Retrieving the Height of Smoke and Dust Aerosols by Synergistic Use of VIIRS, OMPS, and CALIOP Observations

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ASHE Algorithm

Introduction

Aerosol Single scattering albedo and Height Estimation (ASHE) algorithm was first introduced in Jeong and Hsu (2008) to provide aerosol layer height as well as single scattering albedo (SSA) for biomass burning smoke aerosols. One of the advantages of this algorithm was that the aerosol layer height can be retrieved over broad areas, which had not been available from lidar observations only. The algorithm utilized aerosol properties from three different satellite sensors, i.e., aerosol optical depth (AOD) and Ångström exponent (AE) from Moderate Resolution Imaging Spectroradiometer (MODIS), UV aerosol index (UVAI) from Ozone Monitoring Instrument (OMI), and aerosol layer height from Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP). Here, we extend the application of the algorithm to Visible Infrared Imaging Radiometer Suite (VIIRS) and Ozone Mapping and Profiler Suite (OMPS) data. We also now include dust layers as well as smoke. Other updates include improvements in retrieving the AOD of nonspherical dust from VIIRS, better determination of the aerosol layer height from CALIOP, and more realistic input aerosol profiles in the forward model for better accuracy.

Method

The algorithm utilizes the sensitivity of UVAI to AOD, SSA, aerosol type, and aerosol height. The SSA or height can be retrieved if the other parameters are constrained by other data sources.

