The Goddard Earth Sciences and Technology Center

Final Report

May 11, 2010 - May 10, 2011

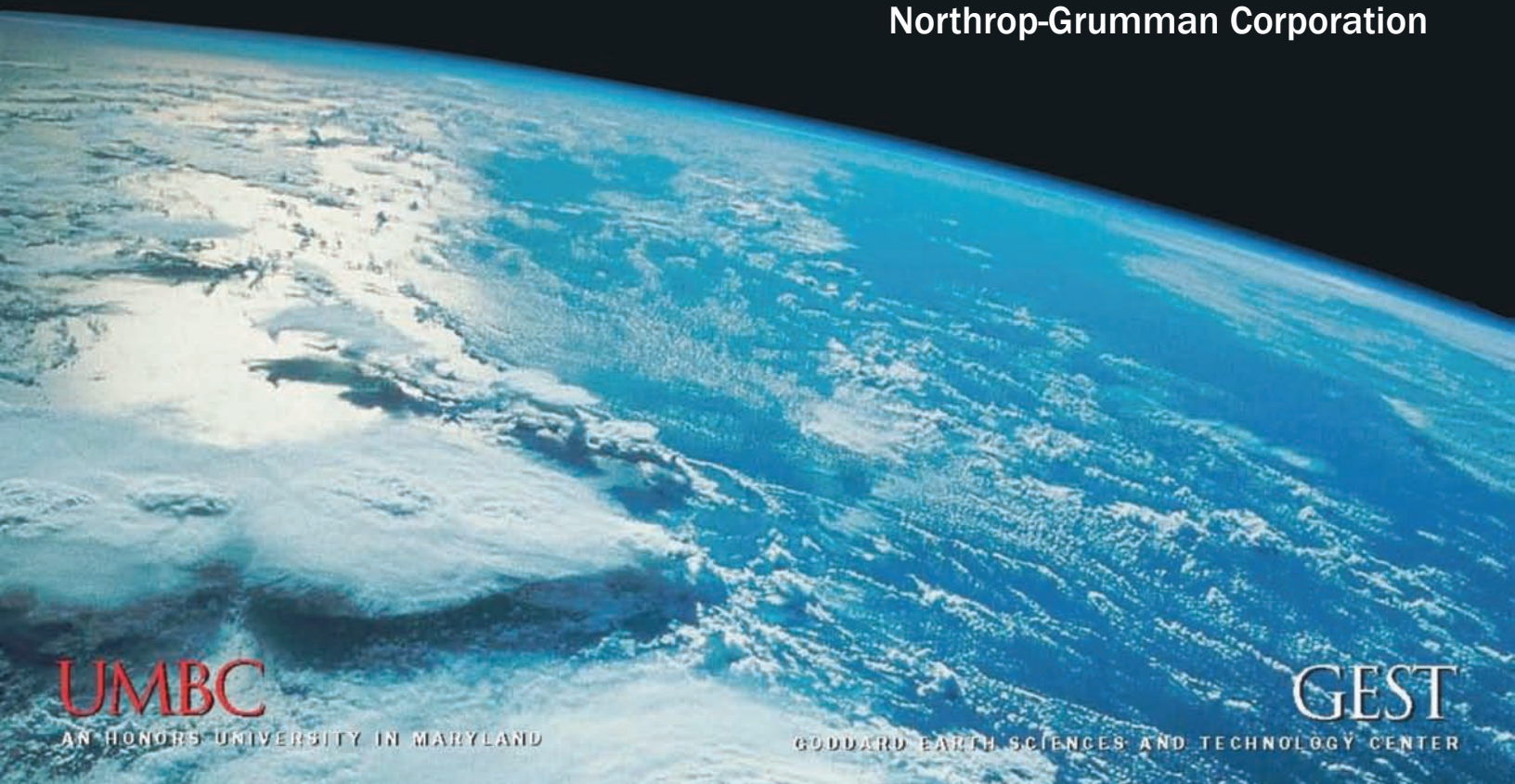
University of Maryland, Baltimore County

Howard University

Hampton University

Caelum Research Corporation

Northrop-Grumman Corporation



Goddard Earth Sciences and Technology Center (GEST)

Final Report

10 May 2011

This page intentionally left blank

TABLE OF CONTENTS

TABLE OF CONTENTS iii

FINAL REPORT SUMMARY 15

Office of the Director and AETD (Code 100-500) 19

GSFC Earth Science and Education Multimedia and Visualization Production 21

Jefferson Beck, Ryan Fitzgibbons, Matthew Radcliff, Brooke Harris, Katherine Lewis, Robert Garner, Silvia Stoyanova, Ernest Wright, Trent Schindler, Scott Wiessinger, Genna Duberstein, Michael Lentz, Helen-Nicole Kostis, Neema Mostafavi, Jennifer Shoemaker, Michelle Williams, and Laura Motel 21

Strengthening Astrobiology Research and Education Strategic Alliances Among Minority Institutions 22

Benita Bell 22

Learning Technologies 23

Marcianna Delaney, Susan Hoban, and Daniel Laughlin 23

Educator Interns 23

Marcianna Delaney and Susan Hoban 23

NASA's Best Students (Beginning Engineering, Science and Technology) 24

Marcianna Delaney, Susan Hoban and staff: Laurie Cook and Michelle Graf (consultant) 24

Development of Active and Passive Sensors for Remote Sensing Applications 25

Elena Georgieva 25

Planetary Data Systems 26

Susan Hoban 26

L1B TB Algorithm Lead for the Soil Moisture Active Passive (SMAP) Mission 26

Priscilla Mohammed 26

Microwave Engineering and Communications 27

Jinzheng Peng 27

Global Climate Change Research: USGCRP - Global/Water Energy Cycle; GEO-UIC/GEOSS; NASA/GEWEX/TRACE 27

Sushel Unninayar 27

Imaging Research Center (IRC) at UMBC, Earth Science Animation 29

Ryan Zuber, Tyler Chase, and Rachel Kreutzinger (all from the IRC at UMBC) 29

Global Modeling and Assimilation Office (Code 610.1) 31
GEOS Model Development for Aerosol-Cloud Interactions 33
Donifan Barahona 33
Simulations of Stratospheric Chemistry and Polar Stratospheric Clouds 33
Craig Benson 33
The Linkages between Extreme Winter Storms and Global Scale Climate Variability 34
Yehui Chang 34
The Linkages between Extreme Winter Storms and Global Scale Climate Variability 35
Amelia Colarco 35
Goddard Earth Observing System Data Assimilation System 35
Gabriëlle De Lannoy 35
Goddard Earth Observing System Data Assimilation System 36
Ronald Errico 36
Development of Initialization Techniques for the GEOS-5 Coupled-Atmosphere Ocean Model 36
Yoo-Geun Ham 36
Satellite Analysis of Fire Radiative Energy Release and Aerosol and Carbon Monoxide Emission Rates 37
R. M. Hoff (Physics Department), Thishan Dharshana (Graduate Student, Physics) 37
Research and Advisory Activities for NDACC, SPARC, IO3C, GCOS, WMO, UNEP, and the NASA/JPL Panel for Data Evaluation 37
Michael J. Kurylo 37
Simulating and Predicting Sub-seasonal and Longer-term Changes in Tropical Storm Characteristics using High-Resolution Climate Models 38
Young-Kwon Lim 38
Global Precipitation Measurement Mission 39
Xin Lin 39
Simulations of the Aerosol Index and Comparisons with OMI Retrievals 40
Virginie Buchard-Marchant 40
Improving Current MODIS cloud retrieval (MOD06) capabilities for thin cirrus optical property retrievals 40
Kerry Meyer 40

Cloud Data Assimilation 41

Peter M. Norris 41

Data Assimilation Office Analysis Group Leadership and Joint Center for Satellite Data Assimilation 41

Lars Peter Riishojgaard 41

Remote Sensing and Public Health 42

Radina Soebiyanto 42

Improving Gravity Wave Parameterization in NASA GEOS-5 GCM 43

In-Sun Song 43

Snow data assimilation into the Modern Era Retrospective-Analysis for Research and Applications (MERRA) 43

Ally Toure 43

Coupled Climate Modeling 44

Yury Vikhliaev 44

On the Nature and Predictability of Interannual to Decadal Changes in the Global Hydrological Cycle and its Regional Impacts 45

Hailan Wang 45

Mesoscale Atmospheric Processes (Code 613.1) 47

The Micro-Pulse Lidar Worldwide Observational Network (MPLNET) 49

Timothy Berkoff 49

Small Portable Lidar for MPLNET 49

Timothy Berkoff 49

Development and Applications of the Goddard Multi-Scale Modeling Framework 50

Jiun-Dar Chern 50

Precipitation Estimation from Satellite Active and Passive Microwave Observations 50

Mircea Grecu 50

Algorithm Development for Space-Borne Dual Frequency Radar 51

Mei Han 51

Algorithm Development for Space-Borne Dual Frequency Radar 52

Raymond Hoff (Physics Dept.), Jamie Compton (Graduate Student, Physics), Ruben Delgado (Faculty Research Asst., JCET) 52

Algorithm Development for Space-Borne Dual Frequency Radar 52

Hyokyung Kim 52

Development of Cloud Thermodynamic Phase Retrievals for MODIS Collection 6 53

Benjamin Marchant 53

Evaluating and improving the representation of cloud microphysical processes and cloud-aerosol-radiation interactions for regional and mesoscale models 53

Jainn J. Shi 53

Study of the Influence of the Saharan Air Layer on Tropical Cyclone Development and Intensity 54

Chung-Lin Shie and Jason Sippel 54

Using Airborne Measurements to Improve Physical Assumptions in DPR and GMI Algorithms 54

Lin Tian 54

Using the Goddard Cloud-Resolving Model (CRM) to Study Aerosol Indirect Effects on Clouds and Precipitation 55

Xiping Zeng and Xiaowen Li 55

Climate and Radiation (Code 613.2) 57

Improve EPA's AIRNow Air Quality Index Maps with NASA Satellite Data 59

D. Allen Chu 59

EOS and NPP Satellite Data Fusion to develop a Long-Term Record on Aerosol Absorption 59

Santiago Gassó 59

Characterization of Surface Bidirectional Reflectance Distribution Function, Aerosols and Clouds from Airborne Radiation Measurements 60

Charles K. Gatebe 60

Aerosol-Climate effects over South Asia 60

Ritesh Gautam 60

Effect of Tropospheric Aerosols on Climate 61

Jingfeng Huang 61

A Cross-Calibrated Multi-Satellite Ocean Surface Wind – Vector Product 61

Juan Carlos Jusem 61

Aerosol-Water Cycle Interaction 62

Kyu-Myong Kim 62

Improvement of GEOS-5 Radiation and Microphysics Parameterizations 62

Dong Min Lee 62

Sounder Research Team (SRT) Activity Support 63

Gyula I. Molnar 63

MISR Aerosol Air Mass Type Mapping over Mega-City – Validation & Applications 63

Falguni Patadia 63

Relationships among precipitation characteristics, atmospheric water cycles, climate variability and change 64

Oreste Reale 64

Simulating and Predicting Sub-seasonal and Longer-term changes in Tropical Storm Characteristics using High Resolution Climate Models 65

Oreste Reale 65

Investigating the impact of atmospheric aerosols on the Earth 65

Andrew Sayer 65

Atmospheric Solar Radiative Transfer 66

Guoyong Wen 66

Use of CALIPSO in understanding the effect of clouds on aerosol properties and interpreting MODIS aerosol observations near clouds 66

Weidong Yang 66

Studies with Observations from the Geoscience Laser Altimeter System (GLAS) for Thick Cloud Optical Depth Retrieval and in Support of the Icesat-2 Mission 67

Yuekui Yang 67

Algorithm Preparation for the Earth Polychromatic Imaging Camera (EPIC) onboard the future Deep Space Climate Observatory (DSCOVR) 68

Yuekui Yang 68

Data analysis and modeling studies of the impacts of absorbing aerosols on snow impurity changes and glacier mass balance in the Himalayas and possible effects on the South Asian monsoon 68

Teppei J. Yasunari 68

Aerosol Impacts on Energy and Hydrology Cycles 69

Yan Zhang 69

Toward infrared remote sensing methods for cloud optical and microphysical properties monitoring: Application to MODIS 69

Zhibo Zhang 69

Relationships Among Precipitation Characteristics, Atmospheric Water Cycle, Climate Variability and Change 70

Yaping Zhou 70

Atmospheric Chemistry and Dynamics (Code 613.3) 71

Development of Small Spectrometer Systems 73

Nader Abuhassan 73

Improvement and Application of multiple Chemical Transport Models (CTMs) in Atmospheric Chemistry study and mission support 73

Huisheng Bian 73

Nitrogen Dioxide Measurements from the Ozone Monitoring Instrument (OMI) 74

Edward A. Celarier 74

Three-Dimensional Modeling of Atmospheric Chemistry and Aerosol Processes 74

Thomas L. Diehl 74

Regional Modeling and Variability analyses in support of GEO-CAPE 75

Melanie Follette-Cook 75

Data Analysis of Satellite Cloud Property Retrievals and Other Parameters from Multiple Satellites 76

Pawan Gupta 76

Aerosol Distribution and Radiative Effect Study Using GOCART Model 77

Dongchul Kim 77

Radiometric Calibration and Development Laboratory and Ground-Based Instrument Development 77

Matthew Kowalewski 77

Modeling and Analysis Scientific Support 78

Tom Kucsera 78

Stratospheric Dynamics and Chemistry 78

Leslie R. Lait 78

Climate Change and the Stratospheric Ozone Layer 79

Feng Li 79

Stratospheric-Troposphere Exchange and its Impact on Atmospheric Ozone 80

Qing Liang 80

Stratosphere-Troposphere Exchange 81
Mark Olsen 81
Aerosol and Chemistry Modeling 81
Xiaohua Pan 81
The Impacts of absorbing aerosols on global and regional climates 82
Cynthia Randles 82
EOS-Aura Instrumentation Validation and Support 82
Christian Retscher 82
Effects of Tropospheric and Stratospheric Composition on Climate 83
Henry Selkirk 83
Balloon Sounding for Aura Validation 84
Henry Selkirk 84
The NASA Global Modeling Initiative (GMI) and Process-oriented Model Evaluation 85
Susan Strahan and Stephen Steenrod 85
Study of Aerosol Variability Using both Observation and Models 86
Qian Tan 86
Integrated Modeling of Aerosol, Cloud, Precipitation and Land Processes at Satellite-Resolved Scales 86
Zhining Tao 86
Assimilation Studies 87
Clark Weaver 87
The Development of Tropospheric Ozone Data Products from Aura OMI/MLS and their Scientific Evaluation 87
Jerry Ziemke 87
Hydrospheric and Biospheric Sciences (Code 614) 89
Studies of Earth's Surface Interannual Variability Using data from Satellites and Distributed Ground Stations 91
Assaf Anyamba 91
ICESat-2 Support 92
Robert Bindschadler 92
Effect of Atmospheric Variations on Snow-Depth-on-Sea-Ice Retrievals 92
Ludovic Brucker 92

ICESat-2 Support and Deployment of MABEL 92

Kelly M. Brunt 92

Remote Sensing of Sea Surface Salinity from Space 93

Paolo de Matthaeis 93

AERONET Ground-Based Remote Sensing of Aerosol Optical Properties 94

Thomas F. Eck 94

Melt Water Routing System Studies 94

Matthew Hoffman 94

Development of numerically efficient code for the atmospheric radiative transfer problem with polarization for aerosol/cloud satellite remote sensing 95

Sergey Korkin 95

Operation IceBridge Sea Ice Research 95

Nathan Kurtz 95

Capacity Building Program 96

Richard (Rick) Lawford 96

Application of Air/Space-borne Radar to Atmospheric Remote Sensing 97

Liang Liao 97

Development of Atmospheric Correction Algorithm for MODIS, and Algorithm Analysis for Land Surface and Atmospheric Products for VIIRS 97

Alexei Lyapustin 97

Fusion of Vegetation Structure from ICESat, SRTM and MODIS with a Global Vegetation Dynamic Model (DESDynI mission planning) 98

Wenge Ni-Meister 98

CMS Project 98

Jacqueline Rosette 98

NASA Energy and Water Cycle Study (NEWS) Program Office Support 99

Robert A. Schiffer and Deborah Belvedere 99

Operation Ice Bridge 100

Michael Studinger 100

Validation of Aquarius Faraday Rotation Angle Retrieval Algorithm and Modeling Impact of Topography on Microwave Radiometry 100

Cuneyt Utku 100

Provide Analysis of Synthetic Aperture Radar data of Antarctic and Greenland for Glaciological Research 101

Boris S. Yurchak 101

Development of Level 2 Science Products for Current and Future Hyperspectral and Multi-Spectral Sensors 102

Qingyuan Zhang 102

Heliophysics Division, Solar System Exploration Division (Code 660-699) 103

Development of UV Laser Beam Parameters and Delivery Optics for Laser Desorption Mass Spectrometry 105

Martina Atanassova 105

Numerical Modeling of Planetary Magnetospheres and Exospheres 105

Mehdi Benna 105

Miniature Two-Step Laser TOF Mass Spectrometer with Reversible Ion Polarity 106

Mehdi Benna 106

Coupling Between Mercury's Exosphere and Magnetosphere and the Study of Planetary Magnetospheres 106

Scott A. Boardsen 106

Plasma in the Saturnian Magnetosphere and its Interactions with Icy Satellites 107

Matthew H. Burger 107

Studies of Mercury’s Exosphere in the MESSENGER Era 107

Matthew H. Burger 107

Analysis of the Earth’s and planetary gravity fields and geophysical applications 108

Shin-Chan Han 108

NASA’s Magnetospheric Multiscale (MMS) Mission 108

Kyoung-Joo Hwang 108

Collisionless Reconnection Simulation and Detector Response Study 109

Alex Klimas 109

Statistics of Turbulent Reconnection in Earth’s Magnetotail 110

Alex Klimas 110

Wind Magnetic Field Investigation (MFI) 110

Andriy Koval 110

Study of the Interaction Between Space Objects and Plasma Flow: 3D Hybrid/Kinetic Simulation 111

Alexander S. Lipatov 111

Study of the Interaction Between Moons and Plasma Flow: 3D Hybrid/Kinetic Simulation 111

Alexander S. Lipatov 111

Remote Sensing of CO_2 and Other Atmospheric Compositions 112

Jianping Mao 112

Solar Wind and Magnetospheric Environment 112

Jan Merka and Tom Narock 112

Space Geodetic Networks' Data Analysis 113

Erricos Pavlis 113

Modeling neutrals and ions that are generated from collisionless exospheres of planetary bodies 114

Menelaos Sarantos 114

Ionosphere-Thermosphere Models at Community Coordinated Modeling Center 114

Ja Soon Shim 114

Swath Laser Altimetry Instrument Incubator Program and Ice Sheet Research 115

Christopher A. Shuman 115

Investigation of non-tidal ocean signals in land observatory and satellite magnetic measurements 116

Kumar Hemant Singh 116

Fabrication, Characterization and Modeling of field emission sources for the VAPOR miniaturized pyrolysis time-of-flight mass spectrometer 116

Adrian Southard 116

Survey of Cusp Electrodynamics using FAST Data/Investigations of the Near-Lunar Space Environment 117

Timothy J. Stubbs 117

Comprehensive Modeling of the Geomagnetic Field: Version 5 118

Zhibin Sun 118

CCMC Solar and Heliospheric Modeling 118

Aleksandre Taktakishvili 118

VAPoR (Volatile Analysis of Polar Regolith) and the Development of a Laser Desorption Mass Spectrometer 119

Inge L. ten Kate 119

Characterizing the Composition of Large Mid-latitude Topside-ionospheric/plasmapheric Gradients 120

Yongli Wang 120

Characteristics of Flux Transfer Events 120

Yongli Wang 120

Establishing Links Between Solar Wind and Topside-Ionospheric Parameters 121

Yongli Wang 121

Numerical Modeling and Satellite/Rocket Observations of Ionospheric Electric Fields and Irregularities 121

Tatsuhiro Yokoyama 121

Global Energy and Water Cycle Experiment (GEWEX) Project 123

International Global Energy and Water Cycle Experiment (GEWEX) Project; International GEWEX Project Office (IGPO) 125

Petrus (Peter) J. van Oevelen, Robert (Bob) Schiffer, Richard (Rick) Lawford 125

APPENDICES 127

Peer-Reviewed Publications 129

Inactive Tasks 147

Faculty and Staff 153

This page intentionally left blank

FINAL REPORT SUMMARY

This page intentionally left blank

Summary

On March 29, 2011, the GEST Consortium was informed that the continuation proposal submitted to NASA for the Goddard Earth Science Technology And Research (GESTAR) Center was awarded to a consortium led by the University Space Research Association. This ends UMBC's cooperative research agreement with NASA for the GEST Center and this report becomes a final summary report to close out the GEST Agreement. GEST was tranformational to UMBC. In the words of Elliot Hirshman, Provost, "The GEST Faculty have been instrumental in advancing UMBC's national research rankings and for that we thank you, the Faculty". The Goddard Earth Sciences and Technology (GEST) Center had a staff of over 170 research faculty and staff plus an excellent administrative staff of 12 professionals. Most of those research faculty have moved over to the new GESTAR Center, although nearly 30 faculty have chosen to stay with UMBC through their own grant funding. Since UMBC continues to manage the Joint Center for Earth Systems Technology (JCET), which was GEST's sister center, a number of those faculty have chosen to join JCET and to refocus their efforts towards a combination of grant funded research and teaching. JCET Faculty have the opportunity to affiliate with UMBC campus departments and those faculty that teach can obtain Research Professorial appointments in the University. UMBC appreciates the loyalty of those faculty who remained and who have chosen their path with the University.

We structure this report in the same manner as our previous 10 annual reports. The report outlines each of the tasks and grants that supported the work of the center, and each faculty member was asked to provide a small project abstract and to report on the productivity elements for the period April 1, 2010 to May 31, 2011.

We need to recognize the successes that GEST brought GSFC. Over 250 scientists have been GEST faculty. We use the term *faculty* for GEST and GESTAR scientists because, under this model, post-docs and more experienced Ph.D.s are hired into the partner universities as Research Scientists at the Research Associate, Assistant, Associate and Senior Research Scientist levels (generally parallel to GS 12-15 levels and the similar professorial designations in the University). Fourteen of these faculty have gone on to civil service positions at GSFC and ten have gone on to faculty positions in universities (see Table 3.1 in the management portion). GEST Graduate Fellowships (each contributed from UMBC overhead for a two-year term) were provided to five students at UMBC: Nathan Kurtz, Michelle McCourt, and Sam Trahan in Physics, Tetyana Vodovina in Math, and Eric Eaton in CSEE. GEST faculty regularly mentored external graduate students in the Graduate Summer Student Program (GSSP). Over the last 10 years, GEST brought in 52 faculty from other universities on sabbatical in the Goddard Visiting Fellows program.

GEST faculty have received the following awards: Best Paper Awards (Code 613, 614 awards), the USGS William T. Pecora award (Eck), the ACS Hillebrand Prize and EPA Ozone Protection Award (Kurylo), NASA Special Service Award (Delaney), as well as countless group and team awards. GEST faculty published **1994** papers over the last 10 years, 206 last year. Those papers led the Institute for Scientific Information's ScienceWatch to name UMBC the number 3 university in the nation in terms of Geosciences citations for the period 2000-2005. GEST faculty have been PI or co-I on 1406 proposals with an average success rate of 56%. In the period of 2009-2010, over 62% of our proposals have been funded. Our researchers have been awarded 155 UMBC PI-led external proposals and leveraged an additional $22,350,202 in research dollars to the Center, providing significant additional capacity to Code 600 research that, arguably, could not have been accomplished with scientists on contract, rather than collaborators in a Cooperative Center. UMBC has ranked in the top 5 universities with NASA grant and cooperative agreement funding since 2006, largely because of the success of GEST and its sister centers, JCET and the Center for Research in Exploration, Space Science and Technology (CRESST). Figure 1.1 shows the metrics by year for the GEST Center in terms of numbers of faculty, papers, proposals submitted and proposals awarded (we did not track the last figure prior to 2005).

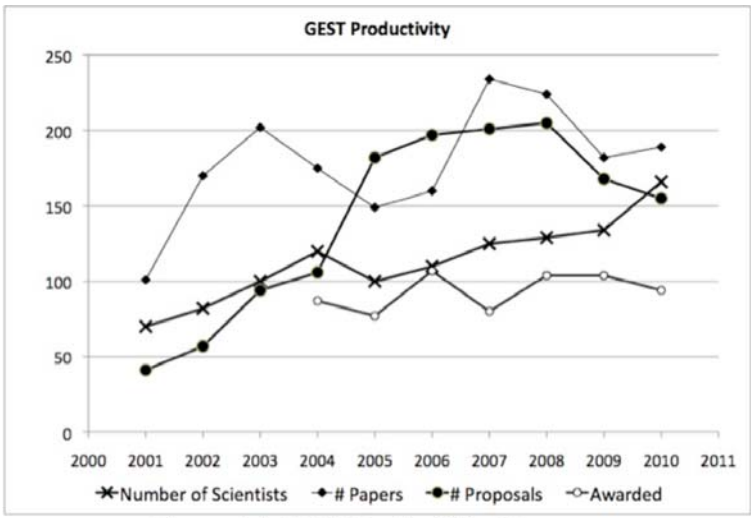


Figure 1.1: GEST Productivity Measures.

To our partners at Hampton Unviersity, Howard University, Caelum Research and Northrop-Grumman Corporation, we convey a sincere thank you for your efforts over the last decade. While GEST will not continue with NASA GSFC, we want to thank the visionary leadership at NASA, particularly Vince Solomonson and Franco Einaudi, for holding true to the vision of University Research Centers. UMBC continues to have three such Centers, in Earth Sciences, Astrophysics, and Heliophysics.

On a personal note, this will end my leadership of NASA's JCET and GEST Centers and I will return to teaching. This has been a remarkable experience for me in working with a large number of excellent scientists and I will miss that daily interaction. As the noted Greek orator and philosopher Seneca noted:

"Every new beginning comes from some other beginning's end."

Raymond M. Hoff

Director

Office of the Director and AETD
(Code 100-500)

This page intentionally left blank

Task 130-67-234: **GSFC Earth Science and Education Multimedia and Visualization Production**

GEST Multimedia Team: Jefferson Beck, Ryan Fitzgibbons, Matthew Radcliff, Brooke Harris, Katherine Lewis, Robert Garner, Silvia Stoyanova, Ernest Wright, Trent Schindler, Scott Wiessinger, Genna Duberstein, Michael Lentz, Helen-Nicole Kostis, Neema Mostafavi, Jennifer Shoemaker, Michelle Williams, and Laura Motel

Collaborator: *Wade Sisler (Sponsor, GSFC 130)*

Task Description

UMBC producers, visualizers, web producers, and animators support a wide range of NASA Goddard Public Affairs' activities on groundbreaking scientific discoveries in Earth science, heliophysics, and astrophysics. They support breaking news and feature stories, informal and formal education activities, internal science needs, special venue visual resources, and social media platforms. The team helps maintain Goddard's presence on nasa.gov with daily science features and press releases while creating and overseeing mission landing pages. They also support external producer requests, spreading NASA science, stories, and imagery to audiences worldwide.

Highlights

This year, GEST visualizers contributed to a major new stereoscopic demonstration project and developed infrastructure for a new Goddard iPad application. They also innovated 3-D flow-fields animation techniques and volumetric rendering of the MERRA climate reanalysis. In addition, they provided extensive lunar visualization in unprecedented detail as well as an animation of the future Earth observing fleet, while animators produced a signature branding animation of a polar bear, Nippy, for the NPP satellite team. The web team produced an upcoming virtual tour of Goddard and a 3-D Webb Telescope interactive for nasa.gov. The Education Department supported national Earth Science Week and Summer of Innovation campaigns with live webcasts, educator-focused videos, and online multimedia galleries. Producers supported two new unmanned airborne campaigns, GRIP and GloPac, and several satellite launches, and produced a high-profile 40-minute show at the National Air and Space Museum. They also traveled with Operation IceBridge to Chile and Greenland, produced a media campaign for the GOES Search & Rescue program, and provided core content for Goddard's Technology Transfer office. Finally, they produced several items for the Landsat and LDCM programs, supported NASA's science results at AGU, and achieved unprecedented social media success with videos on the Gulf Oil Spill and the 30th anniversary of Mt. St. Helens' eruption.

Task 606-73-250: **Strengthening Astrobiology Research and Education Strategic Alliances Among Minority Institutions**

GEST Investigator: Benita Bell

Collaborators: George Cooper (PI, NASA Ames Research Center), Todd Gary (Tennessee State Univ.), *James Harrington (Sponsor, GSFC 606)*

Task Description

The goal of this project is to develop and strengthen research and education alliance initiatives within the field of astrobiology among minority institutions. The focus has been to identify colleges and universities with similar research capabilities and an interest in astrobiology and education projects and to align these institutions with each other as well as with other organizations. This field continues to serve as a great scientific avenue to bring together students and faculty from diverse cultures and backgrounds to address key scientific questions. As the world continues its global outreach and focus in science and technology, astrobiology will be a key tool to stimulate interest in the exciting field of scientific exploration. The Minority Institution Astrobiology Collaborative (MIAC) and the NASA Astrobiology Institute Minority Research Support Program (NAI-MIRS) continue to strengthen and broaden their scope to assist faculty from minority institutions to conduct cutting-edge research. Faculty members who have participated in the NAI-MIRS research sabbatical have been successful in their submission of numerous publications to peer-reviewed journals. In addition, the pipeline to stimulate student careers in science for students from minority institutions has increased. Bell continues to serve as Co-Director of MIAC along with Dr. Todd Gary of Tennessee State University. MIAC, which originated through the MUSPIN Program at NASA GSFC, is a virtual collaboration of minority universities with the goal of generating research opportunities for faculty and students in the area of astrobiology; currently, there are 10 institutions in the collaborative. The virtual collaborative now includes more underrepresented institutions such as Hispanic serving institutions, Native American Institutions, and other minority serving institutions. The NAI-MRS program aims to strengthen the infrastructure of astrobiology research at minority institutions, increase diversity at all levels of NAI activities, and ensure that the next generation of astrobiologists reflects the ethnic and racial diversity of the U.S. and international scientific communities.

Highlights

In late 2010, Bell was invited by Congresswoman Eddie Bernice Johnson to serve on a Congressional Science and Technology Brain Trust Panel. She also continues to recruit faculty fellows for the NAI-MIRS sabbatical program; to date, 10 Fellows have participated in this program, among them Dr. Michael Ceballos, who was awarded an NSF Green Energy Grant to develop a new technology to produce eco-friendly ethanol, a direct result of his collaboration that began in the program. She provides content on research conducted at Minority Institutions for the Astrobiology HQ web portal. Bell continues to work with Dr. Cooper at NASA AMES on analyzing and characterizing citric acid and homologs in carbonaceous meteorites, and she conducts reviews for NASA Jenkins, CiPAIR, and NSTI proposals.

Task 130-05-085: **Learning Technologies**

GEST Investigators: Marcianna Delaney, Susan Hoban, and Daniel Laughlin

Collaborators: James Harrington (GSFC 606), Darryl Mitchell (GSFC 220), Shane Keating (GST), *Robert Gabrys (Sponsor, GSFC 160)*

Task Description

This task comprises several separate but related activities that involve the research, development and application of educational technologies to communicate NASA science and engineering concepts to educators and students. The Learning Technologies (LT) Project seeks to infuse innovative technologies with NASA mission content and best learning practices, and includes research into the use of computer games and virtual worlds as educational tools. The *GSFC Digital Learning Network* team provides NASA STEM content to K-12 classrooms across the country through videoconferencing. Research areas include studying the use of virtual environments and games as educational tools as well as roadmapping for NASA Education.

Highlights

Learning Technologies facilitated the signing of a space act agreement to develop a NASA-themed massively multiplayer online (MMO) STEM learning game between Astronaut Moon, Mars and Beyond, LLC and NASA. LT manages the technical elements and coordinates the efforts of the partners. LT published *Moonbase Alpha* in the summer of 2010. Built on the award-winning Unreal Engine 3 from Epic and developed by ARA's Virtual Heroes division, the game is a commercial quality release set on a hypothetical lunar outpost using models from NASA's lunar architecture. The game won the Serious Game of the Year (government category) at IITSEC, has had more than 250,000 downloads, generated more than 100 articles and holds an "E for Everyone" rate from the ESRB. It is a precursor and proof-of-concept for the MMO.

Task 130-67-233: **Educator Interns**

GEST Investigators: Marcianna Delaney and Susan Hoban

Collaborator: *Robert Gabrys (Sponsor, GSFC 160)*

Task Description

This task was designed to provide a mechanism to bring pre-service and in-service educators to Goddard Space Flight Center for research internship opportunities during summers or internship opportunities supporting the Office of Education in summers or throughout the year.

Highlights

In the five years since the creation of this task, GEST was able to support a total of 22 educators with internship opportunities. About half of our educators had the opportunity to have a real research experience with Code 600 scientists, while others provided critical support to various projects within the Office of Education, such as supporting professional development workshops and assisting in the design of NASA-themed curricula. We have also had teachers support the e-education group to provide live presentations to students via videoconferencing and assist in formative evaluation of education projects.

Task 130-84-296: **NASA's Best Students (Beginning Engineering, Science and Technology)**

GEST Investigators: Marcianna Delaney, Susan Hoban and staff: Laurie Cook and Michelle Graf (consultant)

Collaborators: Robert Gabrys (GSFC 130), *Carmel Conaty (Sponsor, GSFC 130)*

Task Description

The NASA's BEST Students project involves the research, development and application of educational technologies to communicate NASA science and engineering concepts to educators and students. The NASA's BEST Students team provides professional development for educators and curriculum support resources with a space exploration theme for engineering clubs for elementary and middle school students and for robotics clubs for high school students. The project also hosts engineering challenges and two-week Summer Bridge programs centering on lunar exploration for middle and high school students. More information may be found on the NASA Portal: www.nasa.gov/audience/foreducators/best/.

Highlights

The NASA's BEST Students project designed and implemented curricular support resources and professional development for after-school engineering clubs and robotics activities. As part of the development, the NASA's BEST Activity Guides were developed in three volumes, one each for grades K-2, 3-5 and 6-8. The engineering clubs were offered in 23 schools in Anne Arundel County, MD, as a pilot project in 2008, with more than 300 students participating. Feedback from teachers, parents and students was overwhelmingly positive, and the pilot was continued as a fully-funded project in 2009. Since that time, Anne Arundel County Public Schools have incorporated the clubs as part of their standard offerings, no longer supported with NASA funds. The St. Michael School in Hudson, MA has incorporated the NASA's BEST Students curriculum into their school day, so now NBS bridges informal and formal education. In addition to the engineering clubs, the project designed and implemented a robotics activity that has been delivered to various audiences: educators (as a 500-level course in the Master of Arts in Education program at UMBC), high-school students (as two-week Summer Bridges in collaboration with Anne Arundel County) and middle school students in the Maryland Summer Center for Lunar Robotics (co-funded by the Maryland State Department of Education). The NASA's BEST Students team has provided professional development for engineering education to over 600 educators nationwide. In 2010, NASA acknowledged the success of the NASA's BEST Students project by expanding it to three additional Centers: Glenn Research Center, Stennis Space Center and Marshall Space Flight Center.

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

GEST Investigator: Elena Georgieva

Collaborators: Elizabeth M. Middleton (GSFC 614.4), Petya K. E. Campbell (JCET/UMBC), Emily Wilson Steel (GSFC 554), Wen Huang (SSAI, GSFC 613.3), Huguens Jean (GSFC 554), *William Heaps (Sponsor, GSFC 613.3)*

Task Description

This research is focused on the development of passive and active sensors for remote sensing determination of various atmospheric trace gases. The objective for the active sensor work (2009-2011) is to build up a unique airborne laser system for measuring CO_2 changes in the lower atmosphere, using as its detector a section of the Fabry-Perot (FP) Interferometer constructed as a passive sensor from 2005-2009. The work includes designing and building a flight-hardened version of the Fabry-Perot radiometer for O_2, H_2O and CH_4 detection; testing the instrument from both ground and aircraft platforms, which occurred in separate flight campaigns at NASA Dryden Research Center and in the New Hampshire Polar Aura Validation campaign on NASA's DC-8 research airplane; collecting daily datasets of the actual atmospheric column at GSFC under various atmospheric conditions using a fiber-coupled sun tracker; modeling the data using IDL routines; building and testing a new laser transmitter for CO_2 measurements using a super-luminescent light-emitting diode (SLED); utilizing Nd:YAG laser and an Optical Parametric Amplifier (OPA) for the 1.57 micron lidar transmitter; building and testing a lidar receiver for 2 microns; and developing a miniaturized gas correlation radiometer (GCR) for column trace gas measurements in the Martian atmosphere.

Georgieva continued to work on improving the passive sensor for methane measurements on Mars. She was a Co-I on approximately twenty proposals for ROSES and a PI on a proposal for sensor development for fluorescence assessment. Georgieva collaborated with Dr. Middleton and Dr. Campbell on a study for a fluorescence measurement system using FP technique.

Highlights

The laboratory work with the flight-hardened version of the passive sensors was completed successfully. Tests show that the passive sensor 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 sensor 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 average.

Georgieva has performed simulations and instrument designs for systems to also detect CO, $^{13}CO_2$, CH_4, CH_2O, NH_3, SO_2, N_2O, NO_2, and O_3. She is working on refining the precision of the CO_2 system as a ground-based and airborne system. She and her collaborators are in the process of developing a lab prototype of their new active sensor for CO_2 measurements.

Georgieva continues to work on data analysis and modeling using IDL routines, reviewing papers for *Applied Optics, Optical Engineering, Measurement Science and Technology* and other scientific journals. She is the author of four refereed publications, with more than 20 publications in conference proceedings. She has collaborated with Dr. Emily Wilson and Huguens Jean (Code 554) on research for a Hollow-Fiber Gas Correlation Radiometer for Column Measurements of Formaldehyde, Methane, and Water Vapor on Mars.

Georgieva has presented the results of her work at the IEEE International Geoscience and Remote sensing symposium (IGARS), SPIE and AGU fall meetings. She has also taught Fundamentals of Polarimetric Remote Sensing and Gas Absorption, a UMBC graduate course (part of PHYS 721).

Task 690-07-243: **Planetary Data Systems**

GEST Investigator: Susan Hoban

Collaborator: *Ed Grayzeck (Sponsor, GSFC 630)*

Task Description

Work under the Planetary Data System task includes investigations into information science and educational technology for using data from NASA's planetary missions to advance education in science, technology, engineering and mathematics. Hoban 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.

Highlights

The Planetary Data System College Student Investigators (CSI) initiative was designed and implemented under this task. The approach adopted by the CSI initiative was to have long-term interactions with a small number of undergraduate students specifically when they would be considering graduate school. The goal of the CSI initiative was to introduce nascent scientists to scientific research using data from the Planetary Data System and to encourage these students to be a part of the NASA family. During the 18-month-program, the students work with a mentor on a research project, present results of their research at a conference of their mentor's choice, and submit a final research paper, which is intended to be a draft for a journal submission. Three cohorts of undergraduates, a total of 8 students, successfully completed the program.

Task 555-71-245: **L1B TB Algorithm Lead for the Soil Moisture Active Passive (SMAP) Mission**

GEST Investigator: Priscilla Mohammed

Collaborators: Christopher S. Ruf (Co-I, The University of Michigan); *Jeffrey Piepmeier, (Sponsor, GSFC 555)*

Task Description

NASA's Soil Moisture Active and Passive (SMAP) Mission will provide global measurements of soil moisture and freeze/thaw state using L-band radar and radiometry. Mohammed is responsible for producing the L1B TB science algorithm that processes radiometer data into calibrated estimates of brightness temperatures. Radio frequency interference (RFI) is expected to contaminate the radiometer measurements and thus compromise science performance. The L1B TB science ground-processing algorithm will therefore include RFI detection and mitigation techniques to generate RFI-free calibrated brightness temperatures (TBs). Since the inception of the task in 2006, Mohammed has conducted research on RFI detection methods in L-band radiometry. The objective of the current work is to apply this research to the L1B TB science algorithm.

Highlights

As team lead for the SMAP Level 1B science algorithm team, Mohammed provided support at meetings, teleconferences and workshops and helped outline the baseline L1B TB algorithm. The first draft of the L1B TB Algorithm Theoretical Basis Document was completed. This document describes in detail the baseline algorithm to be used on SMAP radiometer data. Work involving the baseline algorithm was presented at an engineering peer review as well as the SMAP preliminary design review. As part of the baseline algorithm, science product spreadsheets for the radiometer L1A and radiometer L1B were produced, which define the data to be archived by the mission. Source code was written in Matlab for the multiple RFI detection methods to be included in the algorithm and testing is ongoing. Preliminary work has begun on the use of maximum likelihood estimation to combine the RFI detection methods to enable mitigation of RFI in radiometer data.

Task 555-109-382: **Microwave Engineering and Communications**

GEST Investigator: Jinzheng Peng

Collaborators: Derek Hudson (NASA/GSFC 555), Pricilla Mohammed (GEST/UMBC), *Jeffrey Piepmeier (Sponsor, GSFC 555)*

Task Description

The Soil Moisture Active/Passive (SMAP) radiometer, which is being developed at GSFC/NASA, is a space-borne passive microwave device that measures the electromagnetic emission from the Earth's surface. Peng has worked on a collaborative team of GSFC civil servants and contractors developing this microwave radiometer. Specifically, the effort includes research and development of pre-launch and post-launch calibration theoretical basis, plans and activities, physical standards, and data reduction.

