Near-Infrared Anthropogenic Aerosol and Surface Properties from Narrow-Band Hyperspectral Satellite Measurements

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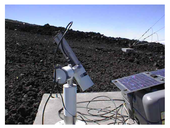
Overview

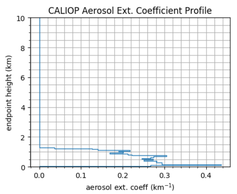
- Uncertainties in aerosol properties lead to uncertainties in our understanding of global radiative forcing
- A significant component of the uncertainty is due to direct effects by the aerosols, i.e. the direct absorption of sunlight
- Use a vector radiative transfer program by Zhai, et. Al. to simulate radiance at the top of the atmosphere
- Use hyperspectral (0.015-nm resolution) measurements of radiance, in a 14-nm-wide window in the oxygen A band, by the Orbiting Carbon Observatory-2 (OCO-2) satellite.
- Aerosol properties are approximately constant within the band, while oxygen absorption varies greatly. Information from OCO-2 channels with different oxygen absorption should allow the effects of the surface and aerosol albedos to be decoupled.
- Constrain the shape of the vertical spatial distribution of aerosols using vertical profiles of aerosol extinction from the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) on board the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite. An example of such a profile is shown.
- The two satellites flew in formation between August 2014 and September 2018, in the Afternoon Constellation (A-train), so they have many measurements that are close in space and time.
- Retrieve surface albedo, aerosol column optical thickness, effective aerosol single-scattering albedo, and other necessary parameters for the radiative transfer program to closely approximate the spectrum observed by OCO-2 in the oxygen A band.
- Compare the aerosol parameters that are found to those found by aerosol inversions by the ground-based Aerosol Robotic Network (AERONET).
- Previous comparison of perturbed radiances to instrument noise has shown that the measurements by OCO-2 in the oxygen A band should be sensitive to aerosol optical depth changes larger than 0.1, aerosol single-scattering albedo changes larger than 0.02, surface albedo changes larger than 0.05, and surface pressure changes larger than around 10 hPa. Small changes in surface pressure should be indistinguishable from instrument noise.
- Radiative transfer in the oxygen A band is performed with the help of a table of oxygen absorption coefficients (ABSCO) at various temperatures and pressures, which was compiled for the OCO-2 mission.

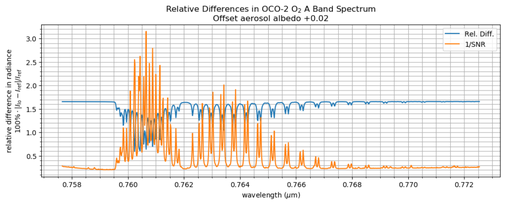
OCO-2 satellite

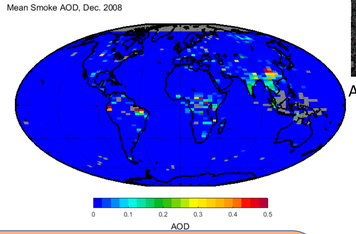
CALIPSO satellite



AERONET ground site

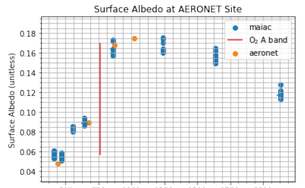


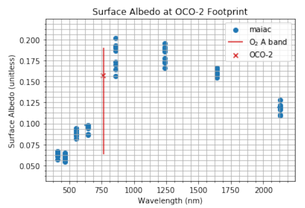


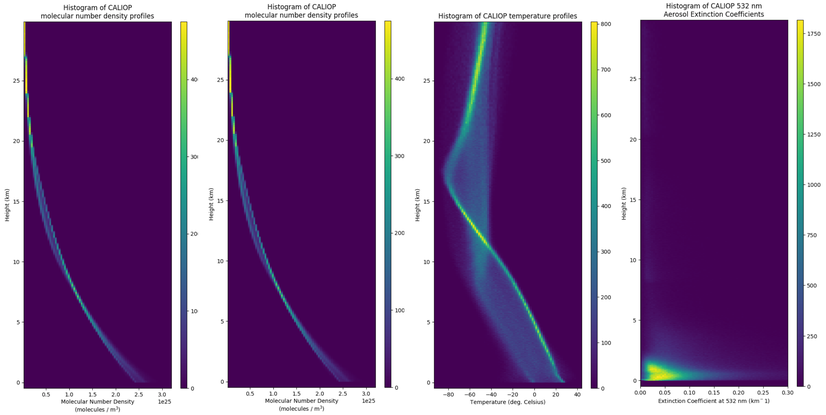


CALIOP Profiles and Surface Properties at other wavelengths

- Profile data products from CALIOP on the CALIPSO satellite provide aerosol extinction coefficients, pressure, temperature, humidity, molecular number density.
- The meteorological profiles in the CALIOP data (which are obtained from the Modern-Era Retrospective Analysis for Research and Applications, Version 2 [MERRA-2]) are used to configure the atmosphere for radiative transfer simulations
- The distributions of the meteorological profiles describe the distribution of atmospheric configurations that the radiative transfer simulation must process, and they will help specify uncertainties in the aerosols parameters that are retrieved.
- Sunlight reflected from the surface nearly overwhelms light reflected from the aerosols, so the surface must be understood before the aerosols can be understood.
- The Moderate Resolution Imaging Spectroradiometer (MODIS) on the AQUA satellite, flew in formation with OCO-2 and CALIPSO. Retrievals of surface albedo from it, e.g. using MAIAC, provide a measure of variation in the surface albedo in the region containing the satellite footprints.
- The oxygen A band occurs near the vegetative signature—a significant change in the albedo of plants across a small spectral range. This makes it impossible to interpolate spectral surface albedos from AERONET inversions, and from MODIS surface products.

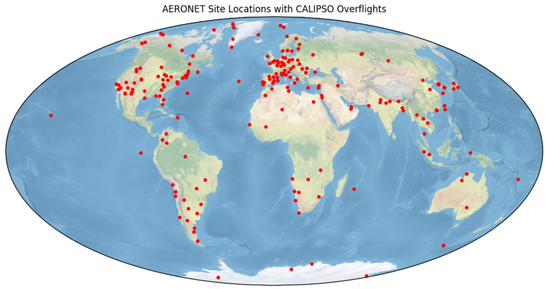


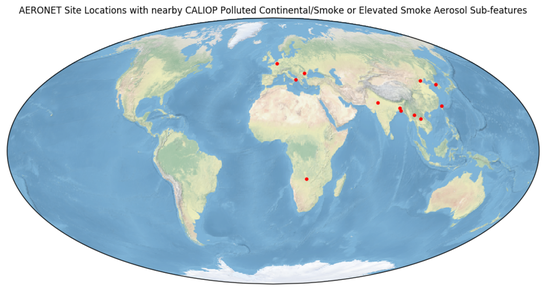




Coincident OCO-2, CALIOP and AERONET measurements

While there are plenty of ground sites over which CALIPSO and OCO-2 fly, there are only 12 over which CALIOP sees polluted continental or smoke aerosols. Between all sites there are 28 satellite overflights with AERONET measurements on the same day, of which only one at each of Bhola, Dhaka, Mongu, and XiangHe have optically thick, spatially homogeneous aerosols, with few clouds.





Selected References

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Image souces:
OCO-2: www.nasa.gov/mission_pages/oco2/images/index.html?id=357077
CALIPSO: www-calipso.larc.nasa.gov/
AERONET: www.esrl.noaa.gov/gmd/obop/mlo/programs/coop/nasa/aeronet/aeronet.html

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