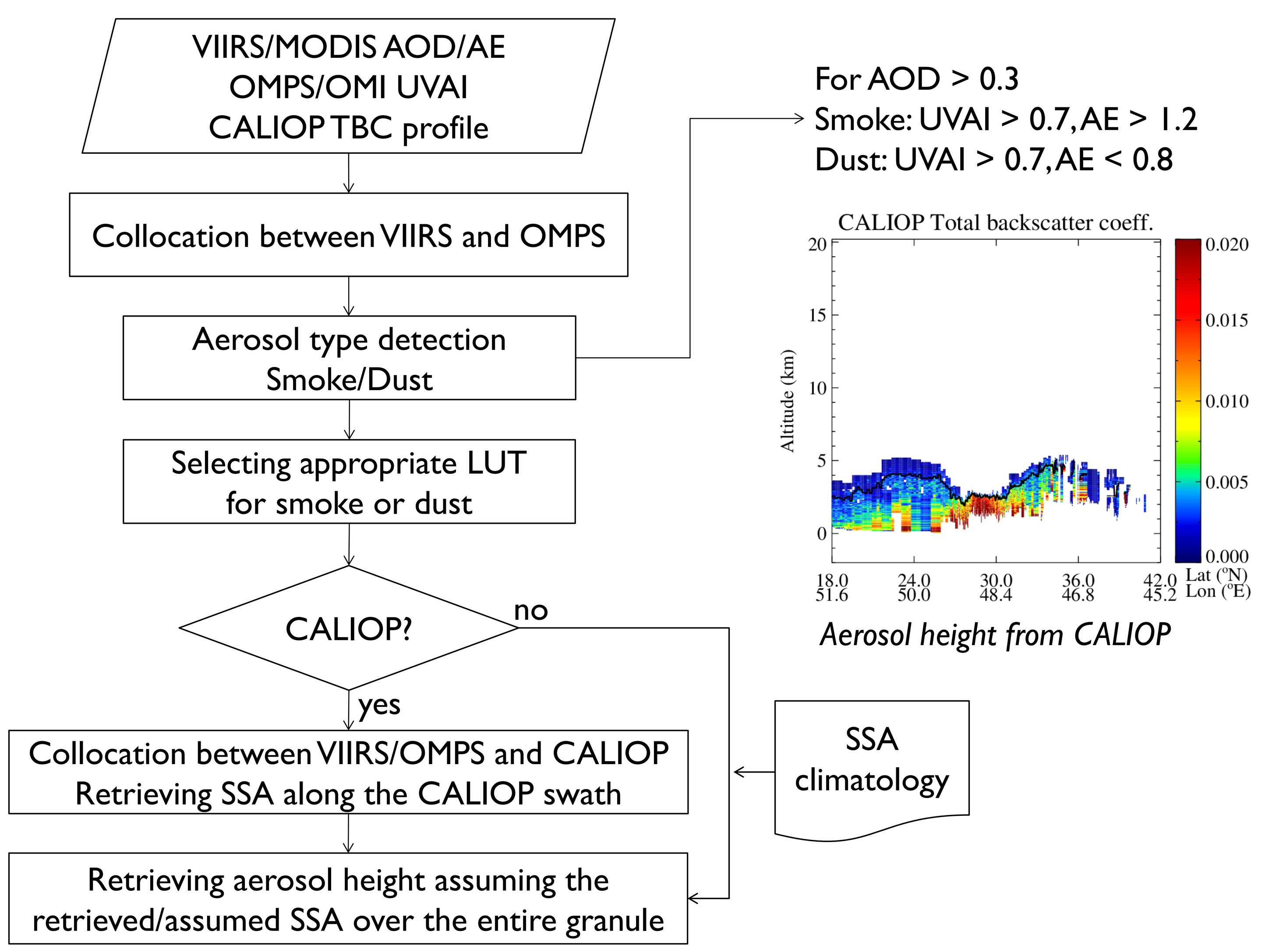

Figure 1. Flowchart of the ASHE algorithm.

e-Deep Blue aerosol optical depth

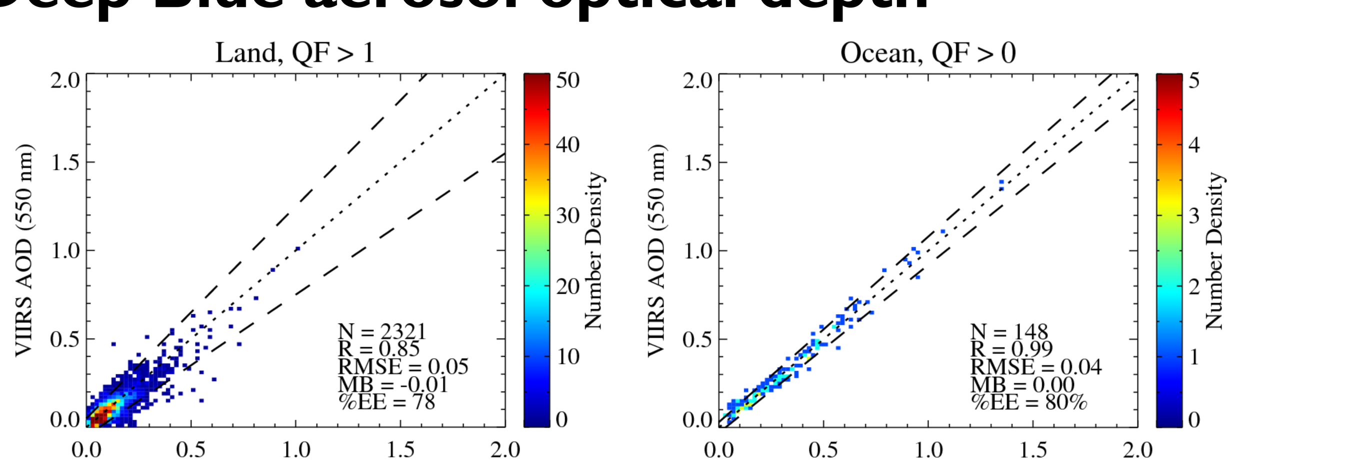

Figure 2. Comparison of AOD from VIIRS e-Deep Blue algorithm (Hsu et al., 2013) over vegetated surfaces in the U.S. (left) and from an over-ocean research algorithm including nonspherical dust aerosol models at Capo Verde (right) against AERONET observations for a period from March, 2012 to October, 2013. A beta version of the VIIRS e-Deep Blue aerosol product is planned to be released in 2015. The operational e-Deep Blue over-ocean algorithm will include the nonspherical dust models used in the research algorithm.

