Assessing MODIS Aerosol Products Using AERONET Ground Measurements

Jing Li[1, 2], Barbara E. Carlson[2] and Andrew A. Lacis[2]

1. Department of Earth and Environmental Sciences, Columbia University, New York, NY
2. NASA Goddard Institute for Space Studies, New York, NY
Contact: jl2862@columbia.edu

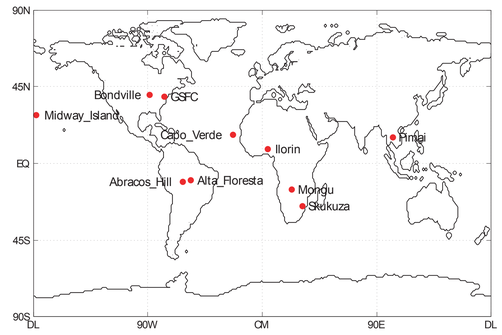
Introduction

MODIS aboard Terra and Aqua provides aerosol products including Aerosol Optical Depth (AOD) at several wavelengths, as well as Angstrom Exponent (AE) which is an indication of aerosol size. The AOD product has been extensively validated and algorithmic changes have been made to improve the accuracy of the AOD retrievals. Changes for MODIS Collection 5 included a new surface reflectance parameterization, aerosol optical models and improved assumptions relating how the 2.12 μm channel relates to surface and surface properties. Aerosol size distribution is also crucial in studying their climate effects, especially when using climate models. Yet it is still a poorly constrained quantity. Here we assess the accuracy of the MODIS Angstrom Exponent and AOD products using AERONET ground measurements. Since the accuracy of AE depends on the magnitude of AOD, it is necessary to simultaneously consider both AOD and AE. Here we report the results of our investigation for 10 AERONET stations representing six different aerosol types. These locations have been chosen based on aerosol type, differences between MODIS and AERONET retrievals and illustrate the dependence of the MODIS AE and AOD products on the details of the retrieval algorithm.

Data and Method

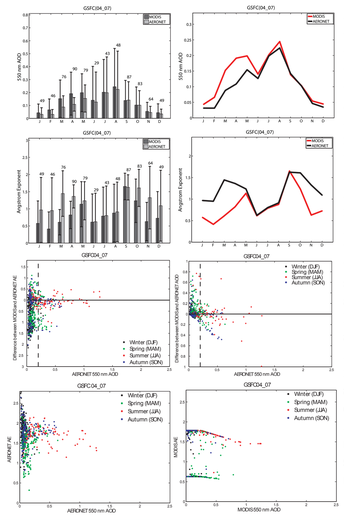
In this study, we use Version 2, Level 2.0 quality assured all points AERONET AOD and Angstrom Exponent data. The MODIS data are collection 5, level 2 land and ocean AOD and AE data from both Terra and Aqua. For each site we have examined all of the data. In this poster, representative years have been selected for illustration purposes. A primary factor in selecting the year is the number of colocated measurements available and overall data quality. In order to select colocated MODIS and AERONET data, we adopted the following strategy:

1. **AERONET AOD that is obtained within +/- 15 minutes of the MODIS overpass time is selected and interpolated to get 550 nm value using the Angstrom relationship;**
2. **At the corresponding MODIS overpass time, we select pixels that lie within +/- 0.25 degree of the AERONET station and calculate their mean and standard deviation;**
3. **We select the five nearest pixels that lie within mean +/- standard deviation, and calculate their distance–weighted average to approximate MODIS data at the AERONET station.**

