"Analysis of Aerosol Properties Derived from MODIS, AERONET, and Shipborne Measurements During AEROSE Field Campaigns"

Tamil Maldonado-Vega
Howard University - Atmospheric Science Program

Mentor: Dr. D. Allen Chu,
NASA Goddard

Abstract.

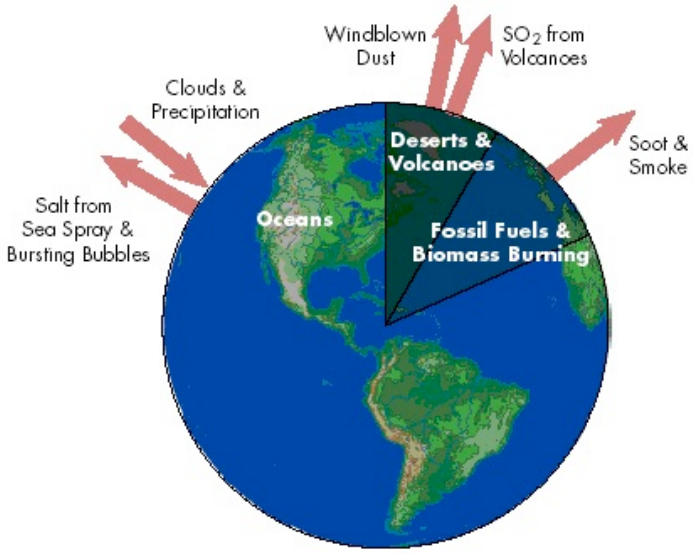
The Trans-Atlantic Saharan Dust Aerosols and Ocean Science Expedition (AEROSE) employed a suite of aerosol instruments onboard the NOAA Ronald H. Brown during spring 2004, summer 2006 and summer 2007 provide a unique set of measurements to characterize aerosol properties and compositions near source regions and during transport across the tropical Atlantic Ocean. The Microtops sunphotometers (one of the instruments used on NOAA Ronald Brown) measure aerosol optical depth (AOD) at 340, 440, 675, and 870 nm, and water vapor from the 936 nm wavelength, which are in tandem with AERONET and MODIS-derived quantities over the visible-near infrared solar spectrum. First we intercompared the measurements of Microtops and AERONET sunphotometers with MODIS aerosol retrievals to study the validity of MODIS retrievals and feedbacks to MODIS algorithm in regard to sphericity and absorption for year 2007.

We present a detailed analysis of aerosol optical depth at and around AERONET sites (Cape Verde, Dahkar, Santa Cruz - Tenerife, Izana, and Puerto Rico) and along the tracks of NOAA Ron Brown RV. Using the validated satellite aerosol retrievals (with estimated errors) is an important step to develop more accurate Earth system models able to characterize the evolution of dust during transports and in turn to predict the effects of dust on microphysical processes.

Introduction.

Aerosols are defined as particles (solid or liquids) suspended in the atmosphere. They range in sizes between nanometers (nm) to tens of micrometers (μm). Atmospheric aerosol chemical composition is highly variable, with respect to both size and to spatial and temporal distribution. Because of different sizes and chemical compositions, aerosol particles have a wide range of lifetimes in air.

There are two layers in the lower atmosphere: the troposphere and the stratosphere, below and above, respectively, of the tropopause, approximately 10 km altitude. Tropospheric aerosols vary significantly in amount and composition by region, with a horizontal spatial scale of variation ranging from 1 km too a few thousand kilometers. Notable examples of regionally defined tropospheric aerosol types are marine aerosol, industrial haze, desert dust, and smoke from biomass combustion.



The direct and indirect radiative effects of aerosols on climate and climate change remain a source of uncertainty in climate research. Aerosol particles influence climate by modifying both the global energy balance through absorption and scattering of radiation (direct effects), and the reflectance and persistence of clouds, and the development and occurrence of precipitation (indirect effects). In particular, we need the impacts of dust

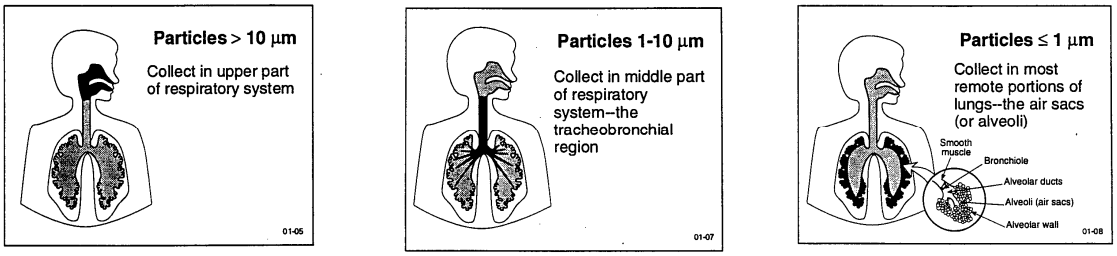
on microphysical processes over the tropical North Atlantic Ocean under dust influence to study the global hydrological cycle.

Aerosols also contribute to a numerous climatically processes, including fertilization of land and oceans through deposition of nitrates, iron, and other nutrients. On the other hand, they also reduce visibility and affects human health (asthma, skin diseases and even morbidity).

An estimated three billion metric tons of mineral aerosols are injected into the troposphere annually from the Saharan desert [Prospero et al, 1996].

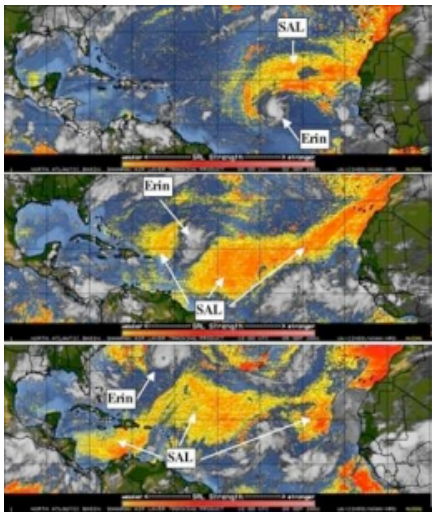
Dust Transported to P.R. May 4, 2007 1:23 p.m.(local time) May 18, 2007 at 11:47 a.m.

