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Time Series of Aerosol Column Optical Depth at the Barrow, Alaska, ARM Climate Research Facility for 2008

Fourth Quarter 2009 ARM and Climate Change Prediction Program Metric Report

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1. Introduction

The uncertainties in current estimates of anthropogenic radiative forcing are dominated by the effects of aerosols, both in relation to the direct absorption and scattering of radiation by aerosols and also with respect to aerosol-related changes in cloud formation, longevity, and microphysics (See Figure 1; Intergovernmental Panel on Climate Change, Assessment Report 4, 2008). Moreover, the Arctic region in particular is especially sensitive to changes in climate with the magnitude of temperature changes (both observed and predicted) being several times larger than global averages (Kaufman et al. 2009). Recent studies confirm that aerosol-cloud interactions in the arctic generate climatologically significant radiative effects equivalent in magnitude to that of green house gases (Lubin and Vogelmann 2006, 2007). The aerosol optical depth is the most immediate representation of the aerosol direct effect and is also important for consideration of aerosol-cloud interactions, and thus this quantity is essential for studies of aerosol radiative forcing.

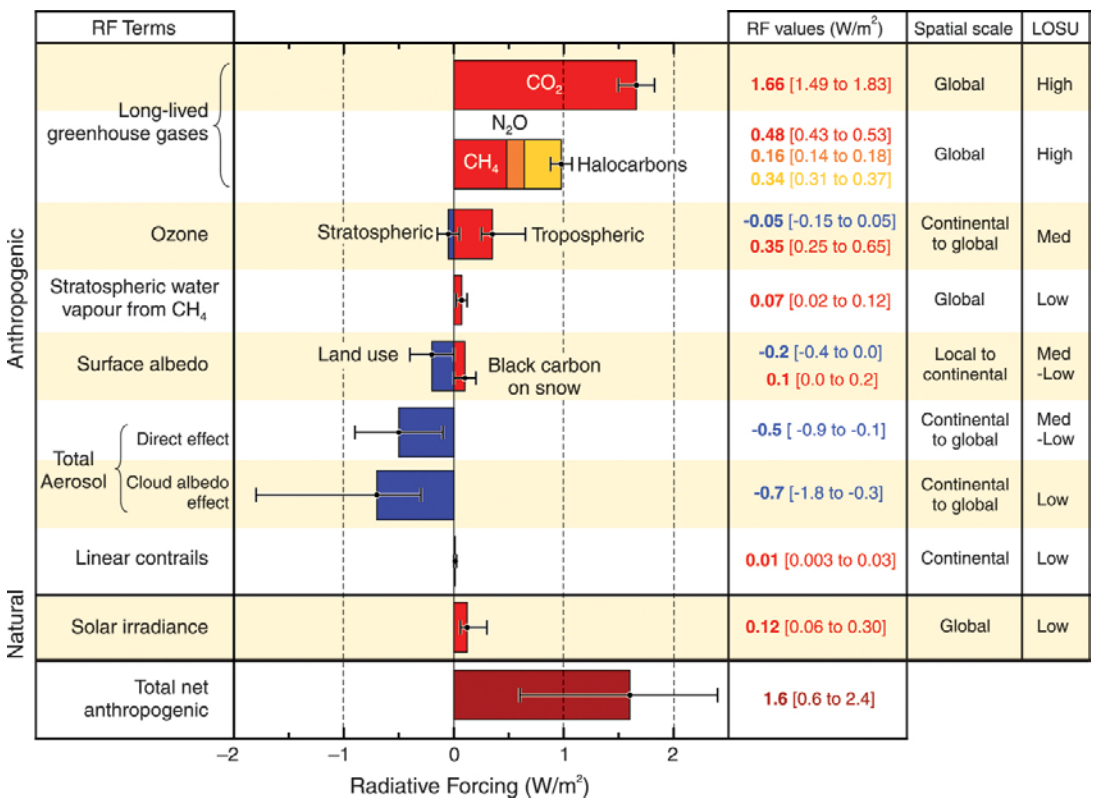

Figure 1. Radiative Forcing Uncertainties. IPCC 4th Assessment Report showing persistent uncertainties associated with aerosol direct and aerosol-cloud albedo affect that continue to dominate current forcing uncertainties.

In 2009, the ARM Program and the Climate Change Prediction Program (CCPP) were asked to produce joint science metrics. For CCPP, the fourth quarter metrics are reported in *Coupled Model Comparisons with Observations: Testing the Impact of Improved Dynamics, Physics and Resolution*. As part of the Department of Energy's participation in the International Polar Year 2007-2008, the ARM Program's metrics for the fourth quarter of FY 2009 are to, "produce and make available new continuous time series of aerosol total column depth based on one year of observations from Barrow, Alaska, during the International Polar Year." To provide this product, observations from the ground-based radiometers and sun photometers were used to determine the aerosol optical depth (AOD; Harrison, Michalsky, and Berndt 1994). These radiometric measurements of AOD were combined with surface measurements of aerosol optical properties by the Aerosol Observing Station (Sheridan, Ogren) and with local meteorology measurements at Barrow, Alaska, to yield a much more continuous record of aerosol optical depth than possible through sun photometry/radiometry alone. As validation, the resulting composite time series is compared with the less frequent aerosol optical depth measurements independently determined from a collocated AERONET Cimel sun photometer.

The time series of aerosol optical depth and related properties is provided on a 10-minute grid, an hourly grid, and as daily averages extending over a period of 229 days from March to mid-October. No aerosol optical depths are reported through the arctic winter.

