Nighttime aerosol optical depth measurements using a ground-based lunar photometer

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A new capability for AERONET has emerged to obtain nighttime AODs!

In recent years it was proposed (Berkoff et al., 2011) to combine AERONET network photometer capabilities with a high precision lunar model used for satellite calibrations (USGS ROLO, see Kieffer et al., 2005) to retrieve column nighttime AODs. The USGS lunar model can continuously provide pre- atmosphere high precision lunar irradiance determinations for multiple wavelengths at ground sensor locations. When combined with measured irradiances from a ground-based AERONET photometer, atmospheric column transmissions can determined yielding nighttime column aerosol AOD and Angstrom coefficients.

Additional demonstrations have utilized this approach (see Barretto et al. 2013 & Stone et al., 2013) to further develop and validate methods and to obtain data in polar regions where extended periods of darkness occur. This new capability enables more complete studies of the diurnal behavior of aerosols, and feedback for models and satellite retrievals for the nighttime behavior of aerosols. It is anticipated that the nighttime capability of these sensors will be useful for comparisons with satellite lidars such as CALIOP/Winker et al. (2007) and MIP/MIgge & Yorks, (2014) in additional to ground-based lidars in MPLENET (Welton et al., 2001) at night, when the signal-to-noise ratio is higher than daytime and more precise aerosol comparisons can be made.

Prior Work: Initial nighttime demonstration with a “sun” photometer

Initial automated measurements started in late 2009, using a “sun” photometer that was never designed for lunar irradiance measurements. Nevertheless, this early-stage measurement combined with ROLO information demonstrated the first nighttime AODs near full-moon, and later in 2010 captured a nighttime pollution event in the Washington-Baltimore region shown here.

Nighttime pollution event: 31 May, 2010

The 31 May data captured the arrival of a pollution event in the Baltimore area. Nighttime, lunar-derived AODs agree with Lidar backscatter and solar data obtained before and after the event. NOTE: Initial 440 nm data was bad due to large air mass attenuation.

Data collection with enhanced photometer in 2013 & 2014

In this work, we present a new 9 month data record (May 2013 to Feb 2014) of nighttime AODs obtained with a prototype lunar photometer modified specifically for lunar irradiance measurements. This photometer is the same size and shape as the sun- photometers used in AERONET. Approximately 1,700 lunar irradiance measurements were obtained from May 2013 to Feb 2014 at NASA/GSFC, providing an extended set of nighttime aerosol AOD data. The plots below show a couple of short time-frame examples (Ltt: 24-hour, Rtt: 14-day) with lunar data as circles, colored by wavelength. A separate co-located sunphotometer recorded daytime data (AERONET level 1.5) and is shown with * markers in between the night observations.

Summary & Future Plans

• The lunar photometer offers a unique opportunity to validate the aerosol optical depth retrievals of CALIOP and other spaceborne lidars at night when the signal to noise ratios are highest. An experimental lunar photometer at NASA Langley could be used to take collocated measurements at CALIPSO nighttime overflights (Williamsburg VA, Duck NC).

• Further analysis of this existing nighttime data will help to assess day/night aerosol characteristics and correlation relationships with models (e.g. GEOS-5).

• Day/night capable photometers are now commercially available (Cimel Electronique) and AERONET is currently incorporating day/night capabilities at multiple sites around the globe.

• A new lunar ROLO interface has been developed by USGS for use by AERONET to enable fully automated multi-site network operations.

• The nighttime photometer that was used to collect this data-set has been relocated to NASA Langley’s CAPABLE trailer (Hampton, Virginia) and is continuing to collect nighttime AOD data. This system can potentially be transported to nighttime CALIOP overpass locations in the future.

• Although the lunar uptake is expected to limit the frequency of observations to 30%--40% compared to solar measurements, this is an attractive extension of AERONET capabilities.

References


McGee & Yorks (see: http://cats.gsfc.nasa.gov)


May 2013- Feb 2014 Data Set

On the left side, all time series data from May2013 to Feb 2014 are shown, colored lines are nighttime AODs while black * markers are co-located daytime AODs (AERONET level 1.5).

In general, magnitude and variability of AODs are larger during summer months for both day and night data. Both day and night data sets have some residual cloud contamination effects, resulting in outliers that will be further reduced once additional data quality steps are applied.

On the right side, day & night AOD distributions are shown, colored lines are nighttime AODs while black lines are the co-located daytime AODs.

The box-and-whisker plot to the lower left summarizes the day and night AOD statistics for each wavelength with median (red line), lower & upper quartile (box) 1.5*IQR (vertical lines) and outliers (* markers).

Nighttime data display lower variability than daytime for all wavelengths. Median AODs are slightly lower at night, with the exception of the 440 nm wavelength. These results are preliminary, and additional review will be needed to bound instrument bias differences between the day and night photometers as well as other factors. However, initial results generally seem consistent with the expected diurnal behavior of aerosols.

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