Griffin et. al. measured and identified the microbes present in the Caribbean air during the African dust events. It turns out that about 25 percent are species of bacteria or fungi that have been identified as plant pathogens and about 10 percent are opportunistic human pathogens (organisms that can infect people who have a lowered resistance).

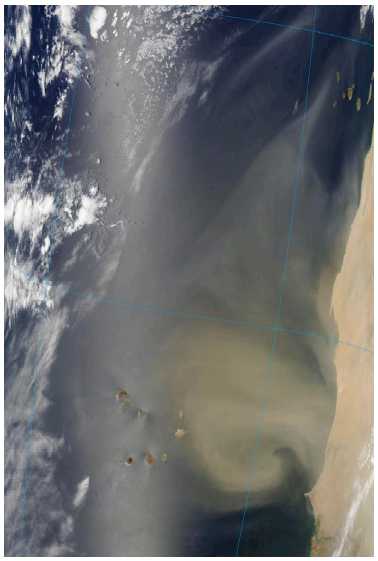


Moreover, active summertime easterly waves over northern Africa and Atlantic Ocean are clearly seen from satellite images. Tropical depressions, subsequently developing

into tropical storms and hurricanes, are frequently formed as a result of wave breaking and cyclogenesis. Under the prevailing easterlies, dust outbreaks from the Saharan Air Layer are a strong seasonal phenomenon, coinciding with hurricane developing region of the northern Atlantic Ocean. Several studies revealed that enhanced convection is shown along the Saharan Air Layer (SAL) western and southern boundaries but prohibited in its interior due to the combination of dry stable air and strong easterly wind shear. Most model studies, however, are focused on tropical storm/ hurricane intensity change with simplified aerosol parameterization schemes or without considering the impacts of aerosols. Thus, the effects of dust radiative and microphysical properties on cloud formation (or suppression), precipitation, and hurricane intensification, are not well understood.



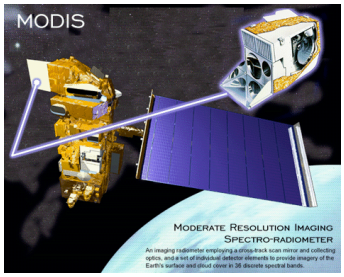
NOAA GOES SAL-tracking
Hurricane Erin 2001 – Dunion and Velden 2004

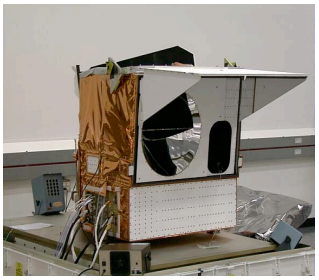


MODIS - May 9, 2007

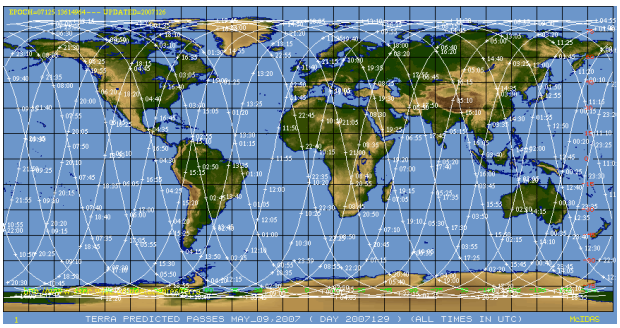
Remote Sensing by satellites are used to have a continuous global coverage of the Earth's atmosphere (aerosol and trace gases) over extended periods of time. Satellites observations of reflected and emitted radiances are being used to monitor aerosols and their interactions with the climate system. There exist two satellites platforms, Terra (since 2000) and Aqua (since 2002), equipped with the Moderate Resolution Imaging Spectrometer (MODIS) instrument. MODIS observes spectral radiances in 36 channels from 0.405 to 14.385 μm and at resolutions from 250 m to 1 km. MODIS is highly suitable for deriving aerosol properties over the oceans (Tanre et al. 1996,1997) at 10 km

x 10 km – known as “level 2” products. The MODIS polar geosynchronous orbit is such that most of the globe is covered each day and completely covered every two days.

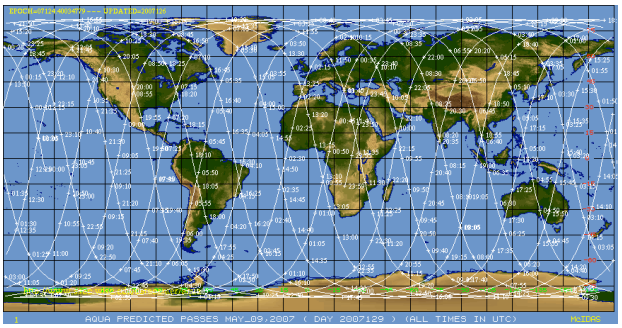




MODIS



Terra Track



Aqua Track

The aerosol optical depth (AOD or τ) is one of the optical properties that MODIS is able to retrieve. AOD defines the integral of the light extinction by aerosols within an atmospheric column. Spectral dependence of τ is related to aerosol size distribution and the fine-mode-weighting, which defines the contribution of the fine aerosol to total τ at a specific wavelength λ.

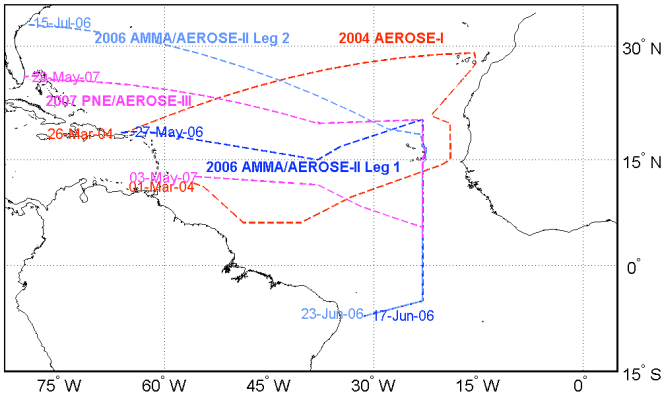
The Aerosol Robotic Network (AERONET) is a sun photometer, which also provides continuous daytime measurements of spectral $\tau(\lambda)$ with an accuracy of $\pm$ 0.01 at most wavelengths (Remer et. al. 2005). By accounting for known effects of molecular scattering (Rayleigh scattering) and gas absorption, sun photometers measurements of spectral direct-beam extinction are directly related to τ as expressed by the Beer-Bouger extinction law.

