Retrieval, Inter-comparison, and Validation of Above-cloud Aerosol Optical Depth from A-train Sensors

Hiren Jethva1,2, Omar Torres2, Pawan K. Bhartia2, Lorraine Remer3, Jens Redemann4, Stephen E. Dunagan5, John Livingston5, Yoheil Shinozuka6, Meloe Kacenelenbogen6, Michal Segal-Rosenheimer6, Rob Spurr7

1Universities Space Research Association, Columbia, MD 21044 USA, 2NASA Goddard Space Flight Center, Greenbelt, MD 20771 USA, 3University of Baltimore County/JCET, MD, USA, 4NASA Ames Research Center, Moffett Field, CA 94035 USA, 5SRIL International, Menlo Park, CA 94025 USA, 6NASA AERONET, Moffett Field, CA 94035 USA and Bay Area Environmental Research Institute, Pataluma, CA 94952

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Abstract

Absorbing aerosols produced from biomass burning and dust outbreaks are often found to overlap lower cloud decks and pose greater potentials of exerting positive radiative effects (warming) whose magnitude directly depends on the aerosol loading above cloud, optical properties of clouds and aerosols, and cloud fraction. Recent development of a ‘color ratio’ (CR) algorithm applied to observations made by the Aura/OMI and Aqua/MODIS constitutes a major breakthrough and has provided unprecedented maps of above-cloud aerosol optical depth (ACAOD). The CR technique employs reflectance measurements at TOA in two channels (354 and 388 nm for OMI; 470 and 860 nm for MODIS) to retrieve ACAOD in near-UV and visible regions and aerosol-corrected cloud optical depth, simultaneously. An inter-satellite comparison of ACAOD retrieved from NASA’s A-train sensors reveals a good level of agreement between the passive sensors over the homogeneous cloud fields.

Direct measurements of ACA as such carried out by the NASA Ames Airborne Tracking Sunphotometer (AATS) and Spectrometer for Sky-Scanning, Sun-Tracking Atmospheric Radiation Measurement (STAR) can be of immense help in validating ACA retrievals. We validate the ACA optical depth retrieved using the CR method applied to the MODIS cloudy-sky reflectance against the airborne AATS and 4STAR measurements. A thorough search of the historical AATS-STAR database collected during different field campaigns revealed five events where biomass burning, dust, and wild fires emitted aerosols were found to overlap lower cloud decks observed during SAFARI-2000, ACE-Asia 2001, and SEAC4RS-2013, respectively. The co-located satellite-airborne measurements revealed a good agreement (RMSE less than 0.1 for AOD at 500 nm) with most matchups falling within the estimated uncertainties in the MODIS retrievals. An extensive validation of satellite-based ACA retrievals requires equivalent field measurements particularly over the regions where ACA are often observed from satellites, i.e., south-eastern Atlantic Ocean, tropical Atlantic Ocean, northern Arabian Sea, South-East and North-East Asia.

The Color Ratio Algorithm

- The presence of absorbing aerosols above cloud decks reduces the amount of upwelling ultraviolet (UV), visible (VIS), and shortwave infrared radiation reaching the top of atmosphere and produces a strong color ratio effect in the spectral reflectance measurement. This is often referred to as “cloud darkening”—an effect caused by the spectral aerosol absorption.
- The CR technique employs reflectance measurements at TOA in two channels (354 and 388 nm for OMI; 470 and 860 nm for MODIS) to retrieve ACAOD in near-UV and visible regions and aerosol-corrected cloud optical depth, simultaneously.

Near-UV Retrieval Domain

- TOA reflectance OMI: 354 and 388 nm MODIS: 470 and 660/860 nm (ocean/land)
- Aerosol Model (size distribution, real/imaginary part of refractive indices, aerosol vertical profile, cloud droplet distribution (modified-Gamma), Cloud top/bottom pressure
- RT Model: VLIDORT V2.6

A priori

- Aerosol Model (size distribution, real/imaginary part of refractive indices, aerosol vertical profile, cloud droplet distribution (modified-Gamma), Cloud top/bottom pressure

Output Parameters

- Aerosol Optical Depth at 388 nm for OMI and at 660/860 nm for MODIS
- Aerosol-corrected COD

Input Parameters

- TOA reflectance OMI: 354 and 388 nm MODIS: 470 and 660/860 nm (ocean/land)
- Aerosol Model (size distribution, real/imaginary part of refractive indices, aerosol vertical profile, cloud droplet distribution (modified-Gamma), Cloud top/bottom pressure
- RT Model: VLIDORT V2.6

Results published in Jethva et al., (2014)

A-train Multi-sensor Comparison of Above-cloud AOD

• Most satellite-airborne matchups falling within the predicted uncertainties in the above-cloud AOD retrieval (≈10% in 70%)
• The co-located CR was found to be equivalent to the MODIS operational cloud product for lower AODs (ACE-Asia) or higher by more than 30% for most absorbing aerosol event of SAFARI-2000

References