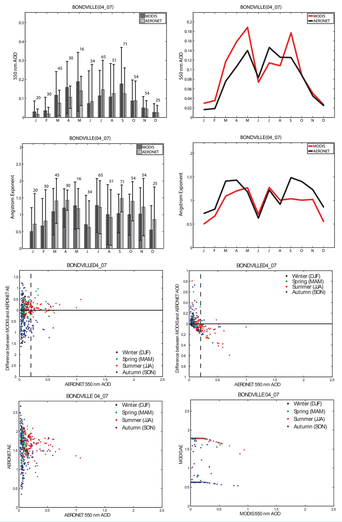


Locations of AERONET stations used in this study

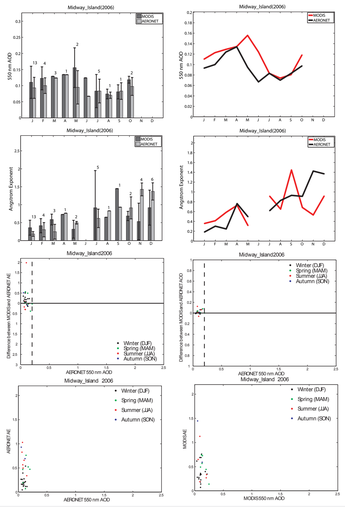
1. Urban/Industrial Aerosols: GSFC and Bondville



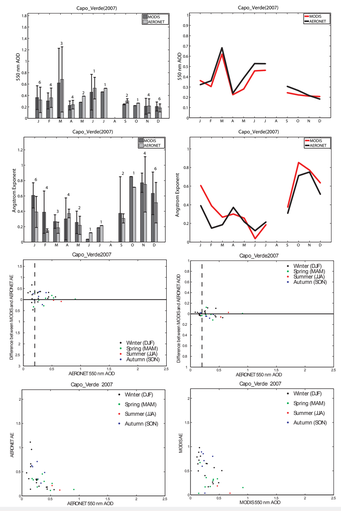
MODIS AOD agrees well with AERONET for both sites, especially during the summer. The bar plots of colocated AE show agreement typically within +/- the standard deviations of the data. Comparatively larger differences are observed in the seasonal variation. Over GSFC, the difference between MODIS and AERONET AOD show that while MODIS and AERONET generally agree for the summer months, the spring and autumn AOD values are biased low. The same comparison for Bondville reveals that MODIS tends to underestimate AOD when AOD is greater than 0.2 during spring, summer and fall. The large spread in the values of AE for low AOD shows the effect of uncertainties in both the MODIS and AERONET retrievals with small aerosol loading. Examination of the difference between MODIS and AERONET AE as a function of AERONET AOD reveals systematic seasonal differences for both GSFC and Bondville that are more clearly illustrated through the comparison of the variation of AE with AOD for MODIS and AERONET (lower panels) which strongly suggest issues with the MODIS algorithm. The seasonal disagreements may be caused by errors in the surface albedo specification in MODIS retrievals. Further examination shows that while there is some agreement between the MODIS and AERONET variability of AE with AOD for summer, the behavior of the MODIS AE in Spring is unlike that found in AERONET. Suggesting inadequacies in the seasonal model of aerosol properties used in the MODIS aerosol processing. And part of this difference is from the different relationship between AE and AOD for AERONET and MODIS (bottom two panels). The MODIS pattern is more related to aerosol size parameterization in the aerosol model and suggests that additional refinements to the MODIS algorithm may be warranted to minimize the seasonal bias in AOD and AE.



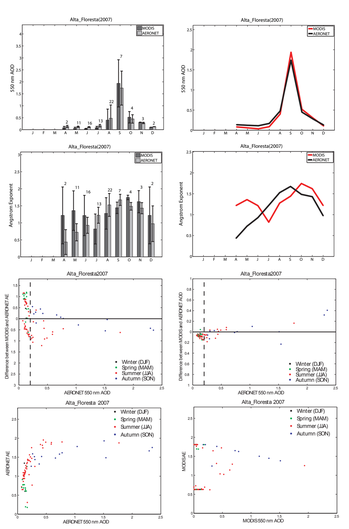
2. Aerosols over the Ocean: Midway_Island and Capo_Verde



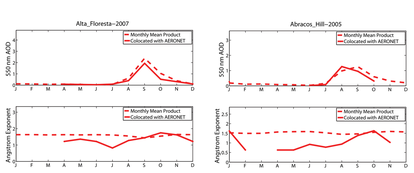
For island locations, representative of the situation of ocean, MODIS achieves good agreement with AERONET for both AOD and AE. Although there exist some differences between the seasonal variation of AE for Midway_Island, the corresponding AODs are too small for the difference to be significant. The results of this comparison for Capo_Verde, dominated by dust aerosols, indicate that the MODIS ocean algorithm is very successful in retrieving dust over dark ocean surfaces. Moreover, the dependence of MODIS AE on AOD more resembles that found in the AERONET data, and is quite different from land cases. This is mainly attributable to differences in the retrieval algorithm such as the greater number of aerosol size combinations in the ocean algorithm relative to the land algorithm.is mainly because ocean algorithm is more straight forward and has more aerosol size combinations compared to land algorithm.