AERONET Sun Photometer

AOD AERONET bands are 1.020, 0.870, 0.670, 0.550, 0.47, 0.44 µm. These are computed for three data quality levels: level 1.0 (unscreened), 1.5 (cloud-screened) and level 2.0 (cloud-screened and quality- assured).

Microtops is another Sun photometer able to calculate Aerosol Optical Thickness at five different wavelengths 0.34, 0.44, 0.675, 0.87 and 0.936 µm. Easy portability is one advantage of this instrument.

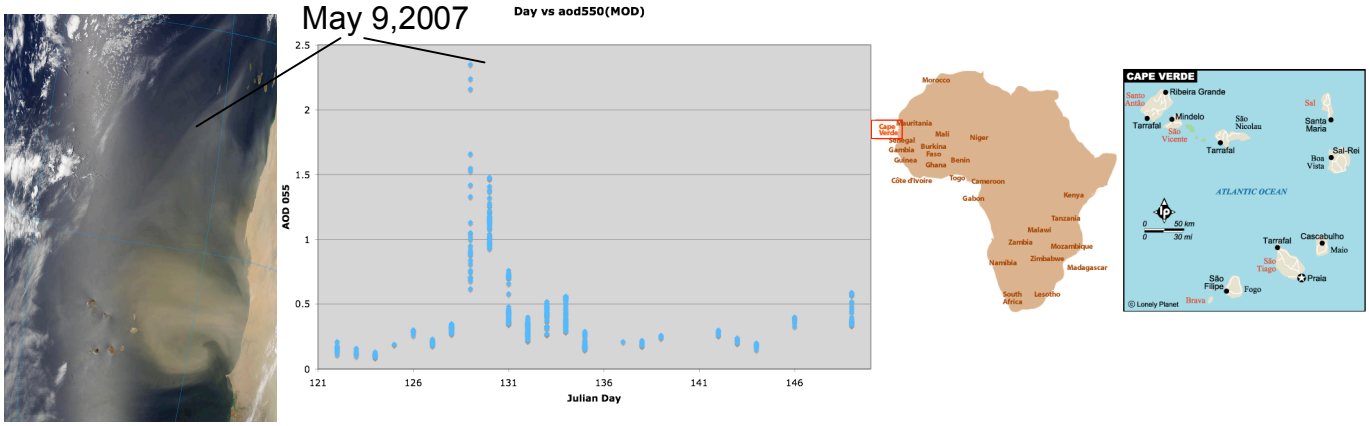
Microtops were used in the Trans-Atlantic Aerosol and Ocean Science Expeditions (AEROSE). These are a series of intensive field experiment conducted aboard the U.S. National Oceanic and Atmospheric Administration (NOAA) ship Ronald H. Brown during the Northern Hemisphere spring (March 2004), summers (June-July 2006 and May 2007). AEROSE mission focuses on providing a set of critical measurements that characterize the impacts and microphysical evolution of aerosols from the African continent as they transit the Atlantic Ocean [Vernon et. al. EOS 2006].



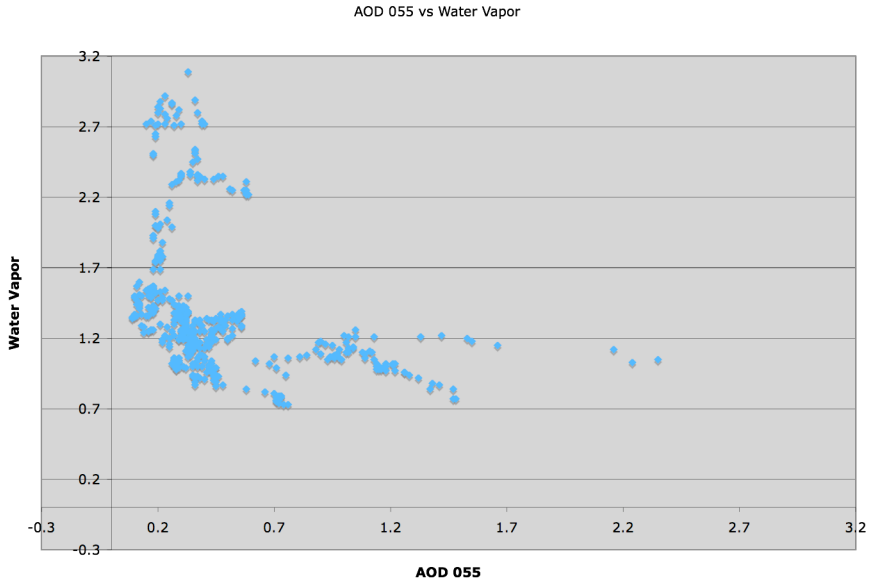
Methods

We used the Moderate Resolution Imaging Spectrometer (MODIS) instrument aboard the Terra (since 2000) and Aqua (since 2002) satellite platforms to observe spectral radiances at level 2.0 derived AOD 0.47 and 0.55, plus 0.67 and 0.87 µm bands. We compared the AOD MODIS retrieval with level 1.5 (cloud-screened) AERONET AOD retrievals at 0.47 and 0.55, 0.67 and 0.87 µm channels for seven sites. The AERONET sites were Santa Cruz – Tenerife, Cape Verde, Izana, Dakar, Cape San Juan, La Parguera and Guadalupe for data during May 2007 (AEROSE Campaign).

