atmospheric aerosols, especially from biomass burning and fossil fuel combustion, and the attenuation of solar flux by aerosols.

Dr. Ronald Errico received a B.S. in physics from the University of Arizona in 1974, where he also took several graduate courses in meteorology. His Ph. D. in meteorology was received in 1979 from the Massachusetts Institute of Technology. With E.N. Lorenz as his advisor, his thesis entitled “The partitioning of energy between geostrophic and ageostrophic modes” examined the fundamentals of why the atmosphere is quasi-geostrophic. It won the department’s award for best thesis that year at the recommendation of Jules Charney. Applications of this thesis have continued throughout his career. After completing his degree, Ron joined the Advanced Study Program at the National Center for Atmospheric Research (NCAR) as a postdoc, followed by a staff appointment in 1981 within NCAR’s Large Scale Dynamics Section of its Atmospheric Analysis and Prediction Division. In 1994 he was appointed Senior Scientist in the Climate and Global Dynamics Division there. During his tenure at NCAR, Ron had sabbaticals from NCAR at the Naval Research Laboratory in Monterey from March 1989 to April 1990 and at ECMWF for 7 months in 1996. He left NCAR to join GEST and work at NASA’s Data Assimilation Office in July 2002. Since 1992, he has been chief organizer of 11 international workshops concerned with data assimilation, including 6 of the 7 International Workshops on the Application of Adjoint Models in Dynamic Meteorology. His past work has included examination of atmospheric balance, development and application of atmospheric adjoint models, atmospheric predictability, scale analysis, regional climate modeling, and data assimilation.

Dr. Francesco Fedele received a M.S. in Civil Engineering from the University Mediterranea in Reggio Calabria, Italy in 1998 and then his Ph. D. in Civil and Environmental Engineering from the University of Vermont in 2004. He continued post-doc work there on problems analogous to those used for his subsequent position at GEST, which he began in June 2005. His research interests are fluid mechanics,

numerical analysis, inverse problems (including data assimilation), and applied mathematics. He left GEST in January 2007 to join the faculty at Georgia Tech.

Mr. Andrew Freeberg is a Media Specialist at GEST. In June 2005, Andrew got his Bachelor of Science from Northwestern University with a major in Radio/Television/Film and with honors in an Environmental Sciences second major. The highlights of Andrew's course work at Northwestern included spending a summer working as a naturalist at Virgin Islands National Park on the island of St. John and completing his honors thesis in conjunction with the Field Museum in Chicago. After graduation Andrew chose to combine his interests and enrolled to work on a Master of Fine Arts degree in Science and Natural History Filmmaking from Montana State University, Bozeman. As he continues toward that degree, Andrew began working for GEST in June 2006. His various duties for the Public Affairs Office at Goddard include producing, writing, shooting, directing, and editing video and media projects, mainly in the area of earth science. Among other things, Andrew is the media lead producer on the Landsat Data Continuity Mission.

Mr. Matthew Garcia has received B.S. degrees in Physics and Geosciences (Montclair State University, 1996) and M.S. degrees in Atmospheric Science (Colorado State University, 1999) and Civil Engineering–Hydrology (Colorado State University, 2003). In the combination of these fields, Mr. Garcia works at the interface of weather and land, where precipitation turns into runoff and streamflow. In his position through UMBC-GEST at the NASA-GSFC Hydrological Sciences Branch, Mr. Garcia's efforts are oriented principally on full LIS-based land-surface meteorological and hydrologic capability for the purposes of research investigations on, and applications to, remote sensing of precipitation and soil moisture, floods and flash floods, and water resources management problems.

Dr. Santiago Gassó received a M.S. in Applied physics at the University of Buenos Aires, Argentina, (1992), a M.S. (1997) and a Ph.D. (2001) in Geophysics at the University of Washington. During his PhD thesis work, Dr. Gassó' worked with Prof. Dean A. Hegg on the analysis and derivation of aerosol optical and hygroscopic properties using remote sensing and in situ methods. He joined the GEST faculty in August 2001. He worked in the Climate and Radition Branch at GSFC under the supervision of Dr. Si-Chee Tsay, development of a radiative transfer module for the Navy Aerosol Analysis Prediction Systems (NAAPS) aerosol transport model. Since 2004, Dr. Gassó' is working on the transport of aerosols into the South Atlantic (in particular dust) and its possible influences on phytoplankton productivity. In addition, he is a member of the NPOESS Preparatory Project (NPP) science team and he is working on the development and testing of the aerosol retrieval algorithm with Dr. Torres (JCET).

Dr. Charles K. Gatebe received the B.Sc. (meteorology, mathematics, and physics) and M.Sc. (meteorology) degrees from the University of Nairobi, Kenya in 1990 and 1994, respectively, and the Ph.D. degree in atmospheric sciences from the University of Witwatersrand, South Africa in 1999. He holds the position of Lecturer in the Institute of Nuclear Science, University of Nairobi, where he teaches courses on air pollution using nuclear related techniques. He came to NASA Goddard Space Flight Center in 1999 as a Resident Research Associate of the Universities Space Research Association (USRA). He is currently an Associate Research Scientist in the Goddard Earth Sciences and Technology Center, University of Maryland Baltimore County, and is on leave from his university position. His research experience includes developing a simple gaussian model to estimate motor vehicle emissions from line sources (highways) in Nairobi, in situ measurements of aerosols and gases, and characterizing aerosol sources using statistical and trajectory methods. He has been involved in International Atomic Energy Agency (IAEA) coordinated research project on air pollution using nuclear related analytic techniques and in 1994/95 was a member of the United Nations Environmental Programme (UNEP)/World Health Organization (WHO), Global Environmental Monitoring System (GEMS)/Air team of experts. Dr. Gatebe has been involved with modification of NASA's Cloud Absorption Radiometer to have modern data acquisition system and UV optical channels suitable for remote sensing of aerosol. He has

participated in several field campaigns namely, SAFARI-2000 field experiment in southern Africa, which took place from August-September 2000, CLAMS 2001, USA eastern coast, July–August 2001 and INTEX-B, March 2006, Mexico. He made measurements using NASA's Cloud Absorption Radiometer aboard the University of Washington Plane, CV–580 (SAFARI 2000 and CLAMS 2001) and Sky Research Jetstream 31 (INTEX-B 2006). Currently, he is interested in remote sensing of aerosols and bidirectional reflectance distributions functions to better understand their role in global change. Dr Gatebe was recognized for his work as a fellow of Global Change System for Analysis, Research and Training (START) during the 5th International Geosphere Biosphere Programme (IGBP)-Scientific Advisory Committee meeting in Nairobi, Kenya, 1998, and is the winner of the 2000 World Meteorological Organization Young Scientist Award. Dr. Gatebe was recently appointed to serve on the Scientific and Technical Advisory Panel of the Global Environmental Facility.

Dr. Yolanda Gayol was a Visiting Scientist at GEST during the reporting period. She received a B.S. in educational psychology from the National Autonomous University of Mexico (UNAM, Mexico) in 1979. She was awarded a M.S. in educational research at the Center for Research and Advanced Studies at the National Polytechnic Institute CINVESTAV/IPN (Mexico) in 1994 and a D.Ed. in adult/distance education at the Pennsylvania State University. She has conducted research education and distance education at the Pennsylvania State University and the University of Maryland University College. Dr. Gayol served as Program Director at the Master of Distance Education at the University of Maryland University College (UMUC) in 2002-2003. Previously, she was distance education specialist at the World Bank and the Inter-American Development Bank (1999-2001). She has been Task Force Leader for USAID/ICMA on e-Learning for municipal management and citizen training in Latin America and the Caribbean. Since 1994, she works on knowledge dissemination on distance education through at a specialized newspaper in Mexico with nationwide distribution U2000: Chronicle of Higher Education.

Dr. Elena M. Georgieva received a B.S. in physics and M.S. in solid state physics, both from the Department of Physics, University of Sofia. She obtained her PhD degree in physics in 1998 from the University of Sofia. Dr Georgieva was Assistant Professor at the Technical University of Sofia (1995-1999). She was a research associate at Lasers and Optical characterization laboratory, Department of Physics, Georgetown University from 01/2000 - 08/2001., where she worked on nanoparticles characterization and correlation spectroscopy. She also was a research associate at NIST Center for neutron research and Johns Hopkins University (08/2001 – 07/2002), where she worked on dynamics and conformations of RNA using neutron spectroscopy and investigated the folding mechanisms of biologically active structures. For four years she was a Senior Systems Scientist/Engineer at Science Systems and Applications, Inc. and worked at Goddard Laser and Electro-optics branch on instrument development for measurement of atmospheric species (7/2002-05/2006). She is currently with GEST, UMBC. Her research is focused on the development of a new type of remote sensing instruments based on the Fabry-Perot interferometric technique. These instruments are able to detect the absorption features of various atmospheric trace species in direct or reflected sunlight, the work includes laboratory, ground-based and airborne testing, modeling and data analysis. Elena Georgieva was contributing to the design and implementation of such an instrument for carbon dioxide and oxygen column measurements. Dr. Georgieva has over 15 years of experience in theoretical and experimental optical physics. She has 28 refereed publications and is currently interested in passive and active instrument development and remote sensing study of greenhouse gases in the planetary atmospheres. She is a member of Optical Society of America and The International Society for Optical Engineering (SPIE).

Dr. Mircea Grecu received a B.S. degree from the Technical University of Civil Engineering, Bucharest, Romania in 1993, and a M.S. in civil engineering from the University of Iowa in 1996, followed by a Ph.D. from the same university in 1999. After a Postdoctoral association with the University of Connecticut, he joined GEST in 2002. His research interests include: rainfall estimation from space and ground observations, assimilation of satellite observations in atmospheric and hydrologic models and

short term atmospheric and hydrologic forecasting. Dr. Grecu is currently involved in the Tropical Rainfall Measuring Mission (TRMM) project in progress at the Mesoscale Atmospheric Processes Branch of NASA GSFC. His work is focused on the refinement and extension of algorithms for rain estimation from TRMM observations. Specifically, he investigates the combined use of active and passive microwave observations for rainfall estimation by employing radar and radiative transfer models in a variational estimation framework.

Dr. Guojun Gu received a B.S. in atmospheric physics from Nanjing University in 1986, and a Ph.D. in meteorology and physical oceanography from University of Miami in 2001. Prior to joining the UMBC/GEST center, he was a postdoctoral research scientist at Columbia University. Dr. Gu's research is primarily in the fields of tropical meteorology and climate dynamics, covering tropical convection and waves/oscillations, tropical atmospheric large-scale dynamics and circulation, monsoon processes, air-sea-land interaction, global climate variability/change. Currently he is primarily involved in the Tropical Rainfall Measuring Mission (TRMM) at the Mesoscale Atmospheric Processes Branch of NASA GSFC.

Dr. Bruce Guenther holds a B.A. degree from Gettysburg College (1965) and a M.S (1969) and Ph. D. (1974) in aeronomy from the Physics Department, University of Pittsburgh. He has served as co-investigator on the Sodium Airglow Experiment (OGO-6), several back-scatter ultraviolet sensors, and lead the Moderate Resolution Imaging Radiometer Characterization Support Team for the MODIS Terra mission. He has held several NASA-Goddard Space Center Project Scientist positions, including the Earth Observing Mission Project Scientist for Calibration and Validation. He serves as the VIIRS Sensor Scientist in a joint role with the NOAA-NPOESS Integrated Program Office and the NASA NPP Project Office and Project Science Group. Dr. Guenther’s research topics have included Mesospheric scatter layers (Noctilucent clouds), atmospheric nitric oxide, laboratory and sensor calibration, operational data product development, and space-borne sensor development throughout the reflected solar spectrum and out into the thermal emissive infrared. He developed and served as the first Head of the Calibrations Office in the Earth Sciences Directorate at Goddard. Dr. Guenther worked at the GSFC for more than 26 years before accepting an appointment as Systems Engineering Fellow at the Lockheed Martin Corporation, and joined the GEST program in 2002.

Dr. Mei Han received her Ph.D. in Atmospheric Sciences from University of Illinois at Urbana-Champaign in 2004. She also holds an M.S. degree in Meteorology (1999) and a B.S. degree in Meteorology (1996) from Nanjing University, China. She joined GEST in January 2005. Her past research efforts have been using mesoscale models to study the dynamics of frontal circulations associated with the trowal and warm front in wrapped wintertime extratropical cyclones and the mechanisms for fine scale banding and heavy snowfall. During her stay in GEST, she has applied cloud-scale and mesoscale models for research into atmospheric precipitation systems with particular emphasis on model validation and evaluation using satellite and airborne remote sensing data. Her current research focuses on the dynamics, kinematics, and microphysics of frontal rainbands within extratropical cyclones.

Dr. Susan Hoban is a Senior Research Scientist at GEST. She received her Ph. D. in astronomy from the University of Maryland in 1989. She conducted research in cometary science at NASA Goddard Space Flight Center, first as a National Research Council fellow, then as part of USRA Visiting Scientist Program, from 1989 - 1993. In 1993, she began working on information systems for science and education. In 1996, Dr. Hoban received the NASA Special Service Award for her work on web-based educational outreach. Dr. Hoban joined the University of Maryland Baltimore County in the Computer Science and Electrical Engineering Department in 1996 as part of the Center of Excellence in Space Data and Information Science (CESDIS) at Goddard. From 1998-99 Dr. Hoban served as Acting Associate Director of CESDIS and from 1999 through the conclusion of its contract in 2000 as Acting Director. Dr. Hoban is currently a Senior Research Scientist in the UMBC Goddard Earth Science and Technology Center, spokesperson for the Information Science and Educational Technology Faculty group. Her

interests include scientific information systems, digital library technologies and information technologies for science, technology, engineering and mathematics (STEM) education. Dr. Hoban has a particular interest in contributing to the STEM foundation of our nation's K-12 educators.

Dr. Yang Hong received his Ph.D. in Hydrology/Water Resources and Remote Sensing/GIS (2003) from the University of Arizona, and a MS in Environmental Sciences (1999) and a BS in Earth Sciences (1996) from Beijing University, China. He worked two years as a Post-doctoral Research Associate at the Center for Remote Sensing and Hydrometeorology, Department of Civil and Environmental Engineering at University of California, Irvine where he expanded his work to global precipitation estimation (http://hydis8.eng.uci.edu/GCCS) and applied to land surface hydrology. In 2005 he joined the Goddard Earth Sciences and Technology Center at the University of Maryland, Baltimore County, as a member of the research faculty. He has over 30 peer-reviewed journal publications in areas of remote sensing/GIS, hydrology and water resources, natural hazard prediction/mitigation, and environmental sustainable development.

Dr. S. Daniel Jacob received a B.E. (Hons.) in Civil Engineering from the Madurai Kamaraj University, Madurai, India, a Masters degree in Ocean Engineering from Indian Institute of Technology, Madras, India. He worked for a few years at the Indian Space Research Organization analyzing Synthetic Aperture Radar data of ocean surface waves and other satellite data before pursuing a Ph.D. at the University of Miami. He was awarded his Ph.D. in Meteorology and Physical Oceanography from the University of Miami Rosenstiel School of Marine and Atmospheric Science in 2000. His dissertation examined the upper ocean heat budget variability due to oceanic mesoscale variability and its effect on the intensification of tropical cyclones. He served as a Postdoctoral Research Associate at the University of Miami, where he was involved in acquiring oceanographic data from the NOAA hurricane hunters using expendable probes and in the Eastern Pacific as part of the Eastern Pacific Investigation of Climate project. He was appointed as an Assistant Research Scientist in GEST in May 2002 based in the Oceans and Ice Branch at GSFC. In May 2005, he was transferred to Instrumentation Sciences Branch. As a member of Aquarius science team, Daniel conducts research on the effects of surface forcing and ocean mixing on sea surface salinity and also leads an effort to identify an appropriate mixing scheme for use in coupled predictive models of hurricane intensity.

Dr. Jeffrey C. Joseph received a Doctoral Degree (1999) in Physical-Analytical Chemistry at Rensselaer Polytechnic Institute, Troy, New York. Received a Master's Degree in Conservation (1991) at Queen's University, Kingston, Ontario, Canada. Received a Bachelor's Degree in Chemistry (1987) at Hamilton College, Clinton, New York. Doctoral Thesis was entitled: "Part I: A Study of the Photochemical Reactions in the Atmosphere of Titan Using a Photochemical Flow Reactor; Part II: Photochemical Reactions of Ammonia and Cyanopropyne." and involved simulation of Titan and prebiotic Earth atmospheric photochemical reactions with subsequent quantitative and qualitative analyses of gas and solid phase reaction products. Joined UMBC GEST in mid-2006 working on the MSL and SAM instrument suite directly reporting to NASA GEST host Dr. Paul Mahaffy, Chief of the Atmospheric Experiments Laboratory. Most recently worked as a scientist in a conservation analytical laboratory at the Smithsonian Institution. Previously worked as a scientist in research and development in the pharmaceutical industry.

Dr. Juan Carlos Jusem started his meteorological activity in January 1957 as an aerological observer in the Meteorological Service of Argentina. In 1959, he received his diploma of forecaster and in 1961 obtained the title of "Licenciado" in Meteorology at the University of Buenos Aires Argentina. Until 1966, Dr. Jusem worked simultaneously at the University as an instructor and at the Meteorological Sertvice as an analyst and forecaster. From 1966 to 1969, Dr. Jusem performed as an investigator at the University of Chile and collaborated with the World Meteorological Organization from 1969 to 1976 in two countries: Costa Rica and El Salvador; in the former, as a GARP consultant in charge of the Tropical

Center of the Basic Data Set Project and as teacher at the University of Costa Rica. From 1974 to 1976, Dr. Jusem co-operated with the Meteorological Service of El Salvador. From 1976 until 1984, Dr. Jusem studied at Florida State University, where he received the degrees of Master in 1979 and PhD in 1984. From July 1984 up to the present time, Dr. Jusem has worked in the Laboratory of Atmospheres at GSFC/NASA.

