Chesapeake Bay AOT comparisons between AERONET CIMEL measurements and ocean color products from MODIS-Aqua and SeaWiFS

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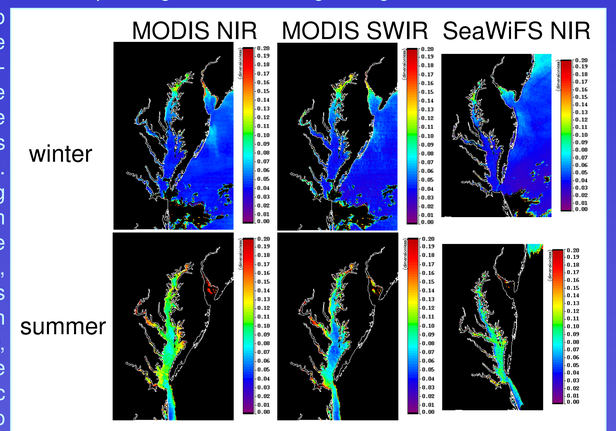
CHESAPEAKE BAY PROGRAM

The Chesapeake Bay Program (CBP) is a multi-state, multi-agency consortium (MD, VA, PA, DC, Federal EPA) dedicated to the monitoring and restoration of the watershed. The Ocean Biology Processing Group (OBPG) and other collaborators (University of Maryland, Old Dominion, NOAA Coast Watch) are working to augment the CBP field campaign with geophysical products from satellite remote sensing, evaluate the quality of those products for operational monitoring of climactic and anthropogenic impacts on the Bay, and investigate alternate atmospheric models and derived product algorithms for improving the reliability of remote sensing observation in this complex environment.

OCEAN COLOR

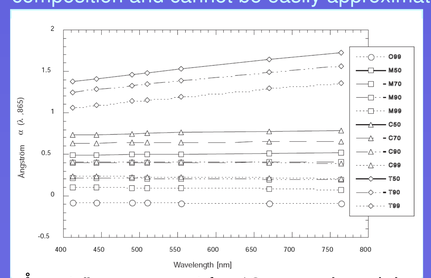
Space imagery is provided by ocean color sensors, MODIS and SeaWiFS. These sensors measure the visible (VIS) and near-infrared (NIR) radiance exiting the top of the atmosphere, $L_t(\lambda)$, with detectors operating within wavelength ranges and accuracies especially suited to extract oceanic surface properties. Semi-analytical algorithms are used to retrieve the portion of $L_t(\lambda)$ that exits the upper sea layer. These water-leaving radiances are applied in turn to estimate surface geophysical parameters, such as concentrations of the phytoplankton pigment chlorophyll-*a*, C_a. In the course of the process, atmospheric properties are also extracted, like aerosol optical thickness, AOT.



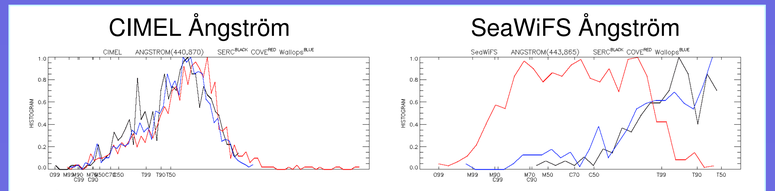
AOT_{870} images for same-day sensor coverage

ATMOSPHERIC CORRECTION

A satellite observes both oceans and the atmosphere. The atmosphere contributes approximately 90% of the measured signal in the blue-green spectral range and must be accurately modeled and removed. Atmospheric contribution comes from the gaseous absorption, molecular scattering, and from scattering and absorption by aerosols. Out of these contributors, the aerosols significantly vary spatially, temporally, in size and composition and cannot be easily approximated. As a part of the atmospheric correction, a set of 12 bimodal lognormal aerosol particulate distributions are used for the operational processing of MODIS and SeaWiFS data. These distributions are constructed from Shettle and Fenn's (1979) tropospheric, coastal and maritime models with varying degrees of atmospheric humidity. These models work well in estimating the atmospheric correction over most of the open ocean that is free from dust and smoke aerosols.