Case Study

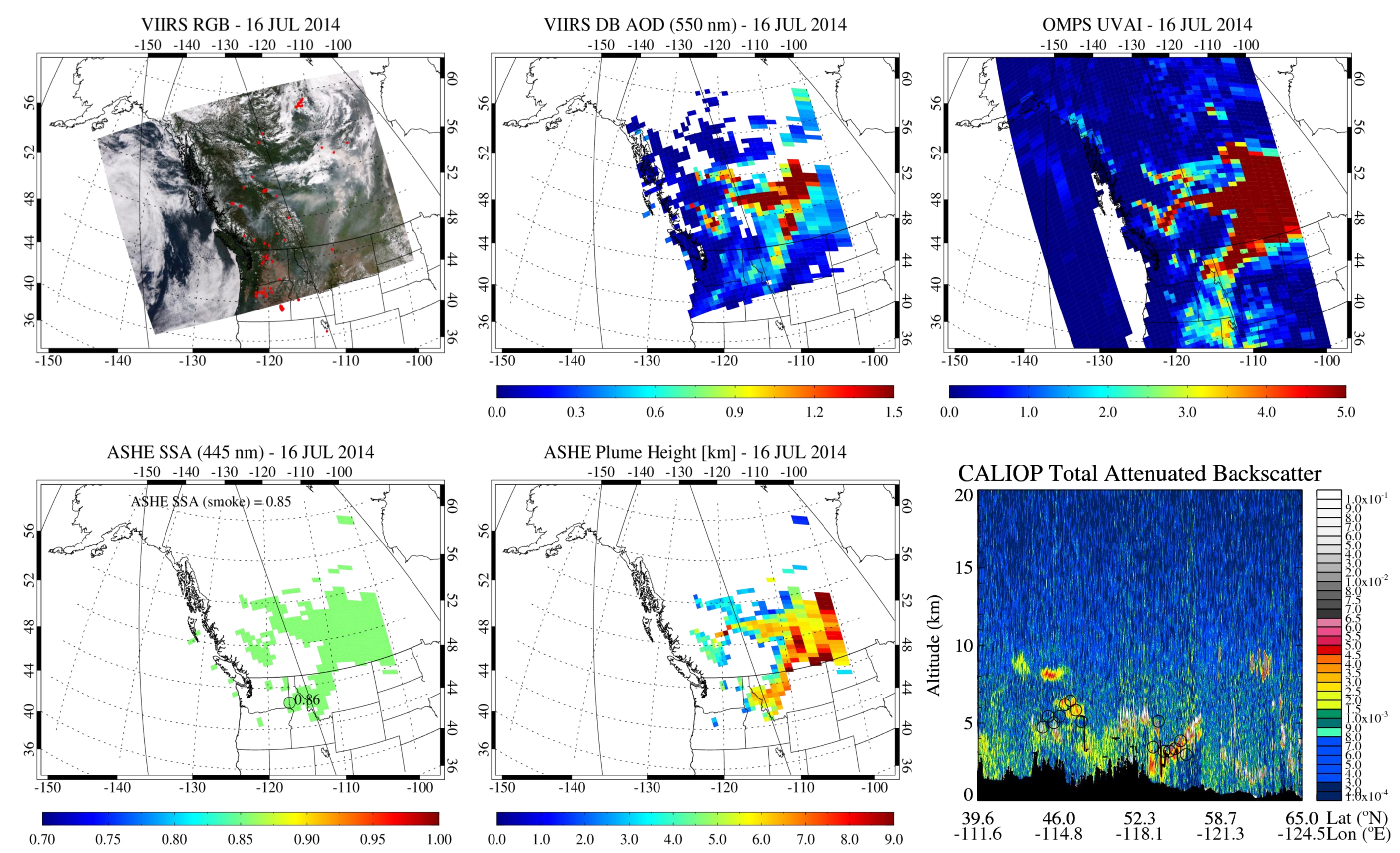

Figure 3. Application of the ASHE algorithm to a smoke event observed over North America on 16 July 2014. The median SSA retrieved in the VIIRS-OMPS-CALIOP collocated pixels is 0.85, which is comparable to that from the level 1.5 AERONET inversion data at Rimrock site (0.86). The retrieved aerosol layer height generally ranges from 3 to 6 km along the CALIOP path. Smoke at higher altitude (> 9 km) is also detected outside of the CALIOP path.