Dr. Hyung Rae Kim received a B.Sc. in Department of Geology from Yonsei University, Seoul, South Korea in 1993, a Masters degree majoring in Geophysics in Department of Earth and Atmospheric Sciences from Purdue University, Indiana in 1997. His Masters thesis examined aspects of the external geomagnetic field in the POGO satellite data. He investigated the nature of equatorial electrojet in terms of local time and longitude. He continued studying the geomagnetic field of the Earth in the Department of Geological Sciences at The Ohio State University under Dr. R. von Frese's direction and earned a Ph.D. in June of 2002. His Ph. D. thesis investigated the lithospheric magnetic anomalies from Ørsted magnetometer satellite and near-surface (i.e., ground, shipborne and airborne) data in Antarctic. After he finished his Ph.D. degree, he spent one year as a postdoctoral researcher at the Ohio State University working for ADMAP and preparation for Mars Data Analysis Program. In 2003, Dr. Kim has received a GEST visiting scholarship and conducted as a postdoctoral research associate until 2006 and now serves as an assistant research scientist in Terrestrial Physics Group at GEST, where his research activity has focused on developing the advanced model of Antarctic magnetic field anomaly as an active member of ADMAP in cooperation with other international geophysical community.

Dr. Kyu-Myong Kim received a Ph. D. in atmospheric sciences from Seoul National University, Korea, in 1996. His Ph. D. thesis is on the temporal and spatial structures of the seasonal and interannual variability of the tropical Pacific atmosphere and ocean based on in situ observation as well as ocean circulation model. In 1996, he came to Goddard Space Flight Center, as a National Research Council Resident Research Associates, where he worked on El Nino-Asian summer monsoon interaction and tropospheric biennial oscillation. Since then, he has been at Climate and Radiation Branch at NASA/GSFC as a USRA (Universities Space Research Association) Associate Scientist (1998-2000) and as a senior supporting scientist of Science Systems and Applications, Inc. (2000-2006). He joined GEST as an associate research scientist in January 2006. His research interest includes seasonal-to-interannual climate variability and predictability, climate modeling, and diagnostics. More recently, he has been worked on the effect of aerosol radiative forcing on the monsoon water cycle over various monsoon regions.

Dr. Anuradha Koratkar is an Associate Research Scientist at GEST. She graduated with a B. Sc in Mathematics, Physics and Chemistry from the Osmania University (1981) in India, a Masters degree in Astronomy from State University of New York (1989) and A Ph. D. in Astronomy from University of Michigan (1990). Her thesis examined the dynamics and kinematics of the Broad Line Region in Active Galactic Nuclei. She was a research scientist at the Space Telescope Science Institute for 10 years where she was involved in many aspects of science operations for the Hubble Space Telescope mission. She has also been a scientific lead on IT projects that will optimize science operations and maximize scientific returns. She has been awarded a number of awards for her activities related to the Hubble Space Telescope. Her innovative ideas have also received recognition via the NASA Software of the Year Award, Honorable Mention for 2001. In 2003 she came to GEST as a visiting research associate. Anuradha has published over 50 original refereed journal publications and 20 contributed papers in the field of Active Galactic Nuclei (AGN) physics. Her science community activities involve serving on several peer review committees, working groups and organizing scientific and technical meetings. Recently Anuradha was appointed to the board of the Fulbright Commission's Luso-American Board.

Dr. Nickolay A. Krotkov received a BS from Moscow Institute of Physics and Technology in Physics in 1983, MS (with honor) in Remote Sensing in 1985 and a Ph.D. in oceanography (physics and mathematics) in 1990 from the P.P.Shirshov Institute of Oceanology Russian Academy of Sciences where

his major research was using polarization properties of light in the oceanic remote sensing. Since 1993 he worked in close collaboration with NASA/TOMS scientists to study volcanic clouds, surface and underwater ultraviolet radiation and aerosols. Dr. Krotkov has over 20 years experience in UV radiative transfer modeling, satellite and ground based UV data analysis. He has published over 40 refereed papers where the most recent ones are concentrated on satellite estimation of the surface ultraviolet irradiance, SO_2 and measuring of aerosol UV absorption properties. He is currently employed by the UMBC/GEST Center as a senior research scientist.

Dr. Sujay V. Kumar received a Ph.D. in computer aided engineering from North Carolina State University, Raleigh, NC. in 2002. Prior to that, he received a Bachelor of Technology in civil engineering from the Indian Institute of Technology, Bombay in 1996 and a Master of Science in environmental engineering from North Carolina State University in 1998. His Ph.D. thesis is on the development of a generic, high resolution, distributed computing framework for engineering decision support systems. In 2002, he joined the Goddard Earth Science Technology Center at the University of Maryland, Baltimore County, as a member of the research faculty. His research interests include land surface hydrology, mesoscale meteorological modeling, data assimilation systems, hydrological applications, mathematical optimization and decision support systems.

Dr. Kwo-Sen Kuo received his BS in Atmospheric Science in 1983 from National Taiwan University, Taiwan, Republic of China, his MS in Meteorology in 1987 form South Dakota School of Mines and Technology, and his Ph.D. in Atmospheric Science in 1995 from Colorado State University. Although his main interest of research is in atmospheric radiative transfer and its applications in remote sensing, he also has expertise in image processing and interpretation using both conventional methods and artificial intelligence. He developed a three-dimensional radiative transfer model as his dissertation research. He joined his alumni mater, South Dakota School of Mines and Technology (SDSM&T), as a Research Scientist in 1994 continuing his research in radiative transfer modeling and cloud-field property analyses. His position at SDSM&T changed to Research Assistant Professor in 1995 and to Assistant Professor in 1996 while engaging in a variety of research topics including retrievals of cloud and aerosol properties using satellite data, investigation of cloud three-dimensional effects on retrievals, cloud mask development for ASTER and CERES, and classification of objects within satellite images. Dr. Kuo moved in July 1997 to University of Alabama in Huntsville to take a Research Scientist position and continued his areas of research. In late 1999 he started investigating improvements to precipitation retrievals using spaceborne radar. Dr. Kuo took a leave-of-absence from November 2000 to January 2002. He started his position as an Associate Research Scientist with Caelum Research Corporation in the Goddard Earth Science and Technology (GEST) Program in January 2002, working to create a more realistic physical radiative transfer model for the Global Precipitation Measurement mission.

Dr. Leslie Lait received a B.A. in Physics and Mathematics from Union College in Lincoln, Nebraska, in 1981; followed by a Ph.D. in Physics from Iowa State University in Ames, Iowa, in 1987. His doctoral thesis described the first applications of M. Salby's asynoptic space-time Fourier transform analysis to real satellite measurements. After being graduated from Iowa State, Leslie spent two years as a National Research Council Fellow at NASA's Goddard Space Flight Center. Subsequently, he remained at Goddard, where his research has centered on applications of quasi-conservative coordinate analysis of non-coincident measurements of trace gases from satellite remote-sensing instruments and airborne in-situ instruments. He also provides support for NASA airborne field experiments. Dr. Lait joined GEST in March 2006, as Senior Research Scientist.

Dr. David Lary completed his education in the United Kingdom. He received a First Class Double Honors B.Sc. in Physics and Chemistry from King’s College London (1987) with the Sambrooke Exhibition Prize in Natural Science, and a Ph.D. in Atmospheric Chemistry from the University of Cambridge, Churchill College (1991). His thesis described the first chemical scheme for the ECMWF

numerical weather prediction model. David then held post-doctoral research assistant and associate positions at Cambridge University until receiving a Royal Society University Research Fellowship in 1996 (also at Cambridge). A Royal Society University Fellowship is one of the most prestigious awards for young scientists in the UK. The Royal Society is the world's oldest scientific academy in continuous existence, and has been at the forefront of enquiry and discovery since its foundation in 1660. From 1998 to 200 David held a joint position at Cambridge and the University of Tel-Aviv as a senior lecturer and Alon fellow. An Alon Fellow is the highest award Israel can give a young scientist. In 2000 the chief scientific adviser to the British Prime Minister and Head of the British Office of Science and Technology, Professor Sir David King, recommended David to be appointed as a Cambridge University lecturer in Chemical Informatics. In 2001 David joined UMBC/GEST as the first distinguished Goddard fellow in earth science at the invitation of Richard Rood. His automatic code generation software, AutoChem, has won five NASA awards. In 2006 David joined the Atmospheric Chemistry and Dynamics Branch at GSFC.

Dr. Daniel Laughlin is an Assistant Research Scientist at GEST. He received the first M.A. ancient history from the University of Newcastle upon Tyne and a Ph.D. in Education from American University in 2001. His area of focus was information technology in education, and he did research in cognitive science experimenting with methods to explicitly teach critical and scientific thinking skills. Before coming to GEST, Dr. Laughlin taught for fourteen years at a number of institutions including American, Loyola and Villanova Universities. From 1997 to 2002, he taught pre-service and in-service teachers to use computers and the Internet in their classrooms. Dr. Laughlin joined GEST in 2002. Dr. Laughlin is the NASA Learning Technologies project manager and leads research and development efforts for NASA in the area of educational applications of computer games and synthetic environments.

Mr. Rick Lawford has served as the Director of the International GEWEX Project Office (IGPO) for the past two and a half years. Previously he worked for more than eight years for the University Corporation of Atmospheric Research (UCAR) with NOAA as the program manager for the GEWEX Americas Prediction Project, one of the GEWEX CSEs. In this position he managed 40 to 50 projects and a peer review grant selection process, organized science meetings, and developed planning documentation, reports, synthesis presentations and publications. His current scientific interests include water cycle science and the contributions of remote sensing, droughts (all aspects) and the effective incorporation of water science into water policy and management. Prior to joining UCAR, Rick spent many years working in the fields of hydrology and meteorology with the Canadian government. There he served as Division Chief for a research group in hydrometeorology at the National Hydrology Research Center in Saskatoon. He has also worked in the fields of science policy development (Ministry of State for Science and Technology), program planning, evaluation and environmental policy development (Environment Canada) in Ottawa. Early in his career, he worked as a weather forecaster, research meteorologist and an instructor in the government's professional training program in meteorology. He has served as the regional chief of a Scientific Service Division, supervising a group of meteorologists working in applied climatology in Toronto, Ontario. He has served as an adjunct professor (Geography) at the University of Saskatchewan and a lecturer in Physics (Carleton University in Ottawa). Rick Lawford received his undergraduate degree in Physics at the University of Manitoba (Brandon College) and undertook graduate studies in meteorology at the University of Alberta and McGill University. He is a member of the American Geophysical Union, the American Meteorological Society and the Canadian Meteorological and Oceanographic Society. He has published on a broad range of topics, frequently gives invited conference presentations, and has been listed in the "International Who's Who."

Dr. Myong-In Lee received his degrees of B.Sc. and M.Sc. in Atmospheric Sciences, both from the Seoul National University, Korea in 1994 and 1996, respectively. In 2001, he received a Ph.D. degree at the same university by investigating the cumulus parameterizations in the climate model for the tropical Madden-Julian Oscillation simulation, for which he was awarded a prize by the Korean Meteorological

Society. Dr. Lee started his career of post-doc in the Climate and Environment System Research Center (CES), Korea, where he was dedicated to develop the systems for the dynamical seasonal and sub-seasonal prediction. He also got a lectureship in climate modeling class at Seoul National University in 2002. Dr. Lee joined GEST in 2003 and currently works at the Global Modeling and Assimilation Office at NASA/GSFC for the atmospheric modeling and climate studies. His interests are in the examinations of moist convective parameterizations in the NASA's atmospheric general circulation models.

Dr. Lihua Li received a B.S. in electrical engineering from Tsinghua University, China in 1988, a M. S. in high energy physics from Chinese Academy of Sciences in 1991 and a Ph.D in electrical engineering from the University of Massachusetts at Amherst in 2000. Before joining GEST, he was a research engineer in the Microwave Remote Sensing Laboratory (MIRSL), University of Massachusetts. At NASA GSFC/GEST, Dr. Lihua Li's research efforts involve remote sensing radar development, instrument calibration and data analysis for atmospheric research. As a lead system engineer, Dr. Li has made substantial contribution to the development the NASA GSFC 94 GHz cloud Radar System (CRS), field deployment and data analysis. Currently, Dr. Li is leading a group of engineer on the development of a new X-band UAV Radar (URAD) and a NASA IIP funded High-altitude Imaging Wind and Rain Airborne Profiler (HIWRAP). Both radars will fly on NASA high altitude research aircrafts, such as WB57 or Global Hawk for study of tropical cloud and storm systems. Dr. Li also works closely with other scientists on data analysis and the retrieval of cloud microphysical properties using radar, Lidar and radiometer measurements.

Dr. Xiaowen Li received her B.S. degree in atmospheric sciences from Beijing University, China. She worked as an associate researcher in Chinese Academy of Meteorological Sciences for two years after she received her M.S. degree there. Dr. Li finished her Ph.D. degree at the University of Chicago in 2002, studying cloud microphysics and radar meteorology. She joined GEST as a research associate in July 2002. Dr. Li pioneered the research on direct radiative effect of anthropogenic aerosols in regional climate change in her early career. She was also a member of China-Japan East Asia monsoon study project, and participated surface turbulence observation on Tibetan Plateau from 1994 to 1996. Her Ph.D. dissertation studied the evaporation in stratiform rain region using both 1-D and 2-D simulations. Dr. Li is currently involved in studying the impact of aerosols on cloud and precipitation systems using numerical models, and the improvement of both bulk type and bin spectra microphysical schemes in the Goddard Cloud Ensemble Model.

Dr. Liang Liao received the B.S. degree in Radio Physics and the M.S degree in Space Physics from Wuhan University, Wuhan, China, in 1982 and 1985, respectively, and the Ph.D. degree in Meteorology from the University of Utah, Salt Lake City, in 1993. His research interests include the radio wave propagation, electric field scattering, and atmospheric radar and radiometer remote sensing on clouds and precipitation. Currently, he is a Senior Scientist at the Goddard Earth Sciences and Technology Center/Caelum Research Corp.

Dr. Ruei-Fong Lin is currently an assistant research scientist in the GEST Center. Dr. Lin received her B. S. degree in atmospheric Sciences from National Taiwan University (NTU), Taiwan in 1990, and M. S. and Ph. D. in meteorology from Pennsylvania State University in 1993 and 1997. Before joining GEST Center, she spent 8 months in NTU working as a post-doctoral research scientist followed by 2 years in Universities Space Research Association as a visiting scientist. Dr. Lin's expertise and research interests are numerical modeling of cirrus, cloud physics and radiative transfer. She participated in the GCSS (Global Energy and Water Cycle Experiment Cloud Systems Studies) Working Group on Cirrus Cloud Systems (WG2). She, together with Dr. David O'C Starr of NASA/GSFC and Dr. Paul DeMott of Colorado State University, lead the Cirrus Parcel Model Comparison Project of the GCSS WG2 between 2000-2002.

Dr. Xin Lin received a B.S. in meteorology from Peking University in 1990, and M.S. and Ph.D. degrees in atmospheric science from Colorado State University in 1992 and 1997, respectively. His Ph.D. research focused on meso- and large-scale observational studies in both the tropics and midlatitudes. He worked as a postdoctoral researcher and then as a research associate at Colorado State University between 1997 and 2001. Dr. Lin joined GEST in 2001, and has been working in NASA Global Modeling and Assimilation Office on rainfall and cloud assimilations. His interest includes atmospheric convection, cloud parameterization, and remote sensing.

Dr. Alexander Lipatov received a MSc in Physics and Mathematics from the Department of Aerophysics and Applied Mathematics at the Moscow Institute of Physics and Technology (MIPT) in 1969. He became a Doctor of Sciences in Physics and Mathematics (Theoretical and Mathematical Physics) at the Russian Space Research Institute in 1988. He worked at the Russian Space Research Institute (IKI) from 1972-1996. From 1997-2006, He worked at the A.A. Dorodnitsyn Computer Center of the Russian Academy of Sciences. Dr. Lipatov served as a visiting professor at the East-West Space Center at the University of Maryland in 1992 and 1993-1994. From November 1995 to November 1996, He was a visiting professor at the Max Planck Institute for Extraterrestrial Physics. He was also a visiting professor at the Bartol Research Institute at the University of Delaware from January 1997 to September 1998. Dr. Lipatov has also been a visiting professor at the Max Planck Institute for Aeronomy and for Solar System Research, the Institute for Theoretical Physics at the Technical University Carolo-Wilhelmina and the Space Physics Research Laboratory at the University of Michigan. Dr. Lipatov's projects include being the Principal Investigator (PI) of the Russian Science Foundation Grant 96-02-163 26: Three-dimensional hybrid simulation of nonstationary processes at the boundaries of the magnetosphere. He has also been co-PI of several projects including NSF/DOE Grant ATM 9713223: The plasma physics of diffusive shock acceleration and NASA Grant NAG5-6469: Using ULYSSES Observations to Constrain Global Models of the Heliosphere. His book, The Hybrid Multiscale Simulation Technology: an introduction with application to astrophysical and laboratory plasmas was published in 2002. Dr. Lipatov was named Goddard Senior Visiting Fellow at UMBC/NASA Goddard in 2007.

Dr. Alexei I. Lyapustin received an MS/BS in physics from Moscow State University in 1987, and Ph.D. in Aerospace Remote Sensing from Space Research Institute, Moscow, Russia in 1991. Before joining GEST in February 2002, Dr. Lyapustin was a Research Fellow for two years in the Universities Space Research Association (USRA) and assistant research scientist in JCET UMBC. Dr. Lyapustin actively works on the 3D radiative transfer over anisotropic non-homogeneous surfaces, developing the method of spherical harmonics. At present, he develops algorithms of the aerosol retrieval and atmospheric correction of the Landsat ETM+, EOS MODIS, and future NPOESS VIIRS instrument based on the new theory. Since 2004, his group has been developing the AERONET-based surface reflectance validation network (ASRVN) designed for global validation of land surface reflectance products from space-borne instruments and sensor calibration support. Dr. Lyapustin has delivered a series of lectures on atmospheric correction on invitations from Boston University, UMBC and George Mason University. A. Lyapustin has been an associate member of VIIRS Operational Algorithm Team (VOAT) since 2000. Dr. Lyapustin is a science team member of MODIS and NPP Science Teams (since 2004), and GOES-R Algorithm Working Group since 2005.