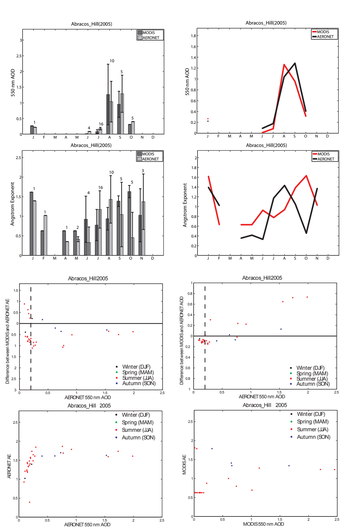


3. South America Biomass Burning: Alta_Floresta and Abracos_Hill

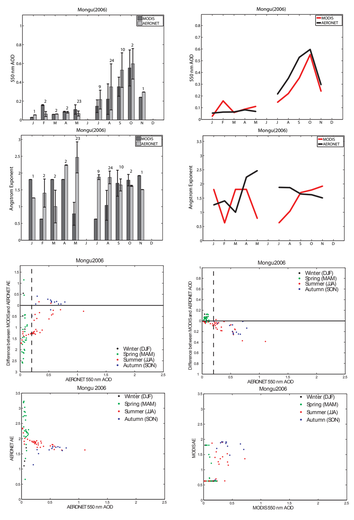


Over the two South American sites dominated by biomass burning aerosols, while MODIS AOD agrees well with AERONET, their AE differ. The difference between the AEs also decreases as AOD increases. However, even at larger AOD, MODIS still underestimates AE while overestimates AOD. We suspect that this results from cloud contamination. In the two figures shown below, we compare the MODIS level 3 monthly mean product with the monthly mean calculated using colocated data, which includes only the AERONET determined clear-sky values. We find that during the peak in the biomass burning season (September and October), MODIS AOD decreases while AE increases going from monthly mean to AERONET colocated average data suggesting that there is some degree of cloud contamination in the MODIS data that effects the AOD and AE values.

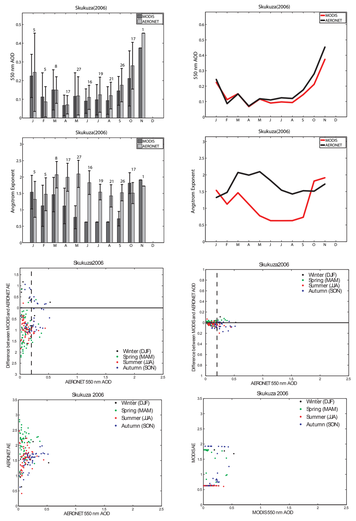




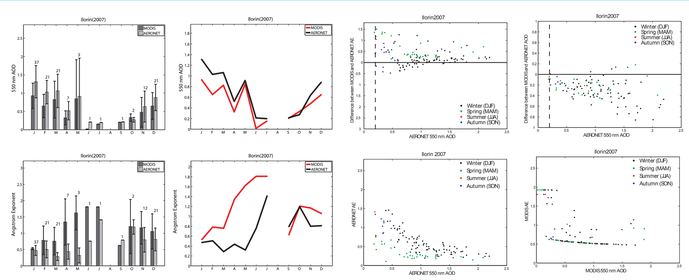
4. South Africa Biomass Burning: Mongu and Skukuza



While the bar plots for the South American sites generally agreed within the standard deviation of the data, that comparison for Mongu and Skukuza, shows greater disagreement. Here the seasonal variation of AOD generally agrees while the seasonal variation of the AEs are completely different and almost appear to be anticorrlated. During the dry season when biomass burning aerosol dominates, MODIS underestimates AOD while overestimates AE. MODIS AE is related to aerosol size parameterization, as well as absorption by black and organic carbon aerosols. These results suggest that the aerosol model adopted by MODIS land retrieval over South Africa needs improvements in order to better agree with the seasonal variation of AERONET AE.