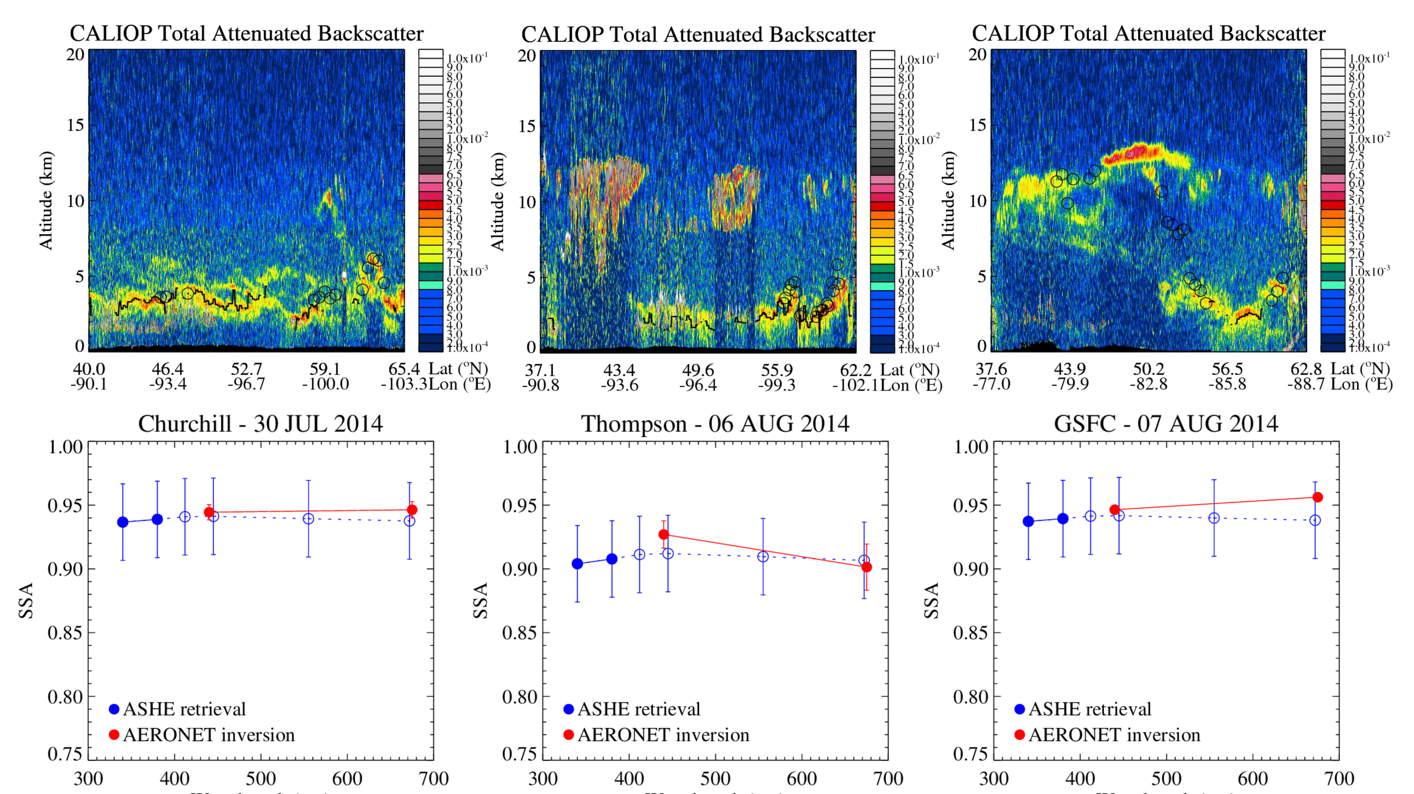

Figure 4. Comparison of the aerosol layer heights between the ASHE algorithm and CALIOP observations for the smoke layers over North America (upper), and the corresponding SSA retrievals compared with the AERONET inversion data (lower) for three different days. The error bars in the SSA from ASHE algorithm show 0.03 uncertainty, and those from AERONET represent temporal standard deviation within 2 h of VIIRS observation.