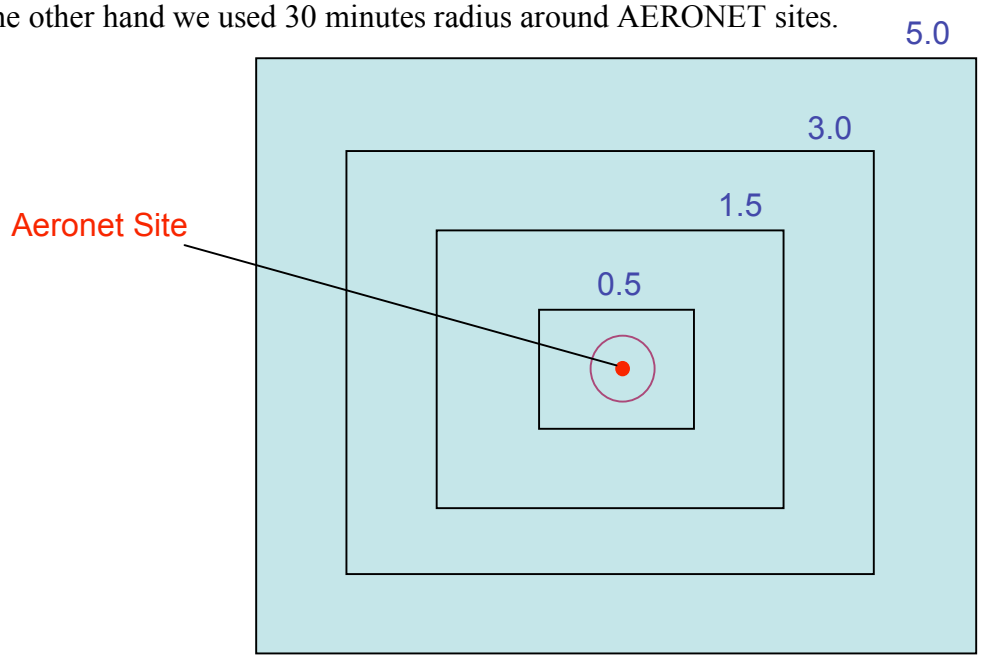
In the following illustration we plotted a time series vs AOD at 0.55 µm for Cape Verde site. Notice a rise on May 9, 2007 where we know a dust laden happened.



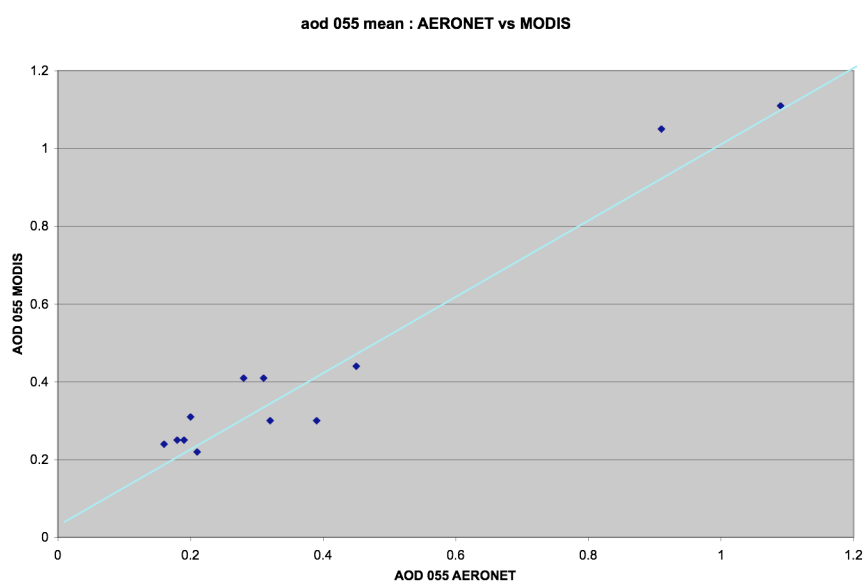
Observe how water vapor decreases with bigger size particles at AOD at 0.55 µm for Cape Verde.



We chose parameters for MODIS and AERONET validations. For MODIS we took a ±30 minutes overpass at four different distances (boxes): 5, 3, 1.5, and 0.5 degrees. On the other hand we used 30 minutes radius around AERONET sites.

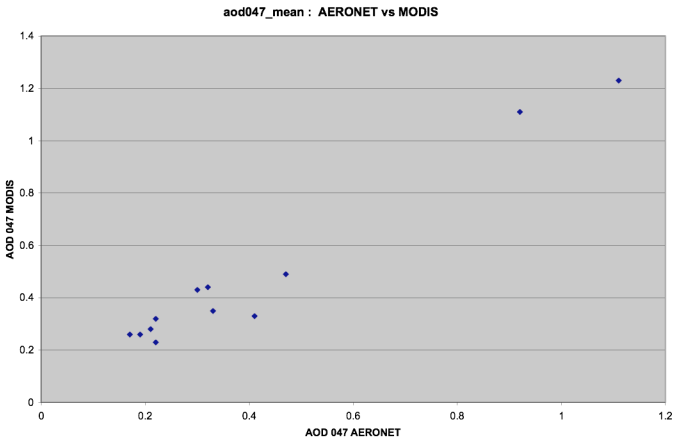


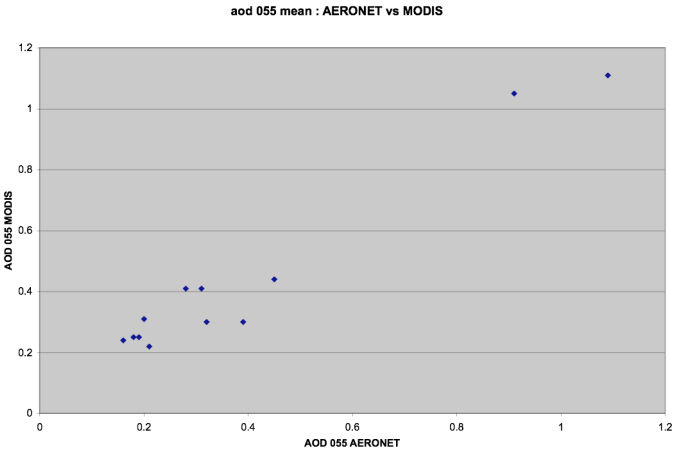
For each site (7), each wavelength (4) and each "box" (4) we developed the correlations and performed a statistical analysis. Therefore we did a 112 plots and statistics. I presented only one site (Cape Verde) results for this report.