Dr. Sarith Mahanama received a B.Sc.Eng from the University of Peradeniya, Sri Lanka in 1993, and a Ph.D. in water and environmental engineering in 2000 from the University of Hong Kong where his major research interest was water balance studies at the land-atmosphere boundary and predicting river discharges in large-scale river basins using large-scale meteorological forcings. In 2000 he joined Universities Space Research Association to work at the NSIPP. Later in 2000, he joined GEST/UMBC where he is still employed, to continue at the GMAO. His main research interest is studying the role of the land surface on seasonal forecasting of AGCMs.

Dr. Toshihisa Matsui received a Ph.D. in Atmospheric Science (2006) from Colorado State University, M.S in Earth & Environmental Resource Management (2002) from University of South Carolina, and a BS in Civil Engineering (1999) from Kobe University in Japan. In 2007, he joined the Goddard Earth Sciences and Technology Center at the University of Maryland, Baltimore County, as a member of the research faculty. His current research topics include land-atmosphere interactions and aerosol-cloud-precipitation interactions, using atmosphere-aerosol-land surface modeling, data assimilation, satellite remote sensing, and analytical solutions.

Dr. Jesse Meng received a Ph.D. (2001) and a M.S. (1997) in meteorology from the University of Maryland, College Park, Maryland, and a B.S. (1991) in atmospheric sciences from National Taiwan University, Taipei, Taiwan. His research at the University of Maryland mainly focused on the development and implementation of methods to estimate, monitor, and evaluate the Earth's land surface radiation and energy budgets from satellite observations. He joined UMBC/GEST in March 2001 as a member of research faculty, spending half time at NASA/GSFC, Hydrologic Sciences Branch (Code 614.3), and half time at NOAA/NCEP Environmental Modeling Center, working on the NASA/NOAA joint project of GLDAS and LIS. His primary duty in GLDAS and LIS includes: 1) generate near real time global land surface shortwave and longwave radiation fields, based on satellite observations, to support the land surface modeling, and evaluate the impact on the land simulation corresponding to the alternative radiation forcing; 2) implement a parallel GLDAS/LIS at NOAA/NCEP to support the NCEP operational GFS and CFS and other land and hydrological research; and 3) evaluate land surface radiation and energy components over a wide range of products including operational and experimental NWP prediction, data assimilation, satellite retrieval, and surface observations.

Dr. Jan Merka received a Ph.D. in Plasma Physics (2000) from the Charles University, Prague, Czech Republic, and a MS in Astrophysics (1996) from the same university. His Ph.D. thesis is on the properties of the high-altitude magnetospheric cusp regions. In 2001, he was awarded a National Research Council Research Associateship Award and worked for three years as Resident Research Associate at the Laboratory for Extraterrestrial Physics at NASA/GSFC where he studied solar wind interaction with the Earth magnetosphere. From 2004 to 2006 he worked as Senior Research Scientist for the L-3 Communications Government Services, Inc., in the Laboratory for Solar and Space Physics at NASA/GSFC. In March 2006, he joined the Goddard Earth Sciences and Technology Center at the University of Maryland, Baltimore County, as an Associate Research Scientist. His main research interests are the formation and properties of magnetospheric boundaries, application of data assimilation methods in space physics, and distributed data systems. He is the Principal Investigator of the Virtual Magnetospheric Observatory development at NASA/GSFC. His publications include papers on magnetospheric cusps, bow shock models, and solar wind data assimilation.

Ms. Stefanie Misztal a media specialist in the Information Science and Educational Technology faculty group. In 2004, she received a B.S. in environmental studies with an emphasis in biology from the University of Southern California, and is currently pursuing a Master's of Fine Arts in science and natural history filmmaking from Montana State University. As a Master's student she has produced an educational video for the Grizzly and Wolf Discovery Center in West Yellowstone, and is currently finishing a film about whirling disease, slated for release on PBS in the summer of 2006. She began employment at GEST in October 2005, and has since been working on producing various environmental and solar science media products for GSFC.

Dr. Priscilla Mohammed received a Ph.D. in Electrical Engineering (2005) and a Master's Degree in Electrical Engineering (2001) both from the Georgia Institute of Technology, Atlanta GA, and a BS in Electrical Engineering (1999) from the Florida Institute of Technology, Melbourne, FL. As a Ph.D. student, Priscilla performed microwave measurements of gaseous phosphine and ammonia under simulated conditions for the outer planets and used these measurements to develop a radio occultation

simulator to predict absorption and excess Doppler due to Saturn's atmosphere. Much of this work was in support of the Cassini mission to Saturn. Based on these laboratory results, the Cassini Project Science Group made the decision to extend the Ka-band (32 GHz) operation throughout the mission tour. The predicted attenuation profiles for the Cassini radio occultation maneuver of May 2005, earned her an invitation by the Cassini Radio Science Team to present a paper on their behalf at the 37th Annual Meeting of the Division for Planetary Sciences in Cambridge, England. In 2006 she joined the Goddard Earth Sciences and Technology Center at the University of Maryland, Baltimore County, as a member of the research faculty. Her current research interests include microwave remote sensing of atmospheres and radio frequency interference mitigation in microwave radiometers.

Dr. Gyula I. Molnar received an M.S. in physics and a Ph.D. in meteorology from the Roland Eötvös University of Budapest, Hungary. He was civil servant for the Hungarian Meteorological Service until 1982, while in 1976-77 he won a British Council Scholarship at the Department of Atmospheric Physics, Oxford University, Oxford, England to work on multispectral satellite retrievals of atmospheric parameters. He came to the U.S. in 1982 (NCAR, Boulder, CO) to work on developing a satellite imagery-based cloud retrieval schemes. He has joined AER, Inc. in Cambridge, MA in 1983 and worked on projects related to the greenhouse warming. In 1994, he started to work for the GOES Project at NASA/GSFC for improving cloud retrievals, and later to assess cloud/water vapor/climate interactions for the areas viewable from geostationary satellites. He has also developed a novel satellite-based sea surface temperature retrieval scheme. More recently, he was working in the AERI Project at UMBC to develop CO, CO_2, and CH_4 retrievals for an upward-looking infrared spectrometer. Most Recently, he has been working for the AIRS-Project with Dr. Susskind at NASA/GODDARD. He has published nearly 30 refereed papers so far in satellite remote sensing/sounding, as well as in global climate change related topics.

Dr. Gary A. Morris is an Associate Professor in the Department of Physics & Astronomy at Valparaiso University with joint appointments as an Adjunct Assistant Professor in the Department of Physics & Astronomy at Rice University and as an Intermittent Assistant Research Scientist through GEST at UMBC. He earned his M.S. and Ph.D. degrees in Space Physics & Astronomy from Rice University in 1992 and 1995 respectively. His research focuses on studies of ozone, both stratospheric loss and tropospheric pollution. He has developed and employed numerous models of atmospheric chemistry and dynamics, including trajectory mapping. During the summer of 2004, he established an ozonesonde station at Rice University in Houston, TX and participated in NASA's IONS mission. Since the establishment, the Rice University site has employed 6 undergraduate students and launched over 90 ozonesondes. He has continues to supervise ozonesonde launches from Rice University and will be a funded participant in MILAGRO, INTEX-B, and TexAQS 2005 – 2006 launching ozonesondes from sites in Houston, Beaumont, and East Texas. In his spare time, he enjoys ballroom dancing and serves as the faculty advisor for Valparaiso University's Dance Etc., a student ballroom dance organization.

Dr. Raimund Muscheler received a Ph.D. in the field of environmental physics (2000) from the Swiss Federal Institute of Technology in Zurich (ETH Zurich), Switzerland and a diploma in physics (1997) from the University of Konstanz, Germany. His PhD thesis is on the interpretation of ice core 10Be records and the comparison with radiocarbon records. He continued this work for two years as a Postdoctoral Research Associate at the Swiss Federal Institute of Aquatic Science and Technology (EAWAG) in Switzerland. In 2003 and 2004 he worked at Lund University, Sweden as a Postdoctoral Research Associate funded by the Swiss National Science Foundation. In 2005 he worked at the National Center for Atmospheric Research (NCAR) in Boulder with funding from the Swiss National Science Foundation. In 2006 he joined the Goddard Earth Sciences and Technology Center at the University of Maryland with a one-year NASA/Goddard fellowship. His main research interest is the relationship between solar activity changes and climate. His publications deal with the different aspects that can be

studied with cosmogenic radionuclides records as, for example, solar influence on climate, geomagnetic field reconstructions, carbon cycle changes and solar activity reconstructions.

Dr. Katsuhiro Nakagawa received bachelor in engineering from Kinki University in 1993, master and doctoral degree in Global Environment Engineering from Kyoto University in 1995 and 1998. In 1998, he joined the Communications Research Laboratory (CRL) (presently called National Institute of Information and Communications Technology (NICT)). He has been engaged in development on the multi-parameter weather radar (COBRA) in Okinawa, Japan. Since November 1st, 2006, he joined the Goddard Earth Sciences and Technology Center at the University of Maryland, Baltimore country, as a member of the research faculty. His main research interest is the vertical variation of precipitation for improving the accuracy of space-borne and ground-based radar estimated rainfall intensity and rain retrieval algorithms for space-borne microwave radiometers and his goal is to develop the dual frequency radar (DPR) algorithm of the Global Precipitation Measurement Mission (GPM) and the calibration and validation system for the GPM/DPR.

Dr. Lars Nerger received a M.S. in physics in 2000 and a Ph.D. in mathematics in 2004, both from the University of Bremen, Germany. His master's thesis work at the Max Planck Insitute for Graviational Physics in Golm, Germany was in the field of general relativity on the numerical simulation of collisions of black holes. He performed research work for his Ph.D. thesis on parallel filter algorithms for data assimilation in oceanography at the Alfred Wegener Instute for Polar and Marine Research (AWI), Bremerhaven, Germany. Subsequently, he worked at the AWI as a postdoctoral fellow, where he continued and expanded his work on the application and characterization of sequential data assimilation algorithms based on the Kalman filter with regard to their application on parallel computers. This work led to the development of the Parallel Data Assimilation Framework (PDAF), which simplifies the implementation of data assimilation systems with existing numerical models on parallel computers. Dr. Nerger joined GEST in August 2005 and is working on the assimilation of satellite ocean color data into the NASA Ocean Biogeochemical Model.

Mr. Tom Narock received a MS in Applied Physics (2005) from Johns Hopkins University, Baltimore, MD, and a BS in Astronomy (2000) from the University of Maryland, College Park. In 2006 he joined the Goddard Earth Sciences and Technology Center at the University of Maryland, Baltimore County, as a research analyst. His research areas include distributed computing and applications of computer science and information technologies to space physics problems. His goal is to support the Virtual Magnetospheric Observatory (VMO) project aimed at developing a common interface to distributed disparate and heterogeneous data sets. Mr. Narock's publications include papers on modeling of solar wind transient structures known as magnetic clouds as well as publications in preparation regarding the applications of grid computing and ontologies to the VMO.

Dr. Peter M. Norris received a BS and MS from the University of Auckland, New Zealand, in 1986 and 1989, and a Ph.D. in Oceanography in 1996 from Scripps Institution of Oceanography (SIO), University of California, San Diego, where his major research interest was numerical modeling of the stratocumulus-topped marine boundary layer. He continued this research in 1996 as a Research Oceanographer in the Marine Meteorology Research Group at SIO, and then in 1997-1998 took up a New Zealand Science and Technology Postdoctoral Fellowship at the National Institute for Water and Atmospheric Research in New Zealand, where he worked on marine boundary-layer modeling. In 1999 he joined the GSFC Center for Excellence in Space Data and Information Science (CESDIS) as a Staff Scientist working on cloud parameterization behavior in a high-resolution global belt version of NCEP's Eta model. In 2000 he joined UMBC/GEST as an Assistant Research Scientist, working at the NASA Data Assimilation Office (DAO), now the Global Modeling and Assimilation Office (GMAO), on cloud modeling and assimilation. Together with Dr. Arlindo da Silva, also of the GMAO, Norris implemented one of the first cloud assimilation systems, using a variational parameter estimation technique, with very successful results. He

has also participated in numerous atmospheric field experiments, including the FIRE Cirrus II, Kansas, 1991, FIRE ASTEX, Azores, 1992, TOGA-COARE, Solomon Islands, 1993, and CRYSTAL-FACE, Florida, 2002, taking roles in data collection, aircraft flight direction, and data analysis.

Dr. Mark A. Olsen received a B.S. in physics from the University of Northern Iowa in 1993 and a Ph.D. in physics from Iowa State University in 2000. His doctoral research examined near-tropopause dynamics and structure of baroclinic systems from total column ozone data and mesoscale model analyses. From 2000 to 2002, he held a National Research Council postdoctoral fellowship at GSFC where his work concentrated on midlatitude stratosphere-troposphere exchange of ozone and mass. Dr. Olsen became a research associate at GEST in December 2002 and later appointed assistant research scientist in December 2004. With GEST, Dr. Olsen has continued to concentrate on many facets of upper-troposphere/lower-stratosphere structure and dynamics, including cross-tropopause transport.

Dr. Judit M. Pap received her Ph.D. in astrophysics in 1986, from Eötvös University, Budapest, Hungary, where she worked as a research associate until 1988. In 1988 she was a visiting scientist at the Institute for Solar Physics at Freiburg, Germany. She was appointed as a research associate at the University of Colorado at Boulder in 1989. She was a staff member of the California Institute of Technology Jet Propulsion Laboratory between 1991 and 1997, and Research Astronomer at the Department of Physics and Astronomy at UCLA until the end of November 2001. Dr. Pap has been a senior research scientist at GEST since June 2001. She conducts research on solar irradiance variations and their effect on the Earth's atmosphere and climate using ground- and space-based measurements. She is a NASA-funded co-investigator on the ESA/NASA SOHO/VIRGO and MDI experiments, was guest investigator of the UARS mission, and co-investigator on the French PICARD experiment, and Associated Scientist on HMI/SDO. She is principal investigator on various grants from NASA's Office of Space Science. Dr. Pap is involved in a wide range of collaborations with scientists from JPL, UCLA, NRL, the University of Alabama, NCAR/HAO, NOAA/SEC, C.N.R.S, (Paris, France), PMOD/WRC (Davos, Switzerland), and the Heliospheric Observatory (Debrecen, Hungary). She is member of the Editorial Board “Weather”, a journal of the Hungarian Meteorological Service. Dr. Pap has organized several international meetings on solar irradiance variations, she chaired the last workshop of Working Group 1 of the International Solar Cycle Studies, working under the auspices of the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP). She is the chair of Working Group 1 “Solar Variability” of Theme 4 “Space Climatology” of the newly implemented program of SCOSTEP: “Climate And Weather of the Sun-Earth System” (CAWSES). CAWSES performs in collaboration with the International Living With a Star (ILWS) program, which will play a major role in solar-terrestrial physics in the next decade or beyond. Since July 2004 she has been serving as US National Disciplinary Science Representative for the SCOSTEP Bureau on sun-climate connections. She was the chief editor of the AGU Monograph Series, No. 141: Solar Variability and Its Effect on Earth's Climate. This Monograph, Monograph Series 141, was published in March 2004.

Dr. Antti Pulkkinen is currently Assistant Research Scientist in the University of Maryland, Baltimore County, Goddard Earth Sciences and Technology Center operated at NASA Goddard Space Flight Center. Dr. Pulkkinen received his PhD in theoretical physics from the University of Helsinki, Finland in 2003. Subsequently he joined the non-linear dynamics group at NASA GSFC to carry out his postdoctoral research for years 2004-2006. The main components of Dr. Pulkkinen's PhD and postdoctoral research involved studies on the ground effects of space weather and studies of the complex dynamics in the magnetosphere-ionosphere system. Dr. Pulkkinen has been involved in numerous collaborative space weather-related projects between scientists and industrial partners. Most of these projects have involved the modeling of space weather effects on pipelines and power transmission systems. Recently he has been working on extending these modeling capabilities to semi-operational now-casting and forecasting of space weather. Dr. Pulkkinen is the main or co-author in total of more than 30 peer reviewed scientific articles.

Dr. Oreste Reale received his Laurea in geophysical engineering from the University of Trieste, Italy, in 1990. From 1990 to 1992, Dr. Reale worked on applied geophysics at the University of Trieste. From 1992 to 1996 he was a graduate student at the University of Maryland, College Park, where he received his Ph.D. in meteorology in 1996. Upon completing his doctorate, from 1996 to 1999 Dr. Reale worked as a visiting scientist at the International Center for Theoretical Physics (ICTP), Physics of Weather and Climate Section, Trieste. He also consulted for a weather forecasting operational center (CMIRL, Genoa, Italy), as an invited lecturer on synoptic-dynamic meteorology and he was co-advisor on three theses on synoptic meteorology at the University of Trieste. From 1999 to 2001 Dr. Reale moved to the Center for Ocean-Land-Atmosphere Studies, Institute for Global Environment and Society (COLA-IGES), Maryland, where he worked on the impact of land-surface evaporation variability and on the dynamics of Mediterranean floods. He joined GEST in July 2001 as an Associate Research Scientist. Dr. Reale's current research focus is on the synoptic and dynamic meteorology of extreme events. In particular, he investigates the sensitivity of extreme events, such as tropical cyclones and extratropical sub-synoptic scale cyclones, to model improvement, different data types and different data assimilation procedures. Dr. Reale received the Outstanding Performance Award from the Data Assimilation Office in the Laboratory for Atmospheres at GSFC in December 2002, and the Outstanding Performance Award from the GMAO/SRT at GSFC in December 2004 and the Outstanding Performance Award from the Laboratory for Atmosphere in July 2005. He is PI of a funded NASA proposal on Observing System Simulation Experiments and co-I on a funded NASA proposal on the African Monsoon.