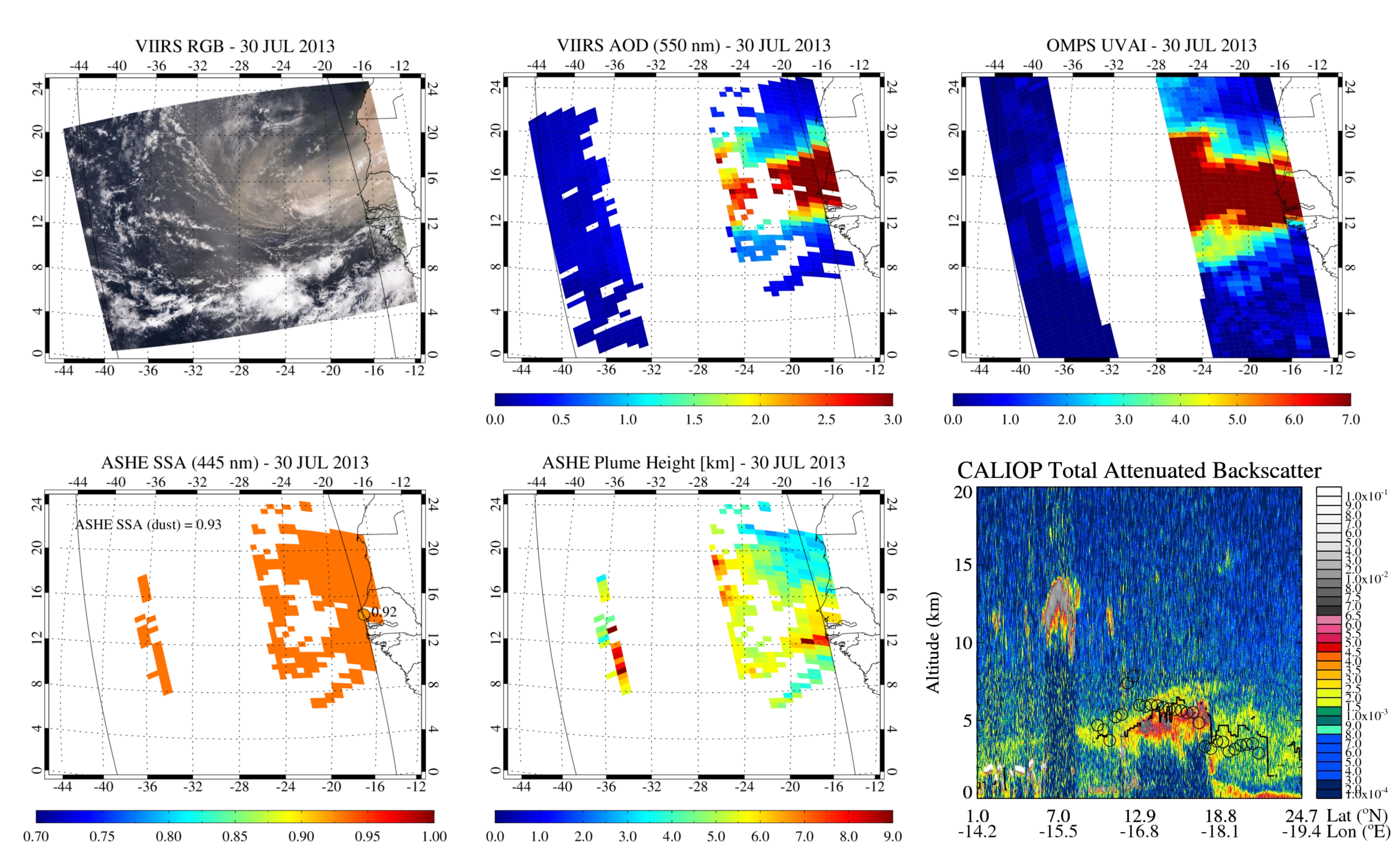

Figure 5. The same as Figure 3 except for a Saharan dust event observed on 30 July 2013. The median SSA retrieved in the VIIRS-OMPS-CALIOP collocated pixels is 0.93, which is comparable to that from the level 2.0 AERONET inversion data at Dakar site (0.92). The retrieved aerosol layer height ranges from 3 to 6 km along the CALIOP path. The low bias in the retrieved aerosol layer height over latitude > 18° is likely due to multiple aerosol layers.