2. Aerosol Optical Depth Time Series

The aerosol optical depth is a measurement of the extinction of light by the total atmospheric column of suspended aerosol. The dependence of the optical depth on wavelength is expressed by the Angstrom exponent. Taken together these terms comprise the most basic expression of the direct aerosol effect on radiation. Each of the ACRF measurement sites includes instrumentation to measure AOD based on the extinction of sunlight detected at the surface. These measurements represent firmly established techniques dating back many decades (Shaw 1979 and many others). They are however only applicable when direct sunlight is present, so overcast periods and night-time represent unavoidable data gaps despite the fact that aerosol effects (especially aerosol-cloud interactions) are still present. For short periods (1-2 hours) simple interpolation over gaps is acceptable but for longer periods more sophisticated techniques are required.

The Aerosol Best-Estimate product retrieves AOD from the Normal Incidence Multi-Filter Radiometer (NIMFR). A combination of interpolation for short intervals and multivariate linear regression for longer intervals is used to provide a more continuous time series. We have adopted a regression involving surface measurements of aerosol optical properties, relative humidity at the surface, and the mean relative humidity throughout the boundary layer to predict the AOD when direct solar measurements are unavailable. The regression has been shown to provide maximum correlation to AOD with a minimum error.

Using the technique outlined we have provided a time series of AOD extending over the sunlight period from March to mid-October 2008 with useful AOD values on nearly twice as many days as through sun photometry or radiometry alone, from fewer than 100 days to nearly 200 (See Figure 2). The AOD time series exhibits a strong seasonal variation with a minimum of about 0.05 in mid-summer and maximum values in excess of 0.3 in late winter to early spring. The winter-time maximum corresponds with the well-known "arctic-haze" phenomenon representing a gradual accumulation of mostly man-made aerosols (industrial as well as biomass burning) generated throughout the Arctic Circle but prevented from dissipating by the arctic circulation.

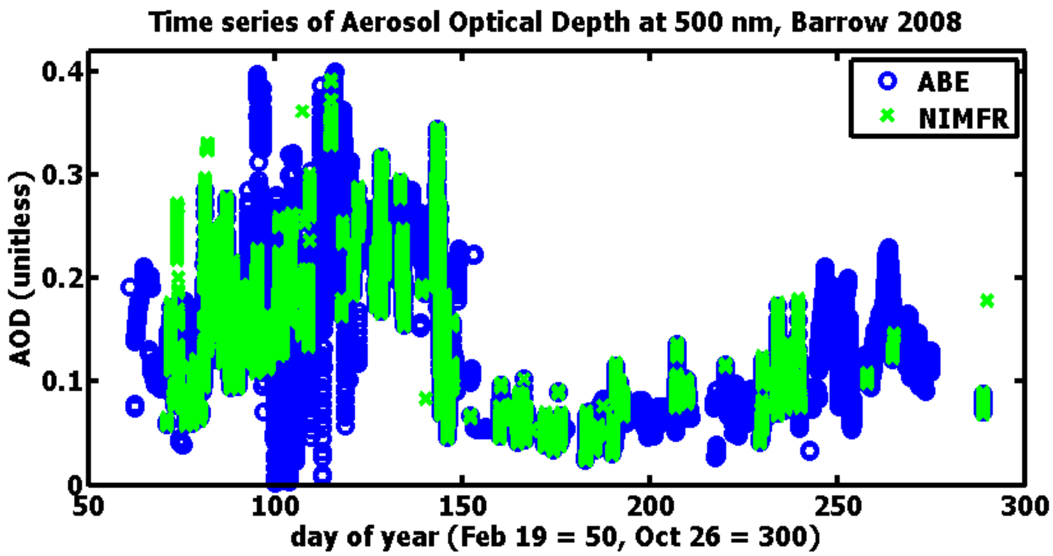

Figure 2. Time series of AOD at 500 nm for 2008 Barrow, Alaska, from Normal Incidence Multi-Filter Radiometer (NIMFR) and Aerosol Best-Estimate (ABE).

To provide an assessment of this product, we have compared the resulting AOD time series with independent measurements by a co-located AERONET Cimel sun photometer (See Figure 3). The agreement between these independent determinations is quite good with negligible bias, a root-mean square error (RMSE) of 0.013 that is well within measurement error, a near-unity slope of 1.03, and a correlation r-squared factor of greater than 0.96. The few outliers present represent different threshold criteria for rejecting data as cloud contaminated.

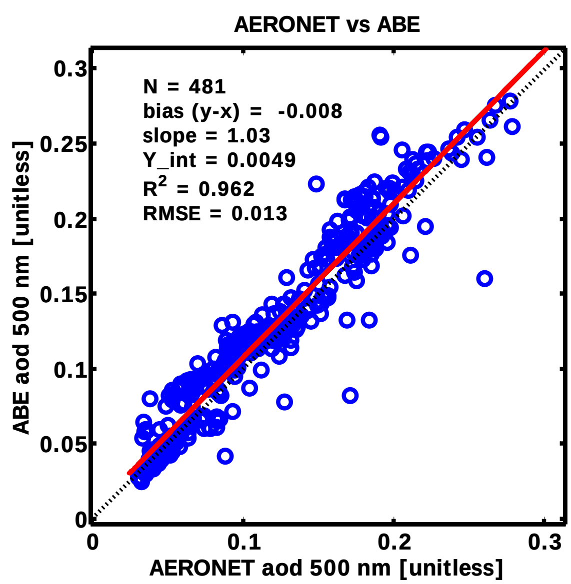

Figure 3. Correlation between independent measurements of AOD at 500 nm by AERONET and AEROSOL Best Estimate.

The final data product is provided as a text file containing daily-averaged AOD and angstrom exponent values. In addition, netcdf files are provided containing data on finer time grids (10-minute, hourly, and daily) and also containing all related data quantities contributing to the yearly time series of AOD.

3. References

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