Extending MODIS Deep Blue aerosol retrieval coverage to cases of absorbing aerosols above clouds: first results

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Absorbing smoke or mineral dust aerosols above clouds (AAC) are a frequent occurrence in certain regions and seasons. Operational aerosol retrievals from sensors like MODIS omit AAC because they are designed to work only over cloud-free scenes. However, AAC can in principle be quantified by these sensors in some situations (e.g. Jethva et al., 2013; Meyer et al., 2013).

We present a summary of some analyses of the potential of MODIS-like instruments for this purpose, along with two case studies using airborne observations from the Ames Airborne Sunphotometer (AATS; http://geo.arc.nasa.gov/sgg/AATS-website/) as a validation data source for a preliminary AAC algorithm applied to MODIS measurements. AAC retrievals will eventually be added to the MODIS Deep Blue (Hsu et al., 2013) processing chain.

Representative optical models for smoke and dust aerosols

- We consider four smoke and two dust aerosol models for our simulations.
- For smoke, we use models from Sayer et al. (2004), spanning the common range of global smoke single scattering albedo (SSA) for burning near different Aerosol Robotic Network (AERONET) sites.
- For dust, we use the model of Lee et al. (2012), for models distinguished by different SSA.
- The above figures show the spectral dependence of aerosol optical depth (AOD), SSA, and asymmetry parameter (ASY) in these models for a reference 550 nm AOD of 0.5.
- Smoke models tend to have strong spectral dependence of AOD and ASY, but weak spectral dependence of SSA. For dust, the converse is true.

AAC retrieval algorithm concept

- We plan to retrieve AOD, COD and a choice between a small number of appropriate aerosol models, using MODIS bands centered near 470, 550, 670, and 865 nm, by a multispectral weighted least-square fit. For this demonstration, retrievals are performed at 1 km resolution.
- Omitting the 412/443 nm bands, which often saturate for MODIS for AAC cases, decreases ambiguities related to aerosol-cloud separation, SSA, and fine-mode aerosol fraction.
- Omitting the longer wavelengths decreases ambiguities related to cloud effective radius and altitude.
- Using synthetic data, retrieval simulations suggest <30% uncertainty on the retrieved AOD (not shown here), dependent on situation, as a result of these simplifying assumptions.
- Using this spectral range, the algorithm could also be applied to similar sensors (e.g. SeaWIFS, VIIRS, MERIS, CERES).
- PoOIs with a poor fit to measurements, low COD, or poor sensitivity to AOD, will be discarded.
- Eventually, estimates of the direct radiative effect of these AAC cases will also be calculated.

Sensitivity of MODIS-like sensor spectral bands to aerosol/cloud parameters

- We have performed extensive radiative transfer simulations of AAC situations. The plots below illustrate the relative sensitivity of various spectral bands to aerosol/cloud parameters for the case of smoke aerosols typical of central African burning (Mongu aerosol model), specifically: AOD, aerosol fine mode fraction (FMF), aerosol-cloud vertical separation, cloud optical depth (COD), cloud effective radius (CER), and cloud altitude.
- The relative standard deviation (RSD) of simulated reflectances across an ensemble of simulations holding all parameters bar one constant is shown. A larger RSD indicates greater sensitivity to that parameter for the particular wavelength and geometry. A broad distribution indicates strong contextual dependence of sensitivity.

SAFARI-2000, 13 September 2000

- SAFARI-14, aboard the University of Washington’s Concerto-580 off the coast of Namibia, spiraled over a stratocumulus deck of ~1 km altitude (based on simultaneous lidar observations) with an overlying smoke aerosol layer, beginning around 30 minutes after a MODIS Terra overpass.
- The mean (+/- standard deviation) 550 nm AOD AATS measured from near cloud-top upwards, within the green box, was 0.49 +/- 0.04. The Ångström exponent (ANG) around 1.7 is consistent with smoke.
- The corresponding AOD from our MODIS retrieval using the ‘Mongu’ aerosol model is 0.51 +/- 0.09, showing good agreement, although greater spatial variability.
- Our COD retrievals are well-correlated with the operational MODIS cod product, with a high offset of order 50% in the green box, which is as expected from the aerosol absorption given that no correction for these aerosols is presently made in the MODIS cod product.

ACE-Asia, 4 May 2001

- ACE-6 flew aboard the US NSF/UCAR’s C-130 flying between Korea and Japan. The aircraft spiraled near a stratotcumulus deck with an overlying dust aerosol layer, between around 30 minutes before and 30 minutes after a MODIS Terra overpass. No cloud height ground truth data are available, but median MODIS liquid cloud top height retrievals within this box, after filtering for quality (R. Frey), is 1 km (central 68% of data 0.75–1.75 km).
- The mean (+/- standard deviation) 550 nm AOD AATS measured from 1 km upwards, within the green box, was 0.66 +/- 0.02: the likely range is from 0.50 (if the cloud top is around 1.75 km) to 0.69 (if the cloud top is around 0.75 km). The Ångström exponent (ANG) is 0.3 is consistent with dust.
- The AOD from our MODIS retrieval using the ‘weak dust’ aerosol model is 0.62 +/- 0.06, within this range.
- The COD for much of the water cloud field was too low for the AACS retrieval, so there was a spatial mismatch between the AATS and AACS data, which may contribute to the AOD difference and variability.
- Our COD retrievals are well-correlated with the operational MODIS COD, and of similar magnitude, consistent with dust aerosols having weak absorption in the bands used for COD retrieval by the operational cloud algorithm.

References