Monitoring Aerosol Optical Depth During the Arctic Night: Development of a Lunar Photometer for Use at the NOAA Barrow Observatory

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The objectives of the Polar-Aerosol Optical Depth (AOD) community are to characterize aerosol properties and gain an understanding of factors that control their distribution and climate impacts. NOAA has played a major role in this effort by establishing Sun Photometer Programs at a number of high-latitude sites, including Barrow, AK (BRW), where the surface radiation budget is influenced by airborne pollutants and natural aerosols transported from lower latitudes. Arctic aerosols are chemically and optically inhomogeneous over space and time. Of special interest is the burden of black carbon, which during sunlit periods warms the atmosphere and accelerates snow/ice melt if deposited on the surface. A mixture of aerosol tends to accumulate within the Arctic vortex during winter, when it is most difficult to observe, so their role in forcing climate is poorly understood. Polar orbiting satellites (e.g., CALIPSO) are used to derive properties of the aerosol at night, but validating retrievals have been limited due to the lack of ground-truth data. AOD measurements made at Arctic sites during periods of darkness would aid this effort, begin to fill gaps in our time series and contribute to the understanding of aerosol transport and chemistry in the context of global climate change.

Nighttime photometry using star and moon light is not new. However, star systems are very costly and sophisticated to operate, and the variation in lunar irradiance with phase has been a major deterrent to using the moon as a light source. A simple, cost-effective approach is needed. Although the Moon's luminosity is variable, it is periodic and predictable and its photometric properties are virtually invariant. In recent years, lunar brightness variations, librations, spatial non-uniformity, and non-Lambertian reflectance properties have been well-characterized and modeled by the USGS Robotic Lunar Observatory Project. Taking advantage of these advances, GMD has successfully modified a sun photometer to measure lunar irradiance and derive spectral AOD throughout the Arctic winter.

Here, we give an overview of the prototype lunar system developed by GMD, calibrated at the Mauna Loa Observatory and then deployed to BRW during winter 2012/2013. The feasibility of monitoring AOD through the Arctic is demonstrated. Efforts are underway to improve the system for future operational use, enabling year-round monitoring of AOD at BRW. In conjunction with surface radiation measurements, we will be able to evaluate the longwave radiative forcing by the aerosol and gain insights about nocturnal cloud-aerosol interactions. The data will also be used to validate satellite retrievals of AOD.

Figure 1. A layer of Arctic haze settles off the north coast of Greenland as the sun sets, April 2009;

Figure 2. A 4-channel SP02 Sun Photometer was modified for monitoring AOD at BRW during winter 2012/2013.