Highlights

Peng has been engaged in the development, improvement and calibration of the SMAP radiometer. His contributions focused on the radiometer pre-launch calibration error budget analysis; the radiometer level 1A calibration algorithm development; the radiometer nonlinearity correction algorithm optimization; and the standing wave ratio (SWR) effect analysis on the performance of the SMAP radiometer. The radiometer level-1A calibration algorithm has been adopted by the SMAP radiometer L1 algorithm team, and the other algorithms have been submitted to the radiometer calibration team as a guide to improve the calibration accuracy and performance of the SMAP radiometer.

Task 902-00-006: **Global Climate Change Research: USGCRP - Global/Water Energy Cycle; GEO-UIC/GEOSS; NASA/GEWEX/TRACE**

GEST Investigator: Sushel Unninayar

Collaborator: *Lola Olsen (Sponsor, GSFC 610.2)*

Task Description

NASA Headquarters assigned this task to GEST through the Global Change Data Center (GCDC) in GSFC's Earth Science Directorate. It provides the necessary scientific, technological, and research leadership support required by the White House's Office of Science and Technology Policy's (OSTP) Committee on Environment and Natural Resource's (CENR)—in particular, the CENR Sub-Committee on the U.S. Global Change Research Program (USGCRP). The task also supports NASA HQ in a variety of other NASA/SMD's internal, interagency, and international programs, such as the Global Water and Energy Cycles Program (GWC and 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 Group on Earth Observations (GEO) of the Global Earth Observing System of Systems (GEOSS), the international Integrated Global Observing Strategy (IGOS), and the activities the Committee on Earth Observation Satellites (CEOS), among others.

Highlights

There has been demonstrably successful science integration/coordination for the Interagency Working Group on the Global Water Cycle (IWG/GWC), and the analytical science development of the international survey on requirements for the "Water" Societal Benefits Area (SBA) of the Group on Earth Observations coordinating the implementation of the GEOSS. Dr. Unninayar's work involved continued and extensive interactions with all science elements of the U.S. Global Change Research Program (GCRP) regarding the development and implementation of the long-term strategic science plans as directed by OSTP and OMB. The GCRP also represents, *de facto*, the U.S. response to the U.N. Conference of Parties (COP) dealing with the U.N. Convention on Climate Change (UNFCCC). He was involved with the organization and reporting of the multi- and inter-agency activities of the global water cycle program and its sub-elements, such as observations, modeling, process studies, field campaigns and various applications projects. As lead author, Unninayar wrote and finalized the US-GCRP focus areas on the Global Water Cycle in *Our Changing Planet—FY2010 through FY2011*, a program and budget planning report submitted to the OMB and OSTP as a part of the President's national program and budget plans. He also assisted with the development of a decade-long integrated priority programs/projects, the most recent example being TRACE, a NASA-HQ initiative for a "Terrestrial Regional North American Hydro-Climate Experiment", currently in its planning phases for a project to be implemented over the next decade (2011-2021).

Task 130-82-283: **Imaging Research Center (IRC) at UMBC, Earth Science Animation**

GEST Investigators: Ryan Zuber, Tyler Chase, and Rachel Kreutzinger (all from the IRC at UMBC)

Collaborators: Dan Bailey (IRC at UMBC), *Wade Sisler (Sponsor, GSFC 130)*

Task Description

Recognizing imaging as a process that is rooted in art and design, incorporates science and technology, and vividly describes ideas, the University of Maryland Baltimore County's Imaging Research Center (IRC) is a recognized center for interdisciplinary collaboration among artists, researchers, industry partners, and students in creating technologically advanced media that communicates to and resonates with the general public. In collaboration with NASA Goddard's television and web media production team, the IRC creates high-quality technical and conceptual science animations and interactive visualizations used for educational purposes on television, on the web, and in the classroom.

Highlights

The Imaging Research Center has provided visualization and illustration support for a wide variety of current and future NASA satellite missions including The Solar Dynamics Observatory, The Venus Sounder for Planetary Exploration, The Mars Atmosphere and Volatile Evolution Mission, the Earth Climate and Atmospheric Research Satellite, the NPOESS Preparatory Project, Aquarius, and Landsat/LDCM. Additionally, in the areas of earth and climate science, the IRC has provided conceptual animation and science illustration support to the public outreach campaign "Science for a Hungry World: the View from Space," a six-episode video series entitled "Tides of Change," the video "NASA/NOAA/Saved By A Weather Satellite," as well as many other educational and public outreach programs with the goal of making the complex and critically important work conducted by scientists and researchers in these areas available and accessible to the science community and the general public.

This page intentionally left blank

Global Modeling and Assimilation Office (Code 610.1)

This page intentionally left blank

Task 610-122-426: **GEOS Model Development for Aerosol-Cloud Interactions**

GEST Investigator: Donifan Barahona

Collaborator: *Michele Rienecker (Sponsor, GSFC 610)*

Task Description

This task is for research and development to advance the global atmospheric general circulation model (AGCM) that forms the heart of the Goddard Earth Observing System (GEOS) model developed in the Global Modeling and Assimilation Office at NASA Goddard Space Flight Center. The focus of this task is on developments for aerosol-cloud-climate interactions, particularly parameterizations relevant to ice cloud formation to be implemented within the Morrison-Gettelman cloud microphysics component of GEOS-5.

Highlights

Since July 2010, Barahona has worked in updating the cloud microphysics scheme in GEOS to incorporate the effect of aerosols emissions on cloud formation as well as rain and snow precipitation rates. The new double-moment cloud microphysics scheme considers the evolution of the ice and liquid mixing ratio and number concentration, and explicitly treats processes of condensation, evaporation, collection, freezing, melting and sedimentation. Cloud droplet and ice crystal production rates are now computed by considering the precursor aerosol properties and the sub-grid variability in dynamical forcing. The double-moment cloud microphysics scheme was validated against data from the Atmospheric Radiation Measurement (ARM) program and compared favorably against results from the SCAM model.

Task 610-67-232: **Simulations of Stratospheric Chemistry and Polar Stratospheric Clouds**

GEST Investigator: Craig Benson

Collaborators: Anne Douglass, Scott Hannon, S. Randolph Kawa, Hui-Chun Liu, Nicole McKee, J. Eric Nielsen, Lars Peter Riishojgaard, Reinhold Spang, Ivanka Stajner, Rich Stolarski, *Steven Pawson (Sponsor, GSFC 610)*

Task Description

The goals of this project are to evaluate the characteristics of the GEOS-5 model, with a focus on the chemistry of the stratosphere. Polar stratospheric clouds (PSCs) form at extremely low temperatures in the Arctic and Antarctic stratosphere, providing catalytic surfaces for heterogeneous chemical reactions that lead to ozone loss. The GEOS-5 model is evaluated in relation to model behavior in the Arctic and Antarctic stratospheres in light of the key role of PSCs in ozone loss. Model transport of long-lived tracers is an additional focus.

Highlights

A series of GEOS-5 model runs were performed to tune the PSC parameterization. PSC formation in the model relies on a set of six different variables; by carefully tuning these variables, the error in calculated dehydration and denitrification due to PSC formation was minimized. It was found that several of the

variables do significantly affect the vertical distribution of HNO_3 and H_2O due to formation, sedimentation, and sublimation of PSC particles of different sizes and characteristics. Additional analyses of the simulations found that the default PSC formation physics favored excessive amounts of denitrification through the generation of NAT PSCs. While there were some constituent biases relative to MLS data, early denitrification observed in the model was 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. It was additionally found that some implementations of high-resolution replay runs caused dynamic instabilities at or near the model top, which propagated downwards, eventually leading to significant errors in temperature and dynamical meteorological fields. The errors were subsequently corrected.

Task 910-14-123: **The Linkages between Extreme Winter Storms and Global Scale Climate Variability**

GEST Investigator: Yehui Chang

Collaborator: *Siegfried Schubert (Sponsor, GSFC 610.1)*

Task Description

This task seeks to understand the cause of the extreme snowfalls in the East Coast of the United States during the winter of 2009/2010 as a probable response to the combined effects of the warm phase of El Niño-Southern Oscillation (ENSO), warm Indian Ocean SST and the negative phase of North Atlantic Oscillation (NAO). In this assessment, Chang has addressed the individual role of the ENSO, the NAO, the Indian Ocean SST and the tropical Atlantic SST, as well as their combined impact with use of GEOS-5 climate simulations. A large number of the high-resolution ensemble simulations were made from various initial conditions and under various observed and idealized SST boundary forcing. The study has quantitatively evaluated the impact of the modes of climate variability on the precipitation and surface air temperature.

Highlights

Chang has helped to define objectives regarding the extreme winter storms and global scale climate variability research. He found that a warm ENSO state is associated with positive precipitation anomalies in the southeast and east coasts of the U.S. and negative anomalies in surface temperature across much of the U.S. (excluding the Pacific Northwest). A negative NAO decreases the precipitation in the central part of the United States and causes a drop in surface temperature in the southeast and east coasts of the U.S. The combined significant changes of moisture and temperature produced the extreme snowfalls. The key aspects of the study include more reliable estimates of the changes in the severity, frequency and location of the extremes. He has presented his research findings at several conferences.

Task 610-73-253: **The Linkages between Extreme Winter Storms and Global Scale Climate Variability**

GEST Investigator: Amelia Colarco

Collaborators: Watson Gregg, *Arlindo da Silva (Sponsor, GSFC 610.1)*

Task Description

The focus of this task has been on using aerosol output from a global climate model to evaluate the information gained from satellite platforms. In most satellite retrieval algorithms, it is assumed that aerosols exist as distinct species. It is also believed that dust can impact the ocean system in conflicting ways, as both a source of nutrients and an absorber of photosynthetically active radiation. Colarco has used climate models as a way of evaluating these assumptions by explicitly dividing aerosols into their component species and looking at each one separately, something currently impossible from satellite observations. Global maps of aerosol mixtures were created to study the validity of single-species assumption. Modeled aerosol distributions were also used as input into a radiative transfer model to look at how the dust aerosol species impacts both direct and indirect global surface irradiance at various wavelengths throughout the visible spectrum.

Highlights

The research done by Colarco has provided key information not only on how aerosols exist in the atmosphere but also on how global climate models can contribute to scientists' understanding of satellite retrievals and the information gained from them. Analysis of aerosol output from a global climate model has contributed to the understanding of accuracy of satellite aerosol type assumptions, and has shown that a single-species assumption may be a large source of uncertainty in the aerosol retrievals over a significant portion of the globe. In the context of aerosol impacts on photosynthesis, Colarco's model analysis has shown a reduction in surface irradiance that peaks at the key wavelengths, due solely to the presence of dust. The magnitude of this absorption indicates it will have an impact on phytoplankton growth. The results of these studies have been presented at several conferences and at the GEST Symposium.

Task 610-118-413: **Goddard Earth Observing System Data Assimilation System**

GEST Investigator: Gabriëlle De Lannoy

Collaborator: *Rolf Reichle (Sponsor, GSFC 610.1)*

Task Description

The GEST investigator contributes to research and development on land data assimilation within the Goddard Earth Observing System (GEOS) model and its associated Data Assimilation System (DAS) developed in the Global Modeling and Assimilation Office at NASA GSFC. In particular, the research involves using satellite observations of soil moisture, snow, and land surface temperature. The main task of De Lannoy is related to soil moisture assimilation in preparation for the Soil Moisture Active Passive (SMAP) mission.

Highlights

The researcher has been preparing GMAO's land data assimilation system for the assimilation of SMAP data. To support pre-launch Observing System Simulation Experiment (OSSE) research on the future SMAP mission, the system has been adjusted for the SMAP grid specifications and 'nature' simulations have been provided to the SMAP science team. Further, the first year of data from the European Soil Moisture Ocean Salinity (SMOS) mission has been explored, including the different brightness temperature products and the soil moisture retrieval product. An initial model-data comparison has been performed and the initial research findings were presented during the 2011 AMS conference (Seattle, WA), as well as at the 2011 ISSI meeting (Bern, Switzerland).

Task 910-31-155: **Goddard Earth Observing System Data Assimilation System**

GEST Investigator: Ronald Errico

Collaborators: Ricardo Todling (SAIC), Runhua Yang (SSAI), Meta Sienkiewicz (SAIC), Will McCarty, *Ronald Gelaro (Sponsor, GSFC 610.1)*

Task Description

This task covered a broad range of activities concerning the design, development, validation, and application of the GMAO data assimilation system. This included developing adjoint models for diagnostic studies and 4-dimensional variational data assimilation (4DVAR), defining metrics for estimating observation impacts, determining singular vectors of stratospheric circulations, and determining requirements for assimilating observations of clouds and precipitation. Most recently, Errico has been leading the significant portion of this task devoted to the GMAO's ability to conduct truly useful Observing System Simulation Experiments (OSSEs).

Highlights

The development of adjoint model tools at the GMAO have permitted preliminary tests of a 4DVAR system that will soon replace the current GMAO, grid-point statistical interpolation, data assimilation scheme. Determining the requirements for the useful assimilation of precipitation and cloud observations by satellites has resulted in a list of activities required for incorporation of such data into the GMAO data assimilation system. The design and validation strategies for OSSE development at the GMAO have been groundbreaking and present a model for others interested in mimicking OSSE applications. Additionally, the software developed and data sets of simulated observations for the OSSE project have been distributed to investigators outside NASA.

Task 610-112-400: **Development of Initialization Techniques for the GEOS-5 Coupled-Atmosphere Ocean Model**

GEST Investigator: Yoo-Geun Ham

Collaborator: *Michelle Rienecker (Sponsor, GSFC 610)*

Task Description

In order to obtain useful predictions for various time-scales, it is well known that optimal initial conditions are an essential factor to guarantee skillful forecasts, since prediction is fundamentally an initial value problem in a coupled-atmosphere ocean prediction system. To achieve this goal, the ensemble Kalman Filter (EnKF) system is adapted to the GEOS-5 coupled model, and the data

assimilation technique is developed based on the original EnKF algorithm. In addition, the method for generating optimal ensemble perturbation is developed and applied to the GEOS-5 coupled model to measure and reduce the inevitable initial errors.

Highlights

Ham has set up the breeding method to GEOS-5 seasonal/decadal predictions. He has presented his research findings at numerous conferences, heavily emphasizing the development of the new ensemble generation method. This year, he published one paper in *Q. J. R. Meteorol. Soc.* about the EnKF with growing-error reduction, and two more papers have been published in the *Journal of Climate,* and *International Journal of Climatology*. At present, he has submitted four papers about the ensemble prediction systems to international journals.

Task 613-125-433: **Satellite Analysis of Fire Radiative Energy Release and Aerosol and Carbon Monoxide Emission Rates**

GEST Investigator: R. M. Hoff (Physics Department), Thishan Dharshana (Graduate Student, Physics)

Collaborator: *Charles Ichoku (Sponsor, GSFC 613.2)*

Task Description

Mr. Dharshana will perform a detailed quantitative evaluation of satellite measurements of carbon monoxide (CO) from Terra-MOPITT, Aqua-AIRS, and Aura-TES, using available ground truth (*i.e.* ground-based and airborne measurements), in order to determine their levels of uncertainty. He will characterize the spatial and seasonal variability of these uncertainties, and establish the suitability of these data sets for use in estimating CO emissions from biomass burning.

Highlights

Mr. Dharshana began this work in January 2011 and to this point has been accumulating a personal library of references on this research topic.

Task 610-89-310: **Research and Advisory Activities for NDACC, SPARC, IO3C, GCOS, WMO, UNEP, and the NASA/JPL Panel for Data Evaluation**

GEST Investigator: Michael J. Kurylo

Collaborator: *W.-K. Tao (Sponsor, GSFC 613.1)*

Task Description

This task provides support for several international activities important to NASA's Atmospheric Composition Focus Area in Earth Science. It covers programmatic leadership of the Network for the Detection of Atmospheric Composition Change and provides consultancies to the SPARC Project of World Climate Research Programme, to the International Ozone Commission, to the Global Climate Observing System, and to UNEP and WMO on activities associated with the Vienna Convention for the Protection of the Ozone Layer and the Montreal Protocol on Substances that Deplete the Ozone Layer. It also covers participation in the evaluation of photochemical and kinetic data by the NASA/JPL Panel for Data Evaluation.

Highlights

As Co-Chair of NDACC, Kurylo continued to share responsibility for overall network management, operational continuity and growth, and collaboration with international organizations and networks

associated with ozone and climate observations. In particular, he has provided advice to the GCOS Working Group on Atmospheric Reference Observations on the developing operational structure for GRUAN (the GCOS Reference Upper Air Network). As a member of the International Ozone Commission (IO_3C), he helped to develop a series of Ozone Theme Meetings jointly organized by WMO/GAW, NDACC, and IO_3C focusing on critical issues associated with the global measurements of both the ozone column and its profile. As an Ex-Officio member of the Scientific Steering Group for the Stratospheric Processes And their Role in Climate (SPARC) Project of the World Climate Research Programme, Kurylo co-led a SPARC initiative on documenting the Role of Halogen Chemistry in Polar Stratospheric Ozone Depletion. Kurylo was asked by the Co-Chairs of the 2010 Scientific Assessment of Ozone Depletion to participate as co-author for Chapter 1 (Ozone-Depleting Substances and Related Chemicals), as a contributor and primary reviewer for Chapter 2 (Stratospheric Ozone and Surface Ultraviolet Radiation), and as a reviewer for the Prologue of the Assessment. The Space Studies Board of the National Research Council of the National Academies requested that Kurylo serve on a committee evaluating NASA's Suborbital Research Capabilities. The report from this Committee has been published by the National Academies and was presented to Congressional staff and NASA HQ management. As a member of NASA's Panel for Data Evaluation, he helped finalize an updated set of recommendations for photochemical and kinetic parameters having highest priority for modeling calculations performed for the 2010 Assessment, and he assisted in a complete review and update of rate constant recommendations for the reactions of OH radicals with halocarbons. These reviews have been released as JPL Publications. Kurylo is collaborating with researchers at the National Institute of Standards and Technology on laboratory studies of the atmospheric lifetimes of naturally occurring and anthropogenic trace gases.

Task 610-119-416: **Simulating and Predicting Sub-seasonal and Longer-term Changes in Tropical Storm Characteristics using High-Resolution Climate Models**

GEST Investigator: Young-Kwon Lim

Collaborator: *Siegfried Schubert (Sponsor, GSFC 610)*

Task Description

In order to accomplish the major goals of the task, the VAMOS working group on extremes was formed in 2009. The basic objective of the group is to improve their understanding of the mechanisms and predictability of extremes, including tropical storms. Specific focus is on precipitation and temperature extremes on both short-term (weather) and climate scales, and includes such phenomena as heat waves, floods and droughts. Specific tasks include the development of an online atlas of extremes over the Americas, the evaluation of existing and planned simulations including the climate change scenarios (*e.g.*, CMIP5 IPCC/AR5), decadal hindcasts, seasonal hindcasts, ultra-high resolution global climate model simulations, and formulating and coordinating new model simulations to help shed light on the mechanisms and predictability of tropical storms and extremes. Since Lim joined the VAMOS working group, he has studied the extreme indices and set up a NASA GEOS-5 model for high-resolution simulation of tropical storms and extremes.

Highlights

Lim has developed the online atlas based on gridded observations and the recently completed re-analyses from NASA/MERRA and NOAA/CFSR. Lim has produced considerable information about weather and short-term climate extremes throughout the Americas and provided them on the atlas. The atlas is being updated on a frequent time interval. A beta version is available at http://gmao.gsfc.nasa.gov/research/subseasonal/atlas/Extremes.html. Additionally, Lim has been analyzing the extreme climate variabilities at high-spatial resolutions to explain their dynamical

mechanisms. Part of his research products on high-resolution extreme climate analysis and simulation were published in *Climate Dynamics* in 2010 and submitted to *Geophysical Research Letters*. Lim is also working on setting up the high-resolution global model (NASA GEOS-5) to simulate the tropical storm characteristics over the Atlantic and Pacific oceans.

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

GEST Investigator: Xin Lin

Collaborator: *Arthur Hou (Sponsor, GSFC 613)*

Task Description

The Global Precipitation Measurement Mission (GPM) is an internationally sponsored partnership 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 onboard the GPM Core Spacecraft will be able to improve the calibration and retrievals of these passive microwave (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 a 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 retrieval error statistics of current PMW radiometer and sounder data over land and oceans. Lin and Hou have 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 also have been thoroughly evaluated. Such a feasibility study provides valuable information for the GPM mission planning.

Highlights

Using TRMM Precipitation Radar retrievals and merging surface radar/gauge measurements over the U.S. continent as references, they compared instantaneous rainfall estimates provided by the current generation of retrieval algorithms for passive microwave sensors. In particular, statistics of departures of these coincident retrievals from reference measurements were computed as a function of rain intensity over land and oceans. Results of the study provide some important guidance for the GPM planning.

Tremendous amounts of satellite rainfall observations from TRMM PR and TMI, 3 DMSP/SSMI, and AQUA AMSR-E have been analyzed to investigate the frequency distribution of precipitation. Based on the rainfall error statistics obtained from a coincident evaluation of satellite rainfall retrievals, they could determine at what rain intensity ranges that they can have more confidence in rainfall frequency distributions from individual PMW rain retrievals. They also noticed a significant short-term climate change in frequencies of light, moderate, and heavy rain events. Such a study is vital to better understand the occurrence of extreme rain events in a changing climate, and will serve as an important test bed for evaluating the NASA GMAO MERRA analysis and the NASA GSFC Global Cloud Model.

Additionally, they have investigated the impact of GPM satellite sampling at monthly and diurnal time scales, and estimated the sampling capability of GPM constellation and individual satellites on Hurricane Katrina. They evaluated statistics of preliminary GMAO MERRA analyses and prepared the operational analysis data for use in Observation System Simulation Experiments (OSSE).

Task 610-112-405: **Simulations of the Aerosol Index and Comparisons with OMI Retrievals**

GEST Investigator: Virginie Buchard-Marchant

Collaborators: Peter Colarco, Robert Spurr, *Arlindo da Silva (Sponsor, GSFC 610.1)*

Task Description

The UV Aerosol Index (AI) at 354 nm is useful for detecting the presence of absorbing aerosols in the atmosphere. By means of an explicit radiative transfer calculation, the researchers simulate UV AI from aerosol concentrations obtained with the Goddard Chemistry, Aerosol, Radiation, and Transport (GOCART) module running on-line inside the Goddard Earth Observing System version 5 (GEOS-5) Atmospheric GCM. The model-simulated AI estimates are used to assess the quality of the model-absorbing aerosols by direct comparisons to the OMI AI measurements.

Highlights

Buchard-Marchant and her team have developed a VLIDORT (Vector LInearized Discrete Ordinate Radiative Transfer) interface to simulate top-of-the-atmosphere radiances using GEOS-5 aerosol concentrations, and they've calculated the AI at the OMI footprint. For the entire month of June 2008 they have compared model-produced AI with the corresponding OMI measurements, identifying regions where the model representation of absorbing aerosols were deficient. Making use of CALIPSO measurements, they also have investigated the impact of the altitude of the aerosol layer on OMI-derived AI, trying to ascertain misplacement of plume height by the model. In addition, they have extended their analysis to the GEOS-5 aerosol assimilation system, making use of OMI measurements as independent validation for MODIS/MISR assimilated fields.

The implementation of the interface between GEOS-5 aerosols and the VLIDORT radiative transfer code are very promising. The preliminary results have been the subject of a presentation at the A-Train meeting, and a manuscript is in preparation as well.

Task 610-125-434: **Improving Current MODIS cloud retrieval (MOD06) capabilities for thin cirrus optical property retrievals**

GEST Investigator: Kerry Meyer

Collaborator: *Steven Platnick (Sponsor, GSFC 613.2)*

Task Description

This effort is focused on improving current MODIS cloud retrieval (MOD06) capabilities for thin cirrus optical property retrievals. Specifically, the MODIS 1.38 μm channel is used to retrieve thin cirrus optical thickness for cases where MOD06 retrievals fail. Tasks include further developing existing retrieval techniques, performing quantitative uncertainty analyses, investigating retrieval sensitivities to various atmospheric and surface parameters, performing comparisons with co-existing data products, and investigating the statistical and radiative impacts of including additional thin cirrus retrievals to future MOD06 datasets.

Highlights

Since the beginning of the task in September 2010, the investigator has made significant progress towards achieving the goals originally set forth. Specifically, retrieval results have been compared with the MODIS operational cloud product, as well as the CALIPSO cloud product, for thin to moderately thick single-layer cirrus clouds, cases in which all techniques provide retrievals, with encouraging results. In

addition, various aspects of the retrieval, such as above-cloud water vapor amount estimation (and, subsequently, cloud top height estimation), have been evaluated using CALIPSO cloud top height retrievals. Lastly, the effects of minor adjustments to the existing retrieval technique have been investigated, although this remains a work in progress.

Task 910-01-009: **Cloud Data Assimilation**

GEST Investigator: Peter M. Norris

Collaborators: Lazaros Oreopoulos (GSFC 613.2), Arlindo da Silva, Wei-Kuo Tao (GSFC 613.1), Xiping Zeng (GSFC 613.1), *Arthur Hou (Sponsor, 613)*

Task Description

It is widely recognized that clouds play an essential role in moderating the climate. This has prompted continuing efforts to improve the representation of clouds in global climate models. What is currently needed is the ability to test these cloud representations against different sources of observed cloud data with global or large-scale coverage. In particular, NASA has made a large investment in high-resolution satellite cloud observing systems (*e.g.*, MODIS, AMSR-E, and CloudSat) that can be used for this purpose. This is the background for the current task within the NASA Global Modeling and Assimilation Office (GMAO) to use retrieved cloud data to validate cloud properties within the Goddard Earth Observing System (GEOS) model, to measure the capability of trial cloud representations, and to assimilate cloud measurements directly into the GEOS data assimilation system.

Highlights

Norris has focused on comparing GMAO's GEOS model cloud products (cloud fraction, water path, optical depth and cloud height) against ISCCP, CERES, SSM/I, MODIS and CloudSat satellite retrievals, with a particular emphasis on assimilating these data to bias-correct the GEOS model using parameter estimation techniques. Norris has also developed novel and highly capable models for dealing with unresolved horizontal and vertical variability of moisture within a GCM-sized grid-column, using Goddard Cloud Ensemble (GCE) simulations and Atmospheric Radiation Measurement (ARM) data. These include the Generalized Extreme Value (GEV) probability density function for layer moisture and the Gaussian copula model for cloud overlap. Several journal articles and numerous conference papers have been produced. The clear benefits and challenges of cloud data assimilation within the GEOS data assimilation system have also been demonstrated.

Task 610-83-292: **Data Assimilation Office Analysis Group Leadership and Joint Center for Satellite Data Assimilation**

GEST Investigator: Lars Peter Riishojgaard

Collaborator: *Jack Richards (Sponsor, GSFC 610)*

Task Description

As the head of the analysis group in the Data Assimilation Office (the direct predecessor of the GMAO) at NASA GSFC, Riishojgaard's main responsibility was to lead the development of the Physical-Space Statistical Analysis System (PSAS) software package forming the core of the DAO system. His duties also included carrying out research in advanced data assimilation methods, in particular with the aim of increasing and improving the use of satellite data in NWP-related applications. From 2003 to 2007, he

was the head of the satellite data assimilation group in the Global Modeling and Assimilation Office (GMAO) at NASA GSFC.

In addition, in August 2002, Riishojgaard was appointed Deputy Director of the NASA/NOAA Joint Center for Satellite Data Assimilation. The JCSDA is a US interagency distributed center charged with coordinating satellite data assimilation activities for environmental prediction applications between NASA, NOAA and the Department of Defense. The Director reports to a Management Oversight Board that consists of representatives from the three partner agencies, and he is responsible for the strategic direction and the daily execution of the research and development work undertaken by the Center. He also represents the Center in national and international scientific contexts. The current (Fiscal Year 2011 preliminary) budget of the Center is ~$17M. Also, Riishojgaard was the Principal Investigator for the Molniya Orbit Imager, a Goddard satellite mission proposal aimed at high-latitude Northern Hemisphere applications.

Highlights

An extensive suite of data impact experiments was conducted with DAO's GEOS-4 system. Riishojgaard led the development of the scientific rationale for the U.S. Dual Perspective Doppler Wind Lidar mission, in part by applying the Rapid-Response OSSE (RROSSE) approach to simulating the impact of single-versus-dual perspective observations from a space-borne wind lidar. MODIS winds and AIRS were tested at GMAO. He led the development of the mission concept for Molniya Orbit Imager, as a follow-on to the initial successful demonstration of the impact of the MODIS winds.

As JCSDA Director, Riishojgaard refocused the JCSDA strategy, which resulted in the resources of the Center being applied toward common forecast goals. He also participated in developing a Formal Memorandum of Agreement signed by all JCSDA parent agencies. He coordinated the initial assessment of the impact of IASI and ASCAT satellite sensors on JCSDA systems, and was involved with the formation of Working Groups to plan and execute satellite-specific tasks across the JCSDA partners. His long-standing quest for additional computer resources to the Joint Center led to the procurement of the first JCSDA-owned supercomputer. He was instrumental in organizing and securing the resources for the first JCSDA Summer Colloquium in 2009.

Task 610-92-318: **Remote Sensing and Public Health**

GEST Investigator: Radina Soebiyanto

Collaborators: Richard King (PI, GSFC 610.2), Farida Adimi (GSFC 610.2, Wyle), *Ralph Kahn (Sponsor, GSFC 613.2)*

Task Description

Climatic and environmental factors play significant roles in both the temporal and spatial spread of infectious diseases such as malaria, dengue, cholera and influenza. For example, rainfall can provide a breeding habitat for malaria vector, *Anopheles* mosquitoes, but this does not necessarily increase malaria transmission risk. A heavy but short rainfall or a following storm can flush the larval habitat and in effect reduce transmission. Rather, it is the intensity and timing of rainfall that determine transmission variability. The climatic and environmental factors influence the disease spread in a non-linear fashion that is not intuitively understood. Therefore, this study is aimed at developing mathematical models to forecast and facilitate understanding of disease transmission – specifically for malaria and influenza – using environmental and climatic factors obtained from satellites. The model essentially provides a tool for public health support to prevent or manage disease outbreaks. In addition, the model would be able to address the effect of climate change on communicable disease transmission.

Highlights

Within this task, Soebiyanto has successfully developed a prediction capability framework for seasonal influenza as warranted by climatic and meteorological conditions. Using NASA's remote sensing data that is integrated into nonlinear models, the framework produces influenza prediction not only for temperate regions but also for cities with warmer temperatures, such as Hong Kong; this seasonal influenza study was published in *PLoS ONE* in 2010. Also within this task, Soebiyanto has worked on avian influenza and created a stochastic, spatial model for transmission between poultry farms. The model illustrates how fast an infection in one farm can affect the other farms within its vicinity. In addition, Soebiyanto has developed a spatial model for mosquito-borne disease transmission that takes into account the lifecycle of the mosquitoes based on temperature and rainfall. Along with Drs. Adimi, Safi, and Kiang, she has recently published a study in *Malaria Journal* on the role of environmental factors on malaria transmission in Afghanistan using statistical approaches.

Task 610-80-274: **Improving Gravity Wave Parameterization in NASA GEOS-5 GCM**

GEST Investigator: In-Sun Song

Collaborators: Max Suarez (GSFC), *Michele Rienecker (Sponsor, GSFC 610)*

Task Description

Atmospheric gravity waves propagate the carrying of momentum and energy fluxes and can have great impact on global atmospheric circulations by depositing the momentum and heat fluxes. However, a broad range of spectral characteristics of gravity waves makes it difficult for global weather forecast models to explicitly resolve the waves and interaction between the waves and the large-scale flow, due to the limitation of spatial resolution of the present global models. The major purpose of this task is to improve the gravity wave parameterization of the NASA GEOS-5 GCM by discovering more proper parameters for unresolved gravity waves.

Highlights

Song has stabilized successfully the gravity wave parameterization in the GEOS-5 GCM since he made several drastic modifications: first, to the parameterization for the conservation of momentum and energy across gravity wave parameterization; second, to the generation of the quasi-biennial oscillation in the equatorial lower stratosphere; and third, to the improvement of the strength and seasonal evolution of the Southern subtropical jet. He also found that improvements in momentum, heat, and moisture exchange processes over the ocean can make the evolution of the subtropical jet and stationary planetary waves in the Southern Hemisphere far more realistic. His recent work has involved examining the ocean surface processes as well as gravity wave processes for model improvement.

Task 610-111-391: **Snow data assimilation into the Modern Era Retrospective-Analysis for Research and Applications (MERRA)**

GEST Investigator: Ally Toure

Collaborator: *Rolf Reichle (Sponsor, GSFC 610)*

Task Description

MERRA is a NASA reanalysis for the satellite era using the Goddard Earth Observing System Data Assimilation System Version 5 (GEOS-5). In addition to estimates related to atmospheric fields, MERRA provides global estimates of soil moisture, latent heat flux, snow and runoff for 1979-present. Toure has worked on the quantitative comparison of MERRA-land (which is an improved set of land surface hydrological fields generated by replaying a revised version of the land component of the MERRA

system) against *in situ* snow depth observations taken between 2002 and 2009 at 2,155 World Meteorological Organization (WMO) stations in the northern hemisphere. He has also worked on the quantitative comparison of MERRA-land snow cover fraction with global 0.05 deg Climate Modeling Grid (CMG) MODIS snow cover fraction observations taken between 2000 and 2010. He is currently involved in the implementation of the algorithm to assimilate MODIS snow cover fraction into MERRA.

Highlights

Toure's findings on the comparison of MERRA-land with *in situ* snow data were part of a paper titled "Assessment and enhancement of MERRA land surface hydrology estimates", which was submitted to the *Journal of Climate* in December 2010. His research findings on the assessment of MERRA snow cover fraction have helped researchers to understand the impact of some parameters' changes (made in MERRA-Land to improve the modeled albedo when snow is present) on the accuracy of the snow cover prediction by MERRA-land. The findings helped scientists to choose the appropriate algorithm to use when assimilating the snow data in MERRA.

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

GEST Investigator: Yury Vikhliaev

Collaborators: Max J. Suarez (GSFC 610.1), Andrea Molod (GSFC 610.1), Larry Takacs (SAIC, GSFC 610.1), Bin Zhao (SAIC, GSFC 610.1), *Michele Rienecker (Sponsor, GSFC 610.1)*

Task Description

A goal of this task is the development of the GEOS-5 Atmosphere-Ocean General Circulation Model (GEOS-5 AOGCM), research in climate variability, and predictability on interannual and decadal time scales. The GEOS-5 AOGCM is a state-of-the art coupled climate model developed at the NASA Global Modeling and Assimilation Office (GMAO). The GEOS-5 AOGCM is designed to simulate climate variability on a wide range of time scales, from synoptic time scales to multi-century climate change. The main components of the GEOS-5 AOGCM are the atmospheric model, the catchment land surface model, both developed by the GMAO, and MOM4, the ocean model developed by the Geophysical Fluid Dynamics Laboratory. The model is used at the GMAO for assimilation of climate data and climate predictions as well as for basic climate research.

Highlights

In collaboration with the GMAO model development group, Vikhliaev actively participates in the development of the GEOS-5 AOGCM, in validating the model, tuning physical parametrization, and maintaining the model code. He has conducted and analyzed over 150 multi-decadal high-resolution numerical climate simulations. The results of these simulations are available online for GMAO researchers and have been presented at meetings and seminars. As a result of Vikhliaev's efforts, current performance of the model is comparable to performance of the state-of-the art coupled climate models being used for the next IPCC assessment report. Vikhliaev provides assistance to the GMAO forecast and data assimilation groups in their research using the GEOS-5 AOGCM. He also participates in ongoing decadal climate prediction experiments within the framework of Coupled Model Intercomparison Project (CMIP5).

Task 610-73-252: **On the Nature and Predictability of Interannual to Decadal Changes in the Global Hydrological Cycle and its Regional Impacts**

GEST Investigator: Hailan Wang

Collaborators: Max Suarez (GSFC 610.1), *Siegfried Schubert (Sponsor, GSFC 610.1)*

Task Description

Complex event-driven climate extremes, including drought, flood and heat wave, exert profound impacts on human society and natural environment, and constitute an important component of the energy and water cycle of the Earth's climate system. During the warm season, there is substantial variability on monthly time scales, including periods of extreme heat waves, droughts and flooding that appear to, at times, develop as part of continental (if not planetary) scale circulation changes. One potentially important mechanism that acts to maintain the large-scale summer circulation changes on time scales far beyond those of local weather processes is Rossby wave dispersion, in which the meridional gradients and near circumpolar extent of the warm season jets can support important guides for Rossby waves. The objective of this study is to investigate the role of stationary Rossby waves as contributing to the boreal summer surface temperature and precipitation variability on subseasonal timescales.

Highlights

Using NASA MERRA, Wang has helped to study the characteristics of the boreal summer Rossby waves, quantify their structure, and identify their importance in warm season short-term climate extremes over a number of regions throughout the Northern Hemisphere. A stationary wave model has been used to characterize the preferred regions of forcing of the leading waves, and to provide insights into the nature of the forcing terms. This study provides a new look at the large-scale controls of boreal summer surface temperature and precipitation variability on subseasonal time scales, and constitutes an important component of the MERRA assessment effort at the NASA GMAO. The research findings have been presented in numerous conferences, and have contributed to a paper in *Journal of Climate* (accepted and in press).

This page intentionally left blank

Mesoscale Atmospheric Processes (Code 613.1)

This page intentionally left blank

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

GEST Investigator: Timothy Berkoff

Collaborators: James Campbell (UCAR), Sebastian Stewart (SSAI), Larry Belcher (SSAI), Si-Chee Tsay (GSFC 613.2), Brent Holben (GSFC 614.4), *Judd Welton (Sponsor, GSFC 613.1)*

Task Description

MPLNET is a network of lidars systems (MPLs) that provide long-term observations of aerosol and cloud properties at multiple sites around the globe. 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 guidance is provided for implementation of systems in the field, laboratory calibration/validation facilities and equipment, as well as data characterization efforts.

Highlights

Berkoff has contributed to a wide range of development and technology activities for MPLNET during the past decade under this task. In addition to overseeing a variety of field activities, he was responsible for instrument upgrades and the management of instrumentation matters for the network. He was essential to the network's expansion from a couple of sites to now more than 18 sites around the globe. Development activities included analyzing and investigating key technology and calibration improvements that are routinely used by NASA. This includes the development of the "Type 4" version of the MPL, which is now the standard used throughout the network, and is sold by a commercial entity. His work was presented at numerous conferences, and he has received multiple NASA awards for his contributions.

Task 613-127-438: **Small Portable Lidar for MPLNET**

GEST Investigator: Timothy Berkoff

Collaborator: *Judd Welton (Sponsor, GSFC 613.1)*

Task Description

This task supports the design and construction of a new, small and portable lidar to support field campaigns undertaken by the NASA Micro Pulse Lidar Network (MPLNET). The new lidar must be capable of deployments to very remote areas with limited power and onsite support to fill gaps in coverage where existing MPLNET lidars cannot be deployed. This task will produce a prototype lidar instrument that will be initially tested at UMBC and GSFC, before deployment to SE Asia as part of the 7-SEAS field campaign.

Highlights

Modeling studies have been conducted to determine the ideal lidar configuration for this task. These included analysis and model validation using Micro-Pulse Lidar and Wide-FOV receiver data under different solar background and aerosol loads. From this study, an overall approach was developed, sub-assemblies from various vendors were identified, and the purchase of key components was accomplished. The assembly and full system testing of this new lidar system is planned for collection of atmospheric profiles later this year.

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

GEST Investigator: Jiun-Dar Chern

Collaborators: Bo-Wen Shen (ESSIC), Toshihisa Matsui (GEST), Wei-Kuo Tao *(Sponsor, GSFC 613.1)*

Task Description

The representation of convective clouds and cloud systems is one of the most challenging problems in climate modeling. Since this task's inception in 2004, Chern has developed the Goddard Multi-scale Modeling Framework (MMF) using a novel approach by embedding cloud-resolving models (CRM) inside a global model. The MMF has been applied to simulate many atmospheric phenomena and shown to substantially reduce common systematic errors in climate models. Coupled with forward satellite simulators, the high-resolution CRM outputs from the MMF can provide global detailed cloud statistics that can be compared directly against observations from NASA satellite platforms. Part of the study's goal was to improve the cloud microphysics schemes in CRM along with the representation of moist processes in conventional global models.

Highlights

The Goddard MMF has been successfully applied to long-term climate studies, inter-annual variability, inter-seasonal and seasonal variability (such as Madden-Julian Oscillation, Africa Easterly waves, drought and flood, tropical cyclones), short-term weather events, and diurnal cycle studies. Overall, the MMF is superior to conventional global models in simulating geographical distribution of precipitation, cloud amounts, the Madden-Julian oscillation signal, and the diurnal cycle of precipitation over land and ocean. The model results have been validated directly against the statistics of radiance and backscattering signals from NASA satellite observations using the Goddard multi-sensor satellite simulators.