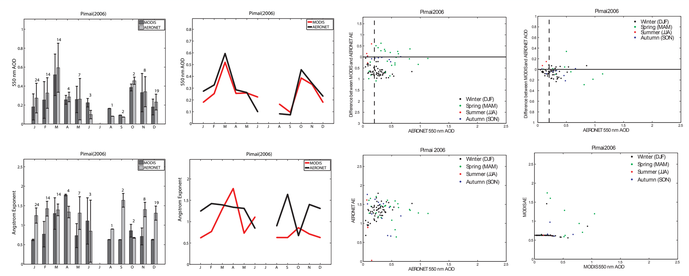


5. Mixture of Dust and Biomass Burning over the Sahel: Ilorin



Significant difference exists in MODIS and AERONET AOD and AE at Ilorin. MODIS underestimates AOD, especially at higher AOD values. Although the difference between the AEs tends to approach zero as AOD increases, significant overestimation in MODIS is still observed. Ilorin is located in the Sahel, and is affected by both windblown dust from the Sahara desert and biomass burning aerosols during the dry season from November to February. Studies [*Kim et al.*, 2009] have shown that during this time period, biomass burning aerosols are transported from the south and brought upward to a 2-5km height while dust are mostly concentrated near surface (to 1.5 or 2km). Here, due to the more complicated layered aerosol structure, it is possible that MODIS underestimates aerosol loading because some dust are not observed or mistaken as the surface. Since biomass burning produces small particles with larger AE, the AE is thus overestimated by MODIS.

6. Mixture of Biomass Burning and Industrial Pollution over SE Asia: Pimai



Over Pimai, the MODIS and AERONET AOD agree well with only slight underestimation in MODIS. However, their AE variations show different characteristics. The sharp decrease in October of AERONET AE might arise from errors or problems for a certain channel in the data. MODIS tends to underestimate AE during most times, especially winter and spring. Similar to South Africa, this location is alternatively influenced by biomass burning and industrial pollution. The comparison of the variation of AE with AOD (right-hand panels) shows that while the spring values of AE overlap, the MODIS AE are much lower than the AERONET values for all other seasons, independent of AOD, strongly suggesting seasonal problems with MODIS aerosol model.

Conclusions

1) While the MODIS aerosol optical depth product generally agrees well with AERONET measurements, comparatively larger differences are observed in the Angstrom Exponent;
2) At urban/industrial pollution sites, the difference between MODIS and AERONET AE depends on the magnitude of AOD and tends to decrease as AOD increases;
3) MODIS AE agrees with AERONET values over the oceans only with small biases at low aerosol loading;
4) MODIS overestimates AOD while underestimates AE over South America, suggesting possible problems due to cloud contamination that are also indicated through the comparison of monthly mean and colocated (AEROENT determined clear) data;
5) MODIS AE seasonal variation significantly differs from AERONET over South Africa and Pimai (SE Asia), even with large aerosol loading, indicating the need to improve the description of aerosol types used in MODIS retrieval for smoke and developing world urban aerosols;
6) Over the Sahel, the complex vertical distribution of the aerosol may be contributing to the MODIS/AERONET differences as MODIS tends to underestimate AOD but overestimates AE.

Future Work

1) Extend this comparison to include additional sites and other data to more fully investigate the nature of the differences and separate aerosol model and surface reflectance model effects;
2) Further investigate the effect of cloud contamination over South America and its influence on the study of global climate using satellite data;
3) Further study the characteristics of biomass burning aerosols over South Africa and Southeast Asia, especially aerosol size distribution and single scattering albedo, in order to provide information to improve MODIS retrieval;
4) Study the effect of different height distribution of dust and biomass burning aerosols over the Sahel region, using lidar data sets such as CALIPSO;
5) Long-term comparisons on the trend of global AOD and AE.