Dr. Rolf H. Reichle received a Ph.D. in Environmental Engineering (2000) from the Massachusetts Institute of Technology (MIT), Cambridge, MA, and a MS in Physics (1996) and a BS in Mathematics (1992) from the University of Heidelberg, Germany. His Ph.D. thesis is on the optimal assimilation of remote sensing data for land surface hydrology applications. He worked for one year as a Postdoctoral Research Associate at the Ralph M. Parsons Laboratory at MIT where he continued and expanded his work on land data assimilation. In 2001 he joined the Goddard Earth Sciences and Technology (GEST) Center at the University of Maryland, Baltimore County, as a member of the research faculty and began working in close collaboration with researchers at the NASA Goddard Space Flight Center. Dr. Reichle received the Outstanding Performance Award of the NASA Global Modeling and Assimilation Office (GMAO) in 2004 for his leadership in developing, organizing, and coordinating the land assimilation activities within the GMAO and with collaborators at Goddard, and again in 2005 for his ground-breaking research on soil moisture data assimilation. In 2005, Dr. Reichle was promoted to the rank of Associate Research Scientist and was selected as Faculty Group Leader for the GEST Hydrological Sciences faculty group. His main research interest is land data assimilation development and the application of land data assimilation to seasonal climate and weather forecasting. His publications include papers on global soil moisture data, land data assimilation, seasonal climate predictability, and on groundwater contaminant transport.

Dr. Lars Peter Riishojgaard received an M.Sc. in geophysics from the University of Copenhagen in 1989 and a Ph.D. in geophysics from the same institution in 1992. His permanent affiliation from 1989 through 1995 was with the research department of the Danish Meteorological Institute in Copenhagen. Part of his thesis work in general circulation modeling with special emphasis on processes relevant for stratospheric ozone was carried out at the Centre National de Recherches Meteorologiques in Toulouse. He took up a visiting scientist position there from 1993-1994, a period during which he pioneered the application of variational assimilation methods to the problem of driving dynamical flow fields from tracer observations. Late in 1995 he came to the Data Assimilation Office (DAO) at NASA Goddard as a USRA visiting fellow. He designed and led the development of a three-dimensional ozone assimilation system, in parallel with carrying out research in the area of state-dependent covariance modeling. In June 1999 he took up a staff position at EUMETSAT in Darmstadt with user requirements for future space-based observing systems as the main responsibility. In August 2000 he returned to the DAO to lead the development of its analysis system, and with the formation of the GMAO in 2003 he became the lead of

its satellite data group. He became the NASA Deputy Director of the Joint Center for Satellite Data Assimilation in 2002. In 2004 he launched the initiative for a new space mission, the Molniya Orbit Imager, the purpose of which is to demonstrate the high temporal resolution imaging capabilities of this orbit for the high-latitude regions. Dr. Riishojgaard has been with GEST since September 2000.

Dr. Mary Elizabeth Russ received her Ph.D. in Environmental Geosciences from Michigan State University in 2003, and her B.S. in Biology/Ecology from the University of Maryland at College Park in 1997. Her dissertation research encompassed the use of stable isotopes of dissolved oxygen to determine the trophic status (respiration to photosynthesis ratio) of Lake Superior and the subtropical and tropical North Pacific Ocean. M.E. Russ is a seasoned oceanographer and limnologist, with participation in over twenty research cruises during her graduate and post-graduate careers, in both oceanic and freshwater ecosystems. The extent of her publication topics include both the development of a method to analyze the stable isotopes of oxygen, as well as, the application, of pre-established stable isotope methods for oxygen and nitrogen, to physical and biological studies in Lake Superior and the North Pacific Ocean. Upon completion of her degree in 2003, she participated in the Oak Ridge Institute for Science and Education (ORISE) Visiting Research Scientist Program, as a post-doctoral research scientist at the FBI Academy in Quantico, VA. While at the Academy, she was involved in the formulation and installation of a stable isotope ratio mass spectrometry laboratory for the application of stable isotope analysis to forensic science. In January of 2005, she was an invited speaker at the 17th Sanibel Conference for Mass Spectrometry in Forensic Science and Counter-Terrorism, in Clearwater, Florida. She joined the Goddard Earth Sciences and Technology Center (GEST) at the University of Maryland, Baltimore County (UMBC) in March of 2005.

Dr. Robert A. Schiffer is Senior Scientist at the Goddard Earth Science and Technology Center (GEST) at the University of Maryland, Baltimore County (UMBC). He retired from NASA in 2002 after 39 years of service to NASA, including 11 years as a research scientist/engineer at the Jet Propulsion Laboratory at the California Institute of Technology, and 28 years at NASA Headquarters, where he most recently served as Deputy Director of the Research Division in the Office of Earth Science. Over a period of 18 years Dr. Schiffer was seconded (part-time) to the World Meteorological Organization (WMO) Secretariat in Geneva, Switzerland, where he served as Director of the Radiation Projects Office for the World Climate Research Programme (WCRP). He subsequently served as interim Director of the International Project office for the WCRP Global Water and Energy Cycle Experiment (GEWEX), located in Silver Spring, Maryland. For over 10 years Dr. Schiffer chaired the U.S. Global Change Research Program (USGCRP) - Interagency Committee on Observations and Monitoring, and co-chaired the Interagency Committee on the Global Water Cycle. He also served as Executive Director of the U.S. Secretariat for International Global Observing Systems Programs. Dr. Schiffer earned his M.S. and Ph.D. degrees (Atmospheric Sciences) from the University of California at Los Angeles, and B.Aero.E and M.Aero.E degrees (Aeronautical Engineering) from the Polytechnic Institute in New York, He was subsequently licensed as a Professional Engineer in New Jersey and in California . While at NASA, he was awarded the Distinguished Service Medal, NASA's highest award, and two Medals for Outstanding Leadership, for his contributions to interagency and international climate research and global environmental observations. He is a Fellow of the American Meteorological Society and currently serves as a consultant to NASA and the WMO on global change scientific planning and is the Principal Investigator for the NASA grant covering operation of the International GEWEX project Office.

Dr. Chung-Lin Shie, originally from Taiwan, R.O.C., received a B.S. in atmospheric sciences from National Taiwan University, then a M.S. in meteorology from Pennsylvania State University, and a Ph.D. in meteorology from Florida State University. He became a research meteorologist at NASA/GSFC in February 1993, affiliated first with SSAI (till March 2001), and then an associate research scientist with UMBC/GEST (since April 2001) ever since. During his early career (from February 1993 to March 1997), he mainly worked on the development and improvement of an EOF (Empirical Orthogonal

Functions) model for surface humidity retrieval over the global oceans using the SSM/I (Special Sensor Microwave Imager) precipitable water data. He later produced a global (2x2.5 grid) daily air-sea surface flux product (GSSTF1) for a 7.5-year period (from July 1987 to December 1994), which was archived and distributed by the Goddard DISC. Since April 1997, he joined a research project involving numerical simulations using 2- and 3-D GCE models, and scientific analysis to study radiative-convective systems and their interactions with large-scale environment. He has recently further extended the scope of his multi-tasking research works. His current research works also involve research projects such as NEWS, TPCP and NAMMA. He is also currently planning to resume the air-sea flux production that he had established during 1993-1997. He recently (2006) won a “Meritorious Service Award” from COAA (Chinese American Oceanic and Atmospheric Association) for his genuine performance serving as one of the COAA Board Directors during 2003-2004. He also won the “Annual Outstanding Performance Award” of Mesoscale Atmospheric Processes Branch, NASA/GSFC in both 2000 and 2004, as well as won an “Outstanding Mentoring Award” from UMBC/GEST in 2003.

Dr. Michael Schulz is currently the leader of the team “Modeling of the Biogeochemical Cycles” at the Laboratoire des Sciences du Climat et de l'Environnement (LSCE) / Commissariat de l'Energie Atomique, Saclay / France, a group for which he is responsible since October 2002. Dr. Schulz visited the NASA/GSFC as a research fellow for four months in summer 2006 to pursue model evaluation with satellite products. He is also coordinating the AeroCom aerosol model intercomparison initiative (http://nansen.ipsl.jussieu.fr/AEROCOM). He acted as lead author in the recent 4th IPCC assessment report on the aerosol direct forcing assessment. He joined the LSCE as senior scientist in 1999, being responsible for aerosol model development in french climate model IPSL-CM4. Before he was a working group leader for characterising the “Atmospheric input of pollutants into marginal European seas” at the Institute of Inorganic Chemistry, University of Hamburg, Germany from 1994-1999 and a Marie-Curie fellow at the Centre des Faibles Radioactivités, Gif-sur-Yvette, France in 1993-1994. He obtained his PhD in Chemistry at the University of Hamburg on the theme "Spatial and temporal distribution of airborne inputs of trace elements into the North Sea" in 1993 and has a Diploma Degree in Chemistry from the University of Hamburg.

Dr. Alexander Smirnov received a M.S. in physics, from St.Petersburg State University, St.Petersburg, Russia in 1980 and a Ph.D. in Oceanology (Physics and Mathematics) in 1988 from Institute of Oceanology, Russian Academy of Sciences, Moscow, Russia, where his major research interest was atmospheric aerosol optical properties over the oceans. From 1980 to 1991, Dr. Smirnov served as a Scientist and Senior Scientist at St.Petersburg Hydrometeorological Institute, developing aerosol models, and participating in marine and coastal expeditions. From 1993 to 1996 he was a Postdoctoral Fellow and Project Scientist at the Université de Sherbrooke, Sherbrooke, Québec, Canada, where he successfully studied the effect of various synoptic air masses on the atmospheric optical parameters. In June of 1996, Dr. Smirnov joined Science Systems and Applications, Inc., and started working on the AERONET Project. He has led an effort and contributed to the design and implementation of the operational cloud screening and quality control algorithm for the AERONET database. His current research interests include ship-borne and ground based studies of atmospheric aerosols, remote sensing instrumentation, and data analysis. Dr. Smirnov has been with the GEST Center since October 2001. He has over 75 peer-reviewed papers in the leading geophysical journals. He is presently one of the Co-Investigators of the AERONET Project.

Dr. Susan Strahan received a BS in chemistry from Stanford University in 1980 and a Ph.D. in chemistry from the University of California, Berkeley in 1986. She was an NRC postdoc at NASA Ames Research Center, where her research involved making stratospheric trace gas measurements with an airborne spectrometer on the NASA ER-2. As a visiting scientist at the NOAA Geophysical Fluid Dynamics Lab (GFDL) from 1990-2, she continued the analysis of those measurements, using the results to evaluate the stratospheric circulation of the GFDL 'SKYHI' model. Since 1992 she has been at the

NASA Goddard Space Flight Center, presently working in the Atmospheric Chemistry and Dynamics Branch. Her research involves analysis of trace gas measurements from aircraft and satellite platforms. The observational analyses are used to develop diagnostics that evaluate the credibility of atmospheric models. She is the Project Manager for the Global Modeling Initiative, overseeing model evaluation and coordinating production of new model simulations. She contributes to the evaluation of the Goddard Chemistry and Transport Model and the NASA GMI models.

Mr. David Stroud is the Multimedia/Education Technology Senior Producer at GEST. Mr. Stroud received a B.S. in Film Production, from Temple University, in 1982 and an M.F.A. in Photography/Digital Media from the University of Delaware in 1994. The first twelve years of his professional life, Mr. Stroud successfully ran his own business freelancing in the commercial production of film, television and video. He gained credits on projects such as: Hollywood Motion Pictures, Music videos, Commercials, Industrial Films, and Network News. After graduating with his MFA in 1994, Mr. Stroud worked as an Assistant Professor of Digital Media and Photography at various colleges and universities, first as an adjunct then as a tenure- tracked, Assistant Professor of Art/Imaging Technologies. During his tenure at Harford Community College, Mr. Stroud developed a new degree program in Visual Communications. Between 1993 and 2000 Mr. Stroud worked as a fine-artist. This work was personal research that supported his work in academia as an Artist/Educator. The research included developing a portfolio, showing the work and conducting lectures. Regional galleries and museums have critically acclaimed his work. In addition, Mr. Stroud's work has been included in the collections of individual art collections. In 2001 Mr. Stroud joined a team of education and outreach specialists within the Earth Science Directorate at NASA's Goddard Space Flight Center. The team focused on utilizing emerging media technologies, to develop and disseminate engaging and relevant Educational and Public Affairs Outreach materials. Mr. Stroud's primary contribution to the team was is to bring his considerable media production experience to every aspect of the budgeting, design, development, administration and execution of a wide range of projects that include: web applications, interactive multimedia kiosks and CD-ROMs, live interactive web-casts, software design and development, and video programs. In 2006, Mr. Stroud joined GEST to both continue his work developing New Media applications for science communication, and to conduct research and development of emerging technologies for the support of NASA Science Missions, Science Outreach and Science Education.

Dr. Timothy J. Stubbs is an Assistant Research Scientist at GEST whose interests are based in the fields of space plasma physics and planetary science. He received his PhD in Space Physics (2002) and MS in Physics (1998) from Imperial College, London. His PhD thesis included statistical studies of ion injection and transport in the high-latitude magnetosphere using data from NASA's Polar spacecraft, as well as multi-instrument cusp studies. In December 2002, he joined the Laboratory for Extraterrestrial Physics at NASA/GSFC on a National Research Council Associateship with Dr Richard Vondrak as his advisor. His work with Dr Vondrak included using simultaneous spacecraft observations of the auroral ovals in both hemispheres to determine global magnetospheric dynamics, as well as developing the dynamic fountain model for lunar dust. Since December 2005, he has been a member of the UMBC/GEST research faculty and continues to work at NASA/GSFC on modeling lunar surface charging and dust transport (Dr William Farrell, and others), cusp electrodynamics using data from the FAST mission (Dr Robert Pfaff), and solar wind-magnetosphere coupling using the multi-spacecraft Cluster dataset (Dr Melvyn Goldstein). Dr Stubbs currently serves on the following committees: Lunar Airborne Dust Toxicity Advisory Group (LADTAG), NASA Advisory Council's Heliophysics Lunar Subpanel, NASA Engineering and Safety Center's Mechanical Systems Lunar Dust Assessment Group, and has most recently joined the Science Director's Council (SDC) at NASA/GSFC. He typically advises on various aspects of the lunar dust-plasma environment and the implications for exploration of the Moon. He is also interested in surface charging and dust transport processes on Mars, Mercury and asteroids.

Dr. Chaojiao Sun received a BS from the University of Science and Technology of China (USTC) and a PHD in oceanography from Oregon State University, where her major research interest was internal waves and turbulent mixing in the upper equatorial oceans. In 1998, she joined UCLA at the Department of Atmospheric Sciences and the Institute of Geophysics and Planetary Physics. She carried out research on data assimilation with an intermediate coupled ocean-atmosphere model for the study of El Nino Southern Oscillation (ENSO), using a sequential estimator—the extended Kalman filter. She joined UMBC GEST in November 2000, and has been working on snow data assimilation with land surface models and ocean data assimilation with general ocean circulation models. Her major research interests are ocean data assimilation, coupled model data assimilation, ENSO, tropical oceanography, and snow data assimilation.

Dr. Marco Tedesco received his 'Laurea' degree in Electronic Engineering from the University of Napoli 'Federico II' (Italy) in May 1999. In October 1999 he joined the Microwave Remote Sensing Group of the Institute of Applied Physics 'Carrara' of the Italian National Research Council (CNR), Firenze, Italy with a one year appointment (scholarship) for the development and validation of techniques for microwave remote sensing of natural surfaces. In 2000, he was visiting scientist of the Chinese Academy of Science (CAS) in Beijing (Prof. Chao Wang) and of the Fudan University (Prof. Ya-Qiu Jin), Shanghai. In February 2004 he obtained his Ph.D. in Methods and Techniques for Environment Engineering (February 2004) from the Institute of Applied Physics 'Carrara' with the thesis titled 'Microwave Remote Sensing of Snow'. In 2002, he was invited student at the Space Laboratory of the Helsinki University of Technology, and in 2001 he attended the School on Hydrological Model Forecasting (Massachusetts Institute of Technology, MIT). He also collaborated with the Group of Interaction between Electromagnetic Fields and Matter of the Institute of Research on Electromagnetic Waves (IROE) of the Italian National Research Council (CNR). In June 2004, he joined the Goddard Earth Sciences and Technology Center at the University of Maryland, Baltimore County, as a member of the research faculty. In August 2005 he was the recipient of a NASA Outstanding PostDoc/Research Associate Peer Award and on October of the same year Dr. Tedesco received the Young Scientist URSI Award during the URSI International Conference in New Delhi 24-28 Oct. 2005. In June 2006, Dr. Tedesco was promoted to the rank of Assistant Research Scientist at GEST. Dr. Tedesco is Member of IEEE Geoscience and Remote Sensing Society, of the American Geophysical Union Society, of the Technical Committee of Frequency Allocation in Remote Sensing (FARS) of the GRSS and he serves as reviewer for the IEEE TGARS and GRSL, Remote Sensing of Environment, Hydrological Processes, Geophysical Research Letters and Scanning The Journal of Scanning Microscopies. He also served as Guest Editor for the Special Issue on 'Remote Sensing of cryosphere' on Remote Sensing of Environment and chaired several sessions at major conferences.

Dr. Inge Loes ten Kate obtained her MS in aerospace engineering from Delft University of Technology, in the Netherlands, in 1999, where she graduated with a thesis on the design of an aerocapture manoeuvre around Mars. During her studies she did an internship at Arianespace working on Ariane 4 and 5 flight data analysis. After her graduation she worked at the National Aerospace Laboratory NLR, the Netherlands, on signal validation of GalileoSat, the European satellite navigation system. A change in working area led to her PhD in 2006 in Astronomy / Planetary Sciences, with a thesis entitled "Organics on Mars – Laboratory studies of organic material under simulated martian conditions". Since September 2006 she works for GEST at Goddard Space Flight Center.

Dr. Lin Tian received a Ph.D in atmospheric science from the University of Chicago in 1995 where her major research interest was radar meteorology and cloud microphysics. In 1997 she joined University Space Research Association and worked at NASA Goddard Space Flight Center. In October 2000, she joined the Goddard Earth Science and Technology Center. In the past three years, she conducted research in the areas related to the remote measurement of precipitation and understanding of storm structures and microphysical characteristics of precipitation using observations from the ER-2 airborne Doppler radar.

She has analyzed EDOP Doppler radar data in support of TRMM to improve rainfall rate estimate. She also studied microphysics of storms such as raindrop size distribution and melting ice particles using EDOP and ground based polarimetric radar data. Other than her scientific research, she has gained tremendous experience in EDOP data collection, processing and software developing. She participated three TRMM field campaigns and CRYSTAL-FACE experiment, and processed all EDOP and CRS data for archiving and distribution.