Task 613-108-376: **Precipitation Estimation from Satellite Active and Passive Microwave Observations**

GEST Investigator: Mircea Grecu

Collaborator: *Robert Meneghini (Sponsor, GSFC 613.1)*

Task Description

Knowledge regarding the three-dimensional variability of precipitation is essential in the development of precipitation retrieval algorithms from satellite radiometer observations. This is because satellite radiometer observations cannot be uniquely associated with precipitation, and statistical information is required to determine optimal precipitation estimates. Space-borne radar observations may be used to derive such information. For example, it is anticipated that in the Global Precipitation Measurement (GPM) era, observations from space-borne dual-frequency radar will be used to develop algorithms capable of providing consistent precipitation estimates from satellite radiometers featuring various channel frequencies and footprint resolutions. Consistency among precipitation retrievals from these various radiometers will be achieved through the development of common precipitation-radiance databases derived from combined radar-radiometer precipitation profile estimates. From this perspective, space-borne radar profiling algorithms are crucial to derive global satellite precipitation estimates.

Highlights

Grecu developed an algorithm to retrieve precipitation from space-borne dual-frequency (13.8 and 35.6 GHz, or Ku-/Ka-band) radar observations. As previously mentioned, such algorithms will be of paramount importance in deriving radar-based and combined radar-radiometer precipitation estimates from observations provided by the upcoming NASA GPM mission, in which dual-frequency Ku/Ka-band radar observations will be available only within a narrow swath (about half the width of the Ku-band radar swath) over the earth's surface. Therefore, a particular challenge is to develop a flexible radar retrieval algorithm that will derive physically consistent precipitation profile estimates across the radar swath, irrespective of the availability of Ka-band radar observations at any specific location inside that swath; in other words, this algorithm would be able to exploit the information provided by dual-frequency measurements, but be robust in the absence of Ka-band channel. Grecu developed a unified, robust precipitation retrieval algorithm able to interpret either Ku-only or dual-frequency Ku/Ka-band radar observations in a manner consistent with the information content of the observations (Grecu, *et al.*, 2011). The formulation is based on (a) a generalized Hitschfeld-Bordan attenuation correction methodology that yields generic Ku-only precipitation profile estimates and (b) an optimization procedure that adjusts the Ku-band estimates to be physically consistent with coincident Ka-band reflectivity observations and Surface Reference Technique (SRT)-based path-integrated attenuation (PIA) estimates at both Ku and Ka bands. The algorithm has been investigated using synthetic and actual airborne radar observations collected in the NASA Tropical Composition, Cloud, and Climate Coupling (TC4) campaign. In the synthetic data investigation, the dual-frequency algorithm performed significantly better than a single-frequency algorithm; however, dual-frequency estimates are still sensitive to various assumptions, such as the particle size distribution shape, vertical and cloud water distributions, and scattering properties of the ice phase precipitation.

Task 912-54-203: **Algorithm Development for Space-Borne Dual Frequency Radar**

GEST Investigator: Mei Han

Collaborators: William Olson (JCET), P. Ola. G. Persson (CIRES, NOAA/ESRL), Jian-Wen Bao (NOAA/ESRL), Christopher Williams (CIRES, NOAA/ESRL), *Scott Braun (Sponsor, GSFC 613.1)*

Task Description

This research emphasizes the use of satellite-based observations from NASA satellites (TRMM and Aqua) and numerical models (MM5 and WRF) to study winter precipitation over ocean and land and to evaluate the performances of cloud and precipitation models and retrieval algorithms in the middle latitudes. Since the task's inception in 2005, Han has studied frontal rainbands and orographic rainfall as seen by TRMM's unique observations. Through collaborations with scientists in other institutions, they performed systematic evaluations of various microphysics schemes in mesoscale models.

Highlights

Han has presented her research findings at numerous conferences and NASA Precipitation Measurement Mission (PMM) science team meetings. Han's research regarding alongfront variability of precipitation associated with a mid-latitude frontal zone was published in the *Monthly Weather Review* in 2009. In 2010, Han and her collaborators finished and published the first of its kind study of all the available microphysical schemes in a mesoscale model using a multi-sensor satellite instrument in the *Journal of Applied Meteorology and Climatology*. Its findings provide implications on improving the cloud microphysical schemes through remote-sensing techniques and on advancing the satellite retrieval algorithms for precipitations.

Task 613-127-443: **Algorithm Development for Space-Borne Dual Frequency Radar**

GEST Investigators: Raymond Hoff (Physics Dept.), Jamie Compton (Graduate Student, Physics), Ruben Delgado (Faculty Research Asst., JCET)

Collaborator: *Judd Welton (Sponsor, GSFC 613.1)*

Task Description

Mr. Compton will develop an improved algorithm to determine routinely the height of the Planetary Boundary Layer (PBL) in the MPLNET lidar data using the Haar Wavelet Transform. This work is expected to lead to an algorithm that can routinely derive this parameter in the MPLNET processing suite with a minimum of quality assurance and manual intervention, and that will have a documented level of mis-assignments of the height. A related journal publication will be expected from this work.

Highlights

Mr. Compton has completed the algorithmic development of the wavelet transform and has shown improvement over the standard product. To date, the transform is not operational and requires additional temporal criteria to choose the parameters of the transform. Mr. Compton will present this work at UMBC's Graduate Research Symposium in April and at the Tropospheric Profiling Technologies Workshop in Boulder, Colorado in April 2011. A draft journal paper is under review.

Task 613-103-354: **Algorithm Development for Space-Borne Dual Frequency Radar**

GEST Investigator: Hyokyung Kim

Collaborators: Jeffrey Jones (SAIC), Liang Liao (GEST), *Robert Meneghini (Sponsor, GSFC 613.1)*

Task Description

In order to measure the global precipitation, the GPM (Global Precipitation Measurement) core satellite will be launched in June 2013. Kim and her collaborators have developed the radar simulator to generate the synthetic level 1 product, which will be used to test the pre-launching radar algorithms and also check and guarantee if the algorithms and processing system are correctly implemented after the satellite launch. The synthetic radar data at Ku- and Ka-band are generated using the Goddard Cumulus Ensemble model in strong convective rainfall cases and the WRF model in winter snowfall cases from C3VP field experiment. The simulated level 1 products are saved in GPM-standard HDF format to be incorporated into the processing system. She has tested and compared the algorithms using the synthetic data.

Highlights

Kim's research developing the space-borne radar simulator has contributed to NASA's Global Precipitation Measure mission and helped the radar algorithm developers to test and evaluate their algorithms using synthetic data. She has presented how to generate the synthetic level 1 product at related meetings and held discussions with the radar algorithms developers and the data processing system developers.

Task 613-112-402: **Development of Cloud Thermodynamic Phase Retrievals for MODIS Collection 6**

GEST Investigator: Benjamin Marchant

Collaborators: Zhibo Zhang, Kerry Meyer, *Steven Platnick (Sponsor, GSFC 610)*

Task Description

Determination of cloud thermodynamic phase retrieval is an important first step in processing MODIS cloud optical products. Since water and ice particles have very different scattering and absorption properties, an incorrect phase determination can lead to substantial errors. Marchant has studied the impact of wrong phase decision on ice or water-effective size retrievals. His main purpose was to provide a new cloud thermodynamic phase algorithm for the next MODIS Collection 6, based on separate ice and liquid cloud-effective size retrievals in different SWIR spectral bands. In addition, he has also used collocated data from MODIS and CALIOP in order to find out how to develop and optimize that new cloud phase algorithm.

Highlights

Since joining GEST in January 2010, Marchant has contributed to the development of the next MODIS cloud optical products (MODIS Collection 6). He has also presented his preliminary results at the A-Train symposium.

Task 613-89-309: **Evaluating and improving the representation of cloud microphysical processes and cloud-aerosol-radiation interactions for regional and mesoscale models**

GEST Investigator: Jainn J. Shi

Collaborators: Wei-Kuo Tao (GSFC 613.1), Christa Peters-Lidard (GSFC 614.3), William K-M. Lau (GSFC 613.0), Ken Pickering (GSFC 613.3), Toshihisa Matsui (ESSIC), *O.C. St. Cyr (Sponsor, GSFC 670)*

Task Description

Activities within this task have focused on the research and development of mesoscale models for investigating precipitation processes associated with various mesoscale convective systems, tropical cyclones, and hurricanes. The researchers evaluated and improved the representation of cloud processes for regional models. Another goal is to understand and quantify the cloud-aerosol forcing and its dynamical transport over tropical regions over local and regional scales.

Highlights

Shi has implemented the Goddard cloud microphysics, Goddard long-wave and short-wave radiation schemes into the WRF model to improve the capability and the prediction accuracy of the model. These new physics schemes and modules have now been transferred to the NCAR-WRF team and have become parts of the research community model. He also has developed the interface for the inline coupling of the GOCART/WRF-Chem and the Goddard Radiation schemes, which was done to provide the aerosol direct impact to the radiation. He has utilized the improved WRF model in many research efforts for NASA-funded missions and several international projects in recent years, *e.g.* the Global Precipitation Mission (GPM), the Canadian CloudSat/CALIPSO Validation (C3VP) Project, the African Monsoon

Multidisciplinary Analyses (AMMA) project, and the NASA Modeling, Analysis and Prediction (MAP) Program. Since the task's inception in 2008, he has authored and co-authored several peer-reviewed journal articles and also presented his research findings at numerous conferences, highlighting his collaborative method of studying the radiation and cloud microphysics processes, as well as validation methods of precipitation process with a collection of satellite, radar, aircraft and surface measurements.

Task 612-79-272: Study of the Influence of the Saharan Air Layer on Tropical Cyclone Development and Intensity

GEST Investigator: Chung-Lin Shie and Jason Sippel

Collaborators: Liguang Wu (GEST) and *Scott Braun (Sponsor, GSFC 613.1)*

Task Description

The role of the Saharan Air Layer (SAL) in modulating tropical cyclone genesis and intensity has received considerable attention in recent years. The investigators, Shie and Sippel, collaborating with Braun and Wu, respectively, focused their studies on improving the understanding of the influence of the SAL on tropical cyclone development and intensity in the Atlantic basin. Studies regarding the impact of the SAL have been supported with the use of data from the Aqua, CloudSat, CALIPSO and TRMM satellites through observational analysis and numerical simulation.

Highlights

Their studies on the impact of the SAL on tropical cyclone genesis and intensification have yielded some interesting results. In a recent study by Braun, Sippel, Shie, and Boller (2011), they investigated Tropical Storm Debby and Hurricane Helene using a suite of remote sensing data, global meteorological analyses, and high-resolution simulations, and the results suggested only a very limited impact of the SAL once genesis has occurred. In a second study by Sippel, Braun and Shie (2011), they examined environmental influences on the strength of Tropical Storm Debby, and the results showed that the relationship between the SAL and developing tropical cyclones was not straightforward and mainly limited to Debby's pre-depression stage. However, in another study by Pan, Wu and Shie (2011, *Advances in Atmospheric Sciences*), the SAL has played two roles in the formation of Atlantic storms: it first helped trigger the development of two tropical disturbances associated with Hurricane Isabel and Tropical Depression 14 (TD14) in the early stage, and later it slowed down the formation of Isabel and inhibited TD14 from becoming a named tropical cyclone.

Task 613-103-353: **Using Airborne Measurements to Improve Physical Assumptions in DPR and GMI Algorithms**

GEST Investigator: Lin Tian

Collaborators: Bill Olson (JCET), Mircea Grecu (GEST), *Gerry Heymsfield (Sponsor, GSFC 613.2)*

Task Description

Accurate knowledge of how much it rains and how strong the wind is in the earth's atmosphere is essential for improving scientists' understanding of weather and climate. Such knowledge can only be achieved from space with remote sensing instruments, such as radar and radiometers. Airborne measurements are critical for improving the physical assumptions in satellite retrieval algorithms. Since this task's inception in 2008, Tian has studied ice particle size distributions using airborne *in-situ* and radar measurements and its implication on snow and rain retrieval. Studies regarding light rain, snow and

deep convections have resulted in improvements of the radar and radiometer rain retrieval algorithms.

Highlights

Tian has developed the algorithms for light rain retrieval, has helped to develop and test a new radar algorithm with aircraft data, and has contributed to NASA's GPM project. She has presented her research findings at numerous conferences, highlighting her study of the ice particle size distributions and shallow convections. Tian, *et al.*'s research regarding light rain retrieval using Doppler velocity was highlighted in the *Journal of Geophysical Research* in 2009. Her research on ice particle size distribution has been published in the *Journal of Atmospheric Science* in 2010. Also, Tian mentored GSSP graduate summer student Tao Chu, who is now a Ph.D candidate at Stanford University.

Task 912-29-152: **Using the Goddard Cloud-Resolving Model (CRM) to Study Aerosol Indirect Effects on Clouds and Precipitation**

GEST Investigators: Xiping Zeng and Xiaowen Li

Collaborator: *Wei-Kuo Tao (Sponsor, GSFC 613.1)*

Task Description

Of all the key uncertainties on climate forcing, the indirect effect of aerosols on clouds and radiation ranks at the top (IPCC 2007). Since this task's inception in 2002, Zeng and Li have studied the indirect effects of cloud condensation nuclei (CCN) and ice nuclei (IN), two classes of aerosol particles, on clouds and precipitation, using the Goddard CRM, field campaign observations as well as satellite data. Their goal is to address the relationship among aerosols, clouds, and precipitation via dynamics and radiation.

Highlights

Li and Zeng along with their collaborator, under the support of the DOE ARM projects (NASA TRMM/GPM projects as well as the NASA MAP projects), explored the indirect effect of aerosols on clouds and precipitations. They have published 20 papers in referred scientific journals. Li and Tao improved the microphysics scheme in the CRM for better simulations of mid-latitudinal squall lines. They found that increasing aerosol has a profound impact on convection strength in the tropics. Zeng and Tao revealed that the increase in IN, such as that produced by desertification and industrialization, can lead to an increase in high cirrus clouds, which in turn warms the Earth. This discovery explains well the geographic and seasonal patterns of the observed warming over the past decades. They contributed to the mentoring of four graduate students from different universities. Both Li and Zeng received the Best Senior Author Publication Awards issued by NASA/GSFC Laboratory for Atmospheres in 2009 and 2010, respectively.

This page intentionally left blank.

Climate and Radiation
(Code 613.2)

This page intentionally left blank.

Task 613-20-420: **Improve EPA's AIRNow Air Quality Index Maps with NASA Satellite Data**

GEST Investigator: D. Allen Chu

Collaborator: *Lorraine Remer (Sponsor, GSFC 613.2)*

Task Description

The relationship between AOD and $PM_{2.5}$ is important for the application of satellite-based AOD products to air quality assessment. The new lidar measurements provide insights into boundary layer height and extinction profile within the boundary layer. The first-year task tested the hypothesis for improving the relationship between AOD and $PM_{2.5}$ by taking into account aerosol vertical distribution.

Highlights

The main objectives include continual post-mission analysis of ARCTAS satellite and *in situ* measurements, model/satellite intercomparisons, and the retrievals of AOD over snow/ice-covered surfaces. Multi-resolution AOD data in San Joaquin Valley and ARCTAS domains will be evaluated to optimize AOD retrievals in association with surface PM measurements. Specific planned flights of HSRL will be targeted for detailed examination of the effect of vertical distribution.

Task 610-89-311: **EOS and NPP Satellite Data Fusion to develop a Long-Term Record on Aerosol Absorption**

GEST Investigator: Santiago Gassó

Collaborators: Omar Torres (Hampton University), *Lorraine Remer (Sponsor, GSFC 613.2)*

Task Description

Aerosol absorption recently has been linked to the inhibition of cloud formation and the suppression of precipitation. Despite the crucial role of aerosol absorption on the radiation balance and the potentially important effect on the hydrological cycle, the global quantification of aerosol absorption remains a challenge to the aerosol sensing community. This task proposes to use EOS satellite information in an integrated science data analysis to develop a record on aerosol absorption. The task combines the analysis of Aura-OMI aerosol absorption measurements with the Aqua-MODIS aerosol optical depth product to create a data set on visible single scattering albedo and absorption optical depth. This data fusion application using A-train sensors lays the groundwork for the aerosol absorption record to continue during the NPOESS era with the combination of aerosol absorption measurements from the OMPS sensor and optical depth observations from the VIIRS (Visible/Infrared Imager Radiometer Suite) instrument on the NPP and NPOESS platforms.

Highlights

Gassó has helped to define objectives regarding the use of combined products of MODIS and OMI aerosol products and has contributed to NASA's future Aerosol, Clouds and Ecosystems (ACE) mission. He developed a method to process and combine aerosol OMI and MODIS products into a single grid. He has also presented at national and international meetings. Additionally, he mentored graduate student Matthew Johnson from North Carolina State University during his GSSP summer internship at Goddard; since then, Gassó has become a committee member on his PhD Committee.

Task 900-29-151: **Characterization of Surface Bidirectional Reflectance Distribution Function, Aerosols and Clouds from Airborne Radiation Measurements**

GEST Investigator: Charles K. Gatebe

Collaborators: Michael King, Oleg Dubovik, Alexander Sinyuk, Alex Lyapustin, Miguel Román, Crystal Schaaf, Eric Wilcox, and *Ralph Kahn (Sponsor, GSFC 613.2)*

Task Description

In this research, Gatebe and his collaborators use airborne measurements from NASA's Cloud Absorption Radiometer (CAR) taken over different types of surfaces such as snow, sea ice, snow, tundra, cloud, smoke, and ocean to characterize the surface, aerosol and cloud optical properties. Their goal is to build a well-calibrated and feature-rich data set to validate satellite sensors. They incorporate the increased spectral and spatial information available from CAR and perform simultaneous retrievals of aerosol optical properties and spectral bidirectional reflectance distribution function (BRDF).

Highlights

The airborne sensor has a wide scan range (190°) and an instantaneous field-of-view of 1°, and can capture full BRDF including the hotspot under low sun angle conditions, particularly at high-latitude places such as the Arctic. The instrument has a unique ability to measure almost simultaneously both down-welling and up-welling radiances at 14 narrow spectral bands located in the atmospheric window regions of the ultraviolet, visible and near-infrared; therefore, it is suitable for taking measurements even deep inside clouds and smoke layers. It was developed for low- to medium altitude aircraft and can be used to obtain data at different altitudes with varying spatial resolutions, which is important for addressing up-scaling needs for satellite validation. Under this task the CAR has been upgraded, has been successfully integrated on different aircraft and has collected data in five major international field experiments in different parts of the world, including the USA, Canada, Greenland and Africa.

Task 613-103-349: **Aerosol-Climate effects over South Asia**

GEST Investigator: Ritesh Gautam

Collaborators: William K-M. Lau (GSFC 613), *Christine Hsu (Sponsor, GSFC 613)*

Task Description

Aerosol solar absorption over South Asia, more specifically over the Gangetic-Himalayan region, has been suggested to impact the summer monsoon, which is crucial to the livelihood of the large population. Gautam's research is in the observational assessment of short- and long-term effects of aerosols on the regional climate through the integrated usage of satellite and surface measurements. Gautam has worked on this task since 2009 and has studied the characterization, radiative effects, and possible long-term warming implications of the heavy regional aerosol loading over the Gangetic-Himalayan region. Additionally, he has also recently investigated the impact of dust transport on Himalayan snow albedo by satellite data.

Highlights

Gautam found that the Gangetic-Himalayan region is associated with an enhanced warming trend in the longest record of tropospheric temperatures derived from the Microwave Sounding Unit data from 1979-

2007, possibly amplified due to regional aerosol solar absorption. He also conducted a 3-month-long field experiment in northwestern India, with instrument deployments encompassing source arid regions to the Himalayan foothill/slopes, to characterize the aerosol loading and investigate direct aerosol radiative effect during April-June 2009. This field deployment was in support of the GSFC's Radiation Aerosol Joint Observations in Gangetic Himalayan Area and was carried out in collaboration with scientists based at GSFC and in India. Gautam presented findings of the aerosol-monsoon research at international meetings hosted by IAMAS, AGU, UNEP and COSPAR during 2009-2011. Gautam's findings were published in *GRL*, *JGR* and *Annales Geophysicae*. Additionally, he authored a chapter in a 2009 UNEP report titled "Recent trends in melting glaciers, tropospheric temperatures over the Himalayas and summer monsoon rainfall over India".

Task 613-104-357: **Effect of Tropospheric Aerosols on Climate**

GEST Investigator: Jingfeng Huang

Collaborators: Si-Chee Tsay (GSFC 613), Myeong-Jae Jeong (GEST, GSFC 613), *Christine Hsu (Sponsor, GSFC 613)*

Task Description

Direct (radiative) and indirect (microphysical) effects of tropospheric aerosols on climate are quantitatively evaluated by employing long-term multi-platform satellite and *in-situ* measurements of aerosols, clouds, radiative fluxes, and precipitation. Specific objectives of this task also include evaluating and improving satellite aerosol retrieval algorithms, and constructing long-term aerosol climate data records.

Highlights

Huang and collaborators conducted a systematic investigation to quantify the susceptibility of satellite and ground aerosol retrievals to cirrus contamination. Part of this research was accepted for publication by *JGR*. They explored the potential of the 13+ years of SeaWiFS aerosol products on evaluating aerosol effects on climate. They were also involved in the VIIRS aerosol EDR calibration activities aimed at constructing long-term aerosol climate data records. Huang has presented his research findings at numerous conferences and workshops, not only addressing the data uncertainty issues within aerosol retrievals, but also highlighting his statistical approaches of using multi-sensor datasets to elucidate observational evidence of aerosol-cloud-precipitation-climate interactions.

Task 613-38-236: **A Cross-Calibrated Multi-Satellite Ocean Surface Wind – Vector Product**

GEST Investigator: Juan Carlos Jusem

Collaborators: Joseph Ardizzone (GSFC, 613.0), *M. Seablom (Sponsor, GSFC)*

Task Description

Oceanic surface-winds data have important applications, such as weather monitoring, climate diagnosis, and the initialization of oceanic and atmospheric models for research and prediction. Satellite sensors measure sea-surface stress, which is converted into a neutral wind through a platform-dependent calibration. The task consists in combining multiple satellite data and conventional wind observations to obtain a consistent long-term dataset, by means of a variational analysis method. Jusem's role involves the physical interpretation and meteorological assessments of wind products.

Highlights

Wind products are available in latitude/longitude gridded format at a resolution of 0.25 degree from July 1987 until December 2009, every 6 hours. One remarkable finding is that current numerical analysis models often underestimate the intensity of storms at sea, because small-scale components are filtered out for the benefit of long-term forecasts. In the multi-satellite dataset, this filtering out is absent.

Task 613-71-249: **Aerosol-Water Cycle Interaction**

GEST Investigator: Kyu-Myong Kim

Collaborator: *William K.-M. Lau (Sponsor, GSFC 613)*

Task Description

The goal of this research is to understand the climate impacts of aerosol radiative forcing on the global monsoon water cycle at various time scales, from diurnal cycle to interannual variation of monsoon rainfall. Various satellite observations, including MODIS, TOMS, OMI, and TRMM as well as *in-situ* observations, are being used to diagnose the relations between aerosol distribution and the evolution of the monsoon water cycle. In addition, GCM experiments are also conducted to understand the mechanisms involved. The main objective is to better understand the role of absorbing aerosols such as black carbon and dust as triggering elements of the “Elevated heat-pump” on monsoon circulation, especially over the Indian sub-continent and the West African monsoon region.

Highlights

The effect of aerosols from biomass burning on the climate over East Asia is investigated based on the GEOS-5 simulations with and without biomass burning emissions. Preliminary results show that aerosol radiative forcing suppresses cloud and rainfall in southern China and induce local meridional circulation anomalies, which transport unprecipitated moisture to central China where the spring rainfall increases. These results are consistent with the observational relationship between the number of fire pixels over Indochina and rainfall/cloud over southern China. Also, Kim and Lau examined two record-setting hydrometeorologic extreme events during summer 2010, *i.e.*, the Russian heat wave/wildfires and Pakistan flood, and found that these two seemingly unrelated events were indeed physically related. The intense heat wave and wildfires in Russia were caused by a strong and prolonged atmospheric blocking event and amplified through feedback mechanisms involving land-atmosphere interaction. The blocking initiated a mid-to-upper level Rossby wave train and vorticity perturbations in the leading edge of the eastward propagating trough, which was instrumental in triggering torrential rain over northern Pakistan.

Task 613-130-444: **Improvement of GEOS-5 Radiation and Microphysics Parameterizations**

GEST Investigator: Dong Min Lee

Collaborator: *Lazaros Oraiopoulos (Sponsor, GSFC 613.2)*

Task Description

While fully accounting for 3D effects of cloud in climate models appears unrealistic at the present time when considering computational costs and the unavailability of 3D cloud structure, the incorporation of subgrid cloud variability in radiation schemes described by one-point statistics is feasible. Yet, while a full Independent Column Approximation (ICA) is too intensive, a Monte Carlo spectral integration can be applied, and this "McICA" approach has been implemented in Goddard's GEOS-5 GCM in conjunction with the RRTMG radiation package. GEOS-5 with McICA can adopt horizontally variable clouds, which can be allowed to overlap arbitrarily, both in terms of cloud fraction and layer condensate distributions.

Simulating the climatically important cloud-aerosol indirect effects in GCMs is a challenging task that has only recently been brought to the forefront of global modeling efforts. McRAS is enhanced by new cloud nucleation parameterizations for liquid, ice and mixed-phase clouds. Both stratiform and convective clouds are treated in McRAS-AC.

Highlights

Lee has implemented the McICA approach in Goddard's GEOS-5 AGCM in conjunction with the RRTMG radiation package, and aerosol – cloud indirect effect parameterization, McRAS – AC. He has presented his research findings at numerous conferences, heavily emphasizing the development of new ensemble generation method.

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

GEST Investigator: Gyula I. Molnar

Collaborators: Dr. John Blaisdell (SAIC), Lena Iredell (SAIC), *Dr. Joel Susskind (Sponsor, Code 613)*

Task Description

The AIRS/AMSU instrument is a state-of-the-art infrared/microwave sounding system, and has been providing operational quality measurements since September 2002. In addition to temperature and atmospheric constituent profiles, outgoing longwave radiation (OLR) and basic cloud parameters are also derived from the AIRS/AMSU observations. The SRT's main task is to continuously improve the quality of these retrieval products, both for short-term (weather) and longer-term (climate) use. The GEST investigator has been focusing on the latter, because several key AIRS products have not been rigorously validated and/or evaluated on larger spatial and longer-term temporal scales.

Highlights

Molnar has extended to 8+ years the validation and assessment of the Level 3 (L3) AIRS-retrieved products, available to the public through the GES DISC at NASA/GSFC. In particular, extremely good agreement was found between the CERES-Terra and AIRS OLR anomaly trends, down to general circulation model (GCM) grid-scale spatial resolution. For example, it has been found that El Niño/La Niña Oscillations played a key role in producing a recent negative anomaly time-series "trend" in the observed outgoing long-wave radiation. Molnar also has continued to evaluate the usefulness of AIRS L3 products for climate change assessments in general and climate model development in particular. The results indicate a high level of consistency and accuracy of the AIRS products considered, thus enabling them for use in model validations and (shorter-term) climate trend assessments. The inter-relationships of crucial climate parameters displayed in Molnar's AIRS analyses may also prove useful for testing or improving GCM parameterizations of atmospheric processes. While the current AIRS climatology covers only about 8.5 years, Molnar is hopeful that it will extend many more years further into the future.

Task 613-91-317: **MISR Aerosol Air Mass Type Mapping over Mega-City – Validation & Applications**

GEST Investigator: Falguni Patadia

Collaborator: *J. Masek (Sponsor, GSFC 613.2)*

Task Description

This task focuses on using remote sensing datasets for mapping aerosol air mass type over megacity environments. Specifically, Patadia analyzes data from the Multi-angle Imaging SpectroRadiometer (MISR), along with other ground and *in situ* data acquired as part of an INTEX-B field campaign that took place in the Mexico City metropolitan area during March 2006. The MISR satellite instrument features a unique combination of multi-angle and spectral imaging channels. MISR, onboard the Terra satellite, has an 11-year data record of aerosol amount and type. Patadia is studying the complex aerosol environment around Mexico City, first validating the aerosol type maps produced by MISR, based on suborbital data obtained during the INTEX-B experiment, and then using the extensive MISR data record over this region and elsewhere to analyze aerosol source behavior, transports, and aerosol air mass type evolution.

Highlights

Using ground and *in situ* observations from the INTEX-B field campaign, and the MISR Research Aerosol Retrieval algorithm, Patadia's research helps to characterize the aerosol amount and properties over Mexico City. The research algorithm helps identify limitations of the MISR Standard aerosol product over urban areas, such as the Mexican megacity. She is preparing a manuscript based on her research, which she will submit to the journal *Atmospheric Chemistry and Physics Discussions*.

Task 610-107-366: **Relationships among precipitation characteristics, atmospheric water cycles, climate variability and change**

GEST Investigator: Oreste Reale

Collaborators: M.-I. Lee (GEST), Man-Li Wu (GSFC 610.3), Max Suarez (GSFC 610.3), *Siegfried Schubert (Sponsor, GSFC 610.1)*

Task Description

Reale's contribution is centered on the development of diagnostics to assess the quality of tropical cyclone (TC) representation in global models. In particular, emphasis is placed on the understanding of how global models can reproduce TC structure, dynamics, and properties as a function of resolution, and to develop metrics that can assess the degree of efficiency of TC representation in a resolution-independent manner. Reale analyzed initially a series of long runs produced by Dr. M.-I. Lee (GEST) and later some long runs produced by Dr. Putman (NASA). In addition, Reale has been collaborating with Dr. Man-Li Wu, Dr. Schubert and others to investigate the causes of maintenance and instability of the African Easterly Jet.

Highlights

Reale presented (remotely) his work under this task at an international workshop held in Trieste (Italy) in August 2009. Results of an activity initiated previously, but concluded under this task, produced a publication in the *Journal of Climate*, led by Dr. Wu (NASA) and co-authored by Reale, Dr. Schubert and others. The article discussed the African Easterly Jet (AEJ) structure and maintenance. A follow-up article on the subject of instability properties of the AEJ, led by Wu and co-authored by Reale, Shubert and others, was submitted in 2010 and at the time of this report has been conditionally accepted.

Task 613-110-386: **Simulating and Predicting Sub-seasonal and Longer-term changes in Tropical Storm Characteristics using High Resolution Climate Models**

GEST Investigator: Oreste Reale

Collaborators: Yaping Zhou (GEST), *William K.-M. Lau (Sponsor, GSFC 613)*

Task Description

This task is a part of a larger proposal (PI: Dr. Lau) and Reale's work is specifically focused on the impact of different AIRS data sets on the GEOS-5 data assimilation and forecasting system, with a particular emphasis on precipitation characteristics in the tropics. The purpose of this work is to gain further understanding of precipitation structure in the tropics on different space-and time-scales. Specifically, Reale has investigated the dynamics of the impact of AIRS on tropical cyclone structure and on floods in a monsoon region. In addition, Reale has also continued work on the impact of aerosols on the Atlantic tropical atmosphere (previously initiated under a different task).

Highlights

Results were published in *Geophysical Research Letters* in an article led by Dr. Zhou and co-authored by Dr. Lau and Reale. Research performed under this task was presented by Reale at several invited talks: at the AIRS Science Team Meetings, October 2009 and 2010; at the Naval Research Laboratory, March 2010; and, at the Hurricane Forecasting Improvement Project Workshop in Miami, December 2010. One reply article by Reale and Lau on the possible role of Saharan dust on tropical cyclone was published in 2010 in the *Journal of Atmospheric Science*. Also, one additional article led by Reale on the effect of interactive aerosols on the African Easterly Jet is currently in press.

Task 613-123-428: **Investigating the impact of atmospheric aerosols on the Earth**

GEST Investigator: Andrew Sayer

Collaborator: *Christina Hsu (Sponsor, GSFC 613.2)*

Task Description

The direct and indirect radiative effects of atmospheric aerosols are among the least certain contributions to radiative forcing. Satellites can provide information about aerosols on a global scale; however, current aerosol retrieval algorithms must make assumptions relating to aerosol properties and surface reflectance, due to an insufficient amount of information to retrieve all parameters unambiguously. Specific objectives of this task involve improvements to and evaluations of the performance of satellite aerosol retrieval algorithms for constructing long-term aerosol climate data records, and the use of radiative transfer modeling to investigate the radiative effects of aerosols.

Highlights

Since joining GEST at the end of September 2010, Sayer's primary focus has been on the development of an over-ocean aerosol retrieval algorithm from Sea-viewing Wide Field-of-view Sensor (SeaWiFS) data. As part of this, the properties of marine aerosol were examined using Sun-photometer retrievals of aerosol size distribution over a variety of oceanic regions from the Aerosol Robotic Network (AERONET). This revealed a high level of similarity in the properties of pristine marine aerosol globally, with wind speed being a strong predictor for the total aerosol optical depth and relative contributions of fine-mode and coarse-mode particles to the total aerosol burden. The results of this study were incorporated into the development of the SeaWiFS aerosol retrieval algorithm, which is currently undergoing final validation

before being applied to the 13-year SeaWiFS dataset as part of NASA's Making Earth System data records for Use in Research Environments (MEASURES) project. Sayer is also involved in the group's aerosol retrieval algorithm over land from SeaWiFS data. Publications detailing this research are in preparation.

Task 913-48-190: **Atmospheric Solar Radiative Transfer**

GEST Investigator: Guoyong Wen

Collaborators: Alexander Marshak (GSFC), *Robert F. Cahalan (Sponsor, GSFC 613.2)*

Task Description

Solar forcing is a unique external forcing of climate. One of the objectives of this task is to study solar forcing of climate based on observations from SORCE (Solar Radiation and Climate Experiment) and climate models. Aerosols play an important role in the climate system through direct and indirect effects. Another objective of this task focuses on 3D radiative effects on reflected solar radiation and associated errors in MODIS aerosol retrieval near clouds, an important region to study aerosol-cloud interactions. Since this task's inception in 2003, Wen has studied the climate responses to solar variability on decadal and centennial time-scales. He has performed 3D radiative transfer modeling to assess 3D radiative effects on MODIS aerosol retrieval. Part of his goal is to improve MODIS aerosol retrieval in the vicinity of clouds.

Highlights

Wen developed a Coupled Ocean-Atmosphere Radiative Convective Model (COA-RCM) for Sun-climate study. He applied the COA-RCM and the GISS GCM to investigate the spectral solar forcing of climate. He found that atmospheric temperatures have very different responses to the SORCE-based spectral solar forcing as compared to the proxy reconstructed spectral solar forcing. He also performed a series of 3D radiative transfer modeling simulations to demonstrate that cloud 3D radiative effects can enhance the reflected sunlight in the vicinity of clouds, which leads to large errors in 1D operational aerosol retrieval. He is co-author in a simple 2-layer model for correcting cloud adjacency effects. The results of Sun-climate and cloud-aerosol research were presented at numerous conferences and published in peer review journals. He also mentored summer students, one of whom is now a graduate student at Brown University.

Task 613-97-340: **Use of CALIPSO in understanding the effect of clouds on aerosol properties and interpreting MODIS aerosol observations near clouds**

GEST Investigator: Weidong Yang

Collaborators: Alexander Marshak (PI, GSFC 613.2), *John Cooper (Sponsor, GSFC 672)*

Task Description

Aerosol properties in the vicinity of clouds are different from those in cloud-free regions, and there is a strong correlation between aerosol optical depth and cloud cover. CALIPSO provides a large range-resolved dataset of global cloud and aerosol properties that is not affected by cloud adjacency effects, which generally exist in passive instruments, thus helping to quantify the aerosol direct and indirect radiatve forcings and their uncertainties. The major objectives of this project include understanding the effect of clouds on aerosol properties and aerosol direct radiative forcing with the help of CALIPSO and MODIS observations, as well as improving the interpretation of MODIS aerosol observations near clouds by using CALIOP data for improving and testing models that account for cloud adjacency effect.

Highlights

Yang and Marshak studied the effects of using Cloud-Aerosol-Discrimination confidence level-based data selection method, and effects of cloud separations and cloud sizes on the observation of aerosol properties. The results have been presented at several conferences and related publications have been submitted to *IEEE Transactions on Geoscience and Remote Sensing*. Yang's most recent work has been on the property change of dust aerosol under higher humidity environments. Yang and Marshak found that, as a special subtype of aerosols, dust demonstrates different property change features in the vicinity of clouds compared to that of other non-dust aerosols. The detailed results will be presented at upcoming conferences and in publications.

Task 613-82-282: **Studies with Observations from the Geoscience Laser Altimeter System (GLAS) for Thick Cloud Optical Depth Retrieval and in Support of the Icesat-2 Mission**

GEST Investigator: Yuekui Yang

Collaborators: Christine Chiu (University of Reading), Stephen Palm (SSAI), Tamás Várnai (JCET), Warren J. Wiscombe (GSFC 613.2), and Ping Yang (Texas A&M), *Alexander Marshak (Sponsor, GSFC 613.2)*

Task Description

The Geoscience Laser Altimeter System (GLAS), which was onboard the Ice Cloud and Elevation Satellite (ICESat) spacecraft, was the first lidar instrument for continuous global observations of Earth. The system measured the time of flight of the arriving photons that were reflected by the surface to deduce the elevation of the underlying terrain. As a follow-up, the Ice, Cloud, and land Elevation Satellite-2 (ICESat-2) mission was recommended by the National Research Council's Decadal Survey as one of the NASA's top-priority missions. The current design of ICESat-2 adopts a 532 nm micro-pulse photon counting lidar system with single photon detectability. Since the inception of this task in 2007, Yang has worked on retrieving cloud optical depth for thick clouds and on studying the impact of clouds on the surface altimetry from space-borne lidar systems.

Highlights

Yang and his collaborators developed an innovative method to retrieve thick cloud optical depth from the GLAS solar background observations. The solar background has been regarded as noise in lidar studies. Yang and collaborators turned the noise into a signal. In support of the ICESat-2 mission, they established a framework that simulated the behavior of space-borne lidars in cloudy and clear atmospheres. Their studies quantified the uncertainties in lidar surface altimetry due to the presence of clouds. The results have been presented in numerous conferences and have resulted in two published papers: one in the *IEEE Transaction of Geoscience and Remote Sensing* (2010), and another in the *Journal of Atmospheric Sciences* (2008), for which Yang won the 2009 Climate and Radiation Branch Best Paper Award. One additional paper has been submitted to *IEEE Transaction on Geoscience and Remote Sensing* and currently is under review. The research has also appeared as "Image of the Week" at the NASA website: climate.gsfc.nasa.gov.

Task 614-126-437: **Algorithm Preparation for the Earth Polychromatic Imaging Camera (EPIC) onboard the future Deep Space Climate Observatory (DSCOVR)**

GEST Investigator: Yuekui Yang

Collaborators: Alexander Cede, Alexei Lyapustin, Jianping Mao, Kerry Meyer, and *Alexander Marshak (Sponsor, GSFC 613.2)*

Task Description

DSCOVR will be the first mission with Earth-observing capability to the Lagrange-1 (L1) point. Onboard DSCOVR, EPIC will observe the Sun-lit side of the Earth and provide continuous and high-time-resolution observations at multiple wavelengths. This task is part of the pre-launch research aimed at providing the analysis needed for launch preparation and the algorithm studies needed for possible after-launch data processing. The specific studies of this task include stray light correction, EPIC simulator development, cloud masking, and cloud pressure retrieval.

Highlights

Since the inception of the task in 2010, the GEST investigators have made significant progress toward the goals of the task. Based on an estimated point spread function (PSF), Cede analyzed the stray light problem in EPIC and finished a report that provided suggestions on obtaining accurate EPIC's PSF; Lyapustin developed the EPIC radiance simulator that provided the group with simulated DSCOVR data for algorithm development and testing; using the Line-by-Line Radiative Transfer Model (LBLRTM), Mao simulated the monochromatic spectral transmittance/absorption for both O2 A and B bands, which is essential for the cloud pressure retrieval; Meyer developed the prototype EPIC cloud mask algorithm by adopting both the UV and visible channels as cloud screening tests, and he successfully tested the algorithm on OMI and MODIS data, respectively; Yang completed the implementation of a cloud pressure retrieving model for EPIC using the oxygen bands, and tests have been conducted with data provided by Lyapustin. The GEST investigators presented their work at the EPIC workshop held at GSFC in November 2010.

Task 613-106-361: **Data analysis and modeling studies of the impacts of absorbing aerosols on snow impurity changes and glacier mass balance in the Himalayas and possible effects on the South Asian monsoon**

GEST Investigator: Teppei J. Yasunari

Collaborators: Randal Koster (GSFC 610), Max Suarez (GSFC 610), Mahanama Sarith (SAIC/GSFC, 610), Gregory Walker (SAIC/GSFC 610), Paolo Bonasoni, Qian Tan (GEST/UMBC, GSFC 613), Angela Marinoni, Paolo Christofanelli, Koji Fujita, Toshihiko Takemura, Yogesh Sud (GSFC, 613), Rocco Duchi, Gianni Tartari, Mian Chin (GSFC 613), Kyu-Myong Kim (GEST/UMBC, GSFC 613), Elisa Vuillermoz and *William K.-M. Lau (Sponsor, GSFC 613)*

Task Description

The *Elevated Heat Pump* effect suggested by Lau and colleagues is the hypothesis that absorbing aerosols, such as dust and black carbon (BC), heats the atmosphere and the snow surface impacting monsoon circulation, precipitation pattern, and Himalayan glacier meltings. To investigate the EHP effect in terms of snow albedo reduction and Himalayan glacier meltings, he and colleagues have researched the two topics: (1) Estimates of dry deposition amount of BC and the related snow albedo reductions during

the dry pre-monsoon period in 2006 over Himalayan glaciers using aerosol and meteorological observation at the foothill of the Himalayas together with outputs from general circulation models (GCMs); (2) Constructing a new snow albedo scheme including the influence of dust, BC, and organic carbons on snow albedo changes so as to incorporate it into the NASA Goddard Earth Observing System version 5 (GEOS-5).