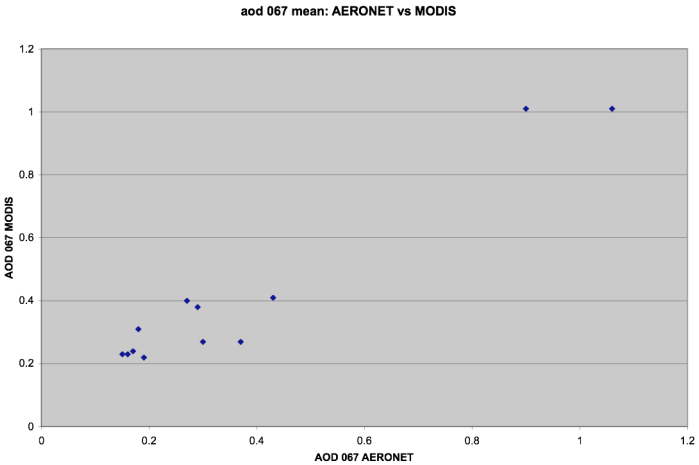


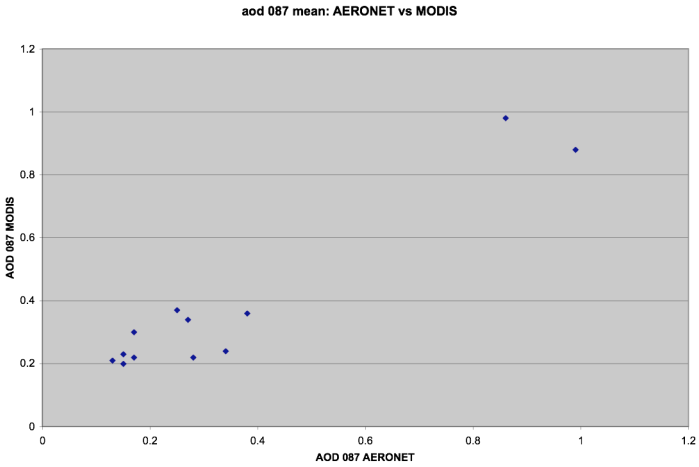
Statistics: correlation coef: 0.974375
slope of linear reg: 0.996978
intercepts linear regresion: 0.0511809

For different AODs, using 0.5 degree box for MODIS

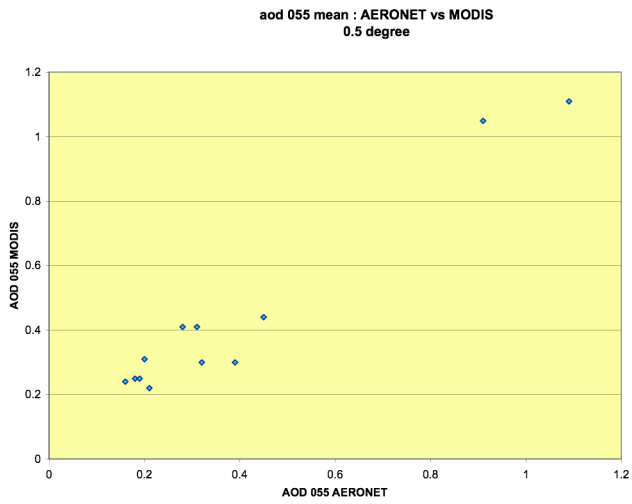


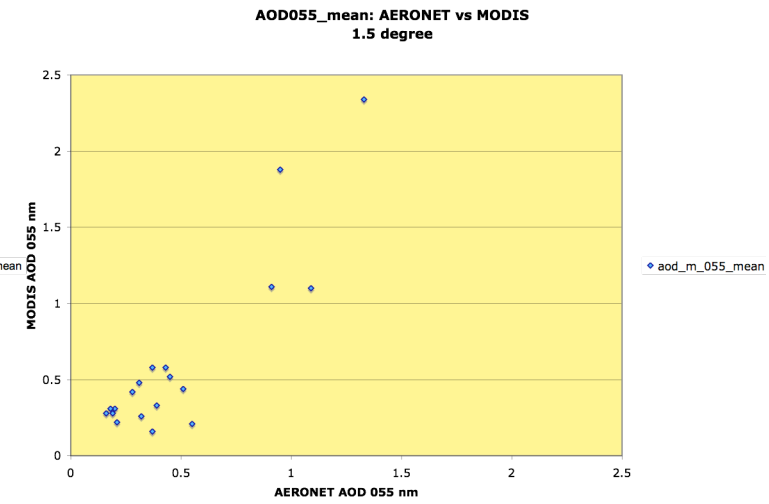


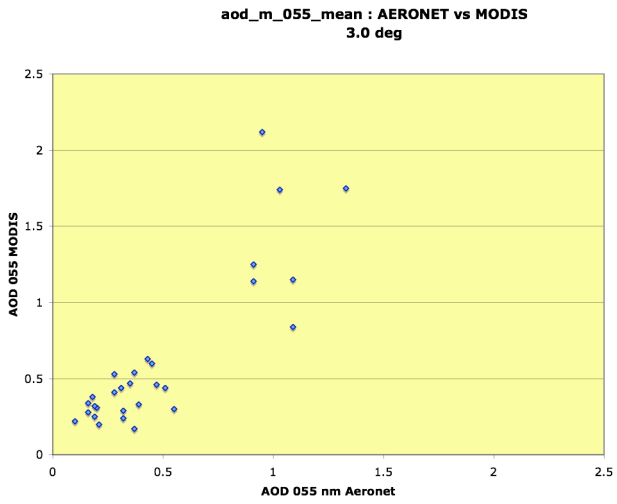


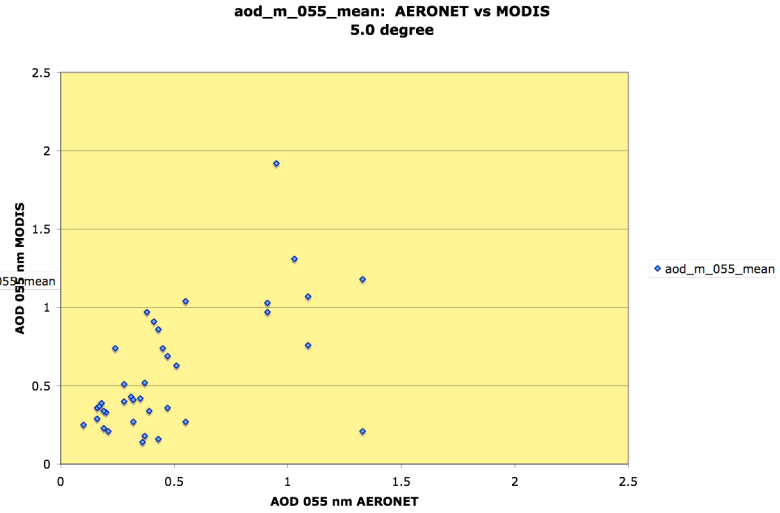


Following plots of Cape Verde site for AOD 0.55 µm for different box sizes 0.5, 1.5, 3.0, and 5.0 degrees.