Dr. Yudong Tian received a Ph.D. in Atmospheric Sciences in 1999 from UCLA, where he conducted research in climate dynamics and geophysical fluid dynamics. He was also one of the developers at UCLA for the popular advanced spectral analysis SSA-MTM Toolkit. Prior to joining GEST, he had been working in the Internet industry, holding positions as systems manager and chief technology officer. In addition to his atmospheric research background, he has extensive professional experience in network architecture, software engineering, database design and system and network security. Since early 2002, he has been working on GSFC's Land Information System (LIS), which won NASA's Software of the Year Award in 2005. Currently he is working on LIS enhancement for Air Force Weather Agency and on integrating LIS with the emerging sensor web technologies.

Dr. Sushel Unninayar is a Senior Research Scientist at GEST. Education: Ph.D (Meteorology) in 1978 from the Institute of Geophysics, U. Hawaii; M.S: Electrical Engineering in 1971 (U. Hawaii); B.Technology (Honors) IIT, and E.E (I.E.E, London), in 1968. Selected past experience/positions held: He has been with NASA-HQ/ESE in various "Senior Scientist" capacities since about 1991. He directed the NASA-HQ Greenhouse Effect Detection project in 19991-93. Was seconded by NASA-HQ to the UN Institute for Training and Research in 1993-94 as Director of International Projects for addressing global change and climate change research. Was Director of the US Vice-Presidential initiative of the GLOBE Project at UCAR/NCAR in 1994-95. Was program Director at NSF (Global Change Research Planning) in 1988-91. Was Senior Scientific Advisor to UNEP, seconded by NASA-HQ, to the UN Environment Program (UNEP) in 1987-88. Was Division Head, World Climate Program (WCP), World Meteorological Organization, in 1981-87. Was Deputy Director, International GARP programs and interdisciplinary, international field campaigns/projects (MONEX (International Monsoon Experiment) and ALPEX (International Alpine Mountain Experiment)), in 1978-81. He has been directly involved and instrumental, from inception, in the planning and implementation of the World Climate Research program, the US Global Change Research program, and the US Climate Change Science program.

Dr. Yury Vikhliaev received his Master's degree in applied math and physics from the Moscow Institute of Physics and Technology in 1996, with specialization in geophysical fluid dynamics and oceanography. From 1996 to 1999 he was a research assistant in the Geological Institution of Russian Academy of Science, where he worked on reconstruction of history of sedimentary basins and participated in creation of geo-information database of tectonic maps of the Pre-Kaspian Sedimentary Basin. From 1997 to 1999 he was employed at SOVGEOINFO as an operational technician and participated in creation of geo-information database of topographic maps of Russia. He received his Ph.D. degree in Climate Dynamics from George Mason University, Fairfax Virginia, USA in January 2006. His Ph.D. research was focused on understanding the decadal climate variability in the Pacific Basin and analysis of low frequency dynamical modes in numerical climate models using the breeding technique. Upon graduation, Dr. Vikhliaev received a position of research scientist at the Center for Ocean-Land-Atmosphere Studies, Calverton, Virginia. His work was focused on understanding climate noise and climate predictability using coupled general circulation model simulations. Dr. Vikhliaev joined the GEST/GMAO in November 2006 to work on a new coupled GCM that will be used for climate studies, data assimilation and climate forecasts.

Dr. Hailan Wang received her M.S. (1997) and Ph.D. (2000) in Atmospheric Sciences from the University of Illinois at Urbana-Champaign, Urbana, IL, and a B.S. in Marine Meteorology from the

Ocean University of Qingdao, China. Her Ph.D. thesis is on understanding the maintenance mechanism of climatological stationary waves in NCEP/NCAR Reanalysis and the GFDL AGCM simulations. Dr. Wang joined the Goddard Earth Sciences and Technology Center at the University of Maryland at Baltimore County in December 2002. Her main research interest is on climate variability and predictability on timescales ranging from seasonal to long-term trends. Her publications include papers on understanding stationary waves and regional climate changes.

Dr. Jian-Jian Wang received his Ph.D. degree in Meteorology from the University of Hawaii in 1995. He also holds a M.S. degree in Meteorology (1990) and a B.S. degree in Meteorology (1987) from Peking University, China. Dr. Wang specializes in tropical meteorology, mesoscale meteorology, and radar meteorology. His research and publications have focused on the structure and evolution of mesoscale precipitation systems and the interaction between the systems with different scales in the tropics. During the last ten years, he has worked extensively with a broad spectrum of instrumentation including conventional and dual-Doppler radars, rawinsonde soundings, Portable Automated Mesonet (PAM) stations, as well as aircraft and satellite data. His observational studies have focused on the syntheses of physical processes revealed by different data sources from mesoscale field experiments (e.g. Hawaiian Rainband Project, SCSMEX). Dr. Wang joined JCET at the University of Maryland Baltimore County in 1999 as an Assistant Research Scientist. He becomes an Associate Research Scientist in GEST/UMBC in 2005. Between 1997 and 1999, he was a postdoctoral Research Associate with the University of Illinois and NCAR. His research during that period led to a better understanding of the thermal and dynamic effects of local topography on large-scale airflow. In 1995, Dr. Wang's proposal was awarded by UCAR for a two-year postdoctoral fellowship working on NCEP’s regional spectral model (RSM) to improve numerical forecasts in the Pacific Region. He has also held positions as a Research Assistant at the University of Hawaii (1990-1995) and Peking University (1987-1990).

Dr. Yongli Wang graduated from University of California, Los Angeles in August 2003 with his Ph.D. degree in Planetary and Space Physics. During his graduate study, under the direction of Professor Christopher T. Russell and Dr. Joachim Raeder, Dr. Wang made an extensive study in interplanetary shocks, Io mass loading, magnetosphere-ionosphere coupling, magnetotail dynamics, geomagnetic substorms, and global magnetohydrodynamic (MHD) simulations. In his thesis, the Plasma Depletion Layer (PDL), he used multi-spacecraft observations and global MHD simulations and made a systematic study of PDL mechanism, dynamics, and dependence on various solar wind conditions. After his graduation, he joined Space Science and Applications group at Los Alamos National Laboratory as a Postdoc Research Associate in September 2003, where he worked with Dr. Richard C. Elphic and Dr. Joachim Birn on large-scale multi-spacecraft statistics of Flux Transfer Events (FTEs) using Cluster observations and magnetotail bubble dynamics using Birn magnetotail model. Dr. Wang joined SP Systems, Inc. in January 2006 as a Senior Scientist and was stationed at NASA/GSFC working with Dr. Guan Le and Dr. James A. Slavin on Space Technology 5 (ST5) spacecraft data calibration, as well as Field Aligned Current (FAC) and Flux Transfer Event (FTE) statistics. In November 2006, Dr. Wang joined UMBC/GEST as an assistant research scientist to continue his ongoing work and new investigations using NASA THEMIS mission data and space weather simulations. Dr. Wang's research interest and expertise include: solar-terrestrial relationships, plasmas physics in space, solar wind-magnetosphere-ionosphere-thermosphere coupling, large-scale modeling of magnetosphere, magnetosheath and magnetopause physics, FTEs, FACs, magnetotail dynamics, interplanetary shocks, Io Mass loading in Jupiter's magnetosphere, computational fluid dynamics, numerical methods and advanced simulation techniques (including adaptive mesh refinements), high performance computing, and multiple satellite observational study. Dr. Wang has authored and co-authored 23 scientific papers in peer-reviewed journals and has made 55 presentations in national and international scientific meetings. He has served as a reviewer for Advances in Space Research, Annales Geophysicae, Geophysical Research Letters, and Journal of Geophysical Research. He is also a proposal reviewer for NASA Geospace Sciences Program.

Dr. Yujie Wang received a BS and an MS in physics from Tsinghua University, Beijing, China in 1994 and 1998 respectively, and PhD in geography from Boston University, Boston, MA in 2002. In July of 2002, Dr. Wang joined GEST as a Research Associate. During his PhD study, Dr. Wang's research was mostly focused on the prototyping and validation of radiative transfer based EOS MODIS LAI/FPAR algorithm. At present, he is developing a new generic aerosol retrieval and atmospheric correction algorithm for the EOS MISR, MODIS and future NPOESS VIIRS instrument.

Dr. Clark Weaver's first scientific initiation was at Ohio State University at the Byrd Polar Research Institute. His Masters Thesis topic was the fractionation of isotopic oxygen in snow over Antarctica. He received his Ph.D. in Atmospheric Science from Colorado State University in 1987. His dissertation was on the mechanism for marine stratocumulus break up. Next, he joined the research group at the Graduate School of Oceanography at University of Rhode Island and studied the transport of mineral dust to ocean drilling sites using paleoclimate models. He joined the Atmospheric Chemistry and Dynamics Branch at NASA Goddard in 1991 and has worked there ever since. His current interests include: stratospheric transport, data assimilation and remote sensing.

Dr. Phillip A. Webb is an Assistant Research Scientist and the Heliophysics Group Leader at the GEST research center, University of Maryland Baltimore County (UMBC) within the Space Weather Laboratory, NASA/GSFC. He obtained his B.Sc. in 1993 and M.Sc. in 1995 from The University of Auckland, New Zealand, and his Ph.D. in 2001 from La Trobe University, Australia. His awards include a Postgraduate Scholarship, La Trobe University, Australia and a National Research Council Resident Research Associateship Award at NASA/GSFC. His Ph.D. work produced a dynamic global model of the plasmaspheric plasma population that reproduced dynamic features observed by both in-situ electron density and total electron content observations. At NASA/GSFC he has undertaken studies to interpret data collected by the Radio Plasma Imager (RPI) on NASA's IMAGE satellite. As principle investigator he recently won a NASA New Investigator Program 3-year award to automate electron density determinations from RPI dynamic spectra. Dr Webb has undertaken research into modeling topside ionospheric ion composition and, also, nanometer sized ice particles believed to play an important role in the formation of polar mesospheric summer echoes. He has published or submitted 17 scientific publications dealing with ionospheric and plasmaspheric physics. He has also presented 63 talks and posters on these topics.

Dr. Guoyong Wen received a B.S. degree from Peking University in 1982, a M.S. in atmospheric sciences in 1987 from Purdue University, and a Ph.D. in atmospheric physics in 1992 from the University of Chicago. He did his postdoctoral work at Argonne National Laboratory. His research interests focus on atmospheric remote sensing, ozone, aerosols, clouds, and atmospheric radiative transfer, climate variations, solar variability. He joined GEST in 2003.

Dr. Mark Wenig received his Intermediate Diploma in physics from the University of Münster, Germany, in 1995, and his Diploma in physics from the Interdisciplinary Center for Scientific Computing at the University of Heidelberg, Germany, in 1998. In 2001 he received a Ph.D. in Physics at the Institute of Environmental Physics at the University of Heidelberg, for his work on Satellite measurement of long-term global tropospheric trace gas distributions and source strengths. He had been awarded a National Research Council scholarship from 2002 – 2005 to work at NASA Goddard Space Flight Center, Atmospheric Chemistry and Dynamics Branch on atmospheric data assimilation. Since 2005 he is affiliated with UMBC/GEST to work at NASA GSFC on new techniques to combine multi-dimensional data sets coming from satellite measurements to analyze the impact of trace gases and aerosols on air quality.

Dr. Liguang Wu is an assistant research scientist at GEST. He received a B.S. in meteorology from Nanjing University, China, in 1984; a M.S. in meteorology from State Oceanic Administration (SOA), Beijing, China, in 1990; and a Ph.D. in meteorology from University of Hawaii in 1999. Dr. Wu served as an operational weather forecaster at SOA from 1984 to 1987 and from 1990 to 1994. From 1994 to 1999, he worked as a research assistant at the University of Hawaii. He developed a coupled hurricane-ocean model system and proposed a new diagnostic approach to quantitatively assess contributions of various physical processes to tropical cyclone motion. From 2000 to 2001, as an AIRS data specialist, he developed the official AIRS data support web site and various tools for accessing Aqua AIRS data at DAAC/GSFC. His current research interest includes tropical cyclone genesis, structure, intensity, and motion; air-sea interaction; numerical modeling; analysis and application of remote sensing data, the relationship between climate changes and hurricane activities.

Dr. Yihua Wu received a Ph.D. in Atmospheric Sciences (1999) and a MS in Horticultural Sciences (1993) from North Carolina State University, Raleigh, North Carolina, and a BS in Agro-meteorology (1982) from Nanjing Institute of Meteorology, Nanjing, China. He worked as an engineer at the State Meteorological Administration of China (SMA) from 1982 to 1991, and earned an academic award from SMA in 1991 for his distinct contributions in agro-meteorological research and service at the national level. He developed a multi-layer biochemical dry deposition model when he worked as a UCAR visiting scientist at US EPA from 2000 to 2002. In 2002 he joined the Goddard Earth Sciences and Technology Center at the University of Maryland, Baltimore County, as a member of the research faculty. His main research interest is modeling the bi-directional exchanges of trace gases between the atmosphere and biosphere. His publications include papers on the formation and structure of low level jets, land use pattern effects on meso-scale circulations, dry deposition modeling, and watershed scale soil moisture simulations.

Dr. Kai Yang received a B.S. in physics from Sun Yat-Sen University, Guangzhou, China in 1984 and a Ph.D. in physics from Kansas State University in 1991. He has over 14 years experience in satellite remote sensing, covering science algorithm development and its operational implementation for multi-spectral (MODIS, TOMS) and hyper-spectral (OMI, GOME) instruments. In 1994 he came to NASA Goddard Space Flight Center and performed radiative transfer simulations from MODIS measurements and developed the MODIS level 2 gridded products. Later he joined the OMI science support team in 2001, implemented the current operational OMI total ozone and sulfur dioxide retrieval algorithms and their automatic quality assessment (QA) schemes. He has developed the sliding median technique for soft-calibration and cross-track bias correction of OMI measurements, and the non-linear least square fitting technique for OMI wavelength registration and spectral response characterization, and perfected the Ring correction technique for UV radiances.

Dr. Kao-San Yeh, also known as Kevin Yeh, has been an Assistant Research Scientist at GEST since December 2001. He has developed a few numerical methods for modeling geophysical fluid dynamics since he joined the GEST center, including the Streamline Subgrid Integration method for applications on arbitrary grid systems. Dr. Yeh received a B.S. in physics from the National Taiwan University in 1987, an M.S. in mathematics from Purdue University in 1992 and a Ph.D. in meteorology also from Purdue University in 1997. He conducted the development of the non-hydrostatic version of the Canadian Global Environmental Multiscale Model as a post-doctor in the Meteorological Research Branch of Environment Canada in 1997-1999. During 1999-2001, Dr. Yeh generalized the NASA/NCAR finite-volume General Circulation Model from uniform to variable resolution as a Research Associate in the Earth System Science Interdisciplinary Center of the University of Maryland, College Park.

Dr. Yasuko Yoshida received her degree of Bachelor of Arts in Science Education from Miyagi University of Education, Sendai, Japan, in 1992. She obtained a Master's degree in Environmental Sciences at Rutgers University, New Brunswick, NJ, in 2001. She received her Ph.D. from the Georgia

Institute of Technology, Atlanta, GA, in Earth and Atmospheric Sciences on August 6, 2006. Her Ph.D. thesis is on study of global source and distribution of atmospheric methyl chloride (CH3Cl) using a global CTM. Since August 2006, she is a visiting research scientist at GEST, UMBC. She is currently studying the chemistry and transport of trace gases (e.g.. carbon monoxide, ozone, etc.) in the troposphere using a CTM, the NASA GMI CTM, and measurements from aircraft and satellites. Her research is currently focused on simulating the long-range transport of boreal forest fire pollution.

Dr. Hongbin Yu received his Ph.D. in Atmospheric Chemistry (2000) from the Georgia Institute of Technology, Atlanta, GA, and a MS (1992) and a BS (1989) both in Atmospheric Physics from the Nanjing University in China. His Ph.D. thesis is on aerosol radiative effects on the environment. He also conducted data analysis and modeling on tropospheric O_3-NOx chemistry during the early years of his Ph.D study. After his graduation in 2000, Dr. Yu then worked at Georgia Tech as a postdoctoral fellow through 2002, and as a research scientist from January 2003 to October 2004, focusing on aerosol-cloud-radiation-climate interactions. Before pursuing his Ph.D. in the U.S., he was the faculty member at the Department of Atmospheric Sciences of the Nanjing University from 1992 to 1996, where he taught and conducted research in air pollution and atmospheric boundary layer. In October 2004, Dr. Yu joined Goddard Earth Sciences and Technology Center at the University of Maryland, Baltimore County, as a member of the research faculty. His current task is to assess the measurement-based estimates of the aerosol climate forcing and aerosol intercontinental transport. Dr. Yu's publications cover topics of global aerosol assimilation and aerosol radiative forcing, aerosol impacts on the evolution of the atmospheric boundary layer and crop yields, tropospheric ozone and nitrogen chemistry, and air pollution and boundary layer meteorology.

Dr. Boris Yurchak received a M.S. in Electronics, from Kharkov Institute of Radioelectronics, USSR in 1969, and a Ph.D. in geophysics (physics and mathematics) in 1980 from the Institute of Experimental Meteorology, Goskomhidromet (USSR Weather Service), Obninsk. His major research interest was radar methodology applications to cloud and precipitation measurements and atmospheric diffusion. From 1969 to 1996, Dr.Yurchak served as a research scientist, senior research scientist at the Institute of Experimental Meteorology, developing radar methodology for atmospheric research. From 1996 to 2001 he served as a senior research scientist and branch head at the Russia Federal Environmental Emergency Response Center (FEERC), Obninsk, Russia, where he developed remote system for detecting clouds of chemical and radioactive pollutants at emergency situation. Also he used remote sensing capabilities for study of environment contamination. In July 2002 Dr. Yurchak joined Caelum Research Corporation and started working on the NASA's Earth Science & Public Health Program. In June 2003 he joined UMBC where continued working on the NASA's Earth Science & Public Health Program. Dr. Yurchak has been with GEST since July 2002. His current research interests include remote sensing applications for cold regions.