Highlights

Regarding their outcomes, BC can at least reduce the snow albedo of 2.0-5.2% over Himalayan glaciers during the pre-monsoon period of 2006, and more albedo reduction due to BC deposition would be expected in the real world in terms of various estimates of BC dry deposition using the observed data and GCMs. The new snow albedo scheme including the absorbing aerosols has been successfully incorporated into the GEOS-5 land surface model; further, it is validated with one winter observation in Sapporo, Japan. The new GEOS-5 is now ready and will be used the Himalayan glacier issues in terms of the absorbing aerosols in works in the near future. Those topics were published in the *Atmospheric Chemistry and Physics* and *Journal of Geophysical Research*, and selected as the Best First Authored Paper Award (Climate and Radiation Branch, NASA/GSFC). The paper on the GEOS-5 land surface model was ranked in the Most Popular Articles in February 2011 on the website of the *Journal of Geophysical Research*.

Task 613-107-370: **Aerosol Impacts on Energy and Hydrology Cycles**

GEST Investigator: Yan Zhang

Collaborators: Hongbin Yu (GEST, GSFC 613.2), Rong Fu (UT Austin), Robert Dickinson (UT Austin), and *Lorraine Remer (Sponsor, GSFC 613.2)*

Task Description

Tropospheric aerosols have large spatial and temporal variations that greatly influence the estimation of radiative forcing and particulate matter (PM) air quality forecast. As one of pre-mission studies for defining aerosol sciences for the Geostationary Coastal and Air Pollution Events (GEO-CAPE), this task documents the daytime variability of aerosol with seasonal distinction by using multi-year measurements of the Aerosol Robotic Network (AERONET) sites over North America, South America, and surrounding oceans (*i.e.*, planned geographical coverage of GEO-CAPE). Both aerosol loading and type, as characterized respectively by aerosol optical depth (AOD) and Angstrom exponent, are examined.

Highlights

Zhang has contributed to NASA's future Geostationary Coastal and Air Pollution Events (GEO-CAPE) mission. She has presented her research findings at many conferences.

Task 613-95-338: **Toward infrared remote sensing methods for cloud optical and microphysical properties monitoring: Application to MODIS**

GEST Investigator: Zhibo Zhang

Collaborators: William Lau (GSFC 613), Oreste Reale (GEST/UMBC), Yogesh Sud (GSFC 613.2), Robert Rosenberg (SAIC), Huey-Tzu Wu (SSAI), *Edward Sittler (Sponsor, GSFC 613.2)*

Task Description

The MODIS instrument has proven to be an excellent platform for cloud observations. The current MODIS retrieval algorithm has used the solar reflectance channels to estimate important cloud

microphysical properties such as cloud particle size and cloud optical depth. MODIS has also made measurements at several infrared (IR) wavelengths that provide information for estimating the same cloud microphysical parameters. To date, no infrared approach has been developed and applied to the MODIS observations to fill the nighttime gap in the presence of cloud microphysical properties from MODIS. The major objectives of this project include assessing the capabilities and limitations of MODIS infrared channels for cloud property retrieval, investigating the consistency between cloud property retrievals based on the solar reflective method and infrared method, and investigating the possibility of synergetic use of MODIS solar and infrared bands for cloud property retrieval.

Highlights

Zhang and his collaborators investigated the effects of ice particle size vertical inhomogeneity on two popular passive ice cloud property retrieval methods: the solar reflectance bi-spectral (SRBS) method and the infrared split-window (IRSpW) method, both based on passive satellite observations. Understanding the retrieval difference between these two methods is critical for establishing long-term global satellite-based ice cloud property records and therefore improving researchers' understanding of ice cloud's role in the changing climate. The main findings of this study suggest that the homogenous cloud assumption can affect the solar reflective and infrared split window method to different extents and, consequently, can lead to significantly different retrievals; therefore, caution should be taken when comparing and combining the ice cloud property retrievals from these two methods. A related manuscript has been published in the *Journal of Geophysical Research* (Zhang *et al.*, 2010).

Task 913-12-117: **Relationships Among Precipitation Characteristics, Atmospheric Water Cycle, Climate Variability and Change**

GEST Investigator: Yaping Zhou

Collaborators: Arthur Hou, Oreste Reale (GEST/UMBC), Yogesh Sud (GSFC 613.2), *William K-M. Lau (Sponsor, GSFC 613)*

Task Description

Precipitation and clouds are key components of the Earth's hydrological cycle. The initial task was to use satellite observations of cloud, precipitation and radiation measurements to study cloud-radiation interactions and convective processes in the atmosphere, and to evaluate and improve physical parameterizations of the cloud resolving models and climate models. Lately, the project has been more focused on using satellite observations to detect long-term trends in tropical hydrological cycles in association with large-scale circulations, trends in characteristics and distributions of extreme rainfall events, such as those related to tropical cyclones.

Highlights

Zhou has utilized high-resolution precipitation measurements from Tropical Rainfall Measuring Mission (TRMM), and cloud and radiation measurements from the Clouds and the Earth's Radiant Energy System (CERES) to evaluate the three-dimensional (3D) Goddard Cumulus Ensemble (GCE) model and provide critical insights for improvements in the model's physical parameterizations. A paper published in *Journal of Atmospheric Sciences* was awarded "Best Paper Award" in the Climate and Radiation Branch. Zhou also used TRMM precipitation measurements to evaluate AIRS impact on hurricane precipitation in the reanalysis and forecast of GEOS-5 model. In addition to model evaluation, Zhou used TRMM and Global Precipitation Climatology Program (GPCP) data to study the long-term trend in tropical hydrological cycles and tropical cyclone- related rainfall and identified certain data in homogeneities in the GPCP pentad data. Six papers related to this work have been published, and one is in press while another is ready to be submitted.

Atmospheric Chemistry and Dynamics (Code 613.3)

This page intentionally left blank

Task 613-94-325 **Development of Small Spectrometer Systems**

GEST Investigator: Nader Abuhassan

Collaborators: Jay Herman (JCET), Alexander Cede (UM), Matthew Kowalewski (GEST); *Melvyn Goldstein (Sponsor, GSFC 613.2)*

Task Description

Atmospheric trace gases have a controlling effect on the chemistry affecting ozone and smog formation in the troposphere, and NO_2 partly determines the ozone distribution in the Earth's atmosphere. Tropospheric NO_2's high diurnal variability is influenced by both natural and anthropogenic emissions. Fossil fuel combustion is a major source of NO_2, and high NO_2 concentrations are usually confined to areas with high industrial activities. Ground-based measurements combined with calculations models have played a major role in improving researchers' knowledge of the impacts of trace gases and aerosols on local pollution episodes, as well as its effects on air quality and human health. PANDORA is a ground-based Goddard-built spectrometer instrument system for measuring trace gases' (NO_2, O_3, HCHO, H_2O, and SO_2) column amounts and ozone profiles. This is an innovative concept and a cost-effective approach initiated by the GEST team to address a currently missing component of a local, continuous and real-time monitoring of trace gas amounts and ozone profiles.

Highlights

In collaboration with NASA's Discover-AQ project, with the goal of improving regional modeling capabilities, measurements of the spatial and temporal variability of NO_2 and other trace gases patterns in the Washington, Baltimore, Chesapeake Bay and mid-Atlantic regions will take place this summer. Measurements of NO_2, O_3, HCHO, H_2O, and SO_2 column amounts and O_3 profiles will be obtained using 12 new Pandora systems. Instruments will be remotely monitored, and data will be processed and made available to the scientific community in real-time.

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 613.3), Jose Rodriguez (GSFC 613.3), Allen Chu (GEST/UMBC), Paul Newman (GSFC 613.3), *Randy Kawa (Sponsor, GSFC 613.3)*

Task Description

Aerosol and trace gases are major agents in the atmosphere affecting air quality and climate. Bian has investigated their physical and chemical effects, especially aerosol component nitrate and greenhouse gas CH_4, by introducing new capabilities in two NASA global chemistry transport models and participating and supporting two NASA fields campaigns during the year 2010.

Highlights

Bian led a group effort involving Transcom-CH4, an international multi-model intercomparison for greenhouse gas CH_4. She implemented the CH_4 tracer and its chemistry in the NASA parameterization chemistry transport model (PCTM), and the model's results were presented at a Transcom-2010 workshop by comparing it with other models and observations. She contributed to the work in coupling aerosol and trace gases in NASA GMI and CCM and led the development of new capabilities in GMI for the study of the aerosol components of nitrate and ammonium. This research provides a complete

treatment of nitrate and ammonium aerosol lifecycles, from sources to chemical evolution and atmospheric impacts during transport to their ultimate fate and their subsequent potential effect on ecosystems. The work also assists future SOA studies. In additional to modeling work, Bian also conducted fieldwork to support NASA Global Hawk Pacific (GloPac 2010) and analyzed and presented ARCTAS aircraft measurements and corresponding GEOS5 model simulations. Bian and Prather collaborated on PhotoCom-2008, which evaluated how models calculate photolysis (and indirectly heating) rates in the stratosphere and troposphere with the incentive of locating errors or biases and identifying improved and practical methods. This work is a key part in Chapter 6 of *CCMVal2* (2010).

Task 613-85-300: **Nitrogen Dioxide Measurements from the Ozone Monitoring Instrument (OMI)**

GEST Investigator: Edward A. Celarier

Collaborators: Dr. Eric Bucsela (SRI International), *James Gleason (Sponsor, GSFC 613.3)*

Task Description

Nitrogen dioxide is an important species in the chemistry of ozone in the Earth's atmosphere, and is an air pollutant in its own right. Celarier has been developing, evaluating, and maintaining an algorithm for the retrieval of nitrogen dioxide column amounts (stratospheric, tropospheric, and total) from backscattered spectral radiances measured by the Ozone Monitoring Instrument (OMI), aboard the EOS-Aura satellite. The level-2 data, and level-3 data derived from there, are archived on the NASA Goddard Earth Sciences Data and Information Services Center (GES-DISC). He also provides technical support to the community of data users.

Highlights

Celarier has performed analyses and has developed and implemented improved numerical techniques for the nitrogen dioxide column retrievals. He has also provided analyses of the quality of the data product as the OMI instrument's performance has been affected by an external, semitransparent obstruction to OMI's entrance optics, and implemented data flagging based on the results of those analyses. Celarier has presented results at a variety of conferences, including the 2010 OMI Science Team Meeting, Aura Science Team Meeting, and A-Train Symposium.

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

GEST Investigator: Thomas L. Diehl

Collaborators: Qian Tan (GEST), Hongbin Yu (GEST), Tom Kucsera (GEST), Mariya Petrenko (Purdue University), *Mian Chin (Sponsor, GSFC 613.3)*

Task Description

The goal of this task was 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 aerosols sulfate, dust, black carbon, organic carbon and sea-salt, from both natural and anthropogenic sources. It is a global model and is driven by assimilated meteorological data from the GEOS DAS.

Highlights

Diehl has migrated the GOCART model to new versions of the GEOS DAS, which required major changes in several parameterizations. Another important accomplishment was the compilation of a global emission inventory for the period 1980-2007 for anthropogenic emissions of black carbon, organic carbon and SO_2, and for 1979-2009 for volcanic emissions of SO_2. This inventory was disseminated to the aerosol community via the AeroCom initiative. Diehl participated in an AeroCom study of the effects of unified aerosol sources on the global aerosol fields simulated by different models. He contributed to a study in *Atmospheric Chemistry and Physics* in 2007 on the intercontinental transport of pollution and dust aerosols and its implications for regional air quality. Diehl also performed a hindcast experiment to investigate multi-decadal aerosol trends and effects on surface radiation and air quality, and presented the results at several conferences.

Task 613-104-356: **Regional Modeling and Variability analyses in support of GEO-CAPE**

GEST Investigator: Melanie Follette-Cook

Collaborators: Scott Janz (PI, GSFC 613.3), Bryan Duncan (GSFC 613.3), Bryan Duncan (GEST 613.3), Dale Allen (University of Maryland, College Park), *Kenneth Pickering (Sponsor, GSFC 613.3)*

Task Description

Satellites in geostationary orbit have the capability of both high temporal and spatial resolution. These features will be especially advantageous for measuring the trace gases associated with the emission, transport, and chemistry of air pollution; however, challenges lie in determining the horizontal, vertical, and temporal resolutions needed to adequately represent these previously unresolved processes. This work focuses on quantifying tropospheric trace gas and aerosol variability in order to inform the recommendations for spatial and temporal resolutions of the currently proposed NASA Geostationary Coastal and Air Pollution Events (GEO-CAPE) satellite.

Highlights

In order to quantify trace gas and aerosol variability, WRF/Chem was used to generate 4-km horizontal resolution fields of the trace gases O_3, NO_2, CO, SO_2, and HCHO, as well as $PM_{2.5}$, over the Eastern US for a high ozone episode that occurred on July 9, 2007. Using a spatial autocorrelation analysis, 4-km horizontal resolution yielded 90% explained variance (EV) for O_3, CO, HCHO, and $PM_{2.5}$ but only 50% EV for NO_2 and SO_2. In addition, both NO_2 and SO_2 displayed the most rapid decay of autocorrelation with distance. These two species are dominated by point and line sources and therefore have higher spatial variability than the other more regional pollutants. In addition, it was determined that a temporal resolution of 1-hr yielded 90% EV for O_3, NO_2, CO, and HCHO and 75% EV for SO_2 and $PM_{2.5}$. At a 3-hr temporal resolution, all species showed only 50%, indicating a rapid decay with a coarser resolution.

Data from this simulation was also used to analyze trace gas and variability using structure functions. The O_3 and NO_2 structure functions calculated using WRF/Chem-generated fields were found to yield similar variability to those calculated using data from both *in-situ* and nadir measurements from several aircraft campaigns. Structure functions calculated using WRF/Chem tropospheric columns, along with the current precision requirements for GEO-CAPE, were used to determine what trace gas gradients would be observable by the prospective instrument. Data from this simulation were supplied to other teams preparing for GEO-CAPE, trace gas profiles were supplied to the sensitivity team for the calculation of radiances and testing of retrieval schemes, and model-generated trace gas fields were supplied to other variability groups to analyze. Similar correlation analyses were conducted on a 4-km resolution Community Multi-scale Air Quality (CMAQ) of the Los Angeles Basin during July 2007.

To achieve the most useful results for planning GEO-CAPE, it is necessary to examine how the variability statistics change from one polluted region to another at the same horizontal resolution. A separate WRF-Chem simulation has been performed at 4-km horizontal resolution over the Houston area for the September 2008 NOVICE campaign time period during which the ACAM instrument was flown on the WB-57 aircraft. This coincides with the derivation of slant column NO_2 and O_3 retrievals from the same ACAM data at multiple spatial resolutions. The variability in the ACAM data over Houston will be compared with the variability seen in the regional model output.

Task 613-112-399: **Data Analysis of Satellite Cloud Property Retrievals and Other Parameters from Multiple Satellites**

GEST Investigator: Pawan Gupta

Collaborator: *Joanna Joiner (Sponsor, GSFC 613.3)*

Task Description

This task focuses on the data analysis of satellite cloud properties retrieval and other parameters from multiple satellites including, but not limited to, the Aura OMI, Aqua MODIS, and CloudSat. Gupta is also involved with working on advanced algorithms, utilizing multiple sensors and performing simulation studies for future satellite platforms. Specifically, Gupta is analyzing data on cloud properties from CloudSat, OMI, and MODIS for inter-comparison purposes. He is also working with the Goddard Modeling and Assimilation Office for aerosols and air quality analysis using surface, model and satellite measurements.

Highlights

Cloud top pressure (CTP) retrievals from two OMI algorithms have been inter-compared with CloudSat measurements over the global region for the months of April and December 2008. This research will help to improve the retrievals of cloud properties from OMI measurements. He is also validating $PM_{2.5}$ mass concentration obtained from GEOS-5 with those measured at EPA ground stations.

Task 613-112-404: **Aerosol Distribution and Radiative Effect Study Using GOCART Model**

GEST Investigator: Dongchul Kim

Collaborator: *Mian Chin (Sponsor, GSFC 613.3)*

Task Description

Kim joined GEST in June 2010 and has completed an account setup for the GSFC supercomputing system. He has experience in atmospheric chemistry using numerical models. His task is to support the GOCART modeling group by improving modules and integrating other data. He utilizes satellite observations to evaluate model performance and to constrain uncertainties in the model. Part of his research is on dust-related issues, and he has studied dust optical properties using AERONET data. The goal of this study is to improve the GOCART optical property table in future estimates. He is working to improve the dust emission process by introducing satellite-observed vegetation to the model.

Highlights

Kim has investigated the optical properties of dust based on AERONET data set. Dust-dominant events were selected by optical manner at several sites in North Africa and Arabia from multiple year data. The results are being prepared for a publication to be submitted to a scientific journal. He also conducted a study to use satellite-observed NDVI to improve dust distribution in GOCART model. Old and new simulations were made for 7 years, and then subsequently compared with MODIS AOD. A preliminary result shows that the model improves with the new method. Kim reported these findings at the AMS meeting in 2011.

Task 613-190-379: **Radiometric Calibration and Development Laboratory and Ground-Based Instrument Development**

GEST Investigator: Matthew Kowalewski

Collaborator: *Scott Janz (Sponsor, GSFC 613.2)*

Task Description

The quantification and mapping of atmospheric trace gas constituents in the troposphere and stratosphere provide the means for scientists to determine the sources and effects of man-made pollutants. Ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), formaldehyde (HCHO), and aerosols affect respiratory health, and damage ultraviolet exposure, air traffic safety, and climate change, among others. The methods and accuracy with which scientists can measure these gases has been the focus of Kowalewski's task.

Highlights

Through his participation in ground and air measurement campaigns, laboratory testing, instrument design work, and satellite ground testing, Kowalewski has helped to further the goal of enhancing the measurements and understanding of trace gas pollutants. Kowalewski coordinated the integration and deployment of the Airborne Compact Atmospheric Mapper (ACAM) as part of the Global Hawk Pacific (GloPac) campaign -- the first civilian scientific use of that platform. He also coordinated the successful integration of ACAM into the UC-12 aircraft as part of the DISCOVER-AQ mission, slated to take place in the summer of 2011. He was also involved in the Geo-CAPE Airborne Simulator (GCAS) system design and fabrication, Pandora instrument testing and development, and OMPS FM2 ground calibration planning.

Task 916-58-212: **Modeling and Analysis Scientific Support**

GEST Investigator: Tom Kucsera

Collaborators: Kenneth Pickering, Jonathan Smith, Brent Holben, Hongbin Yu, Thomas Diehl, Huisheng Bian, Qian Tan, Zhining Tao, Dongchul Kim, Melanie Cook, Mariya Petrenko, *Mian Chin (Sponsor, GSFC 613.3)*

Task Description

Since this task's inception in 2007, Kucsera has provided support to global and regional modeling and analysis of atmospheric aerosols and trace gases. He supported NASA observational programs and has compiled observations from satellite, ground-based, and *in-situ* measurements for model input, evaluation, and improvement. He executed and evaluated atmospheric computer algorithms. Kucsera developed diagnostic software for the analysis of model output and satellite data. He developed and maintained websites for user access to a large central database of observations, analysis products, and model output.

Highlights

Kucsera supported atmospheric field campaigns and NASA-sponsored missions, which included TC4, PACDEX, INTEX-B and MILAGRO campaigns. He provided research support for the GOCART atmospheric model. He has compiled data products for model processing and evaluation from satellite data, which included the instruments and products from Terra, Aqua, Aura, CALIPSO, and others. Kucsera generated analyses for the AERONET program, which included a daily production of products for more than 300 site-specific global locations. The analyses and the data product distribution were provided to the global research community through a dynamic and interactive website. The administration of computer software, resources and group hardware were routinely managed and maintained.

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

GEST Investigator: Leslie R. Lait

Collaborators: Tom Clune (GSFC), *Paul Newman (Sponsor, GSFC 613)*

Task Description

Data from a wide variety of sources---satellite, balloon-borne, aircraft, and ground-based instruments---require dynamical context for proper interpretation. Lait applies innovative techniques to combine disparate data sources to yield a unified picture of the whole. In addition, he provides support to aircraft field experiments, including the use of forecasts and modeling results to aid in planning aircraft flights to maximize the scientific return and test the feasibility of various flight path scenarios. His activities also include the oversight of local data systems to facilitate analysis.

Highlights

Lait has continued an ongoing research project investigating the use of quasi-conservative coordinate systems in the analysis of trace gas measurements. He also played an important role in two NASA field experiments: during the 2007 TC4 mission, he created baseline science flight plans for the ER-2 aircraft and provided meteorological data to other participants, and for 2010's pioneering GloPac mission, he designed, implemented, and operated new flight planning software that provided a crucial contribution to the success of the mission. He also worked with the GSFC Software Integration and Visualization Office (SIVO) in the creation of a new, versatile, high-performance trajectory model.

Task 612-76-265: **Climate Change and the Stratospheric Ozone Layer**

GEST Investigator: Feng Li

Collaborators: Richard Stolarski (PI, GSFC 613), Steven Pawson (GSFC 610), Anne Douglass (GSFC 613), Darryn Waugh (JHU), *Paul Newman (Sponsor, GSFC 613)*

Task Description

Stratospheric ozone change has a significant impact on climate in both the stratosphere and troposphere. Long-term climate change in the stratospheric temperature and circulation also affects the recovery of the stratospheric ozone layer. Li has studied the coupled climate-ozone change for the period 1950-2100 using model simulations and satellite observations.

Highlights

Li investigated the interactions between tropospheric and stratospheric climate change in the latter half of the 20th century. This study, published in *Journal of Geophysical Research* in 2010, found that the strengthening of the stratospheric Brewer-Dobson circulation (BDC) is strongly correlated with the tropospheric Southern Annular Mode (SAM) during austral summer. He found that the trends in the BDC and SAM are both driven by Antarctic ozone depletion. Li also investigated the width of the tropical belt in the stratosphere under global warming. He found that while the strength of the tropical upwelling increases, the width of tropical upwelling narrows due to westerly accelerations in the subtropical upper troposphere [*Geophysical Research Letters*, 2010]. Additionally, Li served as a committee member for the 16th American Meteorology Society Conference on Middle Atmosphere that was held in Seattle in January 2011.

Task 613-111-388: **Stratospheric-Troposphere Exchange and its Impact on Atmospheric Ozone**

GEST Investigator: Qing Liang

Collaborator: *Anne Douglass (Sponsor, GSFC 613.3)*

Task Description

The stratosphere and troposphere are tightly coupled, both dynamically and chemically. The troposphere-to-stratosphere transport of man-made ozone depleting substances contributes to the catalytic destruction of the stratospheric ozone layer. The stratosphere-to-troposphere transport of ozone and NOy rich air plays a vital role in tropospheric ozone variability and photochemistry. This research investigates the dynamics of stratosphere-troposphere exchange and how it affects ozone photochemistry in the stratosphere as well as the troposphere.

Highlights

Liang has contributed to improving the understanding of short-lived bromocarbons on atmospheric bromine and the subsequent impact on ozone. She has demonstrated that very short- lived halogen compounds emitted from the ocean contribute an additional 5-10 pptv to bromine in the stratosphere; this additional bromine source can well explain the satellite-observed bromine hotspots in the polar region. Her work led to a first-author paper (Liang *et al.*, 2010, *ACPD*) and a co-authored paper (Salawitch *et al.*, 2010, *GRL*), both being heavily discussed in the World Meteorological Organization's Scientific Assessment of Ozone Depletion 2010. The latter was also highlighted as a Frontier Article in *Geophysical Research Letters* and was selected to be appear on the cover of the *GRL* December 2010 issue. Liang has also led a post-mission data analysis of the NASA ARCTAS mission, examining how various anthropogenic and natural sources contributed to ozone and reactive nitrogen in the Arctic troposphere.

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

GEST Investigator: Mark Olsen

Collaborators: Mark Schoeberl (STC), Richard Stolarski, Paul Newman (GSFC 613.3), Jose Rodriquez (GSFC 613.3), Yasuko Yoshida (GEST 613.3), William Gallus, Jr. (Iowa State University), Susan Strahan (GEST 613.3); *Anne Douglass (Sponsor, GSFC 613.3)*

Task Description

Knowledge of the exchange of air and constituents across the tropopause is important to understanding the global and regional budgets of chemical species such as ozone. In addition, the upper-troposphere/lower-stratosphere (UTLS) region significantly influences the radiative properties of the atmosphere. Since this task was initiated in 2002, Olsen has developed innovative diagnostic methods of estimating the stratosphere-troposphere exchange (STE) of mass, ozone, and other constituents from model output and observations. This work spans across the global scale to mesoscale transport. He has studied the changes and trends in STE of mass and ozone in the changing climate, including the causes of the trends. The variability of meridional transport in the lower stratosphere, its cause, and its relationship to STE have also been investigated.

Highlights

Olsen has been instrumental in evaluating transport processes and STE in NASA model simulations and analyses. The diagnostics developed can be applied equally to observations and model output, facilitating suitable assessments. Olsen has presented his research results at many conferences and workshops. He has been invited to present findings at University-level seminar series, workshops, and international meetings. Olsen provided support to the NCAR START08 aircraft mission by providing daily maps of tropospheric ozone estimates. Additionally, he mentored and sat on the graduate committees of both a Master's student at Iowa State University and a Doctoral student at Georgia Tech.

Task 613-131-451: **Aerosol and Chemistry Modeling**

GEST Investigator: Xiaohua Pan

Collaborator: *Mian Chin (Sponsor, GSFC 613.3)*

Task Description

Aerosols alter Earth's energy budget by scattering and absorbing solar radiation and by altering cloud properties and lifetimes. This task studies the multi-decadal changes (30-year time period of satellite era, 1980-2010) of atmospheric aerosols and their effects on surface radiation using a global chemistry transport model (GOCART) along with the near-term to long-term data records. The goal of this task is to better understand the relationship between the changes of emission, atmospheric loading, and surface radiation during the recent multi-decades, so that scientists can project earth system's response to future change. Pan's major work is to "feed" the model a best set of inputs of anthropogenic aerosol emissions.

Highlights

Pan has examined the anthropogenic aerosol emissions in AeroCom, an emission inventory currently used by the GOCART model, and discovered a problem: by comparing the SO_2 emission with other emission inventories (EDGAR4.1 and EMEP), she found that the anthropogenic SO_2 emission is overestimated in AeroCom. This problem in emission has resulted in an overestimated surface SO_2 concentration in the model over Europe, one of the major anthropogenic pollution sources in the world. Her work has

contributed to a more accurate assessment on the impact of the anthropogenic emission on the aerosol loading and radiative forcing, especially over Europe. In addition to SO_2, Pan also examined other major anthropogenic aerosols (BC and OC) in GOCART. Her works have improved the input of GOCART and also can benefit other aerosol-related models, such as GMI and CCM, which are broadly used by researchers in GSFC.

Task 613-108-375: **The Impacts of absorbing aerosols on global and regional climates**

GEST Investigator: Cynthia Randles

Collaborators: Arlindo da Silva (GSFC 610.1), Bryan Duncan (GSFC 613.3), Huisheng Bian (GEST), Ravi Govindaraju (SSAI), *Peter R. Colarco (Sponsor, GSFC 613.3)*

Task Description

Tropospheric aerosols directly scatter and absorb incoming solar radiation, and aerosol absorption in the atmosphere can impact atmospheric stability and the hydrologic cycle. In the past, general circulation models (GCMs) have imposed aerosol distributions calculated off-line. As a result, changes in model dynamics associated with the aerosol direct and semi-direct effects do not provide feedback on the aerosol forcing. Since the task's inception, Randles has studied the impact of forcing NASA GEOS-5 atmospheric GCM using either (a) aerosol distributions that are fully coupled to the GCM meteorology and radiation fields or (b) aerosol fields calculated off-line that only impact GCM radiation fields. Results indicate that fully coupled aerosol forcing can cause a significantly different climate response than prescribed aerosol forcing on regional scales. In addition to investigating the importance of aerosol-climate coupling on various time-scales, Randles has also worked to analyze GEOS-5 atmospheric GCM aerosol distributions and aerosol optical depth using various satellite and ground-based observations.

Highlights

Randles has helped to improve the representation of aerosols in the GEOS-5 AGCM (*e.g.*, refining the treatment of aerosol hygroscopic growth). She has presented her research findings at numerous conferences, highlighting the importance of characterizing aerosol-climate interactions in climate models. She is currently preparing a manuscript for *Journal of Geophysical Research* regarding the aforementioned aerosol-climate interaction research. She is also working to quantify the aerosol direct and semi-direct effects in the GEOS-5 model forced by prescribed meteorology. She is actively participating in the international AeroCom inter-comparison project (http://dataipsl.ipsl.jussieu.fr/AEROCOM/) as the lead for one of their experiments.

Task 613-85-295: **EOS-Aura Instrumentation Validation and Support**

GEST Investigator: Christian Retscher

Collaborators: J. Gleason (GSFC 613.3), E. Celarier (GEST), J. Herman (JCET), *R. D. McPeters (Sponsor, GSFC 613.3)*

Task Description

This task supports the validation efforts of the data products from atmospheric chemistry instruments onboard the EOS-Aura satellite. It includes the system's redesign and maintenance of the code base as well as scientific data production. The Aura Validation Data Center (AVDC, http://avdc.gsfc.nasa.gov) provides a central data archive, generating data subsets, collecting correlative data, and supporting the validation efforts of the Aura instrument teams and NRA investigators, as well as national and

international ground-truth and satellite validation teams. Further, the task supports NASA aircraft and field campaigns. The AVDC is involved in efforts to standardize datasets for atmospheric research.

Highlights

Retscher has successfully contributed to the validation of the EOS-Aura mission. As the responsible person for the Aura Validation Data Center (AVDC), Retscher was involved in international efforts for coordinating data centers for satellite validation. He co-led the group who developed the new Generic Earth Observation Metadata Standard (GEOMS), which supports the validation of many A-Train satellites as well as sensors on ESA platforms. Retscher has provided direct PI and validation campaign support for Aura and has worked closely with instrument teams responsible for satellite validation. This includes sensors such as FTIR, LIDAR, MWR, ozone and radio-sondes, Brewers, as well as the Pandora instrument, which was developed at Goddard. Further, Retscher has contributed to the research on the NO2 product from OMI, which led to two publications with Retscher as co-author.

Task 613-98-344: **Effects of Tropospheric and Stratospheric Composition on Climate**

GEST Investigator: Henry Selkirk

Collaborators: Anne Douglass (GSFC), Mark Olsen (GEST), Michael Manyin (SSAI); *Mian Chin (Sponsor, GSFC 613.3)*

Task Description

This research is concerned with investigating the composition of the troposphere and stratosphere and its effects on chemistry and climate. It involves developing and testing comprehensive models of the Earth system and their evaluation using measurement data, especially data taken by instruments on NASA satellite, aircraft and ground-based missions. Investigations are focused on the interplay of dynamical transport, chemical and radiative processes in the troposphere and stratosphere in the context of the NASA Goddard chemistry-climate model (GEOS CCM) that has now been coupled with the combined stratosphere-troposphere chemistry model (the GMI Combo). Of particular interest is the role of ozone and water vapor in the upper troposphere and lower stratosphere on climate.

Highlights

Selkirk has been investigating the fine-scale vertical structure of ozone and water vapor in the upper troposphere and lower stratosphere in balloonsonde data and examining the vertical with kilometer-scale data from EOS satellite instruments as well with output from the GEOS CCM and GMI models. The sonde data at Costa Rica show copious supersaturation in the upper tropical tropopause layer in northern summer and downward mixing of stratospheric ozone levels into the tropical tropopause layer, but no lower than ~350 K, which is close to the level of neutral buoyancy for deep convection. The MLS data, remarkably enough, show a similar pattern of downward mixing from the stratosphere and supersaturation, despite its long retrieval path. The sounding data suggest that the ‘write head’ of the atmospheric water vapor tape recorder lies very close to 380 K during the boreal summer.

Task 610-105-359: **Balloon Sounding for Aura Validation**

GEST Investigator: Henry Selkirk

Collaborators: Holger Vömel (Deutscher Wetterdienst), Jessica Valverde (Universidad Nacional, Costa Rica), Jorge Andrés Diaz (Universidad de Costa Rica), Sam Oltmans (NOAA ESRL), Michael Manyin (SSAI), *Anne Douglass (Sponsor, GSFC 613.3)*

Task Description

This research task was initiated in early 2009 after Selkirk received his appointment at UMBC. It continues a program that commenced in 2005 under the direction of Selkirk and collaborator Dr. Holger Vömel of high accuracy and high-resolution balloonsonde measurements to ~30 km of water vapor and ozone in Costa Rica. Water vapor is measured with the Cryogenic Frostpoint Hygrometer (CFH) while ozone is measured with an electrochemical concentration cell (ECC) ozonesonde. The water vapor and ozonesonde data have been used to validate measurements of water vapor, relative humidity and ozone by the Microwave Limb Sounder (MLS) onboard the Aura satellite and to validate the vertical structure and temporal variability of water vapor and ozone in the GEOS CCM chemistry climate model.

Highlights

In 2009, 2010, and the first two months of 2011, a total of 76 soundings were launched by Alajuela and Heredia, Costa Rica by students of the Universidad Nacional under the direction of Dra. Jessica Valverde. These included 19 combined CFH/ECC soundings. The analysis of Costa Rica CFH and ECC data from NASA missions in 2005 and 2007 was the focus of a 2010 paper by Selkirk and his colleagues published in the *Journal of Geophysical Research* on the NASA TC4 mission ("The detailed structure of the tropical upper troposphere and lower stratosphere as revealed by balloonsonde observations of water vapor, ozone, temperature and winds during the NASA TCSP and TC4 campaigns".) In October 2009, Selkirk supported the CFH launch effort of Goddard colleague David Whiteman and his team in the Measurements of Humidity in the Atmosphere and Validation Experiments (MOHAVE) 2009 campaign at the JPL Table Mountain Facility in Wrightwood, CA.

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

GEST Investigator: Susan Strahan and Stephen Steenrod

Collaborators: Jose Rodriguez (GSFC 613.3) and *Anne Douglass (Sponsor, GSFC 613.3)*

Task Description

Since its inception in 2000, this task has focused on the analysis of satellite and aircraft trace gas data sets with the goals of improving the understanding of stratospheric transport processes and improving the representation of transport in models. The data analyses typically assess a stratospheric transport process, *i.e.*, tropical ascent. The results of the transport analyses are then used to evaluate the transport in a model. Observation-based evaluations have been applied to NASA/GSFC models, such as the Global Modeling Initiative chemistry transport model and the GEOS Chemistry-Climate Model (CCM), and to CCMs participating in international assessments.

Highlights

A new model having a full tropospheric and stratospheric chemical mechanism was developed, tested, and used for numerous investigations. Many chemistry and transport processes were shown to be well represented and model simulations were used to explain the impact of biomass burning in the lower stratosphere. Data sets from instruments on the NASA UARS and Aura satellites have been used to reveal numerous stratospheric transport processes. Ten years of HALOE CH4 observations in the Antarctic Spring were combined to reveal how the vortex edge sharpens during spring before gradually eroding while maintaining its isolation. Tropical vertical velocities were determined using observations of the water vapor tape recorder. These results were combined with observationally derived mean age to determine how tropical ascent and mixing combine to produce observed tropical mean age, providing a stringent test for model transport. The effects of meteorological fields and spatial resolution on chemistry transport simulations were investigated in several studies. One study concluded that mean age and Cly together in the Antarctic vortex were a very sensitive measure of transport because Cly depends on the model's mean age and age spectrum.

Task 613-82-281: **Study of Aerosol Variability Using both Observation and Models**

GEST Investigator: Qian Tan

Collaborators: Huisheng Bian (GEST), Thomas Diehl (GEST), *Mian Chin (Sponsor, GSFC 613.3)*

Task Description

Atmospheric aerosols affect both climate and air quality. Because the study of aerosols involves various emission sources, chemical revolutions, and dynamics processes, it is challenging to quantify its variability and its impacts. This task originated in 2007; since then, Tan has worked with the GOCART team as well as certain observation groups to study the variation of aerosols on various temporal and spatial scales.

Highlights

Tan has worked on model development of aerosol-related simulations on various scales, from global to fine scale regional. She has also conducted a long-term global model simulation. This dataset has been utilized by several groups, for studying the quantification of the contributing factors of observed global brightening and global dimming, for analyzing the trend of sulfur emissions in China, for exploring its relation to the new MAN (marine aerosol network) analysis, for studying black carbon deposits on Himalaya glacier, and for examining the impact of volcanic emissions in tropical regions. She also combined both satellite observations and fine scale regional model simulations to analyze the large wild fire plumes and their impacts. Tan has presented her research findings at numerous conferences.

Task 613-98-343: **Integrated Modeling of Aerosol, Cloud, Precipitation and Land Processes at Satellite-Resolved Scales**

GEST Investigator: Zhining Tao

Collaborators: Christa Peters-Lidard (PI, GSFC 614), Wei-Kuo Tao (co-PI, GSFC 613), and Mian Chin, co-PI, GSFC 613); *Steven Pawson (Sponsor, GSFC 610.1)*

Task Description

Understanding transport and chemical/physical transformations of atmospheric trace species is essential to assess their effects on climate and air quality. Improving model representations of those processes will greatly enhance model forecast capability and provide better information to policy makers. The integration of satellite measurements into model development and evaluation provides promising means of improving model skills.

Highlights

Tao contributed to the development of biogenic emissions module of the NASA Unified WRF (NU-WRF). He successfully applied NU-WRF to a region of Southeast Asia and used the preliminary simulation results to support a research proposal on the Southeast Asia Composition, Cloud, and Climate Coupling Regional Study. He also introduced and constructed a pollutant emissions process model, SMOKE, to provide the emissions data support to the 2008 Texas Air Quality study.

Task 910-04-074: **Assimilation Studies**

GEST Investigator: Clark Weaver

Collaborator: *Arlindo da Silva (Sponsor, GSFC 610.1)*

Task Description

This task first investigated the radiative forcing of mineral aerosol. A second goal was the Assimilation and Retrieval of atmospheric aerosol information from satellite (MODIS) and ground-based (AERONET and Pandora) instruments. A third focus was on the development of an algorithm to retrieve CO_2 mixing ratio from an airborne Lidar instrument and from the GOSAT space-borne instrument.

Highlights

The radiative forcing study involved calculating the broadband forcing from model fields of Saharan mineral aerosol. These were compared with observed forcing derived from EREBE broadband fluxes and TOMS aerosol observations. This study uncovered a bias in TOVS temperature retrievals during heavy aerosol loading conditions. Since the TOVS retrievals are used in assimilation systems and weather prediction, the bias has far-reaching implications. The Aerosol Assimilation System used MODIS aerosol radiances along with an aerosol transport model. The resulting optical depths compared reasonably with ground-based AERONET observations. Weaver also developed a retrieval algorithm that obtains aerosol and trace gas information from AERONET & Pandora ground-based instruments. The effort to retrieve column CO_2 is part of the space-borne ASCENDS mission (2017 launch). Since this uses laser- sensing technology, it can identify 'field of views' contaminated by clouds and aerosols. Weaver developed a CO_2 retrieval algorithm for an air-borne instrument version that has flown on several field campaigns. Unfortunately, the orbiting GOSAT CO_2 sensing instrument is subject to cloud and aerosol contamination. Weaver also developed a retrieval for GOSAT CO_2 that accounts for aerosol absorption and scattering based on ground-based data. It is about 5-10 ppmv higher than GOSAT-retrieved CO_2 from the Japanese National Institute of Environment Studies.

Task 916-21-144: **The Development of Tropospheric Ozone Data Products from Aura OMI/MLS and their Scientific Evaluation**

GEST Investigator: Jerry Ziemke

Collaborators: *P. K. Bhartia (Sponsor, GSFC 613.3)*

Task Description

One of the goals of this task is to derive tropospheric ozone from OMI-only or combined OMI/MLS and provide the data to the public on the NASA GSFC Code 613.3 website. These measurements are used to update the NASA GSFC database of tropospheric ozone from 1979 to the present by combining them with previous TOMS measurements. A second objective is to employ the data to address many key science issues ranging from the effects of regional pollution to trends and climate change, ENSO (*i.e.*, El Niño and La Niña), and shorter time scale changes including the Madden-Julian Oscillation.

