Retrieval of Optical and Size Parameters of Aerosols Utilizing a Multi-Filter Rotating Shadowband Radiometer and Inter-comparison with CIMEL and Microtops Sun Photometers

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RETRIVAL OF OPTICAL AND SIZE PARAMETERS OF AEROSOLS UTILIZING A MULTI-FILTER ROTATING SHADOWBAND RADIOMETER AND INTER-COMPARISON WITH CIMEL SUN PHOTOMETER AND A MICROTOPS II SUN PHOTOMETER.

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Introduction

Sun photometry is a means to measure the amount of solar radiation that is attenuated by the atmosphere. It can be traced back to the 17th century to the work of Sir Isaac Newton when he noticed that the atmosphere diminishes solar radiation [1]. Sun photometry has progressed to take advantage of this diminishing effect by transitioning it from a problematic issue into valuable information about the concentrations of trace gases and variations in aerosol loading in the atmosphere. Using sun photometers to measure solar intensity at the surface has developed into a means of retrieving optical and size parameters of aerosols. Aerosols are liquid or solid particles suspended in the air, which can originate from biogenic or anthropogenic sources. One of the ways that aerosol particles can influence climate change is by scattering and absorbing solar radiation, this is called the direct effect. This effect relates to changes in the radiation budget of the earth due to the fluctuation of the concentration of aerosol particles. The presence of aerosols affects the transparency of the atmosphere which is characterized by the aerosol optical depth (AOD). In this experiment we determined AOD values over the course of the summer at Brookhaven National Lab (BNL) utilizing a Multi-Filter Rotating Shadowband Radiometer (MFRSR). Additionally, we calculated the Ångström coefficient which characterizes the dependence of AOD on wavelength and provides information about the size of aerosol particles. Inter-comparison of AOD and Ångström coefficient values from the MFRSR with those determined from a CIMEL Sun photometer and a MICROTOPS II Sun photometer was also performed. All data from the MFRSR had to be processed to determine AOD and Ångström coefficient values, whereas CIMEL AOD and Ångström coefficient values were retrieved from an online archive and MICROTOPS II data were retrieved directly from the machine.

Materials and Methods

Instrumentation

In this experiment three instruments are used to calculate AODs and Ångström coefficients: a Multi-Filter Rotating Shadowband Radiometer (MFRSR), a CIMEL Sun photometer, and a MICROTOPS II Sun photometer co-located at 40° 52' 11.9994" N 72° 53' 20.3994" W, in Upton, NY, 33 m above sea level. The MFRSR measures the global, direct, and diffuse components of solar irradiance at up to seven wavelengths (broadband, 415, 500, 615, 675, 870, and 940 nm; each with 10nm FWHM). A microprocessor-controlled shadowband alternately shades and exposes the instrument diffuser, enabling the system to measure all three irradiance components [3]. The CIMEL Sun photometer measures the same components of solar radiation at eight wavelengths (340, 380, 440, 500, 670, 870, 940 and 1020 nm; each with 10 nm FWHM). Similarly, the MICROTOPS II measures solar radiation at five wavelengths (340, 500, 870, 940, and 1020 nm). From the MFRSR we collect raw data that requires processing, whereas, the CIMEL sun photometer data have already been processed with cloud filtering to provide AOD at the wavelengths, from which the Ångström coefficient can be determined. The MICROTOPS II Sun photometer internally processes all data, which are simply downloaded for inter-comparison.

Data Processing

A program was written in MATLAB to reduce the data from the MFRSR to AODs, from which an Ångström coefficient was determined, and to compare these quantities to those from the CIMEL Sun photometer and the MICROTOPS II Sun photometer.

In order to calculate the AOD based on Beer's Law we must find the extraterrestrial solar radiation for each wavelength band. This quantity was determined from the experimental spectral irradiances provided by Gueymard (2003) by integrating over the filters response for each of the wavelengths. This quantity is then compared with the value determined from Langley analyses of MFRSR data of certain periods when it is thought that the AOD is constant. From this quantity, the AOD for each wavelength can be determined from Beer's Law by the following steps.

$$I = I_o \cdot e^{(-\tau_T m)} \tag{1}$$

$$\ln(I) = -\tau_T m + \ln(I_0) \tag{2}$$

$$\tau_T = \frac{\ln(I_o) - \ln(I)}{m} \tag{3}$$

$$\tau_{aer} = \tau_T - \tau_{Ray} - \tau_{O_3} - \tau_{NO_2} \tag{4}$$

The AOD (τ_{aer}) is calculated from a Langley regression by means of removing Rayleigh scattering (τ_{Ray}), ozone absorption (τ_{O_3}), and nitrogen dioxide absorption (τ_{NO_2}) optical depths from the slope (τ_T).