Dr. Xiping Zeng received his B.S. and M.S. degrees in atmospheric physics from Nanjing Institute of Meteorology. He then taught courses and conducted research of clouds in this institute from 1987 to 1995. From 1995 he began his Ph.D. studies in Physics Department of New Mexico Tech with his focus on the ensemble simulation of tropical convection and its interaction with large-scale vertical circulation. After receiving his degree, he continued his work as Postdoc Research Physicist there for a while, and then he joined GEST center as Research Associate. Now Dr. Zeng is cooperating with the scientists in GSFC and universities, evaluating precipitation and clouds in long-term cloud-resolving model simulations with observational data.

Dr. Seiji Zenitani received a Ph.D. in Earth and Space Science (2006) and a MS in Earth and Space Science (2001) from the University of Tokyo, Japan, and a BS in Science (1999) from Kyoto University, Japan. His Ph.D. thesis is on high-energy particle acceleration and magnetic field dissipation processes in the plasma sheets of celestial magnetospheres. In 2006, he worked for the JAXA/ISAS (science division

of the Japanese space agency JAXA) to extend his research and then he joined UMBC/GEST in November 2006 to start collaboration with Prof. Michael Hesse at GSFC. His research interests are particle acceleration, non-linear dynamics and chaos in space and astrophysical plasmas.

Dr. Qingyuan Zhang received a Ph.D. in Natural Resource and Environmental Study (2006) from the University of New Hampshire (UNH), Durham, NH, a MS in Applied Mathematics (1996) from TsingHua University, and a BS in Mathematics (1994) from the ShanDong University, China. His Ph.D. thesis is on estimation of fraction of absorbed PAR by chlorophyll using daily MODIS data and the development of a vegetation photosynthesis model. In 2006 he joined the Goddard Earth Sciences and Technology Center at the University of Maryland, Baltimore County, as a Goddard Visiting Fellow. His main research interests are the application of daily MODIS data, carbon cycle modeling, estimation of fAPAR by canopy, leaf and chlorophyll, phenology, and the seasonal-to-interannual variation of the canopy. His goal is to support NASA's Light Use Effiency (LUE) and Carbon Cycle Projects with his experience in daily MODIS data application. His publications include papers on estimation of fAPARchl, phenology, and on vegetation photosynthesis model and land use.

Dr. Yunhe Zhao received the B.S. degree in computational mathematics from Xiamen University, Xiamen, China in 1984, and both the M.S. and Ph.D. degrees in mathematics from North Dakota State University, Fargo, ND, in 1993 and 1997, respectively. He has been with Caelum Research Corporation, Rockville, MD, and worked on-site at NASA Goddard Space Flight Center as a contractor since May 1997. He currently is a Senior Analyst and works in the GEST program at Caelum Research Corporation, a GEST partner. During his graduate study, he did research on numerical solutions of boundary integral equations, numerical integrations of improper integrals, and wavelet analysis and its applications in the numerical solutions of integral equations. Since working on-site at NASA/GSFC, he has worked on satellite ocean and sea ice remote sensing data analysis and image processing, especially on deriving sea ice motion and deformation in the Arctic using wavelet analysis method from SSM/I, NSCAT, QuikSCAT, and AMSR-E data, using the derived data sets to study sea ice dynamics and the interaction of sea ice motion and the pressure field, and studying internal wave generation, evolution, and dissipation in the South China Sea by integrating and assimilating both SAR and mooring data into nonlinear internal wave models.

Dr. Yaping Zhou received a Ph.D. in Physical Oceanography and a M.S. in Computer Science in 1999 from Stony Brook University in 1999. After graduation, she worked at NASA Langley Research Center and National Environment Prediction Center for brief periods before she came to Goddard. In 2004, she joined the Goddard Earth Sciences and Technology Center at the University of Maryland, Baltimore County, as a member of the research faculty. Dr. Zhou has worked on various research topics from radiative transfer modeling, surface longwave algorithm development to onboard data compression and climate diagnostics. Her current work focuses on using satellite observations of cloud and precipitation for validating of cloud resolving model and using cloud resolving model to improve the GCM parameterizations.

Dr. Jerry Ziemke came to NASA Goddard in 1994 as an NRC research fellow specializing in atmospheric composition and dynamics. He obtained his education from several university institutions in the United States, terminating with a Ph.D. in Physics from Iowa State University. He has over 50 scientific publications, most all of which are in refereed journals and most of these as first author. Since arriving at Goddard he has collaborated with scientists both at Goddard and elsewhere on a large range of topics, but primarily relating to studies on atmospheric ozone. Since 1996 his main focus has been satellite retrieval of tropospheric ozone, and is Principal Investigator on the American OMI Science Team for retrieval of tropospheric ozone. Jerry Ziemke became an associate research scientist within UMBC GEST in March, 2002.

Faculty and Staff

Faculty	Title
Anderson, Theodore	Visiting Assistant Research Scientist, Goddard Visiting Fellow
Anyamba, Assaf	Associate Research Scientist
Arsenault, Kristi	Research Associate
Bacmeister, Julio	Associate Research Scientist
Bekerat, Hamed	Visiting Research Associate
Bell, Benita	Visiting Assistant Research Scientist
Benna, Mehdi	Assistant Research Scientist
Benson, Craig	Research Associate
Berkoff, Tim	Assistant Research Engineer
Bian, Huisheng	Assistant Research Scientist
Boardsen, Scott	Associate Research Scientist
Bojkov, Bojan	Associate Research Scientist
Bucsela, Eric	Associate Research Scientist
Chandra, Sushil	Senior Research Scientist
Chang, Yehui	Associate Research Scientist
Chekalyuk, Alexander	Research Associate Professor, Hampton University
Chern, Jiun Dar	Associate Research Scientist
Chu, Allen	Associate Research Scientist
Colarco, Amelia	Research Associate
Cook, Laurie	Instructional Designer
Curran, Robert	Senior Research Scientist
de Matthaeis, Paolo	Research Associate
Delaney, Marcianna	Research Associate
Diehl, Thomas	Assistant Research Scientist

Faculty	Title
Dinnat, Emmanuel	Assistant Research Scientist
Dong, Jiarui	Assistant Research Scientist
Duncan, Bryan	Associate Research Scientist
Eastman, Joseph	Assistant Research Scientist
Eck, Thomas	Assistant Research Scientist
Errico, Ronald	Senior Research Scientist
Freeberg, Andrew	Media Specialist
Fristad, Kirsten	Research Assistant
Garcia, Matthew	Research Associate
Gassó, Santiago	Assistant Research Scientist
Gatebe, Charles	Associate Research Scientist
Georgieva, Elena	Visiting Associate Research Scientist
Grecu, Mircea	Assistant Research Scientist
Gu, Guojun	Assistant Research Scientist
Guenther, Bruce	Senior Research Scientist
Han, Mei	Research Associate
Han, Shin-Chan	Assistant Research Scientist
Hoban, Susan	Senior Research Scientist
Hong, Yang	Assistant Research Scientist
Jacob, Daniel	Assistant Research Scientist
Joseph, Jeffrey	Visiting Research Associate
Jusem, Juan Carlos	Visiting Senior Research Scientist
Kim, Hyung Rae	Assistant Research Scientist
Kim, Kyu-Myong	Associate Research Scientist
Koratkar, Anuradha	Associate Research Scientist

Faculty	Title
Kostis Helen-Nicole	Research Associate
Krotkov, Nickolay	Senior Research Scientist
Kumar, Sujay	Assistant Research Scientist
Kuo, Kwo-Sen	Scientist, Caelum Research Corporation
Lait, Leslie Robert	Senior Research Scientist
Lary, David	Senior Research Scientist
Laughlin, Daniel	Assistant Research Scientist
Lawford, Richard	Director, GEWEX IGPO
Lee, Myong-In	Assistant Research Scientist
Li, Lihua	Assistant Research Scientist
Li, Xiaowen	Assistant Research Scientist
Liao, Liang	Scientist, Caelum Research Corporation
Lin, Ruei Fong	Assistant Research Scientist
Lin, Xin	Associate Research Scientist
Lipatov, Alexander	Visiting Senior Research Scientist, Goddard Visiting Fellow
Lyapustin, Alexei	Assistant Research Scientist
Mahanama, Sarith	Assistant Research Scientist
Matsui, Toshihisa	Assistant Research Scientist
Meng, Jesse	Assistant Research Scientist
Merka, Jan	Associate Research Scientist
Misztal, Stefanie	Media Specialist
Mohammed, Priscilla	Research Associate
Molnar, Gyula	Assistant Research Scientist
Morris, Gary	Visiting Research Associate
Nakagawa, Katsuhiro	Visiting Assistant Research Scientist

Faculty	Title
Nerger, Lars	Visiting Research Associate
Norris, Peter	Assistant Research Scientist
Olsen, Mark	Assistant Research Scientist
Pap, Judit	Senior Research Scientist
Pulkkinen, Antti	Assistant Research Scientist
Reale, Oreste	Associate Research Scientist
Reichle, Rolf	Associate Research Scientist
Riishojgaard, Lars-Peter	Senior Research Scientist
Russ, Mary	Research Associate
Shie, Chung-Lin	Associate Research Scientist
Smirnov, Alexander	Senior Research Scientist
Song, In-Sun	Assistant Research Scientist
Strahan, Susan	Senior Research Scientist
Stroud, David	Assistant Research Scientist
Stubbs, Timothy	Assistant Research Scientist
Sun, Chiaojiao	Assistant Research Scientist
Tedesco, Marco	Research Associate
ten Kate, Inge	Visiting Assistant Research Scientist
Tian, Lin	Associate Research Scientist
Tian, Yudong	Assistant Research Scientist
Tremolet, Yannick	Associate Research Scientist
Unninayar, Sushel	Senior Research Scientist
Veselovskii, Igor	Associate Research Scientist
Vikhliaev, Yuri	Research Associate
Wang, Hailan	Research Associate

Faculty	Title
Wang, J.J.	Assistant Research Scientist
Wang, Yongli	Assistant Research Scientist
Wang, Yujie	Assistant Research Scientist
Weaver, Clark	Associate Research Scientist
Webb, Phillip	Assistant Research Scientist
Wen, Guoyong	Assistant Research Scientist
Wenig, Mark	Visiting Assistant Research Scientist
Wu, Liguang	Associate Research Scientist
Wu, Yihua	Assistant Research Scientist
Yang, Kai	Assistant Research Scientist
Yang, Yuekui	Research Associate
Yeh, Kevin	Assistant Research Scientist
Yoshida, Yasuko	Visiting Research Associate
Yu, Hongbin	Assistant Research Scientist
Yurchak, Boris	Senior Research Scientist
Zeng, Xiping	Assistant Research Scientist
Zenitani, Seiji	Visiting Research Associate
Zhang, Qingyuan	Visiting Research Scientist, Goddard Visiting Fellow
Zhao, Yunhe	Scientist, Caelum Research Corporation
Zhou, Yaping	Assistant Research Scientist
Ziemke, Jerry	Associate Research Scientist

Associate Staff	Title
Belcher, Larry	Research Analyst
Franz, Heather	Research Analyst

Narock, Thomas	Research Analyst
Kucsera, Tom	Research Analyst
Steenrod, Stephen	Research Analyst

Administrative Staff	**Title**
Casasanto, Valerie	Program Coordinator
Dawson, Mary	Business Specialist
Eichenlaub, Danita	Associate Director
Engel-Cox, Glen	Communications Manager
Hoff, Raymond	Director
Hyman, Camilla	Accountant I
Low, Tom	Associate Director
Manalansan, Cathy	Administrative Assistant II
Roscoe, A. Grace	Executive Administrative Assistant I
Schneider, Amy	Business Specialist
Stivers, Derek	Business Specialist
Von Gunten, Nina	Administrative Assistant I

Acronyms and Abbreviations

Acronym/Abbreviation	Expansion/Definition
2-D	Two-dimensional
3-D	Three-dimensional
AACGM	Altitude Adjusted Corrected Geomagnetic
AAOT	aerosol absoption optical thickness
ACASIM-3D	Advanced three-dimensional Cometary Atmosphere simulator
ACPD	Atmospheric Chemistry and Physics Discussions
ACRIM:	Active Cavity Radiometer Irradiance Monitoring
ADMAP	Antarctic Digital Magnetic Anomaly Project
AEROCOM	Aerosol Model Intercomparison
AERONET	Aerosol Robotic Network
AFWA	Air Force Weather Agency
AGCM	Atmospheric General Circulation Model
AGRMET	Agricultural Meteorological Model
AGU	American Geophysical Union
AIRS	Atmospheric Infrared Sounder
ALF	Advanced Laserfluorometer
AMF	air mass factor
AMIP	Atmospheric Model Inter-comparison Project
AMMA	African Monsoon Multidisciplinary Analysis Project
AMR	Adaptive Mesh Refinement
AMS	American Meteorological Society
AMSR-E	Advanced Microwave Scanning Radiometer for the Earth Observing System
AMSU	Atmospheric Microwave Sounding Unit;
AMU	Atomic Mass Unit
ANL	Argonne National Laboratory
AOD	Aerosol Optical Depth
AOT	Aerosol Optical Thickness
APAR	Absorbed PAR
ARM/CART	Atmospheric Radiation Measurement/Cloud and Radiation Testbeds
ARM	Atmospheric Radiation Measurement (Program)
ARMS	Army Remote Moisture System
ARS	Agricultural Research Service
A-SRVN	AERONET-based Surface Reflectance Validation Network
ASTEX	Atlantic Stratocumulus Transition Experiment
A-Train	Constellation of formation-flying, polar orbiting satellites: Aqua, CloudSat, CALIPSO, PARASOL, Aura, and (in the future) OCO
AURA	NASA EOS satellite on polar sun synchronous afternoon orbit
AVDC	Aura Validation Data Center
AVHRR	Advanced Very High Resolution Radiometer
AWARDS	Agricultural Water Resource Decision Support

Acronym/Abbreviation	Expansion/Definition
BDSP	Basic Data Set Project.
BIOME	Biophysical Interactions in Ocean Margin Ecosystem
BMJ	Betts-Miller-Janjic
BRD	Band Residual Difference Algorithm for determining SO_2 from OMI
BRF	Bidirectional Reflectance Factors
BUV	Backscattered ultraviolet
CACGP	Commission on Atmospheric Chemistry and Global Pollution
Cal/Val	Calibration and Validation
CALIOP	Cloud and Aerosol LIdar with Orthogonal Polarization (CALIPSO lidar)
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations, launched April 28, 2006 for a three-year mission
CAN	Cooperative Agreement Notice
CAWSES	Climate And Weather of the Sun-Earth System
CB	Chesapeake Bay
CBP	Chesapeake Bay Plume
CCD	Charge coupled device
CCM	chemistry-climate model
CCMC	Community Coordinated Modeling Center
CCRI	United States Climate Change Research Initiative
CCSP	United States Climate Change Science Program
CCSPO	United States Climate Change Science Program Office
CCVEX	The NASA Cloudsat/Calipso Validation Experiment
CDA	Cosmic Dust Analyzer
CDF	Common Data Format
CDOM	Chromophoric dissolved organic matter
CEOP	Coordinated Enhanced Observing Period
CEOS	Committee on Earth Observation Satellites
CERES	Clouds and the Earth's Radiant Energy System; broadband radiometers deployed on both Terra and Aqua satellites for determining top-of-atmosphere energy fluxes
CESDIS	Center for Excellence in Space Data and Information Science
CFAD	cumulative frequency by altitude diagrams
CFS	Climate Forecast System
CGCM	Coupled General Circulation Model
CHAMP	CHAllenging Minisatellite Payload
Chl	Chlorophyll
Chl-a	Chlorophyll-a
CLIVAR	Climate Variability and Predictability
CLM	Community Land Model
CLPX	Cold Land Processes Experiment
CLRTAP	Convention on Long-Range Transboundary Air Pollution
CLSM	Catchment Land Surface Model
CMAQ	Community Model for Air Quality

Acronym/Abbreviation	Expansion/Definition
CMAVE	Center for Medical, Agricultural & Veterinary Entomology
CME	Coronal Mass Ejection
CMOPRH	Climate Prediction Center Morphing Technique
CMS	content management system
CO	carbon monoxide
CO_2	carbon dioxide
COAA	Chinese American Oceanic and Atmospheric Association
COADS	Coupled Ocean-Atmosphere Data Set
COARE	Coupled Ocean-Atmosphere Response Experiment
COBRA	CRL Okinawa Bistatic Polarimetric Radar
Co-I	Co-Investigator
COLA	Center for Ocean-Land-Atmosphere Studies
CONAE	Comision Nacional De Actividades Espaciales (Argeninean National Space Agency)
CPES	Cloud Parameter Estimation System
CPPA	Climate Prediction Program for the Americas
CR-AVE	Costa Rica Aura Validation Experiment
CRM	Cloud Resolving Model
CRS	The NASA Cloud Radar System
CRYSTAL-FACE	Cirrus Regional Study of Tropical Anvils and Cirrus Layers - Florida Area Cirrus Experiment
CSB	Cryospheric Sciences Branch
CSE	Continental-Scale Experiment
CSU	Colorado State University
CTM	Chemistry and Transport Model
CW	Continuous Wave
dAMF	Differential (or Altitude-Dependent) Air Mass Factor
DAO	Data Assimilation Office
DAS	Data Assimilation System
DCF	Direct Climate Forcing; change in Earth's energy balance caused by direct interactions between anthropogenic aerosol particles and sunlight
DD	Double Detector
DE-2	Dynamic Explorer 2
DESWAT	Destructive Waters Abatement program (Romania)
DISC	Data and Information Services Center
DMRT	Dense Medium Radiative Theory
DMS	Dimethylsulphate
DMSP	Defense Meteorological Satellite Program
DOAS	Differential Optical Absorption Spectroscopy
DOC	Dissolved organic carbon
DoD	United States Department of Defense
DOM	Dissolved organic matter
DPR	Dual Frequency Precipitation Radar