Highlights

Several major research highlights resulted in refereed publications during the task period. One accomplishment was the study of ENSO events and their effects on ozone and other trace gases including CO and H_2O in the troposphere. Another was the development of a method to measure ozone inside deep

convective clouds from OMI. A third highlight was the study of biomass burning and resulting effects on ozone and other constituents in the troposphere. Yet another highlight was the development of an ozone ENSO index to be used for both monitoring of the tropospheric ozone over a long record and as a diagnostic tool to aid in developing climate chemistry-transport models of the atmosphere. One major highlight was the study of the tropical Madden-Julian Oscillation variability in ozone and other trace gases in the troposphere.

Hydrospheric and Biospheric Sciences (Code 614)

This page intentionally left blank

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

GEST Investigator: Assaf Anyamba

Collaborators: Christopher O. Justice (University of Maryland College Park), Curt Reynolds (USDA/Office of Global Analysis – Foreign Agricultural Service), Kenneth Linthicum (USDA/Center for Medical, Agricultural & Veterinary Entomology) Clara Witt (D.O.D. - Global Emerging Infection Surveillance and Response System), Wendy Fanaselle, David Oryang (FDA), and Rasmus Fensholt (University of Copenhagen, Denmark); *Compton J. Tucker (Sponsor, GIMMS - GSFC)*

Task Description

Satellite-derived measurements of global vegetation are important in understating biospheric dynamics in relation to climate variations. These measurements are integral to studying the carbon cycle, in understanding the human appropriation of resources through agriculture, and in understanding the influence of the biosphere on the ecology of diseases vectors. These studies all require quality time series vegetation index measurement from a variety of satellite instruments, including NOAA's Advanced Very High Resolution Radiometer, Systeme Probatoire pour l'Observation de la Terre - Vegetation (SPOT Vegetation), and Moderate Resolution Imaging Spectroradiometer Observations from these multiple instruments have been used in various studies on this task including interannual climate variability associated with El Niño/Southern Oscillation (ENSO), long-term trends in global photosynthetic activity, desertification, fire patterns, and applied research and development in such fields as vector-borne disease outbreaks and agricultural monitoring.

Highlights

Anyamba has helped to extend the record of global measurements of vegetation from legacy AVHHR instruments (NOAA-17 and NOAA-18) used in long-term vegetation and vegetation studies published in *Journal of Arid Environments* and *Journal of Global Environmental Change*. He helped initiate the use of MODIS data for global agricultural monitoring, and has led efforts in building disease models that led to the first-ever prediction of a vector-borne disease: *Rift Valley fever*. This work is published in the *Proceedings of the National Academy of Sciences* and was featured on *National Public Radio* and *BBC*. His research on vegetation-climate interaction has led to an improved understating of the influence of ENSO on vegetation and fire regimes in the context of planning field campaigns such as SAFARI 2000 highlighted in the *Journal of Climate* and *Journal of Geophysical Research – Atmospheres*. He has participated in field work validating and utilizing geostationary satellite data published in *Photogrammetric Engineering and Remote Sensing* and *Remote Sensing of Environmen*t. He has presented his work at various inter-disciplinary meetings and has widely published in various journals that highlight the nature of this collaborative work. In addition, Anyamba authored book chapters in *Vector-borne diseases – Understanding the Environmental, Human Health, and Ecological Considerations* with Linthicum, in *Monitoring and Predicting Agricultural Drought: A Global Study* with Tucker, in *The Biosphere: A Global Perspective* with Los and in *Global Climate Change and Extreme Weather Events: Understanding the Contributions to Infectious Disease Emergence* with Chretien, amongst others. He has mentored several undergraduate and graduate students and is a contributor to the *Drought and Crops* section of *NASA's Earth Observatory*.

Task 614-120-417: **ICESat-2 Support**

GEST Investigator: Robert Bindschadler

Collaborator: *Thorsten Markus (Sponsor, Code 614)*

Task Description
This task provided glaciological expert support to planning of the ICESat-2 mission, including participation in the ICESat-2 Science Definition Team. Bindshadler specifically studied the relative merits of different measurement sampling strategies of the ice sheets with the ICESat-2 laser altimeter to ensure that the scientific objectives of the mission are met.

Highlights
Bindschadler has been a strong voice for the necessary measurements to characterize the most dynamic portions of the ice sheets. This objective is a critical aspect of the ICESat-2 mission. He also has concluded a number of outstanding research projects with significant publications and data releases. Most notable among these has been the release of a new, detailed grounding line and hydrostatic line around the Antarctic ice sheet.

Task 614-112-393: **Effect of Atmospheric Variations on Snow-Depth-on-Sea-Ice Retrievals**

GEST Investigator: Ludovic Brucker

Collaborator: *Thorsten Markus (Sponsor, Code 614)*

Task Description
Sea ice and its overlying snow cover are key components of the polar oceans and subsequently the Earth's climate system. Accurate knowledge of the distribution of snow thickness on sea ice is essential, for instance, to assess the ocean-ice-atmosphere heat exchange and the fresh water budget of the polar oceans. Snow depth on sea ice is operationally retrieved using the Advanced Microwave Scanning Radiometer (AMSR-E). Nevertheless, the AMSR-E snow-depth-on-sea-ice product is known to be sensitive to the physical evolution of the snowpack (*e.g.* changes in grain size, growth of buried ice crust) and to variations in the atmosphere (*e.g.* variations in cloud liquid and ice water content, water vapor). Since this task's inception in 2010, Brucker has studied the latter effects and quantified the errors in snow-depth-on-sea-ice retrievals due to variations in the atmosphere.

Highlights
The investigator joined GEST in January 2010. Brucker presented his research findings at the American Geosciences Union conference in December 2010.

Task 614-121-424: **ICESat-2 Support and Deployment of MABEL**

GEST Investigator: Kelly M. Brunt

Collaborator: *Thorsten Markus (Sponsor, Code 614)*

Task Description
Brunt joined GEST in June 2010 and works closely with NASA Cryosphere scientists Thorsten Markus and Thomas Neumann. Brunt's role with GEST is to provide support to the Ice, Cloud, and land

Elevation Satellite 2 (ICESat-2) mission as an ice-sheet scientist. To that end, Brunt continues to apply ICESat-1 data to ice-shelf related applications. Further, Brunt has been involved in the deployment of an airborne instrument, Multiple Altimeter Beam Experimental Lidar (MABEL), which is intended to simulate ICESat-2 data. Finally, Brunt is also involved in organizing the ground-based component of the calibration and validation of elevation data from the ICESat-2 laser altimeter.

Highlights

Since June 2010, Brunt has presented an application of the use of ICESat data at both the International Glaciological Society Meeting in August 2010 and at the West Antarctic Ice Sheet Meeting in September 2010 (Analysis of ice plains of Filchner/Ronne Ice Shelf using ICESat data: K.M. Brunt, H.A. Fricker, and L. Padman). Additionally, Brunt presented preliminary results of the MABEL deployment, five days after the data were collected, at the American Geophysical Union Fall Meeting in December 2010 (ICESat-2 simulated data from airborne altimetry: K.M. Brunt, T.A. Neumann, T. Markus, A.C. Brenner, K.A. Barbieri, C.T. Field, and J.M. Sirota).

Task 975-34-167:	**Remote Sensing of Sea Surface Salinity from Space**
GEST Investigator:	Paolo de Matthaeis
Collaborators:	Saji Abraham (RSIS), Emmanuel P. Dinnat (Chapman University), Daniel S. Jacob (GEST), *David M. Le Vine (Sponsor, GSFC 614.6)*

Task Description

The work on this task is done in support of the Aquarius mission, whose goal is to provide global sea surface salinity maps from space for the study of large-scale ocean processes and climate change. The Aquarius science instruments will include an L-band radiometer, whose received signal is sensitive to salinity, and a radar scatterometer, which will help correct for the effect of the sea surface roughness. Models have been developed for both instruments to simulate their response to geophysical parameters of the ocean surface and atmosphere. In preparation for the launch of Aquarius in June 2011, algorithms for retrieving the sea surface salinity from the Aquarius brightness temperature measurements are being evaluated using the simulated output obtained using these models.

Highlights

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 his work, de Matthaeis has examined several of the factors that affect the accuracy of the Aquarius measurements, particularly the effect of the coordinate transformation, the Faraday rotation of the electromagnetic field in the ionosphere, and the non-ideal radiometer antenna patterns on the polarimetric measurements of the brightness temperature, whose implications were reported in a journal article that was awarded the Hydrospheric and Biospheric Sciences Laboratory Peer Award for Outstanding Publication in 2008. He has also examined the radiometric emission from the atmospheric layer that could potentially enter the radiometer antenna, has developed a simulation model for the Aquarius scatterometer and an inverse model to retrieve the backscattering coefficient from the instrument-received power. He is currently focusing his efforts on the development and improvement of the retrieval algorithm for the sea surface salinity.

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

GEST Investigator: Thomas F. Eck

Collaborator: *Brent N. Holben (Sponsor, GSFC 614.4)*

Task Description

The primary motivation for investigating the optical properties of atmospheric aerosols within AERONET is to apply the findings to studies of the effects of aerosols on the atmospheric radiation balance and climate and to validate satellite retrievals of aerosol properties. Eck's research in this GEST task focused on analyzing measurements made by automatic sun-sky scanning radiometers that are globally distributed as a part of the NASA-managed Aerosol Robotic Network. He has utilized ground-based remote sensing retrievals of aerosol optical properties to analyze and better understand the dynamics of aerosol properties as a function of source region, transport, aging processes, and interaction with clouds.

Highlights

Eck has helped to define scientific and operational objectives regarding aerosol research, and has contributed to the growth of NASA GSFC's AERONET project. He has presented his research findings at numerous conferences, and authored 56 papers on aerosol optical properties while engaged in this task from 2001 through 2010. This includes first authorship of 8 papers published in the *Journal of Geophysical Research*. He has participated in major field experiment research campaigns in Africa (SAFARI 2000), United Arab Emirates (UAE2 in 2004) and India (TIGERZ in 2008), and continues to plan for field campaigns in Japan and Korea in 2012).

Task 614-111-390: **Melt Water Routing System Studies**

GEST Investigator: Matthew Hoffman

Collaborator: *Thomas Neumann (Sponsor, Code 614)*

Task Description

Access of meltwater to the bed of glaciers and ice sheets generates sliding, which speeds the transport of ice to lower elevations and into the ocean where ice melts more rapidly and contributes to the rise of the sea level. Since this task's inception, Hoffman has investigated the routing of meltwater on the surface of and within the Greenland Ice Sheet and the associated effects on the ice sheet's velocity. One primary objective has been to determine the connection between supra-glacial lake location, bed topography, and surface energy-balance feedbacks that help to determine lake location. A related objective is to understand the spatial distribution of surface meltwater channels and moulin locations in relation to the surface lakes that act as water sources of these features. The task has integrated remote-sensing data set products with field data on bed topography and surface ice velocity.

Highlights

Hoffman has completed the processing and analyses of existing velocity data sets, resulting in one of the most detailed investigations into the relationship between the hydrology and sliding of the Greenland Ice Sheet to date. In addition to *in-situ* velocity measurements with GPS, this work has integrated optical imagery from MODIS, ASTER, and Landsat, with altimetry data from ICESat and Operation IceBridge. He has presented his research findings at national conferences and has participated in a workshop with the ice sheet modeling community, where he highlighted ways in which ice sheet models used for sea level

rise prediction may be able to better incorporate these processes. Additionally, Hoffman took the lead in planning and conducting a field campaign in west Greenland in August 2010 to collect a new suite of ice velocity measurements. This work continues in 2011 and lays the foundation for an ambitious ice-drilling project by collaborators to directly observe conditions at the glacier/bed interface in the summers of 2011 and 2012.

Task 614-112-395: **Development of numerically efficient code for the atmospheric radiative transfer problem with polarization for aerosol/cloud satellite remote sensing**

GEST Investigator: Sergey Korkin

Collaborators: Alexei Lyapustin (GEST); *J. Ranson (Sponsor, GSFC 614.4)*

Task Description

The main objective of this research is to support the development of an advanced algorithm for simultaneous retrievals of aerosol properties and surface bidirectional reflectance from EOS MODIS imaging spectrometer. The new Multi-Angle Implementation of Atmospheric Correction (MAIAC) algorithm for MODIS has recently been developed by A. Lyapustin and Y. Wang. It is based on the look-up tables (LUT), which were generated with the scalar radiative transfer code that require correction for polarization effects to achieve improved accuracy.

Highlights

During the past year, when the task was established, a polarization correction LUT was developed and implemented in MAIAC code. A comparison with AERONET data showed that this correction has improved the accuracy of MAIAC aerosol retrievals. The radiative transfer (RT) research has also been conducted on optimal synthesis of different numerical techniques to achieve the best computer speed and accuracy in cases with high scattering asymmetry typical of large aerosol particles or cloud droplets. A particular combination of a small-angle approximation and a single-scattering source function was found to provide the best results. Finally, an analysis was conducted to study the accuracy of the first and second orders of scattering for polarization computations. This analysis aims to develop fast RT codes, which would have processed data with polarization from the Glory satellite.

Task 614-120-418: **Operation IceBridge Sea Ice Research**

GEST Investigator: Nathan Kurtz

Collaborator: *Lora Koenig (Sponsor, GSFC 614)*

Task Description

Variations in the Earth's sea ice cover are considered harbingers of change in the global climate system and are integral to determine future temperature increases across the planet. The goal of this task is to utilize a suite of airborne remote sensing instrument data collected from NASA's Operation IceBridge to study Arctic and Antarctic sea ice. The linking of these IceBridge measurements with those previously collected from NASA's Ice, Cloud, and Land Elevation Satellite (ICESat) to create a long-term sea ice thickness record is anticipated to provide valuable information on the state of the global sea ice cover.

Highlights

Kurtz has created algorithms for the retrieval of snow depth from the IceBridge FMCW snow radar and sea ice freeboard from the IceBridge laser altimeter systems. Researchers plan to combine these data sets to form an operational product for the retrieval of sea ice thickness from past and future NASA IceBridge campaigns. Additionally, Kurtz has designed and validated algorithms for the retrieval of sea ice

freeboard and thickness from satellite data using ICESat. Validation of these measurements with *in-situ* data sets has shown the capability of the sea ice thickness products to be produced with sufficient accuracy, which will be useful for the generation of a long-term climate record.

Task 614-91-320: **Capacity Building Program**

GEST Investigator: Richard (Rick) Lawford

Collaborators: David Toll (NASA); *J. Ranson (Sponsor, GSFC 614.4)*

Task Description

This task is striving to conceptualize and implement a comprehensive, sustainable regional framework for developing the capacity to apply Earth Observations (EO) data and products, and associated decision support tools for improving water management and for demonstrating the value of EO in water resource management. The geographical focus for this activity includes the USA, Latin and Caribbean Americas, as well as the rest of the world. The work is carried out within the Group on Earth Observations (GEO) framework and emphasizes the Water Societal Benefit Area. The project places a special emphasis on NASA data products and resources. The research and development activities include: assessing the requirements for geo-spatial information by water resource managers in key theme areas (evapotranspiration, drought) and select geographical areas (the U.S., Latin America and the Caribbean), identifying opportunties for the use of NASA data and products in these areas and themes; launching demonstration projects and showing how global EO products can be applied locally to assist in resolving water management problems; organizing workshops to train users of EO products and water resource managers; identifying gaps and opportuntities for new or improved information services; developing a coordinating function to oversee a broad-based capacity building program for the water sector, and soliciting services, data, expertise (from space agencies and international bodies) and funding to ensure that these capacity building activities become sustainable.

Highlights

During 2009, Lawford spent a substantial part of his time for this task organizing a workshop in Lima Peru. He established a workshop committee, chaired committee teleconference calls, secured travel support for workshop attendees, and organized and assisted in chairing the workshop. The workshop attracted regional experts from 15 countries who remain interested in Earth Observation applications. In 2010 the workshop proceedings were prepared; a network regarding the Caribbean and Latin Americas, known as the Hydrological and Space network of Information for Latin American and the Caribbean (CIEHLYC) was formed; and a website (www.watercycleforum.com) was launched for people who want information on these projects. In addition, preparations began for theme-based workshops on Evapotranspiration (USDA and NASA) and Global Drought monitoring (NASA). Other related activities carried out under this task included leading the GEO's regional drought impacts task and coordinating an advisory committee for a GEO study of user needs for water cycle information. Lawford also served on the writing team for a white paper on capacity building for water cycle activities in Africa and served on the planning committee for the Second African Water Cycle Coordination Initiative Symposium. In addition, Lawford gave a number of presentations in support of these activities at AGU and GEO meetings and elsewhere.

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

GEST Investigator: Liang Liao

Collaborator: *Robert Meneghini (Sponsor, GSFC 613.1)*

Task Description

The analyses of airborne and spaceborne weather radar generally and the Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar (PR) and (Global Precipitation Measurement (GPM) Dual-Wavelength Precipitation Radar (DPR) specifically are essential to improving the accuracy of satellite radar in inferring microphysical properties of hydrometeors. The task includes single- and dual-wavelength radar analysis of hydrometeor profiles, simulation of polarimetric radar signatures in rain, snow and mixed-phase hydrometeors, retrieval of the microphysical properties and characteristic parameters of drop size distribution, using data from dual-wavelength airborne weather radar, computation of electric scattering properties of mixed-phase particles, and validation of the TRMM-standard products using ground-based measurements.

Highlights

Liao has conducted a compressive study on the derivation of effective dielectric constant of melting snowflakes and developed an accurate melting layer model that can be used for radar and radiometer algorithms for GPM. With NASA collaborator, Dr. Robert Meneghini, Liao originally developed a framework for validation of TRMM-standard products through comparisons with ground measurements, laying an important foundation for the GPM validation task. He has also performed a variety of studies on the retrieval of hydrometeor profiles using airborne dual-wavelength and dual-Doppler radars. Much of his research findings have resulted in publications in peer-reviewed journals.

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

Collaborators: Yujie Wang (GEST); *J. Ranson (Sponsor, GSFC 614.4*

Task Description

The current MODIS operational algorithms for global aerosol retrievals and atmospheric correction rely on certain empirical assumptions about surfaces, which work well over dark and vegetated surfaces but become less accurate over heterogeneous and bright surfaces, including urban land and deserts. The main objective of Lyapustin's research has been the development of an advanced algorithm for aerosol/surface retrievals that overcomes this limitation and provides better accuracy, coverage and spatial resolution.

Highlights

Lyapustin and Wang have developed a new Multi-Angle Implementation of Atmospheric Correction (MAIAC) algorithm for MODIS, which uses a time-series analysis and an image-based processing for simultaneous retrievals of atmospheric aerosols and surface spectral bi-directional reflectance/albedo. The new algorithm is generic and works over vegetated regions of the Earth as well as over bright deserts. The aerosol retrievals are performed at high 1 km resolution, which is highly requested in different science and application disciplines, such as Air Quality/Urban Pollution. In snow-covered regions, MAIAC provides an estimate of the snow grain size and sub-pixel snow fraction. MAIAC has an advanced cloud mask (CM) and an internal dynamic land-water-snow classification; this helps the algorithm to flexibly choose a processing path in changing conditions. MAIAC has been extensively tested on the local and regional scales. MAIAC and its applications were featured in several publications, including a book

chapter in *Satellite aerosol remote sensing over land*, Springer Praxis Books (2009) and 3 papers in *JGR* (2008; 2011)

Task 614-127-442: **Fusion of Vegetation Structure from ICESat, SRTM and MODIS with a Global Vegetation Dynamic Model (DESDynI mission planning)**

GEST Investigator: Wenge Ni-Meister

Collaborator: *J. Ranson (Sponsor, GSFC 614.4)*

Task Description

The overall goal of this project is to fuse vegetation structure from the ICESat (Ice Cloud and Land Elevation Satellite) data and to generate structure datasets compatible with the Ent Dynamic Global Terrestrial Ecosystem Model (DGTEM) constrained by MODIS land cover for improved estimates of terrestrial carbon stocks and fluxes. This effort will serve as a prototype for the DESDynI mission, and the study will provide support for the value of the DESDynI vegetation structure measurements for a dynamic global terrestrial ecosystem modeling study. She plans to develop remotely sensed vegetation structure (mainly height and foliage profile) from ICESat and SRTM and MODIS land cover data to estimate global carbon fluxes and carbon storage.

Highlights

In the past year, we focused on algorithm development and evaluation. Regarding the development and evaluation of the vegetation height retrieval algorithm, Ni-Meister found that vegetation structure retrieval accuracies from spaceborne Geoscience Laser Altimeter System (GLAS) on the Ice, Cloud and land Elevation Satellite (ICESat) data are affected by surface topography, background noise and sensor saturation. She used a physical approach to remove surface topography effects from lidar returns to retrieve vegetation height from ICESat/GLAS data over slope terrains. Slope-corrected vegetation heights from ICESat/GLAS data were compared to airborne Laser Vegetation Imaging Sensor (LVIS) (20 m footprint size) and to small-footprint lidar data collected in White Mountain National Forest, NH. Slope-corrected GLAS vegetation heights match well with 98 percentile heights from small-footprint lidar (R^2 = 0.77, RMSE = 2.2 m) and top three LVIS mean (slope-corrected) heights (R^2 = 0.64, RMSE = 3.7 m).

Additionally, a physical model was developed to simulate lidar laser energy returns, and this analytical geometric optical and radiative transfer (GORT) model was used to simulate large-footprint lidar waveforms in temperate deciduous, coniferous and mixed forests in New England. Modeled lidar waveforms were compared to Laser Vegetation Imaging Sensor (LVIS) data collected at both plot (20m-25m radius) and forest stand (1 hectare) levels at Harvard Forest, MA; Bartlett Experimental Forest, NH; and Howland Experimental Forest, ME. Modeled lidar waveforms match better with LVIS data at the stand level than at the plot level, due to increased samplings of vegetation structure inputs. Overall, comparison results demonstrate the capability of the analytical GORT to model LVIS waveforms in different forest stands, especially for multilayer and multispecies vegetation canopies through convolution of mixed communities.

Task 614-130-448: **CMS Project**

GEST Investigator: Jacqueline Rosette

Collaborator: *Compton Tucker (Sponsor, GSFC 614)*

Task Description
The focus of this task is to participate in the GSFC Carbon Monitoring System (CMS) activity, which aims to combine active remote sensing and field data in order to provide high-resolution estimates of vegetation carbon stocks (biomass). Rosette's contribution to this involves the analysis of LiDAR remote sensing data to assess vegetation structure and establish relationships with observed biomass in order to extend estimates beyond field measurements.

Highlights
Dr. Rosette joined GEST in late January 2011.

Task 974-52-200: **NASA Energy and Water Cycle Study (NEWS) Program Office Support**

GEST Investigator: Robert A. Schiffer and Deborah Belvedere

Collaborator: *Michael Jasinski (Sponsor, GSFC 614.3)*

Task Description
In 2003, NASA established the NASA Energy and Water-cycle Study (NEWS), whose long-term grand challenges are to document and to enable improved observation-based predictions of water and energy cycle consequences of Earth system variability and change. However, the broad objectives of energy and water cycling-related climate research extend well beyond the purview of any single agency or program, and call for the support of many activities that are matched to each agency's respective roles and missions. Therefore, to achieve the ultimate goal of credible global change predictions and applications across all significant scales, NASA continues to seek collaborations with other federal and international agencies, the scientific community-at-large and private industry. To these ends, the project created four NEWS working groups that identify integration needs and make the needed connections to partner and coordinate with water and energy cycle research and application activities existing at other organizations within NASA, nationally, and internationally. The four groups are *Drought & Flood Extremes*, *Evaporation & Latent Heating*, *Water and Energy Cycle Climatology*, and *Modeling & Water Cycle Prediction.*

Highlights
NEWS: The working groups have been effective in coordinating and integrating NEWS PI science investigations; collaborating with relevant flight missions and NASA R&A Programs; implementing annual assessment of progress in meeting NEWS scientific requirements and promoting the development of scientific papers that integrate various NEWS research within the working group topic area (see nasa-news.org).

TRACE: A consensus is growing on both the importance of reliable regional scale climate predictions for assessing the availability and stresses on clean water supplies and the understanding that climate-related water issues will be a major societal concern in the near future, resulting in a new grassroots initiative: TRACE. The TRACE vision is to coalesce an interdisciplinary, international and interagency effort to make significant contributions to continental and finer scale hydro-climate science and solutions. A TRACE workshop planned for April 18-20, 2011 in the Washington D.C. area should provide an opportunity to outline the needs and opportunities for regional and continental scale hydro-climate studies in North America, as well as to develop the scientific objectives for a new North American regional hydro-climate experiment (RHP).

Task 614-113-407: **Operation Ice Bridge**

GEST Investigator: Michael Studinger

Collaborator: *Thorsten Markus (Sponsor, GSFC 614)*

Task Description

Studinger leads the Project Science Office at Goddard and its day-to-day operations in support of NASA's Operation IceBridge, a six-year mission of annual flights over the Arctic and Antarctic, is the largest airborne survey of polar ice ever flown. In 2010 the mission wrapped up its second year with two successful campaigns, one over the Arctic and one over the Antarctic.

Highlights

During March – May 2010, Operation IceBridge completed a successful Arctic campaign with the DC-8 and P-3 aircraft from NASA's Dryden Flight Research Center and NASA's Wallops Flight Facility. The science targets included sea ice in the Arctic Ocean and glaciers and ice sheet targets over Greenland. In total, Operation IceBridge collected 62,842 nautical miles of data during 28 science missions including laser altimeter data, snow radar and K-band radar data, accumulation radar and ice-penetrating radar data, as well as gravity data and digital photogrammetry. In Fall 2010, the Operation IceBridge team concluded a second successful campaign over Antarctica with NASA's DC-8 flying from Punta Arenas, collecting 40,098 nautical miles of data during 10 science missions.

Task 614-94-327: **Validation of Aquarius Faraday Rotation Angle Retrieval Algorithm and Modeling Impact of Topography on Microwave Radiometry**

GEST Investigator: Cuneyt Utku

Collaborator: *R. D. McPeters (Sponsor, GSFC 613.3)*

Task Description

Ocean salinity and soil moisture are key parameters in Earth's energy cycle. NASA's Aquarius satellite will soon be launched to monitor ocean salinity on a global scale. Equipped with L-band polarimetric radiometers to measure ocean surface brightness temperature, which is directly related to the salinity of the ocean, Aquarius will be succeeded by NASA's Soil Moisture Active-Passive (SMAP) mission, which will monitor soil moisture over land. SMAP will be equipped with a polarimetric L-band radiometer and a polarimetric L-band synthetic aperture radar. Reliable retrieval of ocean salinity and soil moisture from the brightness temperature data requires accurate modeling of Earth's surface involving a multitude of factors. The center theme of this research is to validate the Faraday rotation retrieval and correction algorithm for Aquarius and model the impact of topography on microwave radiometry.

Highlights

Aquarius will be using the 2nd and 3rd Stokes parameters to retrieve and correct for the polarization rotation, the Faraday rotation, of the surface brightness temperature as it propagates through the ionosphere. In order to evaluate the feasibility of Faraday rotation angle retrieval by polarimetric radiometers, data from European Space Agency's Soil Moisture and Ocean Salinity (SMOS) mission is

being analyzed. Equipped with an L-band interferometric radiometer, SMOS was launched in November 2009 to deliver multi-angular full polarimetric brightness temperature products. A Matlab code was developed to interface with SMOS Level 1C Science products. To facilitate collaboration, the code is also made available to other investigators at GSFC who are analyzing SMOS Level 1C Science products. The full polarimetric data from SMOS mission may facilitate testing and evaluation of Aquarius Faraday rotation retrieval and correction algorithm. Currently, using 2nd and 3rd Stokes parameters to apply the Faraday rotation angle retrieval from SMOS data is yielding moderate success. Since SMOS 3rd Stokes parameter is very noisy, various noise reduction techniques were applied to the data and tested to achieve agreement between the retrieved and model estimates of Faraday rotation angle. A persistent bias appears to exist between the retrieved and estimated values; antenna polarization coupling is being investigated as a potential source of bias. These results were presented at the SMOS Calibration and Validation workshop held in Frascati, Italy in November 2010.

Additionally, Utku has completed the development of a model to predict the impact of topography on microwave radiometry. The model incorporates two new techniques to account for the impact of topography on microwave emission. The first involves the use of an integral formulation of thermal emission from sloped surfaces; the second involves the use of a mixed distribution of bi-variate Laplacian and Gaussian distributions for slope statistics of topography. Together, the model yields very good agreement upon comparison with the brightness temperature values calculated using digital elevation models. A shortcoming of the model is that, while it considers direct emissions from the surface, it neglects the effect of the change in atmospheric attenuation with topographic height and heating of surfaces by other facing surfaces. These latter effects will be investigated and incorporated into the model as necessary.

Task 614-73-251: **Provide Analysis of Synthetic Aperture Radar data of Antarctic and Greenland for Glaciological Research**

GEST Investigator: Boris S. Yurchak

Collaborators: Waleed Abdalati (PI, CIRES, Colorado University) and *Thorsten Markus (Sponsor, GSFC 614)*

Task Description

Changes in snow, firn, and ice characteristics near the marginal zones of the Greenland Ice Sheet (GrIS) are indicative of variations in mass balance under conditions of climate change. Since this task's inception in 2006, Yurchak has studied the displacement pattern of the snow cover due to a shift in the equilibrium (or snow) line elevation, as well as radar backscattering features of snow cover in Polar Regions. Studies regarding Synthetic Aperture Radar (SAR) probing of snow have been supported with the use of satellite-based methods, analyses of backscattering models, and various computer data processing methods.

Highlights

Yurchak has helped to define objectives regarding snow research by radar methods, and contributed to current and future international and NASA's radar missions. He has presented his research findings at numerous conferences, highlighting his novel method of studying the radar backscatter from spatially extended geophysical targets (SEGT) and the results of SAR probing of marginal regions of the Greenland Ice sheet. Yurchak's research regarding his analysis of the snow inhomogeneities contribution into radar backscatter was highlighted in the *IEEE Transaction on Geoscience and Remote Sensing* in 2009. He also provided the comprehensive analysis of the volume component of radar backscatter from SEGT in a chapter in *Advances in Geoscience and Remote Sensing* (2009).

Task 614-118-412: **Development of Level 2 Science Products for Current and Future Hyperspectral and Multi-Spectral Sensors**

GEST Investigator: Qingyuan Zhang

Collaborator: *Elizabeth Middleton (Sponsor, GSFC 614.4)*

Task Description

Most ecologists, remote sensing scientists, and climate modeling scientists use level 2 or higher satellite remote sensing products. One of the most important level 2 products is surface reflectance, which is used to study BRDF effect, to calculate indices, to calculate albedo, and to derive many other level 2 vegetation-related products. Zhang has investigated atmospheric correction algorithms to produce surface reflectance for NASA's multiple satellite sensors. He has developed algorithms to derive the fraction of PAR absorbed by canopy chlorophyll ($fAPAR_{chl}$), leaf water content (LWC) and other level 2 products.

Highlights

Zhang has developed level 2 prototype products of $fAPAR_{chl}$, LWC, NDVI, EVI, LSWI and PRI for EO-1 Hyperion and HyspIRI. He has also developed the $fAPAR_{chl}$ and LWC algorithm for MODIS. In addition, he has studied how to use narrow band spectral reflectance to estimate light use efficiency at the canopy chlorophyll level (LUE_{chl}). He has presented his research findings at numerous national and international conferences, highlighting his algorithms and the products of $fAPAR_{chl}$ and LWC that are unique and useful for the studies of plant physiology, ecosystem carbon cycle, land-atmosphere interaction and climate modeling. Zhang's research regarding his $fAPAR_{chl}$ was highlighted in *Agricultural and Forest Meteorology*, *Journal of Applied Remote Sensing*, *Environmental Science & Policy*, *International Journal of Remote Sensing*, and *Forest Ecology and Management* in 2010. Zhang also collaborated on a chapter in *Advances in Environmental Remote Sensing: Sensors, Algorithms, and Applications.*

Heliophysics Division, Solar System Exploration Division
(Code 660-699)

This page intentionally left blank

Task 699-130-445: **Development of UV Laser Beam Parameters and Delivery Optics for Laser Desorption Mass Spectrometry**

GEST Investigator: Martina Atanassova

Collaborator: *Paul Mahaffy (Sponsor, GSFC 699)*

Task Description

Atanassova is involved in the development of laser desorption of the mass spectrometer for NASA's Mars Organic Molecule Analyzer (MOMA), which will investigate organic compounds on the surface of Mars utilizing laser ablation mass spectrometry. The mass spectrometer will detect complex organic molecules as large as peptides, the building blocks of proteins. These are less volatile than smaller organic molecules, such as amino acids, so they would not have been detected by other mass spectrometers. Her work includes hands-on operation of the UV laser and the associated optical elements of the mass spectrometer, including the design of the laser delivery optical system. In addition, she investigates the influence of the laser parameters, such as the output energy, fluence, repetition rates and optical contamination on the ion fragments produced.

Highlights

Atanassova has been involved in developing and testing several mass spectrometer prototypes, which include high energy UV laser and delivery optics. She is also assisting with defining the objectives for the development of the flight UV laser, which is currently being fabricated in Europe. She is also involved in the instrument development strategy discussions during various meetings with MOMA's European collaborators.

Task 699-71-247: **Numerical Modeling of Planetary Magnetospheres and Exospheres**

GEST Investigator: Mehdi Benna

Collaborators: Wayne T. Kasprzak (GSFC 699), James A. Slavin (GSFC 670), Menelaos Sarantos (GEST/UMBC), *Paul Mahaffy (Sponsor, GSFC 699)*

Task Description

This research aims to better understand the magnetospheres of the planets and the small bodies of the solar system targets of planetary missions. This task is achieved through the development of several numerical models that combine chemistry and plasma physics theories. These models are supported and validated by the use of data from active and past space missions.

Highlights

This task allowed the development of several state-of-the-art multi-fluid magnetohydrodynamic (MHD) models to support several active missions. The first of these models is ACASIM-3D, an advanced MHD-chemistry model that simulates the interaction between the solar wind and comets. This model was used to investigate in more detail the data obtained by GIOTTO during comet Halley and comet Grigg-Skjellerup flybys and was extended to provide predictions to support the ROSETTA mission. We also developed, through this task, the MESS-3D model that simulates the magnetosphere of Mercury and its interaction with the solar wind. This model provides predictions and helps analyze the data gathered by the MESSENGER spacecraft. This research also led to the study of icy moons, in particular the moon Enceladus, through the development of the ENCAM-3D model. This model helped investigate more

precisely the structure of Enceladus' tenuous atmosphere in light of the recent data recorded by several CASSINI instruments.

Task 699-119-414: **Miniature Two-Step Laser TOF Mass Spectrometer with Reversible Ion Polarity**

GEST Investigator: Mehdi Benna

Collaborators: Melissa Floyd (GEST), William Brinckerhoff (GSFC 699), Stephanie Getty (GSFC 541), Melissa Trainer (GSFC 699), *Jennifer Eigenbrode (Sponsor, GSFC 699)*

Task Description

A new two-step laser mass spectrometer (L2MS), now under development uses two laser sources to improve the selectivity and sensitivity of the instrument to key classes of organics. An additional instrument enhancement, reversible polarity, features the ability to detect negative ions to eliminate interferences from salt peaks that dominate positive mode and improve detection limits for electronegative species.

Highlights

L2MS' analysis of a small number of "standard" samples amenable to a post-ionization protocol (e.g., containing aromatic organics) is currently being tested with the prototype. Blue ink, containing methyl violet dye with a characteristic neutral loss pattern from a parent ion near 400 Da, and pyrene, a model polycyclic aromatic hydrocarbon (PAH), have been used to develop and optimize L2MS in the miniature TOF-MS. Illumination by Laser 1 (1064 nm) or Laser 2 (266 nm) alone produces minimal effects, but the combination of Lasers 1 and 2 produces a superior post-ionization spectrum. The benefit of using post-ionization with lower intensity has been demonstrated. LDI data are most commonly collected in positive ion mode, such as in the matrix-assisted LDI (or MALDI), in which protonation of an analyte M gives the positive ion MH+. Negative ions are also used; these form by electron attachment to desorbed neutrals, during which the supply of electrons is reduced. At lower laser intensities, negative ionization is electron-supply limited; the ionization probability is strongly correlated to electron affinity. Organics with more electronegative functional groups and/or complex pi orbitals are more likely to ionize. The benefits of additional capabilities must be carefully weighed against the increased complexity of an eventual flight design.

Task 612-71-248: **Coupling Between Mercury's Exosphere and Magnetosphere and the Study of Planetary Magnetospheres**

GEST Investigator: Scott A. Boardsen

Collaborators: Eun-Hwa Kim and Jay Johnson (Princeton Plasma Physics Laboratory-PPPL), Torbjörn Sundberg (Space and Plasma Physics, School of Electrical Engineering, Royal Institute of Technology, Stockholm, Sweden), Mehdi Benna (GEST, GSFC 699.0), L. K. Jian (UCLA Institute of Geophysics and Planetary Physics); *James Slavin (GSFC 670)*

Task Description

Boardsen studies plasma waves, plasma structures and their interaction with particles in planetary magnetospheres. His current research focus is on the analysis and interpretation of ultra-low frequency (ULF) waves detected at Mercury by the magnetometer flown on the MESSENGER spacecraft. He is

studying the role these waves play in energy transfer within plasmas and as a diagnostic of magnetospheric processes and composition. He is also studying the interrelationship between Mercury's magnetosphere and ions, mainly Na+, which is created by the ionization of Mercury's exosphere, by analyzing *in situ* measurements and MHD and hybrid simulations. He is also studying high-frequency Kilometric Continuum (KC) radiation generated in the Earth's magnetosphere, as well as working on other Earth-oriented missions.

Highlights

Boardsen published the first observations of Kelvin-Helmholtz wave at Mercury's magnetopause in *Geophysical Research Letters* observed during the third MESSENGER flyby. He worked with Dr. Jian of UCLA on ion cyclotron waves detected by MESSENGER in the interplanetary medium, and the results were published in the *Journal of Geophysical Research*. He also worked with Dr. Slavin on extreme loading and unloading of Mercury's magnetotail, and their results were published in *Science*. Boardsen worked on magnetometer data science analysis code for the prime MESSENGER mission, which began in March 2011.

Task 673-97-337: **Plasma in the Saturnian Magnetosphere and its Interactions with Icy Satellites**

GEST Investigator: Matthew H. Burger

Collaborators: Edward C. Sittler, Jr.; *C. Long (Sponsor, GSFC)*

Task Description

An important aspect of the Cassini mission to Saturn, one which can only be carried out *in situ* by an orbiting spacecraft, has been the characterization o f the sources, sinks, and distribution of plasma within Saturn's magnetosphere. Burger has been working with the Cassini Plasma Spectrometer (CAPS) team to understand the basic properties (density, temperature, and bulk density) of the plasma during the Cassini prime and extended missions, and to model the interactions between the plasma and neutrals in the magnetosphere.

Highlights

Burger published three papers in a special issue of *Space Science Reviews* dedicated to the satellites of the outer solar system and sponsored by Europlanet and the International Space Sciences Institute (ISSI). He is currently working to use his previously published model of the Enceladus water plume to understand recent Cassini data and understand the formation of the neutral gas clouds in Saturn's inner magnetosphere.

Task 613-121-421: **Studies of Mercury's Exosphere in the MESSENGER Era**

GEST Investigator: Matthew H. Burger

Collaborator: *Rosemary Killen (Sponsor, GSFC 695)*

Task Description

Sodium, calcium, and magnesium have been observed in Mercury's exosphere during three flybys by the MESSENGER spacecraft. Each species shows a distinct spatial distribution pointing to differences in the source and transport processes responsible for ejecting each exospheric component from the surface.

MESSENGER's one-year orbital phase began in March 2011 and includes an extensive survey of Mercury's exosphere. Burger has developed a Monte Carlo model of Mercury's exosphere, which has been used to understand the MESSENGER flyby data and to prepare for future observations during the primary science mission.

Highlights

Burger has been working to understand the composition, sources, and sinks in Mercury's exosphere. He was part of a team that discovered ionized calcium (Ca^+) in the ionosphere using MESSENGER data. He also published two papers that focus on modeling sodium emissions from the ground and MESSENGER, demonstrating that the primary source of exospheric sodium is diffusion-limited photo-desorption. Precipitation of solar wind ions onto the surface increases the diffusion rate of sodium in the regolith in regions of open magnetic field lines. He also presented models of the calcium and magnesium exosphere at a joint MESSENGER and BepiColombo workshop, and submitted a white paper on Mercury's magnetospheric and exospheric interactions to the *NRC Heliophysics Decadal Survey*.

Task 698-79-270: **Analysis of the Earth's and planetary gravity fields and geophysical applications**

GEST Investigator: Shin-Chan Han

Collaborators: Scott Luthcke, Richard Ray, Frank Lemoine, Jeanne Sauber; *David Rowlands (Sponsor, GSFC 698)*

Task Description

The satellite gravity measurements, such as those from the Gravity Recovery And Climate Experiment (GRACE) mission, are sensitive to mass re-distribution on the Earth's surface and interior with a spatial resolution of hundreds of kilometers and a temporal resolution of 10 days or so. In some cases of geophysical mass variation with known temporal frequency (*i.e.*, tides), it is possible to study such phenomena even with a sub-daily interval. The major goal of this task is to optimally process the satellite tracking data to analyze the hydrological mass fluxes over the large river basins, the ocean tides over the coastal areas and polar regions, and the solid earth dynamics related to the coseismic change and postseismic relaxation caused by large earthquakes.