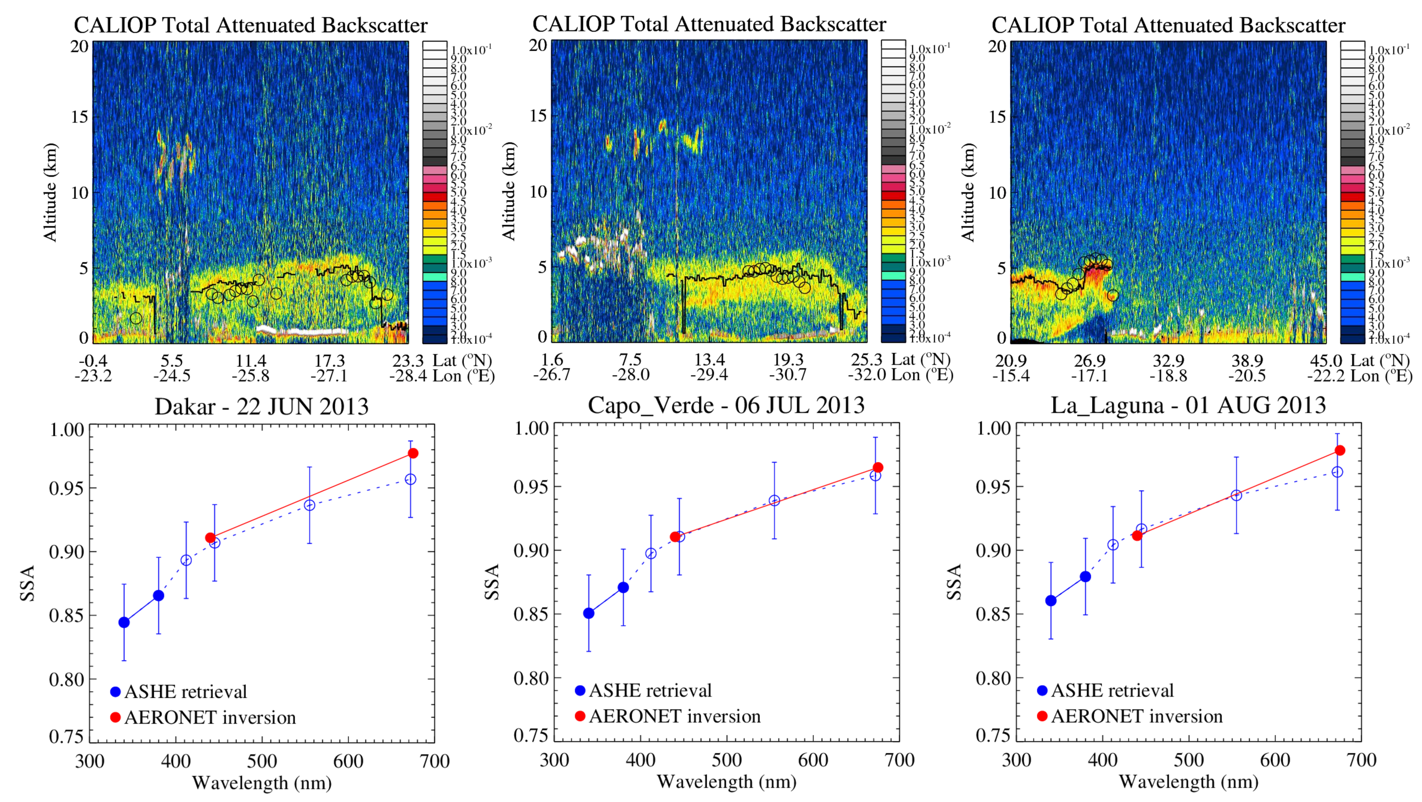

Figure 6. The same as Figure 4 except for Saharan dust layers.