Acronym/Abbreviation	Expansion/Definition
DROPPS	Distribution and Role of Particles in the Polar Summer Mesosphere
EAWAG	Swiss Federal Institute of Aquatic Science and Technology
EC	Environment Canada
ECCO-GODAE	Estimating the Circulation and Climate of the Ocean – Global Ocean Data Assimilation Experiment
ECMWF	European Centre for Medium-Range Weather Forecasting
ECU	East Carolina University
EDOP	ER-2 Doppler Radar
EHP	Elevated Heat Pump
EKF	Extended Kalman Filter
EMC	Environmental Modeling Center
EMEP	Cooperative Programme for Monitoring and Evaluation of Long-range Transmission of Air Pollutants in Europe
ENCAM	Enceladus' Atmospheric Model
EnKF	Ensemble Kalman Filter
ENSO	El Niño Southern Oscillation
ENVISAT	ESA Environmental satellite
EOF	empirical orthogonal fit
EOS	Earth Observing System
EPA	United States Environmental Protection Agency
ERA40	ECMWF 40 Year Re-analysis
ERBS	Earth Radiation Budget Satellite
ERS-2	ESA Earth Research Satellite (2)
ESA	European Space Agency
ESMF	Earth System Modeling Framework
ESSIC	Earth System Science Interdisciplinary Center
ESSP	Earth System Science Partnership
ESTEC	European Space Research and Technology Centre
ET	Evapotranspiration
ETH	echo top height
ETH	Eidgenössische Technische Hochschule Zürich
ETH	Zurich: Swiss Federal Institute of Technology in Zurich
EUV	extreme ultra-violet
FAA	Federal Aviation Administration
FAC	Field-Aligned Current
FAO	United Nations Food and Agriculture Organization
fAPAR	Fraction of absorbed PAR
FAS	Foreign Agricultural Service
FAST	Fast Auroral SnapshoT explorer
FEWSNET	Famine Earl Warning Systems Network
FIRE	First ISCCP Regional Experiment
FLS	Forecast Systems Laboratory
FMF	(aerosol) Fine-mode Fraction (in optical sense)

Acronym/Abbreviation	Expansion/Definition
FMI	Finnish Meteorological Institute
FOV	field of view
FPI	Fabry-Perot interferometry
FSU	Florida State University.
FTE	Flux Transfer Event
Fv/Fm	Variable fluorescence
fvGCM	finite volume General Circulation Model
FVGSI	Finite-Volume Grid-point Statistical Interpolation
GAPP	GEWEX Americas Prediction Project
GARP	Global Atmospheric Research Program.
GC	Gas Chromatograph
GCE	Goddard Cumulus Ensemble
GCM	General Circulation Model
GC-QMS	Gas Chromatographic Quadrupole Mass Spectrometry
GDAS	Global Data Assimilation System
GEIS	Global Emerging Infections System
GEO	Group on Earth Observations
GEOS DAS	Goddard Earth Observing System Data Assimilation System
GEOS	Goddard Earth Observing System
GEOS-4	Goddard Earth Observing System Model, version 4
GEOS-5	Goddard Earth Observing System Model, version 5
GEOS-Chem	Goddard Earth Observing System - Chemistry
GEOSS	Global Earth Observation System of System of Systems
GES	NASA's GSFC Earth Sciences
GEST	Goddard Earth Sciences & Technology Center
GEWEX	Global Energy and Water Cycle Experiment
GFDL	Geophysical Fluid Dynamics Laboratory
GFED	Global Fire Emission Dataset
GFS	Global Forecast System
GHGs	Greenhouse Gases
GHP	GEWEX Hydrometeorology Panel
GIC	Geomagnetically Induced Current
GLA	Goddard Laboratory for Atmospheres
GLAS	Geoscience Laser Altimeter System
GLDAS	Global Land Data Assimilation System
GLRON	Great Lakes Region Ozonesonde Network
GMAO	Global Modeling and Assimilation Office
GMI	Global Modeling Initiative
GOCART	Goddard Global Ozone Chemistry Aerosol Radiation and Transport
GOCE	Gravity and steady-state Ocean Circulation Explorer
GOES	Geostationary Operational Environmental Satellite
GOME	Global Ozone Monitoring Experiment
GPM	Global Precipitation Measurement (Mission)

Acronym/Abbreviation	Expansion/Definition
GRACE	Gravity Recovery and Climate Experiment
GSFC	Goddard Space Flight Center
GSSTF	Goddard Satellite-based Surface Turbulent Fluxes
GSSTF1	Goddard Satellite-based Surface Turbulent Fluxes, Version 1
GWSP	Global Water System Project
HALOE	Halogen Occultation Experiment
HAO	High Altitude Observatory
HAP	Hydrologic Applications Project
HIRDLS	High Resolution Dynamics Limb Sounder
HMI	Heliosesimic Magnetic Imager
HPLC	High performance liquid chromatography
HSB	Hydrological Sciences Branch
HTAP	Hemispheric Transport of Atmospheric Pollutants
HUT	Helsinki University of Technology
HYCOM	Hybrid Coordinate Ocean Model
IAHS	International Association of Hydrological Sciences
ICAP-3	Intercontinental transport and Climatic effects of Air Pollutants – phase 3
ICESat	Ice, Cloud, and Land Elevation Satellite
ICs	Initial Conditions
ICSU	International Council of Scientific Unions
IDL	Interactive Data Language
IDS	Interdisciplinary Science
IEEE	Institute of Electrical and Electronics Engineers
IFM	Ionosphere Forecast Model
IGAC	International Global Atmospheric Chemistry
IGBP	International Geosphere-Biosphere Programme
IGFA	International Group of Funding Agencies
IGOS	Integrated Global Observing Strategy
IGOS-P	Integrated Global Observing Strategy – Partners
IGPB	International Geosphere Biosphere Program
IGWCO	Integrated Global Water Cycle Observations
IHOP	International H2O Program
iLEAPS	International Land Ecosystem-Atmospheric Processes Study
ILWS	International Living With a Star
IMAGE	Imager for Magnetopause - to - Aurora Global Exploration
IMF	interplanetary magnetic field
IMP-8	Interplanetary Monitoring Platform – 8
INMS	Ions and Neutrals Mass Spectrometer
INR	Interference to Noise Ratio
INTEX	Intercontinental Chemical Transport Experiment
INTEX-A	Intercontinental Transport Experiment A
INTEX-B	Intercontinental Transport Experiment B
INTEX-NA	Intercontinental Transport Experiment – North America

Acronym/Abbreviation	Expansion/Definition
IOC	International Oceanographic Commission
IONS	INTEX Ozonesonde Network Study
IOP	Intensive Observation Period
IPA	Intergovernmental Personnel Act
IPCC	Intergovermental Panel on Climate Change
IRI	International Research Institute for Climate and Society
ISAES	International Symposium on Antarctic Earth Sciences
ISAMS	Improved Stratospheric and Mesospheric Sounder
ISCCP	International Satellite Cloud Climatology Project
ISIS	International Satellites for Ionospheric Studies
IT	Information Technology
ITCZ	Intertropical Convergence Zone
IUGG	International Union of Geodesy and Geophysics
JAL	Japan Air Line
JAS	Journal of the Atmospheric Sciences
JAXA	Japan Aerospace Exploration Agency
JCET	Joint Center for Earth Systems Technology
JCSDA	Joint Center for Satellite Data Assimilation
JPL	Jet Propulsion Laboratory
JPS	Joint Planning Staff (for WCRP)
JSC	WMO/ICSU/IOC Joint Scientific Committee (for WCRP)
KC	Kilometric Continuum
KF	Kain-Fritch
KNMI	Royal Netherlands Meteorological Institute
KOMSAT	KOrean Multi-purpose Satellite
LAI	Leaf area index
LAS	Live Access Server
LDAS	Land Data Assimilation System
LF	Linear Fit
LIDAR	Laser Imaging Detection and Ranging
LIS	Land Information System
LISGCE	Land Information System coupled to the Goddard Cumulus Ensemble model
LIS-R	Land Information System, with hydrologic and hydraulic Routing capability
LISWRF	Land Information System coupled to the Weather Research and Forecasting model
LLBL	Low Latitude Boundary Layer.
LMCT	linear mode conversion theory
LS	lower stratosphere
LSE	Laser-stimulated emission
LSM	Land Surface Model(ing)
LST	Land Surface Temperature
LT/BL	Lower Troposphere/ Boundary Layer

Acronym/Abbreviation	Expansion/Definition
MAB	Mid-Atlantic Bight
MAIAC	Multi-Angle Implementation of Atmospheric Correction
MAP	Modeling, Analysis and Prediction
MAX-DOAS	Multi-Angle Differential Optical Absorption Spectroscopy
MCMC	Markov Chain Monte Carlo
MDI	Michelson Doppler Imager
MEMLS	Microwave Emission Model of Layered Snowpacks
MERRA	Modern Era Retrospective-analysis for Research and Applications
MF4	Magnetic Field model ver. 4
MHD	Magnetohydrodynamic
MI	Microwave Imager
MISR	Multi-angle Imaging SpectroRadiometer
MIT	Massachusetts Institute of Technology
MJO	Madden-Julian Oscillation
MLS	Microwave Limb Sounder
MM5	The fifth generation of Pennsylvania State University-National Center for Atmospheric Research (PSU-NCAR) Mesoscale Model
MMCR	Millimeter wave cloud radar
MMF	Multi-Scale Modeling Framework
MODIS	Moderate Resolution Imaging Spectro-Radiometer, deployed on both Terra and Aqua satellites
MOI	Molniya Orbit Imager
MOM	Modular Ocean Model
MOM4	Modular Ocean Model Version 4
MOZAIC	Measurement of Ozone and water vapour by Airbus in-service aircraft
MPI	Message Passing Interface
MPLNET	Micro-pulse Lidar Network
MPMD	multiple programs multiple data
MSFC	Marshall Space Flight Center
MSG	Meteosat Second Generation
MSL	Mars Science Laboratory
MTBSTFA	N-tert.-butyldimethylsilyl-N-methyl-trifluoroacetamide
NAAQS	National Ambient Air Quality Standard
NAM	North American Mesoscale
NAMMA	NASA African Monsoon Multidisciplinary Analysis
NARR	North American Regional Reanalysis
NAS	NASA Ames Reserch Center
NASA	National Aeronautics and Space Administration
NAT	nitric acid trihydrate
NCAR	National Center for Atmospheric Research
NCCS	NASA Center for Computational Science
NCEP	National Centers for Environmental Prediction

Acronym/Abbreviation	Expansion/Definition
NCFR	Narrow cold front rain band
NDACC	Network for the Detection of Atmospheric Composition Change
NDVI	Normalized Difference Vegetation Index
Ne	Electron Density
NEESPI	Northern Eurasian Earth Science Partnership Initiative
NESDIS	National Environmental Satellite, Data, and Information Service
NEWS	NASA Energy and Water Cycle Study
NGIMS	Neutral Gas and Ion Mass Spectrometer
NIA	National Institute of Aerospace
NIP	New Investigators Program
NOAA	National Oceanic and Atmospheric Administration
NOAA/SEC:	National Oceanic and Air Administration/Space Environment Center
NOAH	National Centers for Environmental Prediction (NCEP), Oregon State University (Dept of Atmospheric Sciences), Air Force (both AFWA and AFRL - formerly AFGL, PL), Hydrologic Research Lab - NWS (now Office of Hydrologic Dev -- OHD)
NOBM	NASA Ocean Biogeochemical Model
NP	Normalized Polarization
NPOESS	National Polar-orbiting Operational Environmental Satellite System
VIIRS	Visible/Infrared Imaging Radiometer Suite
NRA	NASA Research Announcement
NRCS	Natural Resources Conservation Services
NRL	Naval Research Laboratory
NSCAT	NASA Scatterometer
NSIPP	NASA’s Seasonal-to-Interannual Prediction Project
NSIT	NEWS Science Integration Team
NSO	National Solar Observatory
NSSL	National Severe Storms Laboratory
NTC	non-thermal continuum
NWP	Numerical Weather Prediction
NWS	National Weather Service
NWSRFS	NOAA National Weather Service, the River Forecast System
O3	ozone
OAP	off axis parabolic
OB	ocean biogeochemical
OCO	Orbiting Carbon Observatory
ODAS	ocean data assimilation system
ODASI	Consortium for Ocean Data Assimilation Consortium for Seasonal-to-Interannual Prediction
ODS	Observational Data System
O-F	observed-minus-forecast
OGCM	Ocean General Circulation Model
OHD	Office of Hydrologic Development

Acronym/Abbreviation	Expansion/Definition
OLR	outgoing longwave radiation
OMI	Ozone Monitoring Instrument
OOODS	Objectively Optimized Observation Direction System
OPAL	Optical Properties Analysis Laboratory
OPeNDAP	Open-source Project for a Network Data Access Protocol
OPF	Operational Parameter File
OSSE	Observing System Simulation Experiments
PAL	Passive Active L-band
PAR	photo-synthetically-active radiation
PAVE	Polar AURA Validation Experiment
PBL	Planetary Boundary Layer
PBP	Phycobiliprotein
PC	Phycocianin
PCT	Polarization Corrected Temperature (PCT)
PDAF	Parallel Data Assimilation Framework
PDE	Partial Differential Equation
PDF	probability density function
PDL	Plasma Depletion Layer
PDP	Pump-during-probe
PECAD	Production Estimation and Crop Assessment Division
PGE	Product Generation Executive
PI	Principal Investigator
PID	Particle Impact Detector
pk	pseudo-kurtosis
PMM	Precipitation measurement missions
PNNL	Pacific Northwest National Laboratory
POAM	Polar Ozone and Aerosol Measurement
POGO	Polar Orbiting Geophysical Observatory
POLDER	Polarization and Directionality of the Earth's Reflectance
PR	Precipitation Radar
PSC	polar stratospheric cloud
PSD	particle size distribution
PSR	Polarimetric Scanning Radiometer
QA	Quality Assessment
QBO	quasibiennial oscillation
QBO:	Quasibiennial Oscillation
QG:	Quasi-Geostrophic
QMS	Quadrupole Mass Spectrometer
QSCAT	Quikscat (a microwave scatterometer)
QuikSCAT	The "Quick Recovery" Mission to Fill the Gap Created by the Loss of Data from NSCAT
RadSTAR	radar-STAR (Synthetic Thinned Array Radiometer)
RETRO	Reanalysis of the Tropospheric chemical composition over the past 40 years

Acronym/Abbreviation	Expansion/Definition
RFI	Radio Frequency Interference
ROSES	Research Opportunities in Space and Earth Sciences
RPI	Radio Plasma Imager
SAC	Science Advisory Committee
SAG	Scientific Advisory Group
SAIC	Science Application International Corporation
SAM	Sample Analysis at Mars
SAP	Superactive-Active-Passive
SAR	Synthetic Aperture Radar
SAUNA	Sodakyla Total Ozone Column Intercomparison
SCA	Snow cover area
SCD	Slant Column Density
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (one of the payload instruments on board the ESA Envisat satellite)
SCM	Single Column Model
SCO	stratospheric column ozone
SCOSTEP	Scientific Committee on Solar-Terrestrial Physics
SCSMEX	South China Sea Monsoon Experiment
SDC	Spectral deconvolution
SDO	Solar Dynamics Observatory
SeaBASS	SeaWiFS Bio-Optical Archive and Storage System
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SEIK	Singular Evolutive Interpolated Kalman
SEM	Solar EUV Monitor
SEVIRI	Spinning Enhanced Visible and Infrared Imager
SFT	Strong Fluctuation Theory
SGI	Silicon Graphics Inc.
SGP	Southern Great Plains
SGT	Stinger Ghaffarian Technologies
SI	Scattering Index
SIM	Solar Irradiance Monitor
SIMION	Simulator for Ion and Electron Optics
SIO	Scripps Institution of Oceanography
SIPS	Science Investigator-led Processing System
SIR	Shuttle Imaging Radar
SIRICE	Submillimeter and Infra-Red Ice Cloud Experiment
SIVO	Software Integration and Visualization Office
SMMR	Scanning Multichannel Microwave Radiometer
SNOTEL	SNOwpack TELemetry
SNTHERM	SNow THERMal (“Temperature”) Model
SNU	Seoul National University
SO	Southern Ocean
SO_2	Sulfur dioxide

Acronym/Abbreviation	Expansion/Definition
SOHO	Solar and Heliophysical Observatory's
SORCE	Solar Radiation and Climate Experiment
SPARC	Stratospheric Processes and their role in Climate
SPASE	Space Physics Archive Search and Extract
SPOT	Systeme Probatoire pour l'Observation de la Terre
SRT	Sounder Research Team
SSAI	Science Systems and Applications, Inc.
SSAV	Space Science Analysis and Visualization
SSF	single scanner footprint
SSG	Scientific Steering Group
SSI	Streamline Subgrid Integration
SSiB	Simplified Version of the Simple Biosphere Model
SSM/I	Special Sensor Microwave / Imager
SSS	sea surface salinity
SST	sea surface temperature
ST5	Space Technology 5
START	SysTem for Analysis, Research, and Training
STE	stratosphere-troposphere exchange
STS	supercooled ternary solution
SV	singular vector
SWARM	Solar Warning And Real time Monitoring
SWE	snow water equivalent
TC4	Tropical Composition, Cloud, and Climate Coupling Experiment
TCO	tropospheric column ozone
TCSP	Tropical Cloud Systems and Processes
TES	Tropospheric Emission Spectrometer
TIM	Total Irradiance Monitor
TIROS	Television and Infrared Observation Satellite.
TLS	Tunable Laser Spectrometer
TMI	TRMM Microwave Imager
TOGA	Tropical Ocean Global Atmosphere
TOMS	Total Ozone Mapping Spectrometer
TOVS	TIROS Operational Vertical Sounder;
TRMM	Tropical Rainfall Measuring Mission
TST	troposphere-to-stratosphere transport
TTL	tropical tropopause layer
UARS:	Upper Atmospheric Research Satellite
UC	University of California
UCLA	University of California at Los Angeles
UIBK	University of Innsbruck
UIC	User Interface Committee (Group on Earth Observations)
UMBC	University of Maryland, Baltimore County
UMCP	University of Maryland, College Park
UMTMR	University of Michigan's Truck-Mounted Radiometer System