Highlights

Han has contributed to NASA's GRACE mission by developing innovative analysis methodologies and applying them to science questions that can be addressed uniquely with large-scale observations. Various research outcomes were published in leading journals and presented at numerous conferences. Some of them were highlighted at the American Geophysical Union conferences. During his tenure at GEST working on this task, Han received three prestigious awards, one each from NASA's Science Mission Directorate, NASA Goddard Space Flight Center, and the American Geophysical Union.

Task 673-94-324: **NASA's Magnetospheric Multiscale (MMS) Mission**

GEST Investigator: Kyoung-Joo Hwang

Collaborators: Melvin Goldstein, Adolfo F-Vinas, Michael Hesse, and John Dorelli; *Elizabeth Middleton (Sponsor, GSFC 614.4)*

Task Description

The Magnetospheric Multi-Scale (MMS) mission, to be launched in 2014, will use Earth's magnetosphere as a laboratory to study the microphysics of magnetic reconnection. MMS will investigate how the energy conversion that occurs in magnetic reconnection accelerates particles and what role plasma turbulence plays in reconnection events. Using existing data from the multi-spacecraft mission, *Cluster*, and applying either analytical or simulation techniques to processes occurring in the ion and electron diffusion regions near the reconnecting magnetic fields, MMS pre-launch research provides an in-depth understanding of the physics of magnetic reconnection.

Highlights

Hwang created an intense data analysis on the Earth's magnetosphere using the Cluster and THEMIS spacecrafts. Three main topics were electron behavior in the reconnection X-line, dipolarization fronts (DFs), and Kelvin-Helmholtz waves (KHW). Hwang reported multiple X-line structures in the magnetotail. The initiation and topology reconfiguration associated with reconnection occur in electron diffusion regions (EDR), which are difficult to identify observationally due to its small-scale size. Hwang identified EDR and showed non-gyrotropic electron distributions accompanied by super-Alfvénic flows, consistent with numerical results. For the first time, she reported developed KHW at the magnetopause during southward IMF. From Cluster observations of DFs she demonstrated that interchange instability leads to the deformation of the mid-tail magnetic topology and generates field-aligned currents, related to the substorm processes. She has been invited to present these studies, and related publications either have been submitted or are in press in *JGR*.

Task 674-84-294: **Collisionless Reconnection Simulation and Detector Response Study**

GEST Investigator: Alex Klimas

Collaborators: Seiji Zenitani (ORAU at GSFC 674), *Michael Hesse (Sponsor, GSFC 674)*

Task Description

Collisionless magnetic reconnection is a ubiquitous process that plays an important role in the dynamics of many space, laboratory, and astrophysical plasma systems. Because it is a complicated nonlinear process, much of what has been learned about collisionless reconnection has come from simulation studies. From these studies, a "Hall reconnection model" has emerged as the generally accepted paradigm for this process. Recently, however, simulations done with open rather than the traditional periodic boundary conditions have challenged the Hall reconnection model. The purpose of this task is to modify an available electromagnetic 2 ½-dimensional particle-in-cell (PIC) reconnection simulation code to incorporate open boundaries and then to investigate this recent challenge to the Hall reconnection model using the modified code.

Highlights

A new and far more general algorithm for open boundaries in PIC simulation codes has been developed. A zero normal gradient is imposed on the particle phase-space distributions at each of the boundaries. Two Fortran versions of an open boundary reconnection simulation code have been delivered; each of them has been successfully parallelized using either the OpenMP or the MPI paradigm. The code has been applied in an ongoing study of the electron role in collisionless reconnection, a central issue in the debate over the Hall reconnection model. Two papers containing early results of this study have been published in a refereed journal.

Task 673-95-331: **Statistics of Turbulent Reconnection in Earth's Magnetotail**

GEST Investigator: Alex Klimas

Collaborators: Melvyn Goldstein, Adolfo Figueroa-Vinas, Vadim Uritsky; *Frank LeMoine (Sponsor, GSFC 698)*

Task Description

It has been shown that the central plasma sheet of the Earth's magnetotail resides in a far-from-equilibrium turbulent state exhibiting stochastic properties over broad ranges of spatial and temporal scales. Such observations suggest that this turbulence is a primary physical process in the plasma sheet, likely generated by localized magnetic reconnection and its fast flows, and possibly playing a role in initiating reconnection by generating strong inhomogeneities in the plasma. An important clue in the search for the origin of this turbulence is that it is strongly intermittent; therefore, its explanation requires a non-classical approach. In this task, Klimas and his team make an attempt in this direction: they ascribe tail intermittency to self-organized criticality (SOC) – a multi-scale stochastic process producing scale-free dissipation regions that may be centers of turbulent magnetic energy conversion. *In situ* plasma sheet observations, remote auroral observations, and plasma sheet turbulent reconnection simulation models are under investigation.

Highlights

Prior to this task, these researchers had shown that auroral emissions exhibit the statistical properties of a system in SOC in the universality class of a directed, non-abelian sandpile model. Considering a variety of observational indications that these emissions are directly related to turbulent reconnection in the plasma sheet, Klimas and his collaborators have constructed plasma sheet turbulent reconnection simulations that exhibit scale-free statistics in the same universality class. By examining the spatial and temporal distribution of auroral emissions in the ionosphere, they have been able to map the auroral emission events into the tail plasma sheet to unambiguously relate the auroral SOC statistics with the dynamics of the midtail region where reconnection is observed.

Task 672-109-377 **Wind Magnetic Field Investigation (MFI)**

GEST Investigator: Andriy Koval

Collaborator: *Adam Szabo (Sponsor, GSFC 672)*

Task Description

The MFI instrument onboard the Wind spacecraft is capable of providing high time resolution measurements (11(22) vector/sec) of magnetic fields in the solar wind and in the Earth's magnetosphere. These measurements are vital to analyzing the properties of solar wind, such as turbulence and kinetic structures of solar wind discontinuities. Since August 2009, when the task began, Koval has worked on production of the high time resolution data and studied the properties of the solar wind turbulence and interplanetary shocks.

Highlights

Koval has developed an improved calibration technique for the Wind spacecraft MFI instrument to allow producing 11(22) vector/sec high time resolution data. The improved technique results in a significantly decreased spin noise in the data as compared to the original calibration technique. He has used the high time resolution data to produce the turbulent spectra of magnetic fluctuations in the solar wind, which allows for analyzing both the inertial and dissipation ranges. Koval has also analyzed the global properties

of interplanetary shocks derived from multi-spacecraft observations. His results demonstrate complex shapes of interplanetary shocks and high corrugation of interplanetary shocks on small scales. The results were presented at the AGU and EGU conferences, and they have been published in a paper [(Koval, A., and A. Szabo (2010)] in the *Journal of Geophysical Research*.

Task 673-90-315: **Study of the Interaction Between Space Objects and Plasma Flow: 3D Hybrid/Kinetic Simulation**

GEST Investigator: Alexander S. Lipatov

Collaborators: Edward C. Sittler (PI, GSFC 673), Richard E. Hartle (GSFC 673), John F. Cooper (GSFC 672); *X. Xiong (Sponsor, GSFC)*

Task Description

The excitation of strong electromagnetic perturbations by the Solar Probe Plus may be a crucial point for both plasma wave and electron plasma measurements onboard SC in the inner heliosphere. Lipatov has studied the electric field in upstream and downstream flow, a polarization electric field in the wing of plasma wake, and fluctuations in the solar wind due to "shot" noise. A second part of this task involves the understanding of Titan's interaction with Saturn's rotating magnetosphere, which is very complex with non-stationary kinetic plasma processes, and it is necessary to analyze the Cassini observations (*e.g.*, Cassini Plasma Spectrometer [CAPS]), with a physically meaningful model such as the researchers' advanced kinetic-fluid (hybrid code) model.

Highlights

Lipatov has studied the spatial distributions of the particles and the electromagnetic perturbations in 2.5 and 3D models of the SPPSC for the distance r=9.5 Rs. The model results are essential in developing the design strategy of the PWI, including the orientation of the antenna and particle instruments planned for the future SPP mission (NASA TM2010-215862, NASA TM2010-215863). For the first time, Lipatov has received 3D velocity distribution functions for pickup ions inside the exosphere of Titan in the case of the Cassini T9 encounter. Special attention was given to the comparisons of his numerical results with (CAPS) observations.

Task 672-97-339: **Study of the Interaction Between Moons and Plasma Flow: 3D Hybrid/Kinetic Simulation**

GEST Investigator: Alexander S. Lipatov

Collaborators: John F. Cooper (GSFC 672), Edward C. Sittler (PI, GSFC 673), Richard E. Hartle (GSFC 673); *Steven Platnick (Sponsor, GSFC 610)*

Task Description

The understanding of the interaction of Jovian plasma torus with atmosphere and the surface of Europa is very important in the course of the future mission. The researchers' numerical modeling will provide important information about the interaction processes between the thermal/energetic plasma and atmosphere, and the surface of Europa. One of the goals of this research is to produce a map of the particle fluxes at the surface of Europa. These models will be used in future missions to Europa to study the composition of the surface. Additionally, the modeling of the interaction between the solar wind and the moon and the comparison with plasma and magnetic field observational data (from Apollo-era to the

recent observations) allows the scientists to study the plasma processes at the surface of the moon. Such information will be very important for an analysis of the composition of the surface.

Highlights

Lipatov has performed a 3D hybrid simulation of the interaction between the Jovian plasma torus and Europa in collaboration with J.F. Cooper. He also has produced global plasma structures near Europa and the fluxes of the incoming and pickup ions on the surface of Europa (Lipatov, Cooper *et al.*, 2010, *Planet. Space Sci.*). Lipatov performed the first hybrid simulation in a case with local source of the magnetic field on the surface of the moon. The results of his research were presented at the AGU meetings and International Meetings/Congresses.

Task 690-107-368 **Remote Sensing of CO_2 and Other Atmospheric Compositions**

GEST Investigator: Jianping Mao

Collaborators: Jay Herman (JCET/UMBC), Randy Kawa (GSFC 613), Clark Weaver (GEST), *James Abshire (Sponsor, GSFC 690)*

Task Description

Global high spatial and temporal resolution remote sensing of atmospheric CO_2 concentration is greatly desired for global and regional carbon studies. The biggest challenge for CO_2 remote sensing is to achieve the high-precision science measurement requirement (~ 1 ppmv or 0.3% on regional scales) so that such a measurement will be valuable to reduce uncertainties about carbon sources and sinks. GSFC is developing an active laser approach for global atmospheric CO_2 concentration measurements from space as a candidate for NASA's future carbon mission ASCENDS - the Active Sensing of CO_2 Emissions over Nights, Days, and Seasons. This pulsed laser approach provides several advantages with respect to passive approaches and other laser techniques toward high-precision measurement of CO_2 from space. The main goal of this task is to support this ongoing development.

Highlights

Mao has continually updated spectroscopy database and line-by-line radiative transfer model and performed radiative transfer calculations toward the CO_2 measurement development. He has helped with data analysis for the ASCENDS science campaign of summer 2010 in the mid-U.S. and West Coast and has performed simulations for ASCENDS mission studies. Meanwhile, Mao also has supported the construction of a global satellite UV reflectance climate data record from multiple U.S. satellites and data analysis for applications of the climate data record to climate studies. He has presented his results at several national and international meetings in the past 12 months and has contributed to four peer-reviewed journal publications.

Task 612-67-235: **Solar Wind and Magnetospheric Environment**

GEST Investigator: Jan Merka and Tom Narock

Collaborators: Yongli Wang (GEST), Shing Fung (GSFC 672), David Sibeck (GSFC 674), *Adam Szabo (Sponsor, GSFC 672)*

Task Description

Changes in solar wind conditions upstream of Earth are the primary driver of the magnetospheric variability. Therefore, a better understanding of solar wind properties, its interaction with magnetosphere and of magnetospheric dynamics are all necessary for further improvements of space weather predictions.

Vast quantities of distributed heterogeneous data sets from spacecraft and numerical simulations are available to researchers; however, management and understanding of such data is difficult. Therefore, NASA called for the development of Virtual Observatories (VxOs) to develop a unified community-specific data environment. This task supported VxO developments together with event and statistical studies of the heliospheric and magnetosperic environments.

Highlights

Merka led the development of the fully functional Virtual Magnetospheric Observatory (VMO) for the magnetospheric physics community. A major part of this task was to identify and adequately describe data products of interests. Merka and Narock worked closely with the Space Physics Archive and Extract international consortium and developed a standard data model now in use for VxO data descriptions. In addition, Narock initiated and presently leads the development of the SPASE Query Language (SPASEQL) that facilitates and standardizes communications among VxOs and related services. Merka and Narock also developed the Virtual Heliospheric Observatory (VHO) that unifies heliospheric data sets (PI: Szabo), and supports two more VxOs: Virtual Energetic Particle Observatory (VEPO) and Virtual Wave Observatory (VWO). The VHO and VMO currently offer their users several data search interfaces, ranging from a straightforward wizard-like series of menus to an advanced-level relational search where complex queries with thousands of individual conditions are possible.

Task 698-112-394: **Space Geodetic Networks' Data Analysis**

GEST Investigator: Erricos Pavlis

Collaborator: Magdalena Kuzmicz-Cieslak, (GEST/JCET); *David Rowlands (Sponsor, GSFC 698)*

Task Description

The task supports a team with substantial involvement and leadership role in NASA's future geodetic networks program and the international program "Global Geodetic Observing System—GGOS" of the Int. Assoc. of Geodesy (IAG). One of the primary goals is the development of an optimized design for the core future geodetic network, which will assist NASA in planning its participation in this international effort.

Highlights

The accomplishments over the past two years covered the initial goals and in many cases Pavlis and his collaborator have completed successfully additional tasks that were not in the original plan. In particular, they maintain a state-of-the-art Satellite Laser Ranging (SLR) data analysis capability, and they generate science products for the International Earth Rotation and Reference Frame Service (IERS) and the International Terrestrial Reference Frame (ITRF) Service as required by the International Laser Ranging Service (ILRS). Additionally, they generate the following: daily quality-checking reports for SLR data; combination products from the ILRS products submitted by all ILRS ACs; combinations using products from other space geodetic techniques (e.g. VLBI, GPS, DORIS). They also execute extensive studies of future geodetic missions for the development of optimized designs of geodetic networks, using simulations on NASA supercomputing facilities, driven by future system (hardware) parameters, to monitor global climate change. At the request of NASA HQ along with Goddard scientists and engineers, they have developed and submitted two proposals related to GGOS: (a) the "Space Geodetic Program" proposal for NASA's prototype global network, and (b) the "Geodetic Reference Antenna in Space (GRASP)" proposal for a new multi-technique mission.

Task 670-108-374 **Modeling neutrals and ions that are generated from collisionless exospheres of planetary bodies**

GEST Investigator: Menelaos Sarantos

Collaborator: *James A. Slavin (Sponsor, GSFC 670.0)*

Task Description

Tools were developed to model *Surface-Boundary Exospheres* and their effects, via pickup ions, on magnetospheric dynamics and structure. The studies under this task supported neutral and plasma ion instrument investigations at Earth, Mercury, and other bodies (Moon, Europa). Exosphere models were interfaced with neutral mass and ultraviolet/visible spectrometers for planning of future missions (*e.g.*, LADEE, JEO) as well as for data analysis from flying spacecraft (MESSENGER).

Highlights

Sarantos demonstrated to several instrument teams how exosphere models can help define objectives and guide the planning of operations (*e.g.*, instrument pointing) in order to maximize scientific returns from spacecraft missions. In two publications, Sarantos led the analysis of ion and neutral measurements obtained by MESSENGER during its Mercury flybys. Additionally, he contributed as a co-author to more than ten MESSENGER Team papers over the period of performance, including two published by *Science*. Tomographic techniques, whose developments were initiated under this task, will substantially speed up the analysis of data expected to be obtained during MESSENGER's orbital phase, which began in March 2011.

Task 674-110-384 **Ionosphere-Thermosphere Models at Community Coordinated Modeling Center**

GEST Investigator: Ja Soon Shim

Collaborator: *Michael Hesse (Sponsor, GSFC 674)*

Task Description

The Community Coordinated Modeling Center (CCMC) is a multi-agency partnership that hosts a set of state-of-the-art space science models ranging from the solar atmosphere to the Earth's upper atmosphere. The CCMC provides the scientific community access to the models through a web-based and Runs-on-Request system by which researchers can readily request simulations to conduct scientific studies for time intervals of interest and a broad range of conditions. The CCMC also provides a variety of modern, visualization and analysis tools to enable users to work with the output of requested model runs. Model output can be specifically tailored for easy comparison with observational data to facilitate data analysis and model validation. Using the ionospheric and/or thermospheric measurements, the ionosphere-thermosphere models at CCMC and new models to be hosted in the near future will be tested and validated.

Highlights

Shim has been working on this ionospheric model validation study, which includes a CEDAR ETI (Electrodynamics Thermosphere Ionosphere) modeling challenge. For the Challenge, simulations of multiple ionospheric models hosted at CCMC were carried out for a selected nine events and for five physical parameters. Shim has analyzed the model results by comparing them with observational data such as electron and neutral density, obtained from the CHAMP satellite, F2-layer peak electron density

(NmF2) and peak height (hmF2) obtained from ISRs (Incoherent Scatter Radar), and vertical drifts at Jicamarca. She has presented the outcome of the preliminary round of the Challenge at several conferences that will be used as an important benchmark reference for further validation studies.

Task 698-83-285: **Swath Laser Altimetry Instrument Incubator Program and Ice Sheet Research**

GEST Investigator: Christopher A. Shuman

Collaborators: Vijay P. Suchdeo (Sigmaspace at NASA/GSFC) and *David J. Harding (Sponsor, GSFC 698)*

Task Description

As part of an Instrument Incubator Program effort (D. Harding, PI), since 2007 Dr. Shuman has supported the Swath Imaging Multi-polarization Photon-counting Lidar (SIMPL) via Greenland field operations in 2007 and laboratory and operational testing of breadboard and flight instruments in 2008, 2009, and 2010 at NASA GSFC and NASA GRC. In addition, he pursued studies using ICESat and Airborne Topographic Mapper data. The long-term goal was to develop accurate and precise airborne and satellite lidar sensors capable of producing small and contiguous-footprint, altimetry data to measure ice elevation change and to assess glacier characteristics. Additional work on ongoing NASA ice sheet, ice cap, ice shelf, and outlet glacier studies supported the above activities and produced high-quality science results, as shown in presentations, and publications. An education and outreach component in support of these activities at meetings and through press materials was also successfully conducted.

Highlights

Besides contributing to SIMPL's successful flights (summarized in Geoscience and Remote Sensing Symposium (IGARSS), *IEEE*, pp. 653-656, 25-30 July 2010, doi: 10.1109/IGARSS.2010.5650862), Shuman also detected and developed a correction for a deci-meter-level bias in the ICESat Mission (2003-2009) satellite altimetry time series, documented an unprecedented 170 m elevation loss on the Crane Glacier from ICESat, ATM, and ASTER digital elevation model data while supporting NASA Operation Ice Bridge flights out of Punta Arenas, Chile.

While working on this task, Shuman also had several notable education and outreach successes. He completed a series of world and polar elevation maps that summarized ICESat altimetry (http://nsidc.org/data/icesat/laser_op_periods.html), served as reviewer for 'Tour of the Electromagnetic Spectrum' (http://missionscience.nasa.gov/ems/TourOfEMS_Booklet_Web.pdf), and was interviewed for *Earth & Sky* (http://www.earthsky.org/radioshows/52217/lakes-under-glaciers-a-key-to-sea-level-rise). He also developed an SVS animation "Ice Fronts on the Larsen B Ice Shelf, 2001-2009" (http://svs.gsfc.nasa.gov/vis/a000000/a003800/a003803/index.html).

Task 698-103-352 **Investigation of non-tidal ocean signals in land observatory and satellite magnetic measurements**

GEST Investigator: Kumar Hemant Singh

Collaborators: Terence Sabaka (GSFC 698), Alexei Kuvshinov (ETH Zurich, Switzerland); *Weijia Kuang (Sponsor, GSFC 698)*

Task Description

The detection of the tide-induced magnetic signals in the satellite data has motivated further research on measuring magnetic anomalies from non-tidal oceanic flow. Despite several simulations on estimating the magnetic signals from non-tidal oceanic flows, they are yet to be detected in the satellite and observatory measurements, mainly because the signals from the oceanic flow are too weak to be detected remotely. To further enhance researchers' understanding of temporal and spatial variability of the oceanic circulation models, Singh and his team conducted several experiments to study magnetic signals from both high-resolution models and from the 3D variation of electrical conductivity within the ocean.

Highlights

Singh and his collaborators have computed induced magnetic signals from a more sophisticated oceanic circulation model, the HYCOM (Hybrid Coordinate Ocean Model) (grid resolution 1/12°). Higher-resolution oceanic motion models generate stronger magnetic signals with more complex spatial distributions. For example, the signal strength with HYCOM is nearly twice as that with OCCAM (1/4°). The different ocean models with the same resolution also produced strong differences. The influence of the electrical conductivities are based on an average conductivity of 3.2 S/m and a 3D electrical conductivity distribution obtained from temperature and salinity distribution in 3D from HYCOM model, as well as some significant differences, which indicate the importance of including high-resolution and 3D conductivity profiles in the modeling effort. These results were presented at the AGU Fall Meeting at San Francisco, CA in December 2010. Singh also published a single-author article for *Encyclopedia of Solid-Earth Geophysics* by Springer Verlag (2011, in press).

Task 699-122-425: **Fabrication, Characterization and Modeling of field emission sources for the VAPOR miniaturized pyrolysis time-of-flight mass spectrometer**

GEST Investigator: Adrian Southard

Collaborators: Stephanie Getty, Nicholas Costen, Larry Hess, Steve Feng, Carl Kotecki, and *Daniel Glavin (Sponsor, GSFC 699)*

Task Description

The VAPoR (Volatile Analysis by Pyrolysis of Regolith) instrument aims to study soil composition, volatiles, and trapped noble gases in the polar regions of the Moon. VAPoR will ingest a soil sample and conduct analysis by pyrolysis and time-of-flight mass spectrometry (ToF-MS). The miniaturized ToF-MS will enable *in situ* chemical analysis of lunar regolith using a low-power, low-mass, small-footprint package. This instrument will use a miniature field emission electron gun as an electron impact ionization source for the ToF-MS. The goal of Southard's research is to fabricate parts for the next-generation electron gun, independently test possible emission sources for it, and simulate the electron impact ionization and subsequent extraction of ions within the ToF-MS.

Highlights

Southard has played a central role in fabricating new electron guns that employ one of two promising emitter materials, including pillars composed of carbon nanotubes, which, due to their anisotropic shape, show field enhancement parameters of >1500. Recent testing has demonstrated strong field enhancement. He has also used simulation software (SIMION) to inform the mechanical design of the new ion source. He achieved the goal of a mass resolution, m/Δm, of >500 at room temperature. He also used SIMION to model electrospray ionization, an alternative to electron impact ionization for characterizing larger biological molecules. Southard has discussed recent developments in the fabrication and optimization of the ToF-MS at two conferences, the Nanotechnology Partnership Forum at NIST (Gaithersburg, MD) and the Mid-Atlantic Micro-Nano Alliance Annual Symposium at JHU/APL (Laurel, MD). In addition, Southard served as an SBIR proposal reviewer (September 2010).

Task 612-68-238: **Survey of Cusp Electrodynamics using FAST Data/Investigations of the Near-Lunar Space Environment**

GEST Investigator: Timothy J. Stubbs

Collaborators: Robert F. Pfaff (674), William Farrell (695), David Glenar (New Mexico St. Univ./693), Richard Vondrak (690), Jasper Halekas (UC Berkeley), Gregory Delory (UC Berkeley), Telana Jackson (695), Erwan Mazarico (MIT/698); *Michael Collier (Sponsor, GSFC 695)*

Task Description

The various investigations of the near-lunar space environment aim to understand how solar irradiation and the ambient plasma environment at the Moon result in the surface becoming electrically charged, and, in turn, how this drives the transport of charged dust. The resulting exospheric dust is believed to scatter sunlight to produce the "lunar horizon glow" (LHG) that was reported during the Apollo era. A predictive modeling code, which simulates LHG and exospheric atomic emission lines in the presence of coronal and zodiacal light, is continuing to be developed. These phenomena likely occur on all airless regolith-covered bodies in the Solar System. This work is also important for lunar-based science and exploration activities, since the charged dust is known to be a nuisance, and could potentially be a hazard. Stubbs is a Participating Scientist with the Lunar Reconnaissance Orbiter (LRO) mission, and is affiliated with the Cosmic Ray Telescope for the Effect of Radiation (CRaTER) instrument team. As part of the LRO science team, he will map surface electric fields and characterize exospheric dust. He is also a member of the NASA Lunar Science Institute's Dynamic Response of the Environment At the Moon (DREAM) team.

Highlights

Stubbs' occurrence frequency analyses of FAST data identified particle populations in the cusp region and inferred the drift-motion transport that determined their spatial distribution.

Stubbs developed a lunar surface-charging model that was used to predict conditions while the Moon was immersed in the solar wind and magnetotail, as well as during space weather events. These results were also used as inputs for electrostatic dust transport models. The Stubbs *et al.* [2006] paper describing the "dust fountain" model is one of the most highly cited in *Adv. Space Res.* in the past 5 years (>51 citations). Related studies included investigations of the lunar wake on both global and local spatial scales (*e.g.*, "mini-wakes"), predicting the flux of ENAs from exospheric dust, modeling the "lunar horizon

glow" believed to be produced by sunlight scattering from exospheric dust, and possible electrostatic discharge hazards affecting lunar astronauts. In addition, optical and plasma shadowing codes developed by Stubbs and Wang have been used to predict solar illumination and surface charging at both the Moon and Vesta.

Research funded by this task contributed to Stubbs' selection as a Participating Scientist with the LRO mission, as well as the NLSI's selection of the DREAM team. Stubbs has frequently been invited to provide advice based on research performed under this task. This work has also been a popular topic for EPO.

Task 698-122-427: **Comprehensive Modeling of the Geomagnetic Field: Version 5**

GEST Investigator: Zhibin Sun

Collaborators: Terry Sabaka; *W. Kuang (Sponsor, GSFC 698)*

Task Description

The Earth's magnetic field is composed of contributions from many sources. Over the past decade, a new approach to geomagnetic field modeling has been developed. This approach, known as "comprehensive modeling", was developed to overcome the problem of separation of spatial and temporal variations from observed magnetic field at ground and satellite levels. Sun's task is to develop the next generation of a comprehensive model (CM5) to model Earth's global geomagnetic environment from satellite and observatory data. CM5 will include more physics and a greater time span than its previous versions.

Highlights

To date, Sun and Sabaka have successfully completed the development and testing of the new system for magnetospheric field using satellite and observatory data.

Task 674-92-321: **CCMC Solar and Heliospheric Modeling**

GEST Investigator: Aleksandre Taktakishvili

Collaborators: Michael Hesse (GSFC 674), Peter MacNeice (GSFC 674), Maria Kuznetsova (GSFC 674), Antti Pulkkinen (GEST), Lutz Rastätter (GSFC 674); *David Toll (Sponsor, GSFC 699)*

Task Description

The most severe geomagnetic storms are caused by coronal mass ejections (CMEs) that reach the Earth. Since he joined GEST in September 2008, Taktakishvili has worked on CME modeling and CMEs' impact on the Earth's magnetosphere. He developed a tool to determine CME parameters from coronograph images used as input in ENLIL heliospheric cone model, and studied CME shock arrival times and magnitude of impact. Simulation results were compared to a reference and empirical model results and observations. He performed uncertainty estimations for the model predictions. These studies

are essential for the scientific community, operational and forecasting users so that they are aware of model capabilities and limitations.

Highlights

Taktakishvili's research provided important feedback to the model developers and has helped to improve model capability and performance. His model validation was used by the NASA/GSFC Community Coordinated Modeling Center (CCMC) and NOAA Space Weather Prediction Center. Additionally, he has presented his research results at several conferences (Fall AGU conferences, SHINE workshops, Space Weather Workshops, etc.). His paper in *Space Weather Journal* on ENLIL cone model performance study was highlighted as the Editor's choice article in 2009. As a first author and a co-author, he has published four papers on his research. Taktakishvili mentored several undergraduate students as well as graduate student T. Falkenberg from Denmark, who is now finishing her Ph.D. at UC Berkeley.

Task 915-50-193: **VAPoR (Volatile Analysis of Polar Regolith) and the Development of a Laser Desorption Mass Spectrometer**

GEST Investigator: Inge L. ten Kate

Collaborators: Daniel Glavin (GSFC 699); William Brickerhoff (GSFC 699), *Paul Mahaffy (Sponsor, GSFC 699)*

Task Description

Ten Kate's research is two-fold. VAPoR (Volatile Analysis of Polar Regolith) has been selected as one of the suitcase-sized instruments in the framework of the Lunar Sortie Science Opportunities. VAPoR is a pyrolysis mass spectrometer for evolved gas analysis designed for both robotic and human missions, to analyze volatile species in the lunar regolith using a pyrolysis oven and a miniaturized time-of-flight mass spectrometer. Additionally, a laser desorption mass spectrometry instrument (LDMS) is currently under development at GSFC, which will be used to analyze rock samples, consisting of drill fines for their chemical and mineralogical composition. The fines are obtained using the precision subsampling system (PSS), also under development, which uses a drill similar to a dentist's drill to precisely drill samples in the order of several milligrams from different layers in rock cores and samples, in order to distinguish between the different mineral phases in the rock. Furthermore, the PSS will consist of a sample transportation system that is currently being designed.

Highlights

The field version of VAPoR built in 2009 has been successfully deployed during the Arctic Mars Analog Svalbard Expedition. Experiments have been performed to investigate the effect of perchlorate on the pyrolysis of organics; the research findings from these experiments are being compiled into a manuscript. A ROSES-MMAMA proposal has been submitted, with ten Kate as science PI, and awarded for further field testing. Also, two manuscripts concerning the instrument have been published.

With regards to the use of the LDMS, clay minerals have been discovered on the Martian surface, and on Earth these minerals have been suggested to be deposits of organic compounds. The project that began last year is continuing as part of the instrument calibration efforts.

Task 673-87-302: **Characterizing the Composition of Large Mid-latitude Topside-ionospheric/plasmapheric Gradients**

GEST Investigator: Yongli Wang

Collaborators: Carola Purser and *Robert Benson (Sponsor, GSFC 673)*

Task Description

Knowledge of mid-latitude topside ionospheric structures is needed to mitigate the ionospheric impacts on advanced technological systems, such as GPS positioning. The goal of this NASA LWS project is to characterize the latitude and altitude dependence of large mid-latitude ionospheric electron and ion density gradients associated with outer-plasmaspheric structures. This task aims to help determine ionospheric electron and ion profiles using Jackson inversion programs and ionograms from Alouette 1-2 and ISIS 1-2 satellites for case and statistical studies of ionospheric electron and ion variations for different conditions.

Highlights

Wang worked with the team to solve Alouette 1-2 and ISIS 1-2 ionogram data formatting problems. He also provided technical support with the use of Jackson's program to make it handle some complex ionograms used for the project. Extensive analysis of the program has also been conducted. Limitations and critical improvements needed have been identified which have been used for a new generation inversion technique development. He also helped high school summer student William Huang with his summer project using Jackson's program to study the variation of high-latitude electron profiles.

Task 674-106-360: **Characteristics of Flux Transfer Events**

GEST Investigator: Yongli Wang

Collaborators: Masha Kuznetsova (GSFC 674) and *David Sibeck (Sponsor, GSFC 674)*

Task Description

Flux transfer events (FTEs) are an important process for solar wind-magnetosphere interaction. They transfer mass, momentum, and energy from the solar wind to the magnetosphere and affect global magnetosphere dynamics and space weather crucial to space-based systems. The objective of this NASA Geospace project is to understand the characteristics of FTEs at the Earth’s dayside, flank, and high-latitude magnetopause during different solar wind conditions. The focus of this task is to build a large-scale multiple spacecraft FTE observation database and study the statistical properties of such structures and their dependence on various conditions.

Highlights

Wang has built an extensive multiple spacecraft observation database for this study. New software for a large-scale survey of the vast amount of magnetopause observations has been finished, and currently he is working on building the largest FTE database in the field. Machine-learning techniques that will be used

to analyze the statistical properties of the FTE database have also been developed and tested. Wang has also helped the team with analytical and numerical FTE studies for its occurrence, motion, and orientation under various conditions.

Task 673-112-401: **Establishing Links Between Solar Wind and Topside-Ionospheric Parameters**

GEST Investigator: Yongli Wang

Collaborators: Vladimir Truhlik and *Robert Benson (Sponsor, GSFC 673)*

Task Description

Topside ionosphere environment is critical for many practical applications, including navigation and communication. The science question addressed by this NASA Geospace project is whether solar-wind drivers directly modify the high-latitude topside ionosphere, and, if so, what is the quantitative linkage between them? The goal of this task is to obtain the topside density and temperature profiles, and to check the validity of different assumptions under different conditions. A model would then be built to systematically link the profiles and various drivers to study the behavior of polar-cap and auroral topside ionospheric parameters to diurnal, seasonal, annual and solar-cycle variations.

Highlights

Wang has led the development of a new ionogram inversion technique which applies much better magnetic field models, can handle much more complex observations, and has much higher fitting accuracy than the old inversion program used by his group. Various testing has been performed and the significant advantage of this new technique has been clearly demonstrated. He also participated in fixing problems in data formatting and organization of observations from four satellites: Alouette 1-2 and ISIS 1-2. He also has participated in various studies related to high-latitude ionosphere variation during different solar wind and geomagnetic conditions. The results of these studies have been and will be presented in many meetings (including 2009 and 2010 Fall AGU meetings, IES2011 meeting, and 2011 URSI meeting), and have been written up for publications. .

Task 674-121-423: **Numerical Modeling and Satellite/Rocket Observations of Ionospheric Electric Fields and Irregularities**

GEST Investigator: Tatsuhiro Yokoyama

Collaborator: *Robert Pfaff (Sponsor, GSFC 674)*

Task Description

This research involves a detailed study and computer modeling of the electric fields, currents, and motions of the Earth's ionospheric plasma. It utilizes state-of-the-art modeling of the E- and F-region dynamo at Earth's low- and mid-latitude ionosphere. It includes an analysis of Goddard's electric field and magnetic field data gathered on the C/NOFS satellite, currently in orbit, as well as Goddard's electric and magnetic field data gathered from sounding rocket payloads. It focuses on large-scale dynamo processes, as well as the generation of plasma instabilities and irregularities in the low- and mid-latitude ionosphere.

Highlights

Yokoyama has developed his own numerical model that can simulate electrodynamics and generation of ionospheric irregularities in the mid-latitude ionosphere. The model has successfully reproduced nighttime wave structures, in both the ionospheric E and F regions, by taking the coupling process between the E and F regions into consideration. He has also studied post-midnight irregularities in the low-latitude ionospheric F region as observed by the C/NOFS satellite and compared with the ground-based instruments, such as a powerful VHF radar and GPS receivers. The results clearly show that the irregularities during the solar minimum are controlled by a mid-latitude-type plasma instability mechanism. He is collaborating on a sounding rocket experiment, scheduled for June 2011, to measure neutral wind, electric and magnetic fields, and plasma density, all of which are important parameters when studying an ionospheric dynamo current system.

Global Energy and Water Cycle Experiment (GEWEX) Project

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: Petrus (Peter) J. van Oevelen, Robert (Bob) Schiffer, Richard (Rick) Lawford

Collaborators: Paul Try (Science and Technology Corporation); Members of the GEWEX Scientific Steering Group; Chairs and Members of GEWEX Panels and Projects

Task Description

The Global Energy and Water Cycle Experiment (GEWEX) of the World Climate Research Programme (WCRP) unites 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 related to climate and water resources around the world. More than 1500 scientists from over 45 countries participate in 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 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.

The International GEWEX Project Office (IGPO) is responsible for coordinating the activities of the GEWEX and its interactions with WCRP, and other international and national environmental programs, as well as space agencies and other research and operational groups. Under the guidance of Peter van Oevelen, IGPO provides programmatic guidance and directs the coordination of GEWEX research activities, including planning future activities and meetings, coordinating implementation, assisting in synthesizing scientific results, and establishing processes for making the results useful for different scientific communities. The information and synthesis roles are facilitated by the GEWEX web site (www.gewex.org), the organization of international scientific meetings and conferences, teleconference calls, and the preparation of overview and review articles for different publications and conference presentations. The promotion of the program is done through the GEWEX newsletter and participation in committees involved in the development of observational systems.

Highlights

Van Oevelen applied his expertise to promote GEWEX research aimed at a better understanding of regional and global water resource issues and to the development of better Earth observation systems (especially space-based systems) that could support GEWEX science. Some of the highlights of GEWEX results that IGPO facilitated are detailed in the following paragraphs.

GEWEX has shown the usefulness and critical value of satellite data in addressing vital Intergovernmental Panel on Climate Change (IPCC) questions. GEWEX was initially created to explore the use of Earth observation data for climate research, and many current and past satellite missions have drawn upon this community's expertise; in particular, the development of global observational data sets of the water and energy cycle variables has been a great success. These various data sets are now being merged into a comprehensive and consistent global data set. The International Satellite Cloud Climatology Project (ISCCP) data showed, for the first time, the global impact and view of the indirect aerosol effect on clouds. Also, the use of the Global Precipitation Climatology Project (GPCP) and Global Water Vapor Project (GVaP) data sets addressed the atmospheric residence time of water vapor and key

IPCC questions regarding the acceleration of the global hydrologic cycle. GEWEX has been able to show the linkage between local process, global model predictions, and the downscaling to the local scale necessary to determine the impacts on local water resources and society. With the development of regional hydro-climate projects and the network of reference sites, including the many different climate research activities, a unique and comprehensive reference data set has been assembled (Coordinated Enhanced Observation Period) of observations (both *in situ* and from air- and space-borne sensors) and global climate and hydrological model output data of an extensive list of climatology variables.

Additionally, GEWEX has helped to establish reference networks, such as the Baseline Surface Radiation Network and the International Soil Moisture Network, that assist the science community in standardizing data products, as well as calibrating and validating their data (*e.g.*, from Earth observing sensors). Furthermore, GEWEX has had a strong focus on improving various model components and model parameterizations; in particular, the activities with respect to cloud modeling, atmospheric boundary layer modeling and land-atmosphere modeling have had a tremendous boost by the involvement and support of GEWEX through field experiments, knowledge and data exchange as well as providing a platform for discussion and guidance.

APPENDICES

This page intentionally left blank

Peer-Reviewed Publications

Abshire, J. B., H. Riris, G. Allan, **C. Weaver**, **J. Mao**, X. Sun, W. Hasselbrack, and S. Biraud (2010), Pulsed Airborne Lidar Measurements of Atmospheric CO_2 Column Absorption, *Tellus B*, **62**, 759–769, doi: 10.1111/j.1600-0889.2010.00502.x.

Adimi, F.A., R. P. **Soebiyanto**, N. Safi, and R. K. Kiang (2010), Toward malaria risk prediction in Afghanistan using remote sensing, *Malaria Journal*, **9**(1), 125.

Alexeev, I. I., E.S. Belenkaya, J. A. Slavin, H. Korth, B.J. Anderson, D.N. Baker, S.A. **Boardsen**, C.L. Johnson, M.E. Purucker, M. **Sarantos**, and S.C. Solomon (2010), Mercury's magnetospheric magnetic field after the first two MESSENGER flybys, *Icarus*, **209**, 23–39, doi:10.1016/j.icarus.2010.01.024.

Alsdorf, D., **S.-C. Han,** P. Bates, and J. Melack (2010), Seasonal Water Storage on the Amazon Floodplain Measured from Satellites, *Remote Sens. Environ.*, **114**, 2448-2456, doi:10.1016/j.rse.2010.05.020.

An, S.-I., **Y.-G. Ham**, J.-S. Kug, A. Timmermann, J. Choi, and I.-S Kang (2010), The inverse effect of annual mean state and annual cycle changes on ENSO, *J. Climate.*, **23**, 1095-1110.

Anyamba, A., K. J. Linthicum, J. Small, S. C. Britch, E. Pak, S. de La Rocque, P. Formenty, A. W. Hightower, R. F. Breiman, J.P. Chretien, C. J. Tucker, D. Schnabel, R. Sang, K. Haagsma, M. Latham, H. B. Lewandowski, S. O. Magdi, M. A. Mohamed, P. M. Nguku, J.M. Reynes, and R. Swanepoel (2010), Prediction, Assessment of the Rift Valley Fever Activity in East and Southern Africa 2006-2008 and Possible Vector Control Strategies, *Am J Trop Med Hyg*, **83**, 43-51, http://www.ajtmh.org/cgi/content/abstract/83/2_Suppl/43?etoc.

Ashour-Abdalla, M., M. El-Alaoui, M. Zhou, D. Shriver, R. Richard, R. Walker, M. G. Kivelson, M. L. Goldstein, and **K.-J. Hwang** (2010), Observations and Simulations of Non-local Acceleration of Electrons in Magnetotail Magnetic Reconnection Events, *Nature Physics*, doi:10.1038/nphys1903.

Atanassova, M., T. Saha, and W. Zhang (2010), Modeling of Deformed Segmented Mirrors in Grazing Incidence Telescopes, *Optical Fabrication and Testing*, OSA Technical Digest (CD) (Optical Society of America), paper OWF3P.