Ångström exponent for 12 aerosol models



Ångström histograms across 12 aerosol models (SERC, COVE, Wallops)

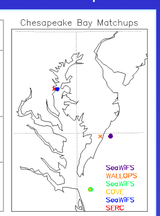
AERONET CIMEL DATA

Level 2.0 AERONET data used in this analysis was

- pre and post field calibrated
- automatically cloud cleared
- manually inspected
- observations within an hour of the satellite overpass were averaged

There are three AERONET sites with established atmospheric measurements over the Chesapeake Bay, Smithsonian Environmental Research Center (SERC), Chesapeake Light Tower (COVE), and Wallops.

name	location	PI
SERC	N 38 52' 58'' W 76 30' 00''	Jay Herman Maria Tzortziou Gordon Labow
COVE	N 36 53' 60'' W 75 42' 36''	Brent Holben
Wallops	N 37 56' 31'' W 75 28' 30''	Brent Holben

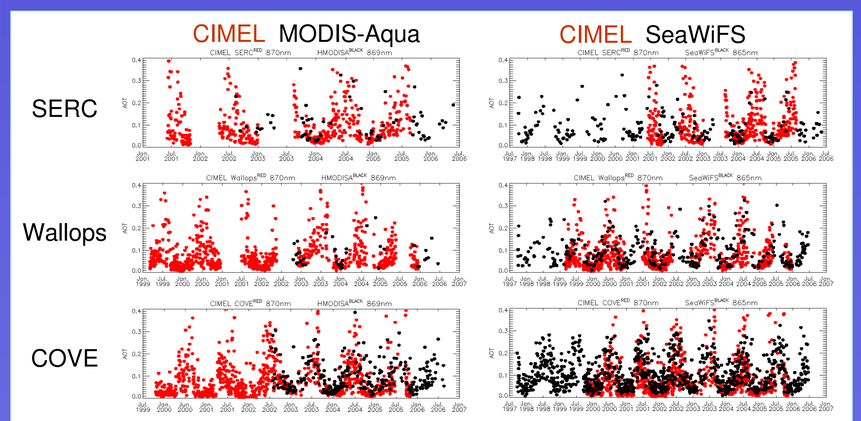


MODIS-Aqua and SeaWiFS DATA

A time series of satellite data was processed using the operational algorithm, where aerosol models are selected based on the reflectance in two NIR channels. For this algorithm to work in coastal waters, the NIR reflectance contribution associated with backscatter from the water must be estimated. Two approaches were investigated:

- **NIR correction** – conventional iterative NIR correction based on modeling of absorption and backscattering in the NIR due to particulates, colored dissolved organic matter, and detritus (Stumpf *et al.*, 2003)
- **SWIR correction** – trial NIR band correction based on characterizing aerosol contribution at MODIS SWIR range (Wang and Shi, 2006)

For two AERONET sites, SERC and Wallops, satellite coverage had to be shifted onto the Bay to obtain corresponding ocean color observations.



CIMEL and satellite AOT_{870} time series for the three sites

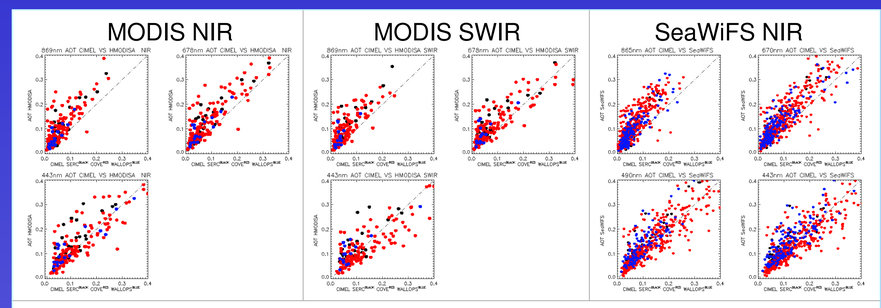
MATCHUPS

To create satellite and CIMEL matchups, the following criteria were applied:

