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A globally calibrated aerosol optical depth gridded dataset for improved solar irradiance predictions

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The shortwave direct normal irradiance (DNI), as well as the diffuse and global irradiance, all depend on aerosol optical depth (AOD). Recent investigations have shown that many existing modeled DNI datasets were severely biased over areas with large and variable AOD, due to errors in the latter data. Unbiased historical DNI data are of crucial importance for the siting, design and financing of large solar power projects, particularly those using concentrators. This requires unbiased AOD data at any site where such projects can be potentially built. Until now, only sunphotometer stations could provide such unbiased data, but these stations are scarce and their records are generally short. For global coverage, gridded AOD data from satellite observations may be used, but their bias is often significant. Moreover, multiwavelength AOD satellite records only exist since 2000 and are not complete over all areas.

In this contribution, a method is developed to optimally combine sources of gridded data from various satellites, calibrate them against ground truth on a regional and seasonal basis, and fill missing data points with an appropriate climatology. The monthly satellite data from MODIS (Terra and Aqua, collection 5.1), generated with or without the Deep Blue retrieval algorithm, and from MISR (version 31), are obtained at 0.5x0.5° resolution using appropriate Digital Elevation Models and scale-height corrections of AOD at 550 nm.

The ground-truth data originates from networks such as Aeronet. All monthly ground-truth data points are subjected to a scale-height correction for elevation (so that they can be directly compared to the corresponding satellite data), and to a wavelength correction to obtain AOD at 550 nm. This process is undertaken separately for summer and winter, owing to the varying magnitude of AOD, and possible seasonal variations in aerosol composition. For the same reasons, it is also undertaken on a regional basis. The importance of this is confirmed by the uneven results obtained over adjacent areas. In North America, for instance, the MISR dataset and the various MODIS datasets exhibit relatively low bias over most of the continent, but an extremely high bias over the southwestern USA and northern Mexico, possibly due to higher elevation, lower AOD, and more reflective ground.

The satellite data calibration (or “debiasing”) is performed by applying appropriate scaling factors on a seasonal and regional basis, after comparison with ground truth. To remove all missing data points during the period 2000–2011, an appropriate climatology is selected from existing sources (including chemical transport models), and is subjected to an identical calibration method.

A similar methodology is applied to obtain a complete, gridded dataset of the mean monthly Ångström exponent (AE) over the same period of 144 months.

The AOD and AE global datasets thus obtained still contain significant random errors, but their regional bias is considerably reduced compared to existing satellite data. Overall, the combination of AOD and AE from these calibrated datasets can significantly improve the derivation of 12-year time series of DNI, which is demonstrated with a few examples.