Uncertainty

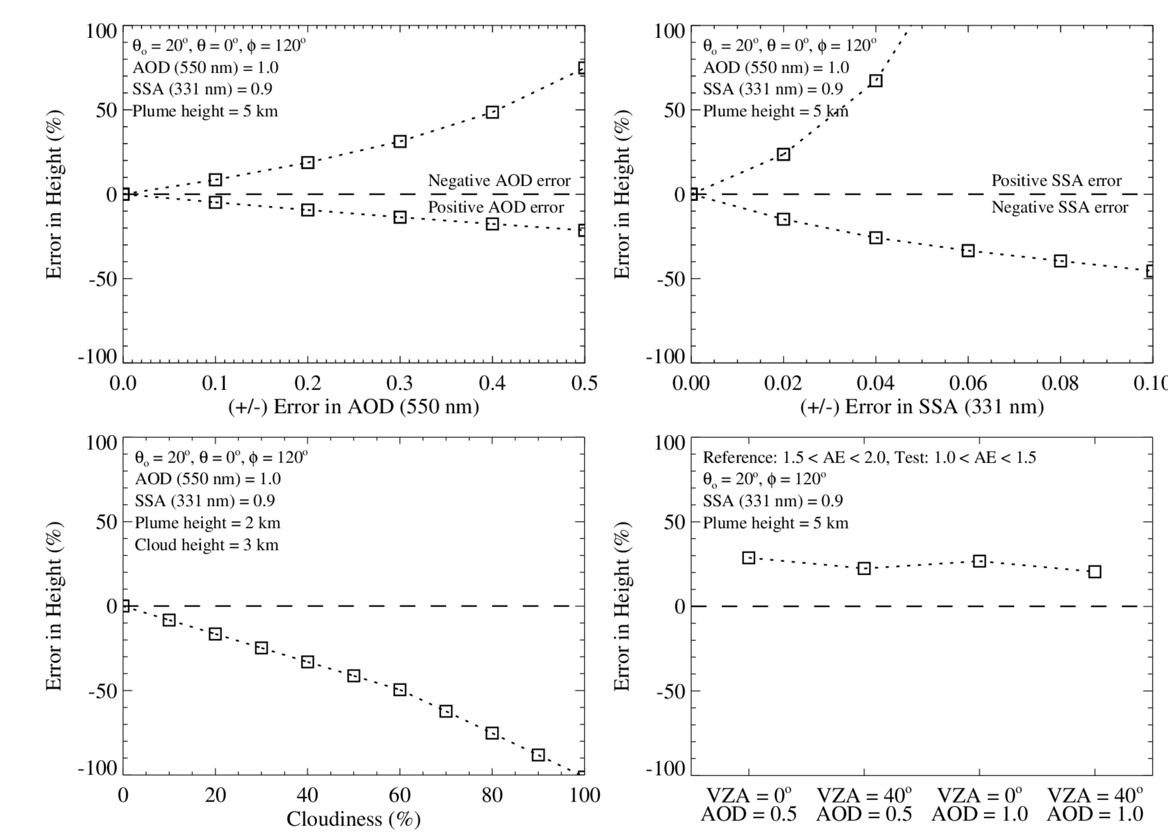

Figure 7. Estimated uncertainties in the aerosol layer height retrievals as a function of AOD, SSA, cloud fraction, and AE. 20% error in AOD can attribute to 10-20% error in the aerosol layer height retrievals. The uncertainty due to SSA can be minimized when CALIOP aerosol layer height is available. Data with high cloud fraction can be filtered or flagged as lower quality. AE dependence is planned to be implemented in the algorithm.

Conclusions

- Aerosol layer height can be retrieved over broad areas by synergistic use of VIIRS, OMPS, and CALIOP observations.
- The algorithm is stronger for large-scale, single-layered aerosol events than small-scale, multi-layered cases.
- The algorithm can be applied without CALIOP observations with a decrease in performance.
- A SSA climatology derived from the algorithm could be used to constrain the SSA for different aerosol types over various regions.
- The retrieved SSA can also be used in the e-Deep Blue algorithm for selecting appropriate aerosol models.
- Currently, only one smoke and one dust aerosol model are used; more sophisticated aerosol models are planned to be implemented for better performance.

References

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