- time difference up to 1 hour
- coverage within 3 km radius
- coefficient of AOT variation within the radius less than 0.5
- pixel masks: ATMFAIL, LAND, HILT, HISATZEN, STRAYLIGHT, CLDICE, COCCOLITH, LOWLW, CHLWARN, CHLFAIL, NAVWARN, MAXAERITER, ATMWARN, HISOLZEN, NAVFAIL, FILTER, SSTWARN, SSTFAIL, HIGLINT
- minimum number of pixels within the radius meeting the conditions more than 30%
- pixels within the given radius and meeting the above criteria were averaged

AOT VALIDATION

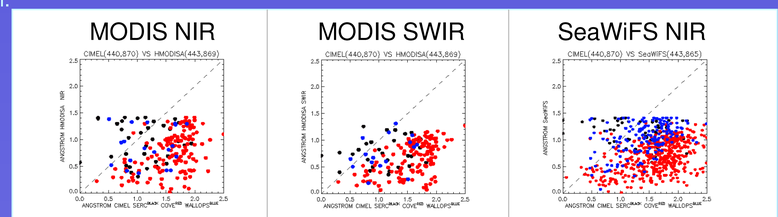
The objective of the current analysis is to estimate the effectiveness of the atmospheric correction and the 12 aerosol models in the coastal regime of the Chesapeake Bay. This is achieved by comparisons of AOT with field measurements obtained over the Bay from ground CIMEL radiometers. CIMEL instruments automatically track Sun position and collect direct sky Sun measurements with a 1.2^0 full field of view every 15 min at 340, 380, 440, 500, 675, 870, 940, and 1020nm. The direct Sun extinction measurements are used to compute aerosol optical thickness at each wavelength. The CIMEL AERONET data create an unrivaled opportunity to validate satellite observations over the Bay. It will also enable the construction of regional aerosol models for the Bay for the ocean color atmospheric correction. The models will make possible specialized local processing of the Chesapeake Bay site and more accurate resolution of its surface phenomena.



AOT scatter plots CIMEL vs. SATELLITE (SERC, COVE, Wallops)

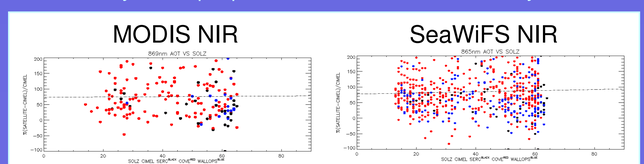
CONCLUSIONS

- AERONET CIMEL and satellite AOT time series exhibit similar temporal trends over the Chesapeake Bay.
- Scatter plots of AOT show that at the NIR wavelength, about 870nm, satellite values are on average 50% higher than those from CIMEL. This difference becomes smaller towards shorter VIS wavelengths and around 440nm satellite AOT matches CIMEL quite well. These discrepancies in VIS and NIR comparisons may indicate that the satellite processing either selects invalid aerosol models over the Bay, perhaps due to NIR surface contribution, or that the 12 models are not representative of aerosols in this region.



Ångström exponent scatter plots CIMEL vs. SATELLITE (SERC, COVE, Wallops)

- The 12 aerosol models do not have the range of the Ångström exponent exhibited by CIMEL AOT measurements. The peak of CIMEL Ångström, 440/870nm, for the Bay falls around 1.5, indicating smaller particles, which is the maximum for the 12 models bounded by the tropospheric aerosol with 50% humidity.



Independence of the solar geometry (SERC, COVE, Wallops)

- Further results show that the differences between satellite and CIMEL AOT values are independent of the solar zenith angle and of the sensor viewing geometry.
- The results are not notably improved by using the trial SWIR correction.
- The following work will create aerosol models better suited for the Bay's environment.