Atanassova, M., W. Zhang, and T. Saha (2010), Compensation of fabrication errors in segmented X-ray optics, *Proc. SPIE 7802*, 780204.

Avery, M., C. Twohy, D. McCabe, J. Joiner, K. Severance, E. Atlas, D. Blake, T. P. Bui, J. Crounse, J. Dibb, G. Diskin, P. Lawson, M. McGill, D. Rogers, G. Sachse, E. Scheuer, A. M. Thompson, C. Trepte, P. Wennberg, and J. **Ziemke** (2010), Convective distribution of tropospheric ozone and tracers in the Central American ITCZ region: Evidence from observations during TC4, *J. Geophys. Res.*, **115**, doi:10.1029/2009JD013450.

Barahona, D., and A. Nenes (2010), Sensitivity of the global distribution of cirrus ice crystal number concentration to heterogeneous freezing, *J. Geophys. Res*. (115), D23213.

Barahona, D., R. West, P. Stier, S. Rommakaniemi, H. Kokkola, and A. Nenes (2010), Comprenhensively Accounting for Inertial Kinetic Limitations in Cloud Activation Parameterizations, *Atmos. Chem. Phys.*, **10**, 2467-2473.

Becker-Reshef, I., C. Justice, M. Sullivan, E. Vermote, C. Tucker, A. **Anyamba,** J. Small, E. Pak, E. Masuoka, J. Schmaltz, M. Hansen, K. Pittman, C. Birkett, D. Williams, C. Reynolds, and B. Doorn (2010), Monitoring Global Croplands with Coarse Resolution Earth Observations: The Global Agriculture Monitoring (GLAM) Project, *Remote Sens.*, **2**, 1589-1609.

Benna, M., B. J. Anderson, D. N. Baker, S. A. **Boardsen**, G. Gloeckler, R. E. Gold, G. C. Ho, R. M. Killen, H. Korth, S. M. Krimigis, M. E. Purucker, R. L. McNutt, Jr., J. M. Raines, W. E. McClintock, M. **Sarantos**, J. A. Slavin, S. C. Solomon, and T. H. Zurbuchen (2010) Modeling of the Magnetosphere of Mercury at the Time of the First MESSENGER Flyby, *Icarus*, **209** (1), 3-10.

Benna, M., S. A. **Boardsen**, *et al.* (2010), Modeling of the magnetosphere of Mercury at the time of the first MESSENGER flyby, *Icarus*, **209**, 3-10, doi: 10.1016/j.icarus.2009.11.036.

Bian, H., M. Chin, S. R. Kawa, H. Yu, T. **Diehl**, and T. **Kucsera** (2010), Multi-scale carbon monoxide and aerosol correlations from satellite measurements and GOCART model: Implication for emissions and atmospheric evolution, *J. Geophys. Res.*, **115**, D07302, doi:10.1029/2009JD012781.

Bindschadler, R.A., *et al.* (2010), Ice sheet change detection by satellite image differencing, *Remote Sensing of Environment*, doi:10.1016/j.rse.2010.01.014.

Boardsen, S. A., T. Sundberg, J. A. Slavin, B. J. Anderson, H. Korth, S. C. Solomon, and L. G. Blomberg (2010), Observations of Kelvin-Helmholtz waves along the dusk-side boundary of Mercury's magnetosphere during MESSENGER's third flyby, *Geophys. Res. Lett.*, **37**, L12101, doi:10.1029/2010GL043606.

Brunt, K.M., H.A. Fricker, L. Padman, T. A. Scambos, and S. O'Neel (2010), Mapping the grounding zone of the Ross Ice Shelf, Antarctica, using ICESat laser altimetry, *Annals of Glaciology*, **51**(55), 71-79.

Brunt, K.M., M. A. King, H.A. Fricker, and D. R. MacAyeal (2010), Flow of the Ross Ice Shelf, Antarctica, is modulated by the ocean tide, *Journal of Glaciology*, **56**(195), 157-161.

Buchard, V., C. Brogniez, F. Auriol, B. Bonnel (2011), Aerosol Single Scattering Albedo retrieved from ground-based measurements in the UV and visible region, *Atmos. Meas. Tech.*, **4**, 1-7.

Burger, M. H., R. M. Killen, R. Vervack, H. T. Bradley, W. E. McClintock, M. **Sarantos**, M. **Benna**, and N. Mouawad (2010), Monte Carlo Modeling of Sodium in Mercury's Exosphere During The First Two MESSENGER Flybys, *Icarus*, **209** (1), 63-74.

Burger, M.H., R. Wagner, R. Jaumann, and T. A. Cassidy (2010), Effects of the External Environment on Icy Satellites, *Space Science Reviews*, **153**, 349-374.

Butchart, N., I. Cionni, V. Eyring, T. G. Shepherd, D. W. Waugh, H. Akiyoshi, J. Austin, C. Bruhl, M. P. Chipperfield, E. Cordero, M. Dameris, R. Deckert, S. Dhomse, S. M. Frith, R. R. Garcia, A. Gettelman, M. A. Giorgetta, D. E. Kinnison, **F. Li,** E. Mancini, C. McLandress, S. Pawson, G. Pitari, D. A. Plummer, E. Rozanov, F. Sassi, J. F. Scinocca, K. Shibata, B. Steil, and W. Tian

(2010), Chemistry-climate model simulations of 21st century stratospheric climate and circulation changes, *J. Clim.*, **23**, 5349-5374.

Cahalan, R. F., **G. Wen**, J. W. Harder, and P. Pilewskie (2010), Temperature responses to spectral solar variability on decadal time scales, *Geophys. Res. Lett*., **37**, L07705, doi:10.1029/2009GL041898.

Cheng, Y-B., E. M. Middleton, Q. **Zhang**, S. G. Ungar, and P.K.E. Campbell (2010), Applications using EO-1 hyperion AT-sensor and surface reflectance: comparisons and case studies, *IGARSS 2010*, 2248-2251.

Cheng, Y., E. Middleton, K. Huemmrich, Q. **Zhang**, P. Campbell, C. Lawrence, A. Russ, and W. Kustas (2010), Utilizing in situ Directional Hyperspectral Measurements to Validate Bio-Indicators for a Corn Crop Canopy, *Ecological Informatics*, **5**(5), 330-338.

Chiacchio, M., T. Ewen, M. Wild, M. Chin, and T. **Diehl** (2011), Decadal variability of aerosol optical depth in Europe and its relationship to the temporal shift of the North Atlantic Oscillation in the realm of dimming and brightening, *J. Geophys. Res.*, **116**, D02108, doi:10.1029/2010JD014471.

Colarco, P., A. da Silva, M. Chin, and T. **Diehl** (2010), Online simulations of global aerosol distributions in the NASA GEOS-4 model and comparisons to satellite and ground-based aerosol optical depth, *J. Geophys. Res.*, **115**, D14207, doi:10.1029/2009JD012820.

Collier, M. R., H. K. Hills, **T. J. Stubbs**, J. S Halekas, G. T. Delory, J. Espley, W. M. Farrell, J. W. Freeman, and R. R. Vondrak (2011), Lunar surface electric potential changes associated with traversals of the terrestrial bow shock, *Planet. Space Sci.*, doi:10.1016/j.pss.2010.12.010.

Coustenis, A., T. Tokano, M. H. **Burger**, T. A. Cassidy, R. M. Lopes, R. D. Lorenz, K. D. Retherford, and G. Schubert (2010), Atomospheric/Exospheric Characteristics of Icy Satellites, *Space Science Reviews*, **153**, 155-184.

Cumnock, J. A., G. Le, S. **Imber**, J. A. Slavin, Y. Zhang, and L. J. Paxton (2011), Space Technology 5 multipoint observations of transpolar arc–related field-aligned currents, *J. Geophys. Res.*, **116**, A02218, doi:10.1029/2010JA015912.

Dabney, P., D. Harding, J. Abshire, T. Huss, G. Jodor, R. Machan, J. Marzouk, K. Rush, A. Seas, C. A. **Shuman**, X. Sun, S. Valett, A. Vasilyev, A. Yu, and Y. Zheng, (2010) The Slope Imaging Multi-polarization Photon-counting Lidar: Development and performance results, *Geoscience and Remote Sensing Symposium (IGARSS), IEEE International*, pp.653-656, 25-30 July 2010, doi: 10.1109/IGARSS.2010.5650862.

De Lannoy, G.J.M., J. Ufford, A. K. Sahoo, P. R. Houser, and P. Dirmeyer (2011), Observed and simulated water and energy budget components at SCAN sites in the Lower Mississippi Basin, *Hydrological Processes*, **25**(4), 634-649, DOI:10.1002/hyp.7855.

De Lannoy, G.J.M., R. H. Reichle, P. R. Houser, K. Arsenault, N.E.C. Verhoest, and V.R.N. Pauwels (2010), Satellite-scale snow water equivalent assimilation into a high-resolution land surface model, *Journal of Hydrometeorology*, **11**(2), 352-369, doi:10.1175/2009JHM1192.1.

Domingue, D. L., F. Vilas, G.M. Holsclaw, J. Warell, N. R. Izenberg, S. L. Murchie, B. W. Denevi, D. T. Blewett, W. E. McClintock, B. J. Anderson, and M. **Sarantos** (2010), Whole-disk spectrophotometric properties of Mercury: Synthesis of MESSENGER and ground-based observations, *Icarus*, **209**, 101-124.

Dong, X., B. Xi, A. Kennedy, Z. Feng, J. Entin, P. Houser, **B. Schiffer**, W. Olson, T. L'Ecuyer, T. Liu, K-L. Hsu, B. Lin, Y. Deng, and T. Jiang (2011), Investigation the 2006 Drought and 2007 Flood Extreme Events at the SGP through an Integrative Analysis of Observationsm, *J. Geophys. Res.*, **116**, doi:10.1029/2010JD014776.

Duncan, B. D., Y. Yoshida, J. R. Olson, S. Sillman, R. V. Martin, L. Lamsal, Y. Hu, K. E. Pickering, C. **Retscher**, D. J. Allen, and J. H. Crawford (2010), Application of OMI observations to a space-based indicator of NOx and VOC controls on surface ozone formation, *Atmospheric Environment*, **44**, 2213–2223, doi:10.1016/j.atmosenv.2010.03.010.

Eck, T. F., B. N. Holben, A. Sinyuk, R. T. Pinker, P. Goloub, H. Chen, B. Chatenet, Z. Li, R. P. Singh, S. N. Tripathi, J. S. Reid, D. M. Giles, O. Dubovik, N.T. O'Neill, and A. Smirnov (2010), Climatological aspects of the optical properties of fine/coarse mode aerosol mixtures, *J. Geophys. Res.*, **115**, D19205, doi:10.1029/2010JD014002.

Faden, J., R. S. Weigel, J. **Merka**, and R. H. W. Friedel (2010), Autoplot: A Browser for Scientific Data on the Web, *Earth Sci Inform*, **3** (1-2), 41–49, doi: 10.1007/s12145-010-0049-0.

Farrell, W. M., **T. J. Stubbs**, J. S. Halekas, R. M. Killen, G. T. Delory, M. R. Collier, and R. R. Vondrak (2010), Anticipated electrical environment within permanently shadowed lunar craters, *J. Geophys. Res.*, **115**, E03004, doi:10.1029/2009JE003464.

Fekete, B.M., R. B. Lammers, A. MacDonald, L. Bowling, and R. **Lawford** (2010), Global Climate: River Discharge [in "State of the Climate in 2009"], *Bull. Amer. Meteor. Soc.*, **91** (7), S35.

Fujiwara, M., and H. B. **Selkirk**, *et al.* (2010), Seasonal to decadal variations of water vapor in the tropical lower stratosphere observed with balloon-borne cryogenic frost point hygrometers, *J. Geophys. Res.*, **115,** D18304, doi:10.1029/2010JD014179.

Gassó, S., A. Stein, F. Marino, E. Castellano, R. Udisti, and J. Ceratto (2010), A combined observational and modeling approach to study modern dust transport from the Patagonia desert to East Antarctica, *Atmos. Chem. Phys. Discuss.*, **10**, 13287-13335.

Gassó, S., V. Grassian, and R. Miller (2010), Interactions between mineral dust, climate, and ocean ecosystems (Invited Paper), *Elements*, an international peer-reviewed magazine of mineralogy, geology and petrology, Impact factor: 3.1, (http://www.elementsmagazine.org/), Theme Topic: Atmospheric Particles, ed. Reto Gieré, Albert-Ludwigs-Universität, Freiburg, Germany, August 2010, **6**(4), 247-252.

Gatebe, C. K., O. Dubovik, M. D. King, and A. Sinyuk (2010), Simultaneous retrieval of aerosol and surface optical properties from combined airborne- and ground-based direct and diffuse radiometric measurements, *Atmos. Chem. Phys.*, **10**, 2777–2794.

Gatebe, C. K., R. Poudyal, E. Wilcox, and J. Wang (2010), Effects of ship wakes on ocean brightness and radiative forcing over ocean, *Atmos. Chem. Phys. Discuss.*, **10**, 21683–21696.

Gautam, R., N. C. Hsu, and K.-M. Lau (2010), Premonsoon aerosol characterization and radiative effects over the Indo-Gangetic Plains: Implications for regional climate warming, *J. Geophys. Res.*, **115**, D17208, doi:10.1029/2010JD013819.

Getty, S. A., I. L. **ten Kate**, S.H. Feng, W. B. Brinckerhoff, E. H. Cardiff, V. E. Holmes, T. T. King, M. J. Li, E. Mumm, P. R. Mahaffy, and D. P. Glavin (2010), Development of the VAPoR

Instrument: a Pyrolysis-Time-of-Flight Mass Spectrometer, *International Journal of Mass Spectrometry*, **295**, 124-132.

Glenar, D. A., **T. J. Stubbs**, J. E. McCoy, and R. R. Vondrak (2011), A reanalysis of the Apollo light scattering observations, and implications for lunar exospheric dust, *Planet. Space Sci.*, doi:10.1016/j.pss.2010.12.003.

Graham, A., W. Hasselbrack, H. Riris, J. B. Abshire, C. Weaver, **J. Mao**, X. Sun and A. Andrews (2010), Remote Sensing Atmospheric CO_2 Column Abundance Using an Airborne Pulsed Laser Sounder at 13 km Altitude, *2010 IEEE International Geoscience and Remote Sensing Symposium*, ISBN 978-1-4244-9564-1, 2595-2598.

Ham, Y.-G., and I.-S. Kang (2010), Growing-Error Correction of Ensemble Kalman Filter using Empirical Singular Vector, *Q. J. R. Meteorol. Soc.*, DOI:10.1002/qj.711.

Han, M., S. A. Braun, W. S. Olson, P. O. G. Persson, and J-W Bao (2010), Application of TRMM PR and TMI measurements to assess cloud microphysical schemes in the MM5 model for a winter storm, *J. Appl. Meteor. and Climatology*, **49,** 1129-1148.

Han, S.-C., I.-Y. Yeo, D. Alsdorf, P. Bates, J.-P. Boy, H. Kim, T. Oki, and M. Rodell (2010), Movement of Amazon surface water from time-variable satellite gravity measurements and implications for water cycle parameters in land surface models, *Geochemistry Geophysics Geosystems*, **11**, Q09007, doi:10.1029/2010GC003214.

Han, S.-C., J. Sauber, and S. Luthcke (2010), Regional gravity decrease after the 2010 Maule (Chile) earthquake indicates large-scale mass redistribution, *Geophys. Res. Lett.*, **37**, L23307, doi:10.1029/2010GL045449.

Han, S.-C., R. D. Ray, and S. Luthcke (2010), One centimeter-level observations of global diurnal ocean tides from monthly mean time-variable gravity fields, *Journal of Geodesy*, **84**, 715-729, doi: 10.1007/s00190-010-0405-3.

Hesse, M., S. Zenitani, M. Kuznetsova, and A. **Klimas** (2010), A simple, analytical model of collisionless magnetic reconnection in a pair plasma (vol 16, 102106, 2009), *Phys. Plasmas*, **17**(7).

Heymsfield, G. M., **L. Tian**, A. J. Heymsfield, L. Li, and S. Guimond (2010), Characteristics of deep convection from nadir-viewing high-altitude airborne Doppler radar, *J. Atmos. Sci*., **67**, 285-308.

Hilker, T., F. Hall, N. C. Coops, A. **Lyapustin**, Y. Wang, Z. Nesic, N. Grant, T. A. Black, M. A. Wulder, N. Kljun, C. Hopkinson, and L. Chaser (2010), Remote sensing of photosynthetic light-use efficiency across two forested biomes: Spatial scaling, *Rem. Sens. Environ*., **114**, 2863-2874.

Hoban, S., **M.P. Delaney** (2011) NASA's Beginning Engineering, Science and Technology (BEST) Student's – an Educator Guide for Grades 6-8.

Hoban, S., **M.P. Delaney** (2011) NASA's Beginning Engineering, Science and Technology (BEST) Student's – an Educator Guide for Grades 3-5.

Hoban, S., **M.P. Delaney** (2011) NASA's Beginning Engineering, Science and Technology (BEST) Student's – an Educator Guide for Grades K-2.

Huang, J. , C. Zhang, and J. M. Prospero (2010), African dust outbreaks: A satellite perspective of temporal and spatial variability over the tropical Atlantic Ocean, *J. Geophys. Res.*, **115**, D05202, doi:10.1029/2009JD012516.

Hurwitz, M. M., P. A. Newman, **F. Li**, L. D. Oman, O. Morgenstern, P. Braesicke, and J. A. Pyle (2010), Assessment of the breakup of the Antarctic polar vortex in two new chemistry-climate models, *J. Geophys. Res.*, **115**, D071075, doi:10.2029/2009JD012788.

Ialongo, I., **V. Buchard**, C. Brogniez, G. R. Casale, and A.M. Siani (2010), Aerosol Single Scattering Albedo retrieval in the UV range: an application to OMI satellite validation, *Atmospheric Chemistry and Physics*, **10**, 331-340.

Imber, S. M., J. A. Slavin, U. Auster, and V. Angelopoulos (2011), A THEMIS survey of flux ropes and traveling compression regions: Location of the near-Earth reconnection site during solar minimum, *J. Geophys. Res.*, **116**, A02201, doi:10.1029/2010JA016026.

Jeon, H. S., S. Cho, Y.S. Kwak, J. K. Chung, J. U. Park, D. K. Lee and M. **Kuzmicz-Cieslak** (2011), Mass density of the upper atmosphere derived from Starlette's Precise Orbit Determination with Satellite Laser Ranging, *Astrophysics and Space Science*, **332** (2), 341-351.

Jian, L. K., C. T. Russell, J. G. Luhmann, B. J. Anderson, S. A. **Boardsen**, R. J. Strangeway, M. M. Cowee, and A. Wennmacher (2010), Observations of ion cyclotron waves in the solar wind near 0.3 AU, *J. Geophys. Res.*, **115**, A12115, doi:10.1029/2010JA015737.

Johnson, M., N. Meskhidze, F. Solmon, **S. Gassó**, P. Chuang, D. Gaiero, Y. Robert, S. Wu, Y. Wang, and C. Carouge (2010), Modeling Dust and Soluble Iron Deposition to the South Atlantic Ocean, *J. Geophys. Res.*, **115**, D15202, doi:10.1029/2009JD013311.

Kahn, R. A., B. J. Gaitley, M. J. Garay, D. J. Diner, T. F. **Eck**, A. Smirnov, and B. N. Holben (2010) MISR Global Aerosol Product Assessment by Comparison with AERONET, *J. Geophys. Res.*, **115**, D23209, doi:10.1029/2010JD014601.

Kar, J., J. Fishman, J. K. Creilson, A. Richter, J. R. **Ziemke**, and S. Chandra (2010), Are there urban signatures in the tropospheric ozone column products derived from satellite measurements?, *Atmos. Chem. Phys.*, **10**, 5213-5222, doi:10.5194/acp-10-5213-2010.

Kawa, S. R., **J. Mao**, J. B. Abshire, G. J. Collatz, X. Sun, and C. J. **Weaver** (2010), Simulation studies for a space-based CO_2 lidar mission, *Tellus B*, **62**, 770–783, doi:10.1111/j.1600-0889.2010.00486.x.

Killen, R.M., A. E. Potter, R. J. Vervack, E. T. Bradley, W. E. McClintock, C. M. Anderson, and M. H. **Burger** (2010), Observations of Metallic Species in Mercury's Exosphere, *Icarus*, **209**, 75-87.

Kim, K. M., K. M. Lau, Y. C. Sud and G. K. Walker (2010), Influence of aerosol-radiative forcings on the diurnal and seasonal cycles of rainfall over West Africa and Eastern Atlantic Ocean using GCM simulations, *Clim. Dyn.*, **35** (1), pp. 115-126, Special Issue on West African Climate, doi:10.1007/s00382-010-0750-1.

King, T., J. **Merka**, T. Narock, R. Walker, and L. Bargatze (2010), A registry framework and Rosetta attributes for distributed science, *Earth Sci Inform*, **3** (1-2), 127–133, doi: 10.1007/s12145-010-0047-2.

Klimas, A., M. Hesse, S. Zenitani, and M. Kuznetsova (2010), Particle-in-Cell simulation of collisionless driven reconnection with open boundaries, *Phys. Plasmas*, **17**, 112904, doi:10.1063/1.3510480.

Klimas, A., V. Uritsky, and E. Donovan (2010), Multiscale auroral emission statistics as evidence of turbulent reconnection in Earth's midtail plasma sheet, *J. Geophys. Res.*, **115**, A06202, doi:10.1029/2009JA014995.

Kokhanovsky, A. A., J. L. Deuzé, D. J. Diner, O. Dubovik, F. Ducos, C. Emde, M. J. Garay, R. G. Grainger, A. Heckel, M. Herman, I. L. Katsev, J. Keller, R. Levy, P. R. J. North, A. S. Prikhach, V. V. Rozanov, A. M. **Sayer**, Y. Ota, D. Tanré, G. E. Thomas, and E. P. Zege (2010), The inter-comparison of major satellite aerosol retrieval algorithms using simulated intensity and polarization characteristics of reflected light, *Atmos. Meas. Tech.*, **3**, 909-932, doi:10.5194/amt-3-909-2010.

Kokhanovsky, A., V. Budak, C. Cornet, M. Duan, C. Emde, I. Katsev, D. Klyukov, S. **Korkin**, L. Labonnote, B. Mayer, Q. Min, T. Nakajima, Y. Ota, A. Prikhach, V. Rozanov, T. Yokota, and E. Zege (2010), Benchmark results in vector atmospheric radiative transfer, *J. Quant. Spectroscopy & Radiative Transfer*, **111**, 1931-1946.

Koval, A., and A. Szabo (2010), Multispacecraft observations of interplanetary shock shapes on the scales of the Earth's magnetosphere, *J. Geophys. Res.*, **115**, A12105, doi:10.1029/2010JA015373.

Krupp, N., K. K. Khurana, L. Iess, V. Lainey, T. A. Cassidy, M. H. **Burger**, C. Sotin, and F. Neubauer (2010), Environments in the outer solar system, *Space Science Reviews*, **153**, 11-59.

Kug, J.-S., K. P. Sooraj, F.-F. Jin, **Y.-G. Ham**, and D. Kim (2010), A Possible Mechanism for El Nino-like Warming in Response to the Future Greenhouse Warming. *Int. J. Climatol.*, DOI: 10.1002/joc.2163.

Kwon, J., K. Seo, D. **Kim**, and D. Lee (2010), Prediction of Indoor Air Pollution Using Meteorological Factors in the Training Rooms of Technical High School: Case Study, *J. Korean Soc. for Indoor Environ.*, **7**, 33-46.

Lamsal, L. N., R. V. Martin, A. van Donkelaar, E. A. **Celarier**, E. J. Bucsela, K. F. Boersma, R. Dirksen, C. Luo, and Y. **Wang** (2010), Indirect validation of tropospheric nitrogen dioxide retrieved from the OMI satellite instrument: Insight into the seasonal variation of nitrogen oxides at northern midlatitudes, *J. Geophys. Res.*, **115**, D05302, DOI:10.1029/2009JD013351.

Lau, K. M., M. K. Kim, **K. M. Kim**, and W. S. Lee (2010), Enhanced surface warming and accelerated snow melt in the Himalayas and Tibetan Plateau induced by absorbing aerosols, *Environ. Res. Lett.*, **5**, 025204, doi:10.1088/1748-9326/5/2/025204.

Lau, K.M., and **K. M. Kim** (2010), Fingerprinting the impacts of aerosols on long-term trends of the Indian summer monsoon regional rainfall, *Geophys. Res. Lett.*, **37**, L16705, doi:10.1029/2010GL043255.

Le Vine, D. M., E.P. Dinnat, S.D. Jacob, S. Abraham, and P. **de Matthaeis** (2011), The Impact of Antenna Pattern on Measurement of the Third Stokes Parameter from Space at L-Band, *IEEE Transactions on Geoscience and Remote Sensing*, **49** (1), 406-414.

Lee, C.K., **S.-C. Han**, and B. Steinberger (2011), Influence of variable uncertainties in seismic tomography models on constraining mantle viscosity from geoid observations, *Physics of the*

Earth and Planetary Interiors, **184**, 51-62, doi:10.1016/j.pepi.2010.10.012.

Lee, S., W. **Ni-Meister**, D. Toll, J. Nigro, A. L. Gutierrez-Magness, and T. Engman (2010), Assessing the hydrologic performance of the EPA's nonpoint source water quality assessment decision support tool using North American Land Data Assimilation System (NLDAS) products, *Journal of Hydrology*, **387** (3-4), 212-220, doi:10.1016/j.jhydrol.2010.04.009.

Lee, T. F., C. S. Nelson, P. Dills, L. P. **Riishojgaard**, A. Jones, L., S. Miller, L. E. Flynn, G. Jedlovec, W. McCarty, C. Hoffman, and G. McWilliams (2010), NPOESS: Next-Generation Operational Global Earth Observations, *Bull. Amer. Meteorol. Soc.*, **91**, 727-740.

Levy, R. C., L. A. Remer, R. G. Kleidman, S. Mattoo, C. Ichoku, R. Kahn, and T. F. **Eck** (2010), Global evaluation of the Collection 5 MODIS dark-target aerosol products over land, *Atmos. Chem. Phys.*, **10**, 10399-10420.

Lewis, J., D. DeYoung, and D. A. **Chu** (2010), A study of air quality in the southern Hampton-Norfolk-Virginia region with airborne lidar measurements and MODIS AOD retrievals, *J. Appl. Metero*, **49**, 3-19, doi: 10.1175/2009JAMC2119.1.

Lewis, J., D. DeYoung, R. Ferrare, and D. A. **Chu**, (2010), Comparison of summer and winter California Central Valley aerosol distributions from lidar and MODIS measurements, *Atmos. Environ.***, 44** (335), 4510-4520, doi:10.1016/j.atmosenv.2010.07.006.

Li, F., P. A. Newman, and R. S. Stolarski (2010), Relationships between the Brewer-Dobson circulation and the southern annular mode during austral summer in coupled chemistry-climate model simulations, *J. Geophys. Res.*, **115**, D15106, doi:10.1029/2009JD012876.

Li, F., R. S. Stolarski, S. Pawson, P. A. Newman, and D. W. Waugh (2010), Narrowing of the upwelling branch of the Brewer-Dobson circulation and Hadley cell in chemistry-climate model simulations of the 21st century, *Geophy. Res. Lett.*, **37**, L13702, doi:10.1029/2010GL043718.

Li, X., W.-K. Tao, T. Matsui, C. Liu, and H. Masunaga (2010), Improving a spectral bin microphysical scheme using long-term TRMM satellite observations, *Quart. J. Roy. Meteoro. Soc.*, **136**, 382-399.

Liang, Q., R. S. Stolarski, S. R. Kawa, J. E. Nielsen, J. M. Rodriguez, D. R. Blake, and E. L. Atlas (2010), Finding the missing stratospheric Bry: A global modeling study of $CHBr_3$ and CH_2Br_2, *Atmos. Chem. Phys.*, **10**, 2269-2286.

Liao, L., and R. Meneghini (2011), A Study on the feasibility of dual-wavelength radar for identification of hydrometeor hases, *J. Appl. Meteorol. Climatol.*, **50**, 449-456.

Lim, Y.-K., L. Stefanova, S. Chan, S. D. Schubert, and J. J. O'Brien, 2010: High-resolution subtropical summer precipitation derived from dynamical downscaling of the NCEP/DOE reanalysis: How much small-scale information is added by a regional model? *Clim. Dyn.*, doi:10.1007/s00382-010-0891-2.

Lim, Y.-K., S. Cocke, D. W. Shin, J. T. Schoof , T. E. LaRow., and J. J. O'Brien (2010), Downscaling large-scale NCEP CFS to resolve the fine-scale seasonal precipitation and extremes for the crop growing seasons over the southeastern U.S., *Clim. Dyn*., doi:10.1007/s00382-009-0671-z.

Lin, J.-T., D. J. Wuebbles, H.-C. Huang, **Z. Tao**, M. Caughey, X.-Z. Liang, J.-H. Zhu, and T. Holloway (2010), Potential effects of climate and emissions changes on surface ozone in the Chicago area, *Journal of Great Lakes Research*, **36**, 59-64, doi:10.1016/j.jglr.2009.09.004.

Lin, R. L., X. X. Zhang, S. Q. Liu, Y.**Wang**, and J. C. Gong (2010), Comparison of a new model with previous models for the low-latitude magnetopause size and shape, *Chinese Sci. Bull.*, **55**, doi:10.1007/s11434-009-0533-4.

Lin, R. L., X. X. Zhang, S. Q. Liu, Y.**Wang**, and J. C. Gong (2010), Statistical analysis of the high-latitude magnetopause location and shape, *Chinese J. Geophys.*, **53**, DOI:10.3969/j.issn.0001-5733.2010.01.001.

Lin, R. L., X. X. Zhang, S. Q. Liu, Y.**Wang**, and J. C. Gong (2010), A Three-Dimensional Asymmetric Magnetopause Model, *J. Geophys. Res.*, **115**, A04207, doi:10.1029/2009JA014235.

Lipatov, A.S., J. F. Cooper, W. R. Paterson, E. C. Sittler, R. E. Hartle, and D. G. Simpson (2010), Jovian plasma torus interaction with Europa: 3D Hybrid kinetic simulation - First results, *Planet. Space Sci.*, **58**, 1681-1691.

Loosvelt, L., V. R. N. Pauwels, W. M. Cornelis, W.M., G. J. M. **De Lannoy**, and N. E. C. Verhoest (2011), Impact of soil hydraulic parameter uncertainty on soil moisture modelling, *Water Resources Research*, **47**(3), W03505, doi:10.1029/2010WR009204.

Lu, Z., D. G. Streets, Q. Zhang, S. Wang, G. R. Carmichael, Y. F. Cheng, C. Wei, M. Chin, T. **Diehl**, and Q. **Tan** (2010), Sulfur dioxide emissions in China and sulfur trends in East Asia since 2000, *Atmos. Chem. Phys.*, **10**, 6311-6331.

Lyapustin, A., C. K. **Gatebe**, R. Kahn, R. Brandt, J. Redemann, P. Russell, M. D. King, C. A. Pedersen, S. Gerland, R. Poudyal, A. Marshak, Y. Wang, C. Schaaf, D. Hall, and A. Kokhanovsky (2010), Analysis of Snow Bidirectional Reflectance from ARCTAS Spring 2008 Campaign, *Atmos. Chem. Phys.*, **10**, 4359-4375.

Lyapustin, A., J. Martonchik, Y. Wang, I. Laszlo, and S. **Korkin** (2011), Multi-Angle Implementation of Atmospheric Correction (MAIAC): Part 1. Radiative Transfer Basis and Look-Up Tables, *J. Geophys. Res.*, **116**, D03210, doi:10.1029/2010JD014985.

Lyapustin, A., Y. Wang, I. Laszlo, R. Kahn, S. **Korkin**, L. Remer, R. Levy, and J. S. Reid (2011), Multi-Angle Implementation of Atmospheric Correction (MAIAC): Part 2, Aerosol Algorithm, *J. Geophys. Res.*, **116**, D03211, doi:10.1029/2010JD014986.

Manning, H. M., I. L. **ten Kate**, S. Battel, and P. M. Mahaffy (2010), Electric discharge in the Martian atmosphere, Paschen curves and implications for future missions, *Advances in Space Research* **46**(10), 1334-1340.

Mao, J., S. R. Kawa, J. B. Abshire and H. Riris (2010), Sensitivity Studies for Space-based Laser Measurements of Atmospheric CO_2 Concentration Towards Future NASA Mission ASCENDS, *2010 IEEE International Geoscience and Remote Sensing Symposium*, ISBN 978-1-4244-9566-5, 643-645.

Markus, T., R. Massom, T. Worby, V. Lytle, **N. Kurtz**, and T. Maksym (2011), Freeboard, snow depth, and sea ice roughness in East Antarctica from in-situ and multiple satellite data, *Ann. Glaciol.*, **52**(57).

Maruskin, Andrea**, M.P. Delaney**, and T. Clopper (2010), Hubble IMAX 3D Educator Resource Guide, IMAX and Discovery Education, Silver Spring, MD.

Masuoka, P., T. A. Klein, H.-C. Kim, D. M. Claborn, N. Achee, R. Andre, J. Chamberlin, J. Small, A. **Anyamba**, D. K. Lee, S. H. Yi, M. Sardelis, Y-R. Ju, and J. Grieco (2010), Modeling the distribution of Culex tritaeniorhynchus to predict Japanese encephalitis distribution in the Republic of Korea**.** *Geospatial Health*, **5**(1), 45-57.

Matgen, P., M. Montanari, R. Hostache, L. Pfister, L. Hoffmann, D. Plaza, V. R. N. Pauwels, G. J. M. **De Lannoy**, R. De Keyser, and H. H. G. Savenije (2010), Towards the sequential assimilation of SAR-derived water stages into hydraulic models using the Particle Filter: proof of concept, *Hydrology and Earth System Sciences*, **14**(9), 1773-1785.

Mazarico, E., F. G. Lemoine, **S.-C. Han,** and D. E. Smith (2010), GLGM-3, A degree 150 lunar gravity model from the historical tracking data of NASA moon orbiters, *J. Geophys. Res.*, **115**, E05001, doi:10.1029/2009JE003472.

Meyer, K., and S. Platnick (2010), Utilizing the MODIS 1.38 μm channel for cirrus cloud optical thickness retrievals: Algorithm and retrieval uncertainties, *J. Geophys. Res.*, **115**, D24209, doi:10.1029/2010JD014872.

Middleton, E.M., P.K.E. Campbell, S. G. Ungar, L. Ong, Q. **Zhang**, K. F. Huemmrich, D. J. Mandl, and S. Frye (2010), Using EO-1 Hyperion images to prototype environmental products for HyspIRI, *IGARSS 2010*, 4256-4259.

Mouawad, N., M. H. **Burger**, R. M. Killen, A. E. Potter, R. J. Vervack, E. T. Bradley, M. Benna, and S. Naidu (2011), Constraints on Mercury's Na exosphere: Combined MESSENGER and ground-based data, *Icarus*, **211**, 21-36.

Moura, R. G., D.L. **Herdies**, D. Mendes, and M.C.D. Mendes (2010), Evaluation of the Eta Model using the CPTEC and NCEP Analysis, *Rev. Brassileira de Meteorologia*, **25**, pp. 46-53 (in Portugese).

Nair, U.S., R. McNider, F. **Patadia,** S.A. Christopher, and K. Fuller (2011), Sensitivity of nocturnal boundary layer temperature to tropospheric aerosol surface radiative forcing under clear-sky conditions, *J. Geophys. Res.*, **116**, D02205, doi:10.1029/2010JD014068.

Nam, J., Y. Wang, C. Luo, and D. A. **Chu** (2010), Transpacific transport of Asian dust and pollution: accumulation of biomass burning CO in the subtropics and dipole structure of transport, *ACP*, **10** (7), 3297-3308.

Narock, T., V. Yoon, J. **Merka**, and A. Szabo (2010), The Semantic Web in Federated Information Systems: A Space Physics Case Study, *Journal of Information Technology Theory and Application (JITTA)*, **11**, Issue 3, Article 3, 25–41.

Nelly, M., M. H. Burger, R. M. Killen, A. E. Potter, R. J. Vervack, E. T. Bradley, M. **Benna**, and S. Naidu (2010), Constraints on Mercury's Na exosphere: Combined MESSENGER and ground-based data, *Icarus*, **209** (1), 21-36.

Nemecek, Z., J. Safrankova, A. **Koval**, J. **Merka**, and L. Prech (2011), MHD Analysis of Propagation of an Interplanetary Shock Across Magnetospheric Boundaries, *Journal of Atmospheric and Solar-Terrestrial Physics (JASTP)*, **73**, 20–29, doi: 10.1016/j.jastp.2010.05.017.

Nemecek, Z., J. Safrankova, L. Prech, A. **Koval**, and J. **Merka** (2010), Propagation of Interplanetary Shocks Across the Bow Shock, *AIP Conf. Proc.*, **1216**, doi:10.1063/1.3395906.

Ni-Meister, W. and H. Gao (2011), Assessing the impacts of vegetation heterogeneity on energy fluxes and snowmelt in boreal forests, *Journal of Plant Ecology*, **4**, 37-47.

Ni-Meister, W., S. Lee, A. H. Strahler, C. E. Woodcock, C. Schaaf, J.Ranson, G. Sun, and J. B. Blair (2010), Assessing general relationships between above-ground biomass and vegetation structure parameters for improved carbon estimate from vegetation lidar, *J. Geophys. Res.*, **115**, G00E11, doi:10.1029/2009JG000936.

Ni-Meister, W., W. Yang, and N. Kiang (2010), A clumped-foliage canopy radiative transfer model for a global dynamic terrestrial ecosystem model I: Theory, *Agriculture and Forest Meteorology*, **150**(7-8), 881-894, doi:10.1016/j.agrformet.2010.02.009.

Nigro, J., D. Toll, E. Partington, W. **Ni-Meister**, S. Lee, A.Gutierrez-Magnesse, T. Engman, and K. Arsenault (2010), NASA-modified precipitation products to improve EPA nonpoint source water quality modeling for the Chesapeake Bay, *Journal of Environmental Quality*, **39** (4), 1388-1401, doi:10.2134/jeq2009.0161.

North, P.R.J., J.A.B. **Rosette**, J.C. Suárez, and S.O. Los (2010), A Monte Carlo radiative transfer model of satellite waveform LiDAR, *International Journal of Remote Sensing*, **31**(5), 1343-1358.

O'Byrne, G., R. V. Martin, A. van Donkelaar, J. Joiner, and E. A. **Celarier** (2010), Surface reflectivity from the Ozone Monitoring Instrument using the Moderate Resolution Imaging Spectroradiometer to eliminate clouds: Effects of snow on ultraviolet and visible trace gas retrievals, *J. Geophys. Res.*, **115**: Art. No. D17305, DOI: 10.1029/2009JD013079.

Olsen, M. A., A. R. Douglass, M. R. Schoeberl, J. M. Rodriguez, and Y. Yoshida (2010), Interannual variability of ozone in the winter lower stratosphere and the relationship to lamina and irreversible transport, *J. Geophys. Res.*, **115**, D15305, doi:10.1029/2009JD013004.

Oman, L. D., D. A., Plummer, D. W. Waugh, and J. R. **Ziemke**, et al. (2010), Multi-model assessment of the factors driving stratospheric ozone evolution over the 21st century, *J. Geophys. Res.*, **115**, D24306, doi:10.1029/2010JD014362.

Oreopoulos, L. and P.M. **Norris** (2011), An analysis of cloud overlap at a midlatitude atmospheric observation facility, *Atmos. Chem. Phys. Discuss.*, **11**, 597-625, doi:10.5194/acpd-11-597-2011.

Ott, L., B. Duncan, S. Pawson, P. Colarco, M. Chin, C. **Randles**, T. **Diehl**, and E. Nielsen (2010), The influence of the 2006 Indonesian biomass burning aerosols on tropical dynamics studied with the GEOS-5 AGCM, *J. Geophys. Res.*, **115**, D14121, doi:10.1029/2009JD013181.

Pan, W., L. Wu, and C.-L. **Shie** (2011), Influence of Saharan Air Layer on Atlantic Tropical Cyclone Formation during 1-12 September 2003, *Advances in Atmospheric Sciences*, **28** (1), 16-32.

Peeters, Z., D. Vos, I.L. **ten Kate**, F. Selch, C. A. van Sluis**,** D. Yu Sorokin, G. Muyzer, H. Stan-Lotter, M.C.M. van Loosdrecht, and P. Ehrenfreund (2010), Survival and death of the haloarchaeon *Natronorumbrum* strain HG-1 in a simulated martian environment, *Advances in Space Research*, **46**(9), 1149-1155.

Peng, J., and C. S. Ruf (2010), Covariance Statistics of Fully Polarimetric Brightness Temperature Measurements, *IEEE Geoscience and Remote Sensing Letters*, **7**(3), 460-463.

Peng, J., and C. S. Ruf (2010), The Effect of Clock Frequency Stability on Digital Microwave Radiometer Performance, *Radio Science*, **45**, RS4005, doi:10.1029/2009RS004272.