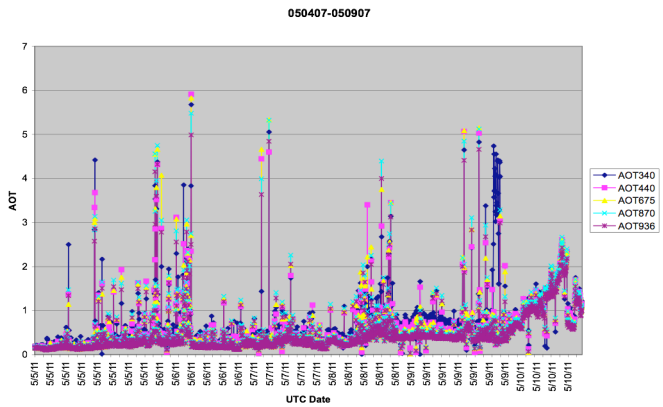


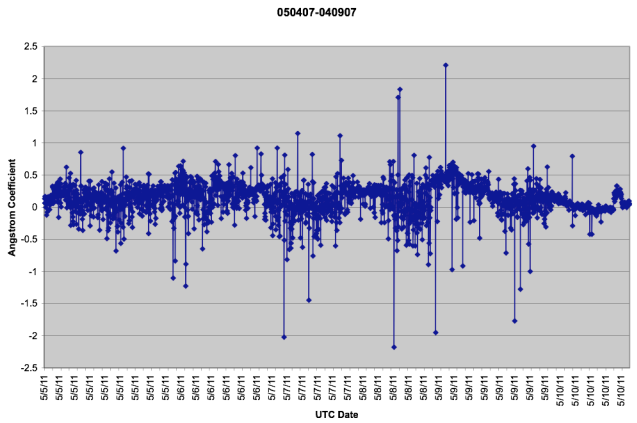


We had good correlations between AERONET AOD and MODIS. As we expected, there are better approximations when used the smallest distance (0.5 degree).

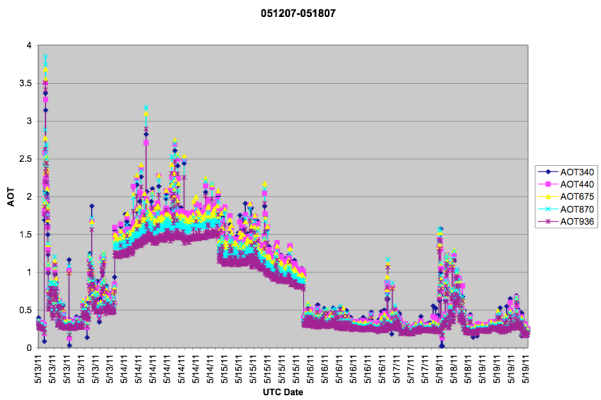
Now looking at two legs Microtops data (west to east leg and south to north leg) we could plot their time series and angstrom exponent.

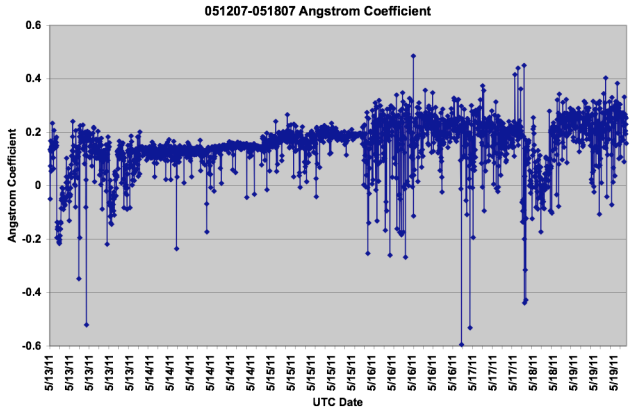
Figures Leg 1:



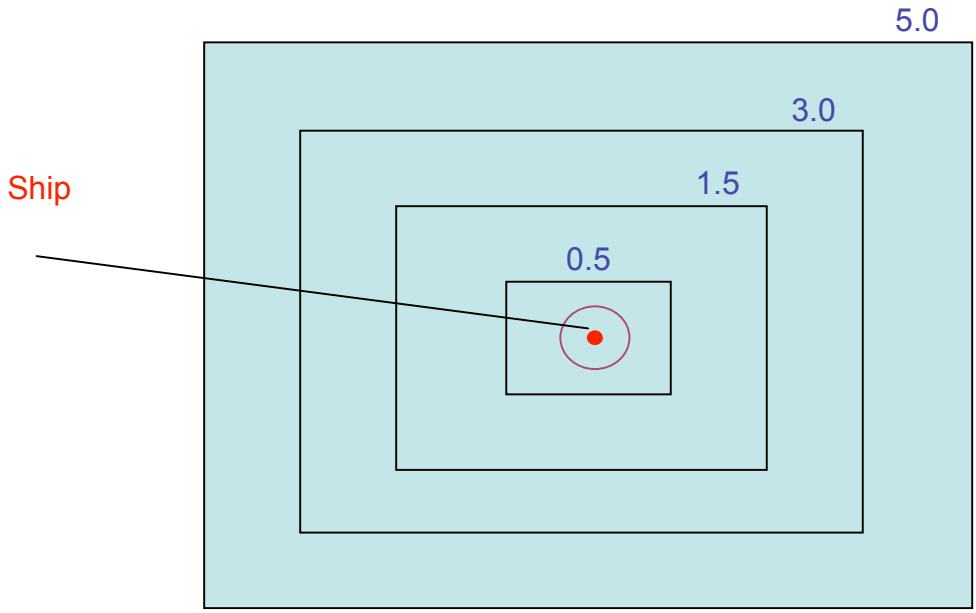


Figures Leg 2:





We also compared AEROSE May 2007 Microtops data with MODIS at 0.87 µm channel.

