DSCOVR-EPIC MAIAC AOD - a Proxy for Understanding Aerosol Diurnal Patterns from space

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The Deep Space Climate Observatory (DSCOVR) spacecraft was launched on 11 February 2015 and in June 2015 achieved its orbit at the first Lagrange point (L1), 1.5 million km from Earth toward the sun. The Earth Polychromatic Imaging Camera (EPIC) onboard DSCOVR views the entire sunlit Earth from sunrise to sunset, every 1-2 hours, at scattering angles between 168.5° and 175.5° with 10 narrowband filters in the range of 317-779 nm. NASA Multiangle Implementation of Atmospheric Correction (MAIAC) algorithm, originally developed for MODIS, has been applied to EPIC data with an Aerosol Optical Depth (AOD) product at 440nm with a 10km spatial resolution. This high temporal resolution product is a unique dataset for investigating diurnal patterns in aerosols from space.

Our work analyzed the capability of the satellite-borne data to capture the aerosol diurnal variation by associating it with AERONET AOD at 440nm data over the contiguous US. We validated the DSCOVR MAIAC AOD data over 100 AERONET stations during 2015-2018, and examined the contribution of the surface reflectance and relevant acquisition angles, derived by the MAIAC algorithm, to the predicted error. We used over 180,000 hourly DSCOVR-EPIC MAIAC AOD observations with collocated with AERONET AOD observations averaged over +-30 minutes from the satellite overpass time. The AERONET and DSCOVR AOD temporal patterns show that the diurnal variation is different across US AERONET sites, with higher diurnal variation in the DSCOVR dataset in general.

Using 5-fold cross-validation by station, we developed an XGBoost prediction model to understand and correct for measurement error estimated from the difference between DSCOVR AOD and AERONET AOD. Our results show that for non-missing pairs for both DSCOVR AOD and AERONET AOD, the RMSE is higher for sites on the west side of the country which exhibits higher daily variation in the AOD data (Figure 1). Our XGBoost model reduced the RMSE from 0.12 to 0.06, with a corresponding R^2 of 0.50 (explaining half of the variance in the measurement error). Figure 2. demonstrates how the model significantly decreases the error (DSCOVR AOD - AERONET AOD). It is clear that before applying the correction (model), the error was biased (grey lines) compared to a more stable error (blue dots), especially in the higher AOD values, when the correction is applied.

We examined the contribution of each DSCOVR MAIAC-based variable to the measurement error model using Shapley Additive Explanations, a machine-learning method to interpret model predictions, and found that DSCOVR AOD has the highest impact, followed by the surface reflectance in 3 different wavelengths, and the surface reflectance solar azimuth angle.

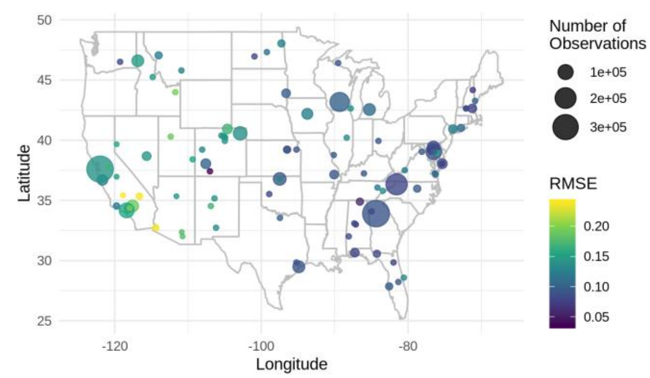

Figure 1. RMSE between hourly DSCOVR MAIAC AOD_{440nm} and collocated AERONET AOD_{440nm} (2015-2018).

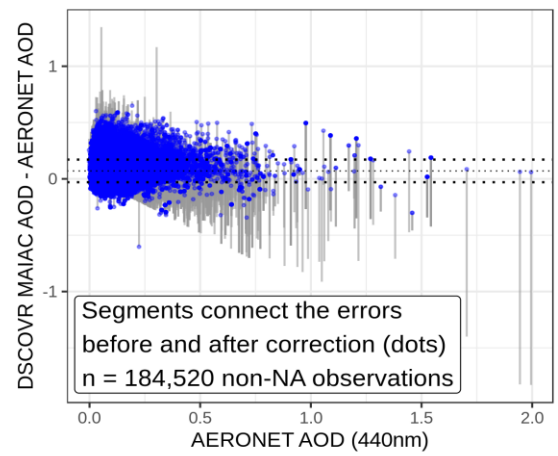

Figure 2. Error (DSCOVR MAIAC AOD-AERONET AOD) before and after applying the correction (model)

The next generation of high temporal resolution aerosol products will soon be available from Geostationary satellites over the US. This is the first study examining aerosol diurnal patterns by using remotely sensed DSCOVR MAIAC AOD data. To date, most satellite-based air quality models have been using daily AOD observations from the overpass of low earth orbit satellites. This temporal resolution may not capture the daily peak concentration of aerosols or certain short air quality events that humans are exposed to because no one breathes “24-hour averaged” air. A better understanding of diurnal variation in AOD and future modeling using more frequent retrievals has the potential to capture peak exposures, monitor rapidly changing conditions, and support improvements in exposure assessment for better evaluating the acute human health risks of particulate air pollution.