Pfister, L., H. B. **Selkirk**, D. O. Starr, K. Rosenlof, and P. A. Newman (2010), A meteorological overview of the TC4 mission, *J. Geophys. Res.*, **115,** D00J12, doi:10.1029/2009JD013316.

Proud, S.R., M.O. Rasmussen, R. Fensholt, I. Sandholt, C. Shisanya, W. Mutero, C. Mbow, A. **Anyamba** (2010), Improving the SMAC atmospheric correction code by analysis of Meteosat Second Generation NDVI and surface reflectance data, *Remote Sensing of Environment*, **114** (8), 1687-1698, ISSN 0034-4257, DOI: 10.1016/j.rse.2010.02.020.http://www.sciencedirect.com/science/article/B6V6V-4YTSM47-1/2/a7a305fd96a0d54f67ac05d54b6428ab.

Quets, J.J., G. J. M. **De Lannoy,** and V. R N. Pauwels (2010), Comparison of spectral and time domain calibration for precipitation-discharge processes, *Hydrological Processes*, **24**, 1048-1062, doi: 10.1002/hyp.7546.

Randles, C. A. and V. Ramaswamy (2010), Direct and semi-direct impacts of absorbing biomass burning aerosol on the climate of southern Africa: A Geophysical Fluid Dynamics Laboratory GCM sensitivity study, *Atmospheric Chemistry and Physics*, **10**, 9819-9831, doi:10.5194/acp-10-9819-2010.

Ray, E. A., F. L. Moore, K. H. Rosenlof, S. M. Davis, H. Boenisch, O. Morgenstern, D. Smale, E. Rozanov, M. Hegglin, G. Pitari, E. Mancini, P. Braesicke, N. Butchart, S. Hardiman, **F. Li**, K. Shibata, and D. A. Plummer (2010), Evidence for Changes in Stratospheric Transport and Mixing Over the Past Three Decades Based on Multiple Datasets and Tropical Leaky Pipe Analysis, *J. Geophys. Res.*, **115**, D21304, doi:10.1029/2010JD014206.

Reale, O., and W. K. Lau (2010), Reply to Comment on: `Atlantic tropical cyclogenetic processes during SOP-3 NAMMA in the GEOS-5 global data assimilation and forecast system', *Journal of the Atmospheric Sciences*, **67**, 2411-2415.

Richard, D. T., D. A. Glenar; **T. J. Stubbs**, S. S. Davis, and A. Colaprete (2011), Light scattering by complex particles in the Moon's exosphere: Toward a taxonomy of models for the realistic simulation of the scattering behaviour of lunar dust, *Planet. Space Sci.*, doi:10.1016/j.pss.2011.01.003.

Richards, E., P. Masuoka, D. Brett-Major, M. Smith, T. Klein, H.C. Kim, **A. Anyamba**, and J. Grieco (2010), The relationship between mosquito abundance and rice field density in South Korea, *International Journal of Health Geographics*, **9**, 32.

Rosette, J.A., J. C. Suárez, P.R.J. North, and S. O. Los (2011), Forestry Applications for Satellite LiDAR Remote Sensing. *Photogrammetric Engineering and Remote Sensing*, **77** (3), 271-279.

Rosette, J.A.B., P. R. J. North, J. C. Suárez, and S.O. Los (2010). Uncertainty within satellite LiDAR estimation of vegetation and topography, *International Journal of Remote Sensing*, **31**(5), 1325-1342.

Rozanov, V. V., and A. **Lyapustin** (2010), Similarity of radiative transfer equation related to the phase function truncation techniques, *J. Quant. Spectrosc. Radiat. Transfer*, doi:10.1016/j.jqsrt.2010.03.018.

Saha, A., N.T. O'Neill, E. Eloranta, R.S. Stone, T.F. **Eck**, S. Zidane, D. Daou, A. Lupu, D. Lesins, M. Shiobara, and L.B.J. McArthur (2010), Pan-Arctic sunphotometry during the ARCTAS-A campaign of April 2008, *Geophys. Res. Lett.*, **37**, L05803, doi:10.1029/2009GL041375.

Salawitch, R.J., T. Canty, T. Kurosu, K. Chance, **Q. Liang**, A. da Silva, S. Pawson, J.E.Nielsen, J.M. Rodriguez, P.K. Bhartia, X. Liu, L.G. Huey, J. Liao, R.E. Stickel, D.J. Tanner, J.E. Dibb, W.R. Simpson, D. Donohoue, A. Weinheimer, F. Flocke, D. Knapp, D. Montzka, J.A. Neuman, J.B. Nowak, T.B. Ryerson, S. Oltmans, D.R. Blake, E.L. Atlas, D.E. Kinnison, S. Tilmes, L.L. Pan, F. Hendrick, M. Van Roozendael, K. Kreher, P.V. Johnston, R.S. Gao, T.P. Bui, G. Chen, R.B. Pierce, J.H. Crawford, and D.J. Jacob (2010), A New Interpretation of Total Column BrO during Arctic Spring, *Geophys. Res. Lett.*, **37**, L21805.

Sander, S. P., J. Abbatt, J. R. Barker, J. B. Burkholder, R. R. Friedl, D. M. Golden, R. E. Huie, C. E. Kolb, M. J. **Kurylo**, G. K. Moortgat, V. L. Orkin, and P. H. Wine (2010), Chemical Kinetics and Photochemical Data for Use in Atmospheric Studies, Evaluation Number 17 of the NASA Panel for Data Evaluation, JPL Publication 10-6, Jet Propulsion Laboratory, Pasadena. Available at http://jpldataeval.jpl.nasa.gov/.

Sapucci, L. F., D.L. **Herdies**, R. V. Andreoli, J.G.Z. Mattos, and J.A. Aravequia (2010), Recent advances in the predictability of moisture fields at CPTEC/INPE, Rev. *Brassileira de Meteorologia*, **25**, pp. 295-310 (in Portugese).

Sarantos, M., R. M. Killen, S. A. Sharma, and J.A. Slavin (2010), Sources of sodium in the lunar exosphere: Modeling using ground-based observations of sodium emission and spacecraft data of the plasma, *Icarus*, **205**, 364-374.

Sayer, A. M., G. E. Thomas, and R. G. Grainger (2010), A sea surface reflectance model for (A)ATSR, and application to aerosol retrievals, *Atmos. Meas. Tech.*, **3**, 813-838, doi:10.5194/amt-3-813-2010.

Sayer, A. M., G. E. Thomas, P. I. Palmer, and R. G. Grainger (2010), Some implications of sampling choices on comparisons between satellite and model aerosol optical depth fields, *Atmos. Chem. Phys.*, **10**, 10705-10716, doi:10.5194/acp-10-10705-2010.

Schmidt, K. S., P. Pilewskie, B. Mayer, M. Wendisch, B. Kindel, S. Platnick, M. D. King, G. Wind, G. T. Arnold, **L. Tian**, G. M. Heymsfield, and H. Kalesse, (2010), Apparent Absorption of Solar Spectral Irradiance in Heterogeneous Ice Clouds, *J. Geophy. Res.*, **115**, D00J22, doi:10.1029/2009JD013124.

Sciarretta, C., V. Luceri, E. C. **Pavlis**, and G. Bianco (2010), The ILRS EOP Time Series, *Artificial Satellites*, **45** (2), DOI:10.2478/v10018-010-0004-9.

Selkirk, H. B., H. Vömel, J. M. Valverde Canossa, L. Pfister, J. A. Diaz, W. Fernández, J. Amador, W. Stolz, and G. S. Peng (2010), Detailed structure of the tropical upper troposphere and lower stratosphere as revealed by balloon sonde observations of water vapor, ozone, temperature, and winds during the NASA TCSP and TC4 campaigns, *J. Geophys. Res.*, **115**, D00J19, doi:10.1029/2009JD013209.

Severinghaus, J.P., M.R. Albert, Z.R. Courville, M.A. Fahnestock, K. Kawamura, S.A. Montzka, J. Mühle1, T.A. Scambos, E. Shields, C.A. **Shuman**, M. Suwa, P. Tans, and R.F. Weiss (2010), Deep air convection in the firn at a zero-accumulation site, central Antarctica, *Earth and Planetary Science Letters*, **293**, 359-367.

Shams, S., E. Zikzok, D. Chen, and J. **Huang** (2010), Estimation and monitoring non-point source pollutant loads: an object oriented hydro information approach, *International Journal of Environment and Waste Management*, **6**, 220 - 236, doi: 10.1504/IJEWM.2010.035059.

Shi, J. J., W.-K. Tao, T. Matsui, R. Cifelli, A. Hou, S. Lang, A. Tokey, N.-Y. Wang, C. Peters-Lidard, G. Jackson, S. Rutledge, and W. Petersen (2010), WRF Simulations of the 20-22 January 2007 Snow Events over Eastern Canada: Comparison with in-situ and Satellite Observations, *J. Applied Meteor. Climatol*, **49**, 2246-2266.

Shim, J. S., L. Scherliess, R. W. Schunk, and D. C. Thompson (2010), Neutral wind and plasma drift effects on low and middle latitude total electron content, *J. Geophys. Res.*, 115, A04307, doi:10.1029/2009JA014488.

Shin, D. W., G. Baiggoria, **Y.-K. Lim**, S. Cocke, T. E. LaRow, J. J. O'Brien, and J. W. Jones (2010), Assessing maize and peanut yield simulations with various climate data in the southeast United States, *J. Appl., Meteor. Climatol*., **49**, 592-603, doi:10.1175/2009JAMC2293.1.

Singh, K. H., W. Kuang, A. V. Kuvshinov, and T. Sabaka (2010), Observability and Implication of Magnetic signals from different ocean circulation models, *AGU Fall Meet. Suppl., Abstract GP21A-0993*, **91**(52), Dec 13-17, San Francisco, CA.

Sippel, J. A., and F. Zhang (2010), Factors affecting the predictability of Hurricane Humberto (2007), *J. Atmos. Sci.*, **67**, 1759-1778.

Sitts, D.J., A. G. Fountain, and M. J. **Hoffman** (2010), Twentieth century glacier change on Mount Adams, Washington, USA, *Northwest Science*, **84**, 378-385.

Slavin, J. A., B. J. Anderson, D. N. Baker, M. **Benna**, S. **Boardsen**, G. Gloeckler, R. E. Gold, G. C. Ho, H. Korth, M. Krimigis, R. L. McNutt Jr., L. R. Nittler, J. M. Raines, M. **Sarantos**, D. Schriver, S. C. Solomon, R. D. Starr, P. Travnicek, and T. H. Zurbuchen (2010), MESSENGER Observations of Extreme Loading and Unloading of Mercury's Magnetic Tail, *Science*, **329**, 5992, 665-668, doi:10.1126/science.1188067

Slavin, J. A., R. Lepping, C.-C. Wu, B. J. Anderson, D. N. Baker, M. **Benna**, S. A. **Boardsen**, R. Killen, H. Korth, S. M. Krimigis, W. E. McClintock, R. L. McNutt Jr., M. **Sarantos**, D. Schriver, S. C. Solomon, P. Travnicek, and T. H. Zurbuchen (2010), MESSENGER Observations of Large Flux Transfer Events at Mercury, *Geophys. Res. Lett.*, **37**(2), L02105.

Soebiyanto, R.P., F. A. Adimi, and R. K. Kiang (2010), Modeling and predicting seasonal influenza transmission in warm regions using climatological parameters, *PLoS ONE*, **5**(3), e9450, March 1.

Spence, H. E., A. Case, M. J. Golightly, T. Heine, J. B. Blake, P. Caranza, W. R. Crain, J. George, M. Lalic, A. Lin, M. D. Looper, J. E. Mazur, D. Salvaggio, J. C. Kasper, **T. J. Stubbs**, M. Doucette, P. Ford, R. Foster, R. Goeke, D. Gordon, B. Klatt, J. O'Connor, M. Smith, T. Onsager, C. Zeitlin, L. Townsend, and Y. Charara (2010), CRaTER: The Cosmic Ray Telescope for the Effects of Radiation Experiment on the Lunar Reconnaissance Orbiter mission, *Space Sci. Rev.*, **150**, 1-4, 243–284, doi:10.1007/s11214-009-9584-8.

Stubbs, T. J., D. A. Glenar, A. Colaprete, and D. T. Richard (2010), Optical scattering processes observed at the Moon: Predictions for the LADEE Ultraviolet Spectrometer, *Planet. Space Sci.*, 58, 5, 830–837, doi:10.1016/j.pss.2010.01.002.

Sundberg, T., S.A. **Boardsen**, J.A.Slavin, L.G.Blomberg, and H.Korth (2010), The Kelvin–Helmholtz instability at Mercury: An assessment, *Planetary and Space Science*, **58**, 1434–1441, doi:10.1016/j.pss.2010.06.008.

Taktakishvili, A., P. Macneice, and D. Odstrci (2010), Model Uncertainties in prediction of Arrival of Coronal Mass Ejections at Earth Orbit, *Space Weather*, **8**, S06007, doi10.1029/2009SW000543.

Tao, W.-K., S. Lang, **X. Zeng**, S. Shige, and Y. Takayabu (2010), Relating convective and stratiform rain to latent heating, *J. Climate* , **23**, 1874-1893.

Tao, Z., G. Hewings, and K. Donaghy (2010), An economic analysis of US pollutant emissions trends from 1970 to 2000, *Ecological Economics*, **69**(8), 1666-1674, doi:10.1016/j.ecolecon.2010.03.016.

ten Kate, I. L. (2010), Organics on Mars?, *Astrobiology*, **10**(6), 589-603.

ten Kate, I. L., E. H. Cardiff, J. P. Dworkin, S. H. Feng, V. Holmes, C. Malespin, J. Stern, T. D. Swindle, and D. P. Glavin (2010), VAPoR - Volatile Analysis by Pyrolysis of Regolith - an instrument for *in situ* detection of water, noble gases, and organics on the Moon, *Planetary and Space Science* **58**, 1007-1017.

Thomas, G. E., C. A. Poulsen, R. Siddans, A. M. **Sayer**, E. Carboni, S. H. Marsh, S. M. Dean, R. G. Grainger, and B. N. Lawrence (2010), Validation of the GRAPE single view aerosol retrieval for ATSR-2 and insights into the long term global AOD trend, *Atmos. Chem. Phys.*, **10**, 4849-4866, doi:10.5194/acp-10-4849-2010.

Tian, L., G. M. Heymsfield, A. J. Heymsfield, A. Bansemer, L. Li, C. H. Twohy, and R. C. Srivastava (2010), A study of cirrus particle size distribution using TC4 observations, *J. Atmos. Sci*., **67**, 195-216.

Toon, O. B., D. O. Starr, E. J. Jensen, P. A. Newman, S. Platnick, M. R. Schoeberl, P. O. Wennberg, S. C. Wofsy, M. J. **Kurylo**, H. Maring, K. W. Jucks, M. S. Craig, M. F. Vasques, L. Pfister, K. H. Rosenlof, H. B. **Selkirk**, P. R. Colarco, S. R. Kawa, G. G. Mace, P. Minnis, and K. E. Pickering (2010), Planning, Implementation and First Results of the Tropical Composition, Cloud and Climate Coupling Experiment (TC4), *J. Geophys. Res.*, **115**, D00J04, doi:10.1029/2009JD013073.

Trávníček, P. M., D. Schriver, P. Hellinger, D. Herčík, B.J. Anderson, M. **Sarantos**, and J.A. Slavin (2010), Mercury's magnetosphere-solar wind interaction for northward and southward interplanetary magnetic field: Hybrid simulation results, *Icarus*, **209**, 11-22.

Utku, C. and D.M. Le Vine (2011), A Model for Prediction of the Impact of Topography on Microwave Emission, *IEEE Transactions on Geoscience and Remote Sensing*, **49**, No.1, 395-405.

Vervack, R.J., W. E. McClintock, R. M. Killen, A. L. Sprague, B. J. Anderson, M.H. **Burger**, E. T. Bradley, N. Mouawad, S. C. Solomon, and N. R. Izenberg (2010), Mercury's Complex Exosphere: Results from MESSENGER's Third Flyby, *Science*, **329**, 672-675.

Wang H., S. Schubert, M. Suarez and R. Koster (2010), The physical mechanisms by which the leading patterns of SST variability impact U.S. precipitation, *J. Climate*, **23**, 1815-1836.

Wang, X., X.-Z. Liang, W. Jiang, **Z. Tao**, J. X. L. Wang, H. Liu, Z. Han, S. Liu, Y. Zhang, G. A. Grell, and S. E. Peckham (2010), WRF-Chem simulation of east Asian air quality: sensitivity to temporal and vertical emissions distributions, *Atmospheric Environment*, **44**(5), 660-669, doi:10.1016/j.atmosenv.2009.11.011.

Wang, Y., **A. Lyapustin**, J. Privette, R. Cook, S. K. SanthanaVannan, E. Vermote, and C. Schaaf (2010), Assessment of Biases in MODIS Surface Reflectance Due to Lambertian Approximation, *Rem. Sens. Environ.*, **114**, 2791-2801, doi:10.1016/j.rse.2010.06.013.

Xue, Y., F. De Sales, K-M Lau, A. Boone, J. Feng, P. Dirmeyer, Z. Guo, **K. M. Kim**, A. Kitoh, V. Kumar, I. Poccard-Leclercq, N. Mahowald, W. Moufouma-Okia, P. Pegion, D. P. Rowell, J. Schemm, S. D. Schubert, A. Sealy, W. M. Thiaw, A. Vintzileos, S. F. Williams, and M.-L C. Wu (2010), Intercomparison and analyses of the climatology of the West African Monsoon in the West African Monsoon Modeling and Evaluation Project (WAMME) first model intercomparison experiment, *Clim. Dyn.*, **35**, pp. 3-27, doi:10.1007/s00382-010-0778-2.

Yang, W., W. **Ni-Meister**, N. Kiang, P. R. Moorcroft, A. H. Strahler and A. Oliphant (2010), A clumped-foliage canopy radiative transfer model for a global dynamic terrestrial ecosystem model I: Validation, *Agriculture and Forest Meteorology*, **150** (7-8), 895907, doi:10.1016/j.agrformet.2010.02.008.

Yang, Y., A. Marshak, T. Varnai, W. Wiscombe, and P. Yang (2010), Uncertainties in Ice-Sheet Altimetry From a Spaceborne 1064-nm Single-Channel Lidar Due to Undetected Thin Clouds, *IEEE Trans. Geos. Remote Sens.*, **48**, 250-259.

Yasunari, T. J., P. Bonasoni, P. Laj, K. Fujita, E. Vuillermoz, A. Marinoni, P. Cristofanelli, R. Duchi, G. Tartari, and K.-M. Lau (2010), Estimated impact of black carbon deposition during pre-monsoon season from Nepal Climate Observatory - Pyramid data and snow albedo changes over Himalayan glaciers, *Atmos. Chem. Phys.*, **10**, 6603-6615, doi:10.5194/acp-10-6603-2010.

Yasunari, T. J., P. Bonasoni, P. Laj, K. Fujita, E. Vuillermoz, A. Marinoni, P. Cristofanelli, R. Duchi, G. Tartari, and K.-M. Lau (2010), Preliminary estimation of black carbon deposition from Nepal Climate Observatory - Pyramid data and its possible impact on snow albedo changes over Himalayan glaciers during the pre-monsoon season, *Atmos. Chem. Phys. Discuss.*, **10**, 9291-9328, doi:10.5194/acpd-10-9291-2010.

Yasunari, T. J., R. D. Koster, K.-M. Lau, T. Aoki, Y. C. Sud, T. Yamazaki, H. Motoyoshi, and Y. Kodama (2011), Influence of dust and black carbon on the snow albedo in the NASA Goddard Earth Observing System version 5 land surface model, *J. Geophys. Res.*, **116**, D02210, doi:10.1029/2010JD014861.

Yokoyama, T., and D. L. Hysell (2010), A new midlatitude ionosphere electrodynamics coupling model (MIECO): Latitudinal dependence and propagation of medium-scale traveling ionospheric disturbances, *Geophys. Res. Lett.*, **37**, L08105, doi:10.1029/2010GL042598.

Yoshida, Y., B. N. Duncan, C. **Retscher**, K. E. Pickering, E. A. **Celarier**, J. Joiner, K. F. Boersma, and J. P. Veefkind (2010), The impact of the 2005 Gulf hurricanes on pollution emissions as inferred from Ozone Monitoring Instrument (OMI) nitrogen dioxide, *Atmospheric Environment*, **44**(11), 1443–1448, doi:10.1016/j.atmosenv.2010.01.037.

Yu, H., M. Chin, D. M. Winker, A. H. Omar, Z. Liu, C. Kittaka, and T. **Diehl** (2010), Global view of aerosol vertical distributions from CALIPSO lidar measurements and GOCART simulations: Regional and seasonal variations, *J. Geophys. Res.*, **115**, D00H30, doi:10.1029/2009JD013364.

Yurchak, B.S. (2010), Contribution of small-scale correlated fluctuations of microstructural properties of a spatially extended geophysical target under the assessment of radar backscatter, Proceedings of the 2010 IEEE International Geoscience and Remote Sensing Symposium, Honolulu, HI, July 25-31, 3557-3560. DOI:10.1109/IGARSS.2010.5652147.

Yurchak, B.S., and W. Abdalati (2010), A possible mechanism for inverse dependence of radar backscatter on snow accumulation rate, *Eos Trans.*, AGU 2010 Fall Meet. Suppl., Abstract 51A-0468.

Zenitani, S., M. Hesse, and A. **Klimas** (2010), Resistive magnetohydrodynamic simulations of relativistic magnetic reconnection, *ApJ*, **716**, L214-L218, doi:10.1088/2041-8205/716/L214.

Zenitani, S., M. Hesse, and A. **Klimas** (2010), Scaling of the anomalous boost in relativistic jet boundary layer, *Astrophys. J.*, **712**(2), 951-956.

Zenitani, S., M. Hesse, and A. **Klimas** (2010), Two-Fluid magnetohydrodynamic simulations of relativistic magnetic reconnection (vol 696, pg 1385, 2009), *Astrophys. J.*, **722**(1), 968-969.

Zhang, Q., and E. Middleton (2010), Introduction to fraction of absorbed par by canopy chlorophyll (fAPARchl) and canopy leaf water content derived from hyperion, simulated HyspIRI and MODIS images, *IGARSS 2010*, 793-796.

Zhang, W.W., **M. Atanassova**, M. Biskach, P. N. Blake, G. Byron, K. W. Chan, T. Evans, C. Fleetwood, M. Hill, M. Hong, L. Jalota, L. Kolos, J. M. Mazzarella, R. McClelland, L. Olsen, R. Petre, D. Robinson, T. T. Saha, M. Sharpe, M. V. Gubarev, W. D. Jones, T. Kester, S. L. O'Dell, D. Caldwell, W. Davis, M. Freeman, W. Podgorski, P. B. Reid, and S. Romaine (2010), Mirror technology development for the International X-ray Observatory mission (IXO), *Proc. SPIE 7732*, 77321G.

Zhang, Z., S. Platnick, P. Yang, A. K. Heidinger, and J. M. Comstock (2010), Effects of ice particle size vertical inhomogeneity on the passive remote sensing of ice clouds, *J. Geophysical Research*, **115** (D17), D17203.

Zhou, Y., W. K. Lau, O. **Reale**, R. Rosenberg (2010), AIRS Impact on precipitation analysis and forecast of tropical cyclones in a global data assimilation and forecasting system, *Geophys. Res. Lett.*, **37**, L02806, doi.1029/2009GL041494.

Ziemke, J. R., J. Joiner, S. Chandra, and P. K. Bhartia (2010), A comment on "Ozone sonde cell current measurements and implications for observations of near-zero ozone concentrations in the tropical upper troposphere", *Atmos. Meas. Tech. Disc.*, C1069-C1072, 13 January.

Ziemke, J. R., S. Chandra, L. D. Oman, and P. K. Bhartia (2010), A new ENSO index derived from satellite measurements of column ozone, *Atmos. Chem. Phys.*, **10**, 3711-3721.

This page intentionally left blank

Inactive Tasks

Since GEST's inception in 2000, in addition to the active tasks described within this final report, the GEST faculty members also worked on several tasks that are now considered inactive. The following is a list of most of these previous tasks, which reflect the faculty members' and sponsors' contributions to GEST's growth over the past decade. (Note, some of the inactive tasks included prior Short-Term Visitor tasks and Summer Programs tasks; the most recent write-ups on GEST's Educational Activities, Short-Term Visitors and Goddard Visiting Fellows can be found in GEST's 10th Annual Report.)

Task #	*Faculty Member*	*Sponsor*	*Last Reported in GEST Annual Report, Page No.*
971-00-002	J. Bacmeister; M. Lee; S. Mahanama	M. Rienecker	10th, p. 55
902-00-005	S. Unninayar	L. Olsen	10th, p. 37
910-01-008	S. Pawson	M. Rienecker	5th, p. 29
910-01-010	P. Norris	M. Rienecker	10th, p. 59
912-01-011	T. Berkoff & J. Welton	J. Spinhirne	2nd, pp. 88-89
912-01-012	R. Lancaster	J. Spinhirne	6th, p. 73
910-01-014	J. Rosenfield	P. Newman	5th, p. 104
916-01-016	M. Gupta	A. Douglass	5th, p. 98
921-01-018	S. Sakimoto	H. Frey	4th, p. 123
935-01-022	U. A. Ranawake	J. Dorband	4th, p. 156
930-01-023	M. Rancic	J. Fischer	4th, p. 153
912-02-027	L. Tian	G. Heymsfield	9th, p. 92
912-02-029	Z. Pu	W-K. Tao	4th, p. 48
912-02-034	A. Rao	W-K. Tao	1st, p. 79
913-02-035	B. Chen	W. Chao	3rd, p. 78
912-02-036	R. F. Lin	D. Starr	8th, p. 67
971-02-040	J. Ukita	A. Liu	3rd, p. 28
900-03-041	C. Gatebe	M. King	7th, p. 128

Task #	*Faculty Member*	*Sponsor*	*Last Reported in GEST Annual Report, Page No.*
910-03-047	W. Choi & P. Colarco	J. Richards	3rd, p. 176 and p. 179
930-03-068	S. Hoban	N. Lal	9th, p. 33
935-03-069	F. Stetina	P. Coronado	2nd, p. 137
974-03-070	J. Meng	M. Rodell	7th, p. 23
693-04-073	R. Dimitrov	D. Reuter	1st, p. 117
910-05-082	S. Li	M. Rienecker	4th, p. 10
974-05-086	R. Kelly	J. Foster	5th, p. 171
550-06-087	G. Solyar	K. Carpenter	4th, p. 147
912-06-088	A. Mahesh	J. Spinhirne	4th, p. 72
910-08-098	G. Wang	A. Hou	2nd, p. 27
910-08-099	O. Reale	M. Seablom	9th, p. 112
910-08-100	D. Herdies	A. daSilva	1st, p. 59
916-08-101	C. Hsu	J. Herman	4th, p. 102
902-09-103	R. Schiffer	L. Olsen	5th, p. 159
971-09-106	C. Hulbe	R. Bindschadler	1st, p. 45
912-10-109	C.-L. Shie	W-K. Tao	7th, p. 73
935-11-113	T. El-Ghazawi	J. Le Moigne	3rd, p. 162
930-12-115	K. Olson	D. Spicer	6th, p. 169
912-10-116	D. Johnson	W-K. Tao	5th, p. 52
913-12-118	A. Plana-Fattori	W. Wiscombe	2nd, p. 101
913-13-120	Y. Zhou	S. Tsay	5th, p. 83
916-13-121	E. Bucsela	J. Gleason	7th, p. 94
423-14-122	J. Sachs	J. Behnke	2nd, p. 125
910-14-125	K. Yeh	M. Seablom	3rd, p. 72

Task #	*Faculty Member*	*Sponsor*	*Last Reported in GEST Annual Report, Page No.*
935-16-127	H. Stone	J. Le Moigne	4th, p. 157
912-18-129	L. Wu	S. Braun	5th, p. 61
913-18-130	P. Kundu	T. Bell	4th, p. 96
912-19-131	L. Li, L. Belcher	G. Heymsfield	8th, p. 64
926-19-132	J. P. Boy	B. Chao	2nd, p. 31
910-19-135	H. Hyashi	M. Rienecker	6th, p. 28
900-19-136	J. Riédi	M. King	3rd, p. 115
912-21-140	M. Grecu	S. Braun	10th, p. 76
924-21-142	Z. Wang	D. Whiteman	5th, p. 80
972-21-143	A. Chekalyuk - Hampton Univ.	J. Gerlach	7th, p. 191
912-21-145	G. Gu	M. Bosilovich	8th, p. 61
912-23-147	K.-S. Kuo - Caelum	E. Smith	6th, p. 71
971-26-149	K. Mizoguchi	S. Hakkinen	4th, p. 168
975-31-154	M. Tedesco	E. Kim	6th, p. 193
970-31-156	C.-H. Lyu	W. Barnes	3rd, p. 138
900-35-168	B. Yurchak	N. Maynard	6th, p. 196
972-37-169	H. Feng - Hampton Univ.	D. Vandemark	6th, p. 185
923-37-170	M. Nirala	J. Privette	4th, p. 132
923-39-175	B. Guenther	J. Gleason	10th, p. 137
693-42-179	G. Solyar	D. Reuter	4th, p. 150
916-43-181	J. Ziemke & S. Chandra	P.K. Bhartia	10th, p. 157
913-43-182	H. Wang	W. Lau	6th, p. 55
974-44-183	Y. Wu	C. Peters-Lidard	7th, p. 209
974-44-184	Y. Tian	C. Peters-Lidard	10th, p. 178

Task #	*Faculty Member*	*Sponsor*	*Last Reported in GEST Annual Report, Page No.*
588-45-185	A. Koratkar	J. Breed	5th, p. 147
923-46-188	P. Kealy	J. Privette	5th, p. 125
923-51-194	H. Margolis	J. Ranson	4th, p. 136
974-52-196	J. Eastman	C. Peters-Lidard	8th, p. 144
974-52-197	X. Zhan	D. Toll	5th, p. 183
974-52-198	J. Dong	D. Toll	8th, p. 143
974-52-199	K. Arsenault	D. Toll	8th, p. 138
900-55-207	L. Nerger	W. Gregg	7th, p. 37
975-56-210	A. Kramer (Caelum)	G. Jackson	9th, p. 165
913-57-211	H. Yu	L. Remer	10th, p. 118
913-60-214	J. Wei	S. Tsay	5th, p. 135
971-60-215	M. Russ	A. Mannino	7th, p. 204
920-63-217	J. Deppe	J. Smith	6th, p. 145
613-65-221	Y. Hong	R. Adler	7th, p. 62
613-65-222	T. Matsui	W-K. Tao	10th, p. 82
612-65-223	P. Webb	R. Goldberg	7th, p. 165
614-66-228	M. Garcia	C. Peters-Lidard	8th, p. 148
610-67-231	W. McCarty	M. Rienecker	10th, p. 53
612-68-239	Y. Wang	G. Le	9th, p. 214
613-70-242	M. Wenig	J. Gleason	7th, p. 112
610-75-262	B. Bojkov	M. Schoeberl	8th, p. 108
699-78-268	J. Joseph	P. Mahaffy	8th, p. 177
614-79-269	K. Nakagawa	R. Meneghini	8th, p. 123
612-79-271	J. Pap	D. Pesnell	8th, p. 185

Task #	*Faculty Member*	*Sponsor*	*Last Reported in GEST Annual Report, Page No.*
614-81-278	C. Williams	J. Collatz	8th, p. 162
673-81-279	H. Bekerat	J. Sigwarth	7th, p. 151
614-81-280	M. Russ	S. Hooker	8th, p. 156
698-82-284	K. LeBail	F. Lemoine	9th, 197
610-83-287	B. Duncan	J. Rodriguez	8th, p. 113
610-87-303	R. Reichle	M. Rienecker	8th, p. 42
674-88-304	P. Webb	M. Hesse	9th, p. 215
614-88-307	D. Stroud	S. Hooker	9th, p. 37
614-89-314	Z. Wang	X. Xiong	9th, p.179
614-95-333	E. Brown de Colstoun	J. Irons	9th, p. 157
614-95-334	E. Brown de Colstoun	J. Masek	9th, p. 157
614-95-335	E. Brown de Colstoun	J. Irons	9th, p. 157

This page intentionally left blank

Faculty and Staff

Faculty	Title
Abuhassan, Nader	Associate Research Engineer
Anyamba, Assaf	Associate Research Scientist
Atanassova, Martina	Assistant Research Engineer
Barahona, Donifan	Research Associate
Barton, Jonathan	Assistant Research Scientist
Beck, Jefferson	Assistant Research Scholar
Bell, Benita	Visiting Assistant Research Scientist
Benna, Mehdi	Associate Research Scientist
Benson, Craig	Research Associate
Berkoff, Tim	Assistant Research Engineer
Bian, Huisheng	Associate Research Scientist
Bindschadler, Robert	Senior Research Scientist
Boardsen, Scott	Associate Research Scientist
Brucker, Ludovic	Research Associate
Brunt, Kelly	Assistant Research Scientist
Burger, Matthew	Assistant Research Scientist
Celarier, Ed	Associate Research Scientist
Chandra, Sushil	Senior Research Scientist/GEST Fellow
Chang, Yehui	Associate Research Scientist
Chern, Jiun Dar	Associate Research Scientist
Chu, D. Allen	Associate Research Scientist
Colarco, Amelia	Research Associate
Cook, Laurie	Instructional Designer
de Lannoy, Gabrielle	Assistant Research Scientist

Faculty	Title
de Matthaeis, Paolo	Research Associate
Delaney, Marcianna	Assistant Research Scientist
Diehl, Thomas	Assistant Research Scientist
Draper, Clara	Research Associate
Duberstein, Gemma	Assistant Research Scholar
Eck, Thomas	Assistant Research Scientist
Errico, Ronald	Senior Research Scientist
Fitzgibbons, Ryan	Assistant Research Scholar
Follette-Cook, Melanie	Assistant Research Scientist
Gassó, Santiago	Assistant Research Scientist
Gatebe, Charles	Associate Research Scientist
Gautam, Ritesh	Research Associate
Georgieva, Elena	Associate Research Scientist
Grecu, Mircea	Associate Research Scientist
Guenther, Bruce	Senior Research Scientist
Gupta, Pawan	Research Associate
Ham, Yoo-Geun	Research Associate
Han, Mei	Assistant Research Scientist
Han, Shin-Chan	Associate Research Scientist
Harris, Brooke	Assistant Research Scholar
Herdies, Dirceu	GVF, Visiting Senior Research Scientist
Hoban, Susan	Senior Research Scientist
Hoffman, Matthew	Research Associate
Holdaway, Daniel	Research Associate
Huang, Jingfeng	Assistant Research Scientist

Faculty	Title
Hurwitz, Margaret	Assistant Research Scientist
Hwang, Kyoung-Joo	Research Associate
Imber, Suzanne	Research Associate
Jacob, S. Daniel	Assistant Research Scientist (Leave of Absence)
Jusem, Juan Carlos	Visiting Senior Research Scientist
Kim, Dongchul	Assistant Research Scientist
Kim, Hyokyung	Visiting Assistant Research Scientist
Kim, Kyu-Myong	Associate Research Scientist
Klimas, Alexander	Senior Research Scientist
Koratkar, Anuradha	Associate Research Scientist
Korkin, Sergey	Research Associate
Kostis, Helen-Nicole	Research Associate
Koval, Andriy	Assistant Research Scientist
Kowalewski, Matthew	Assistant Research Engineer
Kuo, Kwo-Sen	Scientist, Caelum Research Corporation
Kurtz, Nathan	Research Associate
Kurylo, Michael	Senior Research Scientist
Kuzmicz-Cieslak, Magda	Faculty Research Associate
Lait, Leslie Robert	Senior Research Scientist
Lamsal, Lok	Assistant Research Scientist
Laughlin, Daniel	Assistant Research Scientist
Lawford, Richard	Senior Research Scientist
Lee, Dong Min	Research Associate
Lee, Hyesook	Visiting Assistant Research Scientist
Li, Feng	Assistant Research Scientist

Faculty	Title
Li, Xiaowen	Assistant Research Scientist
Liang, Qing	Assistant Research Scientist
Liao, Liang	Associate Research Scientist
Lim, Young-Kwon	Assistant Research Scientist
Lin, Xin	Associate Research Scientist
Lipatov, Alexander	Senior Research Scientist
Lyapustin, Alexei	Assistant Research Scientist
Ma, Zaizhong	Research Associate
Mao, Jianping	Associate Research Scientist
Marchant, Benjamin	Research Associate
Marchant, Virginie Bouchard	Research Associate
Merka, Jan	Assistant Research Scientist
Meyer, Kerry	Assistant Research Scientist
Mohammed, Priscilla	Research Associate
Molnar, Gyula	Assistant Research Scientist
Ni-Meister, Wenge	Associate Research Scientist
Norris, Peter	Assistant Research Scientist
Olsen, Mark	Assistant Research Scientist
Pan, Xiaohua	Research Associate
Parnell, Lynn	Senior Research Scientist
Patadia, Falguni	Research Associate
Pauluis, Olivier	GVF, Visiting Associate Research Scientist (GISS)
Pavlis, Erricos	Research Associate Scientist
Peng, Jinzheng	Research Associate

Faculty	Title
Plummer, Joel	Research Associate
Privé, Nikki	Assistant Research Scientist
Radcliff, Matthew	Assistant Research Scholar
Randles, Cynthia	Assistant Research Scientist
Reale, Oreste	Associate Research Scientist
Reichle, Rolf	GEST Fellow
Retscher, Christian	Assistant Research Scientist
Riishojgaard, Lars-Peter	Senior Research Scientist, Director JCSDA
Rosette, Jacqueline	Assistant Research Scientist
Samsonov, Andrey	Assistant Research Scientist
Sarantos, Menelaos	Assistant Research Scientist
Sayer, Andrew	Research Associate
Schiffer, Robert	Chief Scientist
Selkirk, Henry	Associate Research Scientist
Shi, Roger	Associate Research Scientist
Shie, Chung-Lin	Associate Research Scientist
Shim, Ja Soon	Visiting Research Associate
Shuman, Christopher	Associate Research Scientist
Singh, Kumar	Associate Research Scientist
Sippel, Jason	Assistant Research Scientist
Soebiyanto, Radina	Research Associate
Song, In-Sun	Assistant Research Scientist
Southard, Adrian	Research Associate
Stoyanova, Silvia	Faculty Research Assistant
Strahan, Susan	Senior Research Scientist

Faculty	Title
Stubbs, Timothy	Associate Research Scientist
Studinger, Michael	Associate Research Scientist
Sun, Zhibin	Visiting Research Associate
Taktakishvili, Aleksandre	Associate Research Scientist
Tan, Qian	Assistant Research Scientist
Tao, Zhining	Associate Research Scientist
ten Kate, Inge	Visiting Assistant Research Scientist
Tian, Lin	Associate Research Scientist
Toure, Ally	Visiting Research Associate
Ungar, Steven	Senior Research Scientist
Unninayar, Sushel	Senior Research Scientist
Utku, Cuneyt	Research Associate
van Oevelen, Peter	Associate Research Scientist, GEWEX Director
Veselovskii, Igor	Associate Research Scientist
Vikhliaev, Yuri	Research Associate
Wang, Hailan	Assistant Research Scientist
Wang, Yongli	Assistant Research Scientist
Wang, Yujie	Assistant Research Scientist
Weaver, Clark	Associate Research Scientist
Wen, Guoyong	Assistant Research Scientist
Wiessinger, Scott	Assistant Research Scholar
Wilson, Michael	Research Associate
Yang, Kai	Assistant Research Scientist
Yang, Weidong	Assistant Research Scientist
Yang, Yuekui	Assistant Research Scientist

Faculty	Title
Yasunari, Teppei	Visiting Research Associate
Yokoyama, Tatsuhiro	Visiting Assistant Research Scientist
Yurchak, Boris	Senior Research Scientist
Zeng, Xiping	Associate Research Scientist
Zhang, Qingyuan	Assistant Research Scientist
Zhang, Yan	Research Associate
Zhang, Zhibo	Research Associate
Zhao, Yunhe	Scientist, Caelum Research Corporation
Zhou, Yaping	Associate Research Scientist
Ziemke, Jerry	Associate Research Scientist

Associate Staff	Title
Belvedere, Deborah	Water & Energy Cycle Focus Area Liaison
Kathrine Collins	Research Analyst
Franz, Heather	Research Analyst
Garner, Robert	Media Specialist
Kucsera, Tom	Research Analyst
Lentz, Michael	Media Specialist
Lewis, Katherine	Media Specialist
Martin, Adam	Media Specialist
Mostafavi, Neema	Media Specialist
Schindler, Trent	Media Specialist
Steenrod, Stephen	Research Analyst
Wright, Ernie	Media Specialist

Administrative Staff	Title
Casasanto, Valerie	Program Coordinator
Dawson, Mary	Business Specialist
Eichenlaub, Danita	Acting Director
Hoff, Raymond	Executive Director
Houghton, Amy	Communications Specialist
Hyman, Camilla	Accountant I
Lewis, Brizjette	Executive Administrative Assistant
Manalansan, Cathy	Administrative Assistant II
Nguyen, Katie	Business Specialist
Von Gunten, Nina	Administrative Assistant I
Young, Margo	Business Specialist