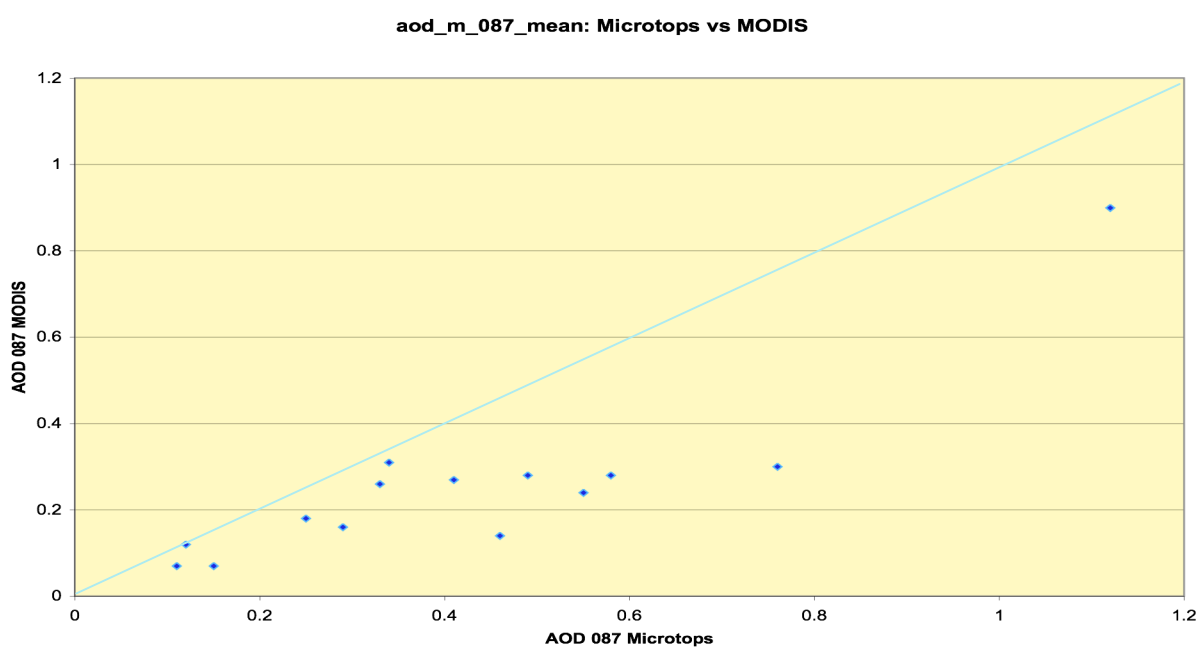


Parameters:

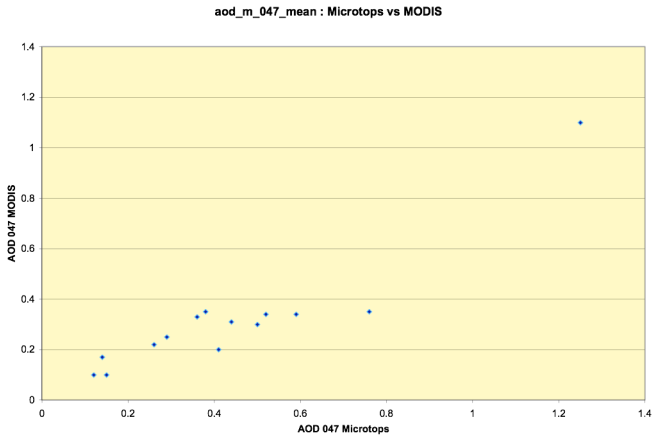
MODIS : ±30 minutes overpass at four different distances

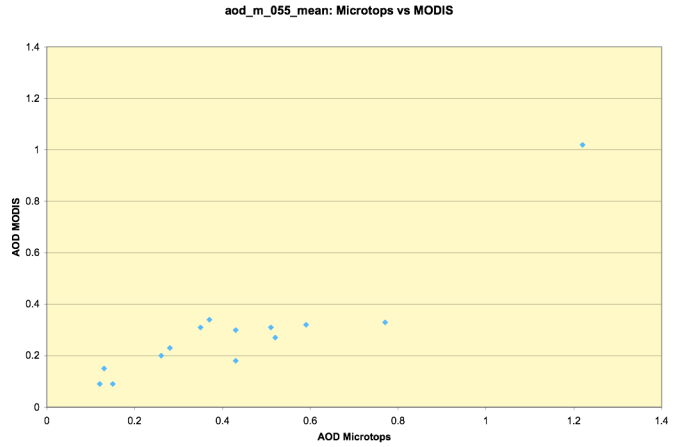
(boxes): 5, 3, 1.5, and 0.5 degrees

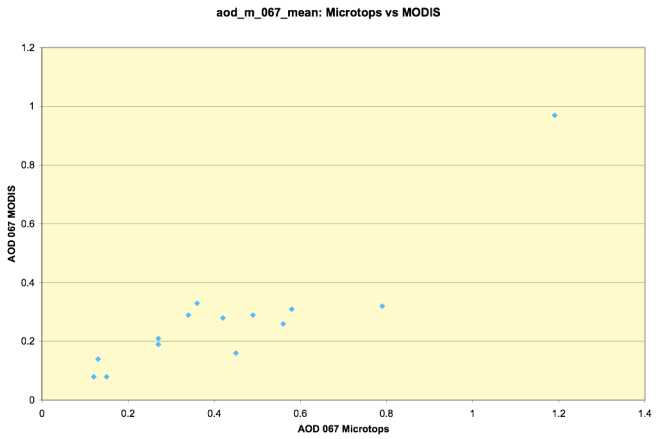
Microtops: Specific (latitude, longitude)