Acronym/Abbreviation	Expansion/Definition
UNESCO	United Nations Educational Scientific and Cultural Organization
USACE	United States Army Corps of Engineers
USAID	United States Agency for International Development
USAMC	United States Army Medical Command
USAMRU	United States Army Medical Research Unit
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USGCRP	United States Global Change Research Program
USRA	Universities Space Research Association
UT	upper troposphere
UTC	Universal Time Coordinate
UV	ultraviolet
VAM	Variational Analysis Method
VCD	Vertical Column Density
VF	Video Frequency
VHO	Virtual Heliospheric Observatory
VIC	Variable Infiltration Capacity
VIIRS	Visible and Infrared Radiometer Suite
VIRGO	Variability Irradiance and Gravity Oscillations
VIRS	Visible and Infrared Sensor
VIS	Visible Imaging System
VMO	Virtual Magnetospheric Observatory
VxO	Virutal Observatory
WAVES	Water Vapor Validation Experiments
WCRP	World Climate Research Programme
WDMAM	World Digital Magnetic Anomaly Map
WMO	World Meteorological Organization
WOAP	WCRP Observation and Assimilation Panel
WRAIR	Walter Reed Army Institute for Research
WRC	World Radiation Center
WRF	Weather Research and Forecasting model
WSAT	WindSat polarimetric microwave radiometer
XML	Extensible Markup Language

This page intentionally left blank

Index of Researchers

AFWA
Eylander, John, 43, 213, 216
Baron
Burnet, Tom, 216
Coats, Carlie, 216
Condrey, Jerry, 216
McHenry, John, 216
Beijing Climate Center
Yan, Yuping, 235
Bureau of Meteorology, Melbourne
Jakob, Christian, 235
CCSPO
Schultz, Peter, 114
CIRES, NOAA/ETL
Persson, P. Ola. G., 79
City Univ. of NY
Rossow, William, 235
CLIVAR
Cattle, Howard, 235
COLA
Manganello, Julia, 44
COLA/GMU
Schopf, Paul, 44
Columbia Univ.
Bellon, Gilles, 27
Sobel, Adam, 27
CONAE
Medico, Anna, 235
Coordinated Enhancing Observing Period
Benedict, Sam, 235
CSU
Kummerow, Chris, 89
Dartmouth College
Denton, Richard, 183
DoD/WRAIR-GEIS
Chretien, Lt. Jean-Paul, 141
DOI/USBR
Hunter, Steven, 207
Sharp, Warren, 207
EAWAG, Switzerland
Beer, Juerg, 246
EPA
Schwede, Donna, 227
ERT
Novakovskaia, Elena, 33
ESSIC
Chen, Junye, 63
Ichoku, Charles, 115
Santanello, Joseph, 216
Shen, Bo-Wen, 74
Euopean Space Agency
van Oevelen, Peter, 235
European Space Agency
Herland, Arne, 235
Finnish Meteorological Institute, Finland
Pirjola, Risto, 178
Viljanen, Ari, 178
Franklin Institute
Elinich, Karen, 199
GEO Secretariat
Herlevi, Antti, 235
George Mason Univ.
Houser, Paul, 41, 207
Murphy, R., 150
Yang, Song, 81
GEST
Anderson, Tad, **245**
Anyamba, Assaf, **141**
Arsenault, Kristi, **207**
Bacmeister, Julio, **27**
Bekerat, Hamed, **169**
Belcher, Larry, **71**, 72, 83, 93
Bell, Benita, **191**
Benna, Mehdi, **170**
Benson, Craig, **28**
Berkoff, Timothy, 71, **72**
Bian, Huisheng, **109**, 115
Boardsen, Scott, **171**, 181
Bojkov, Bojan, **111**, 126
Bucsela, Eric, **112**, 130
Chandra, Sushil, **134**
Chang, Yehui, **30**
Chekalyuk, Alexander, **209**
Chern, Jiun-Dar, **74**
Chu, D. Allen, 92, **143**
Colarco, Amelia, **31**
Cook, Laurie, **193**, **197**
Curran, Robert, **114**
de Matthaeis, Paolo, 35, **211**
Delaney, Marcianna, **195**, **196**
Diehl, Thomas, **115**
Dinnat, Emmanuel, 35
Dong, Jiarui, **213**
Duncan, Bryan, 115, **117**, 128, 133
Eastman, Joseph, **215**
Eck, Thomas, **144**, 245
Errico, Ronald, **33**, 34
Fedele, Francesco, 33, **34**
Freeberg, Andrew, **198**
Garcia, Matthew, 43, **216**
Gassó, Santiago, **118**
Gatebe, Charles, **146**
Georgieva, Elena, **148**
Grecu, Mircea, **76**
Gu, Guojun, **78**, 94
Guenther, Bruce, **150**

Han, Mei, **79**
Hoban, Susan, **193**, **194**, **195**, **196**, **197**, 199
Hong, Yang, **80**
Jacob, S. Daniel, **35**
Joseph, Jeffrey, **151**
Jusem, Juan Carlos, **51**
Kim, Hyung Rae, **152**
Kim, Kyu-Myong, 38, **154**
Koratkar, Anuradha, **197**
Krotkov, Nickolay, **120**, 131
Kucsera, Tom, 115
Kumar, Sujay, **37**, 213, 216
Kuo, Kwo-Sen, **81**
Lait, Leslie, **123**
Lary, David, **125**
Laughlin, Daniel, **193**, **195**
Lawford, Richard, **235**
Lee, Myong-In, **38**
Li, Lihua, 71, **83**, 93
Li, Xiaowen, **85**, 89
Liao, Liang, **86**
Lin, Ruei-Fong, **88**
Lin, Xin, **40**, 74
Lyapustin, Alexei, **155**, 160
Mahanama, Sarith, 27, **52**, 220
Matsui, Toshihisa, **89**
Meng, Jesse, **41**
Merka, Jan, **173**, 175
Misztal, Stefanie, **198**
Mohammed, Priscilla, **218**
Molnar, Gyula, **54**
Morris, Gary, **126**
Muscheler, Raimund, **246**
Nakagawa, Katsuhiro, **90**
Narock, Thomas, 173, **175**
Nerger, Lars, **55**
Norris, Peter, **57**
Olsen, Mark, **127**
Pap, Judit, **176**
Pulkkinen, Antti, **178**
Reale, Oreste, 51, **58**
Reichle, Rolf, 41, 213, **220**
Riishojgaard, Lars Peter, 28, **60**
Russ, Mary, **222**
Schiffer, Robert, **224**, 235
Schulz, Michael, **248**
Shie, Chung-Lin, **92**
Smirnov, Alexander, 115, **157**
Stoyanova, Silvia, **198**
Strahan, Susan, 117, **128**
Stroud, David, 198, **199**
Stubbs, Timothy, **179**
Sun, Chaojiao, **62**
Tedesco, Marco, **225**
ten Kate, Inge L., **159**
Tian, Lin, 71, 83, **93**
Tian, Yudong, **43**, 216
Unninayar, Sushel, **200**
Vikhliaev, Yury, **44**
Wang, Hailan, **63**
Wang, Jian-Jian, **94**
Wang, Yongli, **181**
Wang, Yujie, 155, **160**
Weaver, Clark, **130**
Webb, Phillip, **183**
Wen, Guoyong, **96**
Wenig, Mark, **130**
Wu, Liguang, **97**
Wu, Yihua, **227**
Yang, Kai, 120, **131**
Yeh, Kevin, **65**
Yoshida, Yasuko, **133**
Yu, Hongbin, **162**
Yurchak, Boris, **228**
Zeng, Xiping, **99**
Zenitani, Seiji, **185**
Zhang, Qingyuan, **249**
Zhao, Yunhe, **230**
Zhou, Yaping, **100**
Ziemke, Jerry, **134**
GFDL
Donner, Leo J., 100
Ghent Univ., Belgium
De Lannoy, Gabrielle, 220
Global Science and Technology
Keating, Shane, 196
Global Water System Project
Gates, Lydia, 235
GSFC WFF
Gerlach, John, 209
GSFC, Code 130.0
Gabrys, Robert, 195, 196, 197, 199
Sisler, Wade, 198, 199
GSFC, Code 400
Caffrey, Robert, 176
GSFC, Code 550.0
Heaps, William, 148
GSFC, Code 554.0
Wilson, Emily, 148
GSFC, Code 555
Knuble, Joseph, 218
Piepmeier, Jeffrey, 218
GSFC, Code 587.0
Geiger, James, 216
Jones, Joycelyn Thomas, 199
Marshak, Jelena, 44
GSFC, Code 610.0
King, Michael, 146
Pawson, Steven, 28
Schoeberl, Mark, 111, 123, 125, 126, 127
Simpson, Joanne, 99
GSFC, Code 610.1

Cohn, Steven, 34
da Silva, Arlindo, 31, 130
Gelaro, Ronald, 33
Gregg, Watson, 55
Hou, Arthur, 40, 57, 92, 100
Koster, Randal, 52, 213, 220
Rienecker, Michele, 44, 52, 60, 62, 220
Schubert, Siegfried, 27, 30, 38, 63
Suarez, Max, 27, 38, 44, 52, 63
GSFC, Code 610.2
Olsen, Lola, 200
GSFC, Code 610.3
Clune, Tom, 123
Seablom, Michael, 65
GSFC, Code 613.0
Bell, Thomas, 38
Lau, William, 38, 51, 58, 89, 100, 154
GSFC, Code 613.1
Adler, Robert, 76, 78, 80, 94
Braun, Scott, 79, 92, 97
Demoz, Belay, 111
Heymsfield, Gerald, 71, 83, 93
Shi, Roger, 89
Smith, Eric, 81
Spinhirne, James, 72
Starr, David O'C., 88
Tao, Wei-Kuo, 74, 85, 89, 92, 99, 100
Welton, Ellsworth, 71, 72
Whiteman, David, 111
GSFC, Code 613.2
Cahalan, Robert F, 96
Marshak, Alexander, 96
Remer, Lorraine, 130, 143, 162, 248
Sud, Yogesh, 100
Tsay, Si-Chee, 72, 118
GSFC, Code 613.3
Bhartia, P. K., 111, 112, 120, 126, 134
Celarier, Edward, 112
Chin, Mian, 89, 109, 115, 162, 248
Colarco, Peter, 31, 115
Douglass, Anne, 125, 127, 128
Gleason, James, 112, 130
Herman, Jay, 111, 120
Joiner, Joanna, 134
Kawa, Randy, 28, 109, 130
McGee, T. J., 111
McPeters, R. D., 111
Newman, Paul, 123
Pickering, Kenneth, 112
Rodriguez, Jose, 117, 128
Stolarski, Richard, 125, 127
Wenig, Mark, 112
GSFC, Code 614.0
Middleton, Elizabeth, 249
Tucker, Compton, 141
GSFC, Code 614.1
Abdalati, Waleed, 228
GSFC, Code 614.2
Liu, Antony, 230
GSFC, Code 614.3
Esaias, W., 150
Peters-Lidard, Christa, 37, 41, 43, 74, 213, 215, 216, 227
Rodell, Matt, 41, 220
Toll, David, 207, 213
GSFC, Code 614.4
Butler, James, 146, 150
Holben, Brent, 115, 130, 144, 157, 245
Xiong, X., 150
GSFC, Code 614.6
Gerlach, John, 94
Kim, Ed, 225
Le Vine, David, 35, 211
Markus, Thorsten, 225
Meneghini, Robert, 86, 90
Wang, James, 225
GSFC, Code 614.7
Mannino, Antonio, 222
GSFC, Code 614.8
Hooker, Stanford, 222
GSFC, Code 670
Slavin, James, 171, 181, 183
GSFC, Code 671
Pesnell, Dean, 176
Rabin, Douglas, 176
GSFC, Code 672
Szabo, Adam, 173, 175, 176
GSFC, Code 672.0
Lal, Nand, 194
GSFC, Code 673
Benson, Robert, 183
Collier, Michael, 179
Goldstein, Melvyn, 179
GSFC, Code 674
Goldberg, Richard, 183
Hesse, Michael, 178, 185
Kuznetsova, Maria, 178
Le, Guan, 181
Pfaff, Robert, 179
Rastätter, Lutz, 178
Sigwarth, John, 169
GSFC, Code 690
Vondrak, Richard, 179
GSFC, Code 690.1
Grayzeck, Ed, 194
GSFC, Code 695
Farrell, William, 179
Grebowsky, Joseph, 183
GSFC, Code 698.0
Taylor, Patrick, 152
GSFC, Code 699
Mahaffy, Paul, 151, 159, 170

GSFC, Code 913
Remer, Lorraine, 245
Harvard Univ.
Boersma, Folkert, 112
iLEAPS
Reissell, Anni, 235
International Association of Hydrological Sciences
Askew, Arthur, 235
International Geospher-Biospher Programme
Kabat, Pavel, 235
Iowa State Univ.
Gallus, Jr., William, 127
Japanese Aerospace and Exploration Agency
Ishida, Chu, 235
JCET
Carn, Simon, 120, 131
Hall, Forrest, 249
Halverson, Jeffrey, 199
Huemmrich, Karl, 249
Krueger, Arlin, 120, 131
Mehta, Amita, 81
Olson, William, 79, 92
Oreopoulos, Lazaros, 96
Tokay, Ali, 94
Torres, Omar, 118
Varnai, Tamas, 96
JPL
Froidevaux, Lucien, 134
Fukumori, Ichiro, 62
Kent State Univ.
Lee, Shanhu, 123
KNMI
Brinksma, Ellen, 112
Veefkind, Pepjin, 112
Laboratoire de Météorologie Dynamique du CNRS
Polcher, Jan, 235
LARC
Hu, Yongxiang, 100
LASP, Univ. of Colorado
Fontenla, Juan, 96
Woods, Thomas, 96
Matthews, David, 207
McGill Univ.
Stewart, Ronald, 235
McMurry Univ.
Keith, Wayne, 179
MIT
Entekhabi, Dara, 220
Nagoya Univ.
Miyahara, Hiroko, 96
NASA Ames Research Center
Cooper, George, 191
NASA HQ
Entin, Jared, 235
Green, James, 171, 183
Kaye, Jack, 114
NASA JSC
Shelton, Robert, 193
NASA/MSFC
Robertson, F., 27
National Climate Data Center
Groisman, Pavel, 235
NCAR
Ammann, Caspar, 246
Beres-Richter, Jadwiga, 27
Gochis, David, 216
Matthes, Katja, 246
Rasch, Philip, 100
Tie, Xuexi, 134
Yates, David, 216
NCEP
Behringer, David, 62
Masutani, Michiko, 33
Wang, Jiande, 62
NICT
Iguchi, Toshio, 90
Shusse, Yukari, 90
NOAA
Huang, Jin, 235
Lin, Jia-Lin, 27, 38
Mitchell, Ken, 41
St. Germain, K., 150
Stein, Ariel, 118
NOAA ERSL
Hoerling, Martin, 63
NOAA NCEP
Kumar, Arun, 63
NOAA/ETL
Bao, Jian-Wen, 79
Northrop Grumman Space Technologies
McCarthy, James, 150
NRL/Washington
Eckermann, Stephen, 27
Princeton Univ.
Wood, Eric, 235
Purdue Univ.
Petrenko, Mariya, 115
RSIS
Abraham, Saji, 35
SAIC
Bilanow, Steve, 81
Blaisdell, John, 54
Brubaker, Nicole, 28
Chen, Baode, 27
Engman, Edwin, 207
Iredell, Lena, 54
Keita, Fricky, 54
Liu, Hui-Chun, 28
Mocko, David, 216
Stajner, Ivanka, 28
Susskind, Joel, 54
Takacs, Lawrence, 27

Tassone, Caterina, 27
Todling, Ricardo, 33
Trayanov, Atanas, 27, 44
Zeng, Jing, 43, 216
Science and Technology Corporation
Try, Paul, 235
Scripps Institute of Oceanography
Roads, John, 235
SGT
Celarier, Edward, 130
SNU
Kang, In-Sik, 38
Southwest Research Institute
Goldstein, Jerry, 183
SSAI
Campbell, James, 72
Giles, David, 115
Huffman, George, 80
Nielsen, J. Eric, 28
Ouaidrai, H., 150
Stewart, Sebastian, 71, 72
Valencia, Sandra, 72
Yang, Runhua, 33
STINT, Taiwan
Hsu, Ming-Kuang, 230
Tennessee State Univ.
Smith, Willard, 197
Texas A&M Univ.
Carey, Lawrence, 94
UC Berkeley
Bertram, Tim, 112
Carlson, Charles, 179
Cohen, Ron, 112
Delory, Gregory, 179
Halekas, Jasper, 179
McFadden, James, 179
Perring, Anne, 112
Wooldridge, Paul, 112
UCLA
Ghil, Michael, 62
Kondrashove, Dmitri, 62
UMBC
Sparling, Lynn, 125
Spence, Anne, 197
Zongker, Shirley, 197
UNESCO
Aureli, Alice, 235
Lipponen, Annukka, 235
Univ. Innsbruck
Ehrendorfer, Martin, 33
Univ. of Arizona
Eden, Susanna, 235
Univ. of Berkely
Miller, Norman, 235
Univ. of Berne, Switzerland
Joos, Fortunat, 246
Univ. of Bonn
Zolina, Olga, 235
Univ. of California, Irvine
Sorooshian, Soroosh, 235
Univ. of Chicago
Srivastava, R.C., 93
Univ. of Copenhagen, Denmark
Fensholt, Rasmus, 141
Univ. of Lund, Sweden
Snowball, Ian, 246
Univ. of Maryland
Carty, Hezekiah, 81
Justice, Christopher, 141
Zaitchik, Ben, 220
Univ. of New Hampshire
Vorosmarty, Charles, 235
Univ. of Puerto Rico
Linares, Nicolas, 193
Univ. of San Diego
Omidi, Nick, 171
Univ. of Saskatchewan
Pomeroy, John, 235
Univ. of Tokyo
Koike, Toshio, 235
Univ. of Washington
Lettenmaier, Dennis, 235
Université Laval, Canada
Drolet, Guillaume, 249
Margolis, Hank, 249
USAMRU
Richardson, Maj. Jason, 141
USDA
Crow, Wade, 220
Kustas, Bill, 235
Linthicum, Kenneth, 141
USDA/FAS
Doorn, 141
Reynolds, Curt, 141
WMO/GCOS Secretariat
Sommeria, Gilles, 235
World Climate Research Programme
Ryabinin, Vladimir, 235
Sellers, Ann Henderson, 235
World Meteorological Organization
Grabs, Wolfgang, 235
Tyagi, Avinash, 235