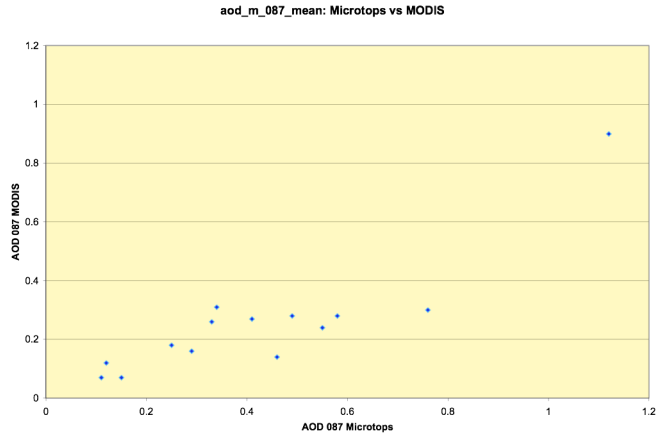


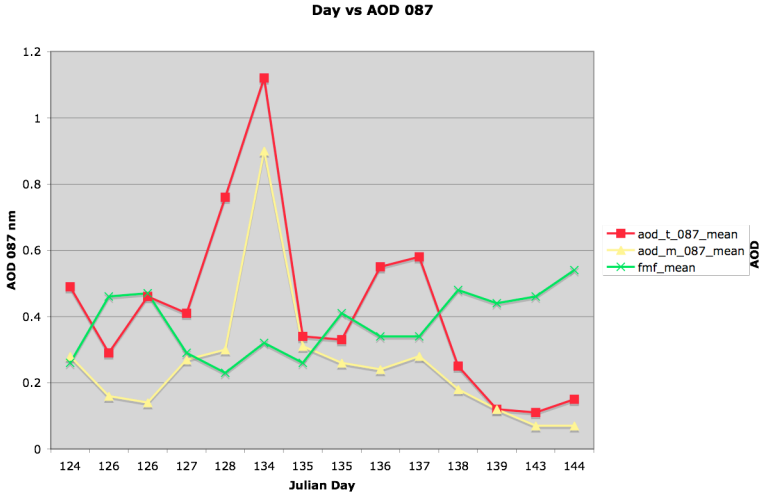
Statistics: correlation: -0.0291141
slopes linear regression : -0.0282723
intercepts: 11.4770

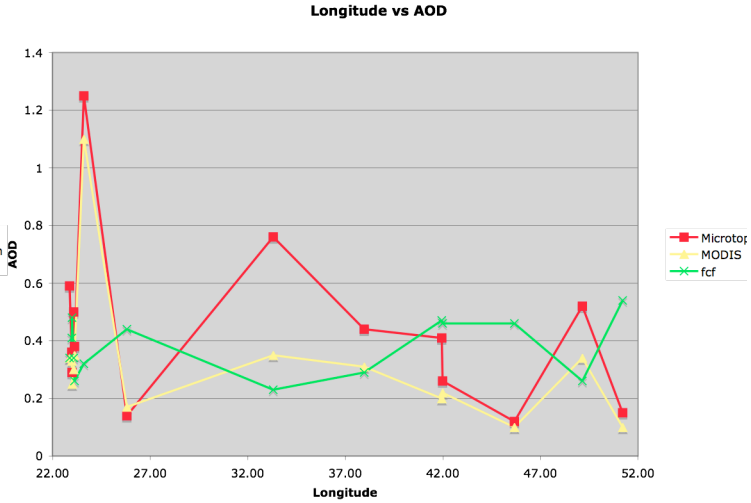

aod_m_047_mean : Microtops vs MODIS
AOD 047 MODIS
AOD 047 Microtops


aod_m_055_mean: Microtops vs MODIS
AOD MODIS
AOD Microtops


aod_m_067_mean: Microtops vs MODIS
AOD 067 MODIS
AOD 067 Microtops


aod_m_087_mean: Microtops vs MODIS
AOD 087 MODIS
AOD 087 Microtops


Day vs AOD 087
AOD 087 nm
Julian Day
aod_t_087_mean
aod_m_087_mean
fmf_mean


Longitude vs AOD
AOD
Longitude
MODIS
fcf

Summary of Results

- Comparisons of measurements of Microtops and AERONET sunphotometers to MODIS aerosol retrievals:

  > Study the validity of MODIS AOD retrievals
  > MODIS-derived AOD values agree better with AERONET than Microtops at all wavelengths
  > Correlation decreases with increasing size of boxes, indicating spatial variability is important
  > Higher Microtops AOD values show discrepancy against MODIS AOD retrievals require further investigations (such as MODIS aerosol models, satellite geometry, etc.)

  — Feedbacks to MODIS algorithm in regard to nonsphericity (size distribution) and absorption (chemical composition)

Future Work

- Investigate changes of aerosol optical properties during transport by following the outbreaks of dust plumes.
- In the late summer of 2006 (August 15-September 15), NASA conducted an aircraft campaign (known as NAMMA) using DC-8 with a number of aerosol sensors onboard to measure the vertical profiles of aerosol extinction, size, and single scattering albedo.
- These vertical distributions of aerosol properties together with the near surface measurements can be used to evaluate its impacts on microphysical processes.

- Important for developing more accurate Earth system models with the ability to characterize and predict the effects of dust on microphysical processes.
- Analysis:

— aerosol optical properties including optical depth, effective particle size, single scattering albedo at and around AERONET sites (Cape Verde, Dahkar, Santa Cruz - Tenerife, Izana, and Puerto Rico)

—Along the tracks of the AEROSE

—Surface aerosol measurements at near the source versus those in the downwind.

—Using the validated satellite aerosol retrievals (with estimated errors)

•Important for developing more accurate Earth system models with the ability to characterize and predict the effects of dust on microphysical processes.

Acknowledgements

- **GEST / JCET**
- **NASA**
- **Dr. Allan Chu**
- **Dr. Vernon Morris**
- **NOAA- Center of Atmospheric Science (NCAS)**
- **Dr. Nicholas Nalli, Dr. Belay Demoz**
- **Valerie Casasanto**
- **Cathy Newman**
- **GEST summer students**

Ms. Tamil Maldonado-Vega & Dr. D. Allan Chu