Once securing the optical parameters of aerosols we can use this data to calculate the Ångström coefficient which provides information on the size of aerosol that are contributing to the scattering and absorption of solar radiation. We accomplish this by mean of the following equation.

$$\acute{\mathring{A}} = -\ln\left[\frac{\left(\frac{\tau_1}{\tau_0}\right)}{\left(\frac{\lambda_1}{\lambda_0}\right)}\right] \tag{5}$$

where subscripts 1 and 0 refer to the 500 nm and 870 nm wavelength bands.

Results

Figure 1 below is a Langley plot for July 14, 2011 at the 500 nm channel of the MFRSR, on which the natural logarithm of the voltages measured by the MFRSR are graphed against the airmass values. The airmass is the ratio of the length of the path of the solar radiation through the atmosphere to that of a vertical path. The slope of the displayed equation is the negative of the total optical depth and the y-intercept is the logarithm of what the Sun photometer would read at the top of the atmosphere.

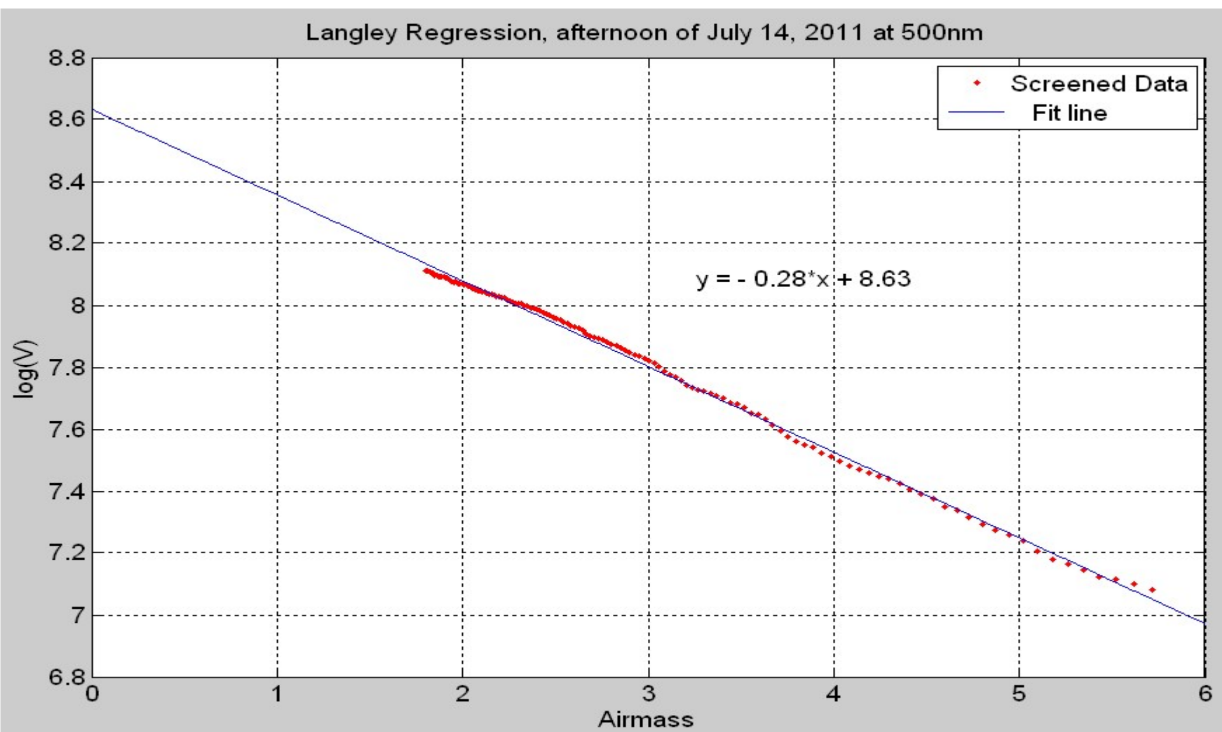

Figure 1. A Langley plot for the 500 nm channel for July 14, 2011.

Figure 2 below illustrates the AOD as a function of wavelength for July 14, 2011.

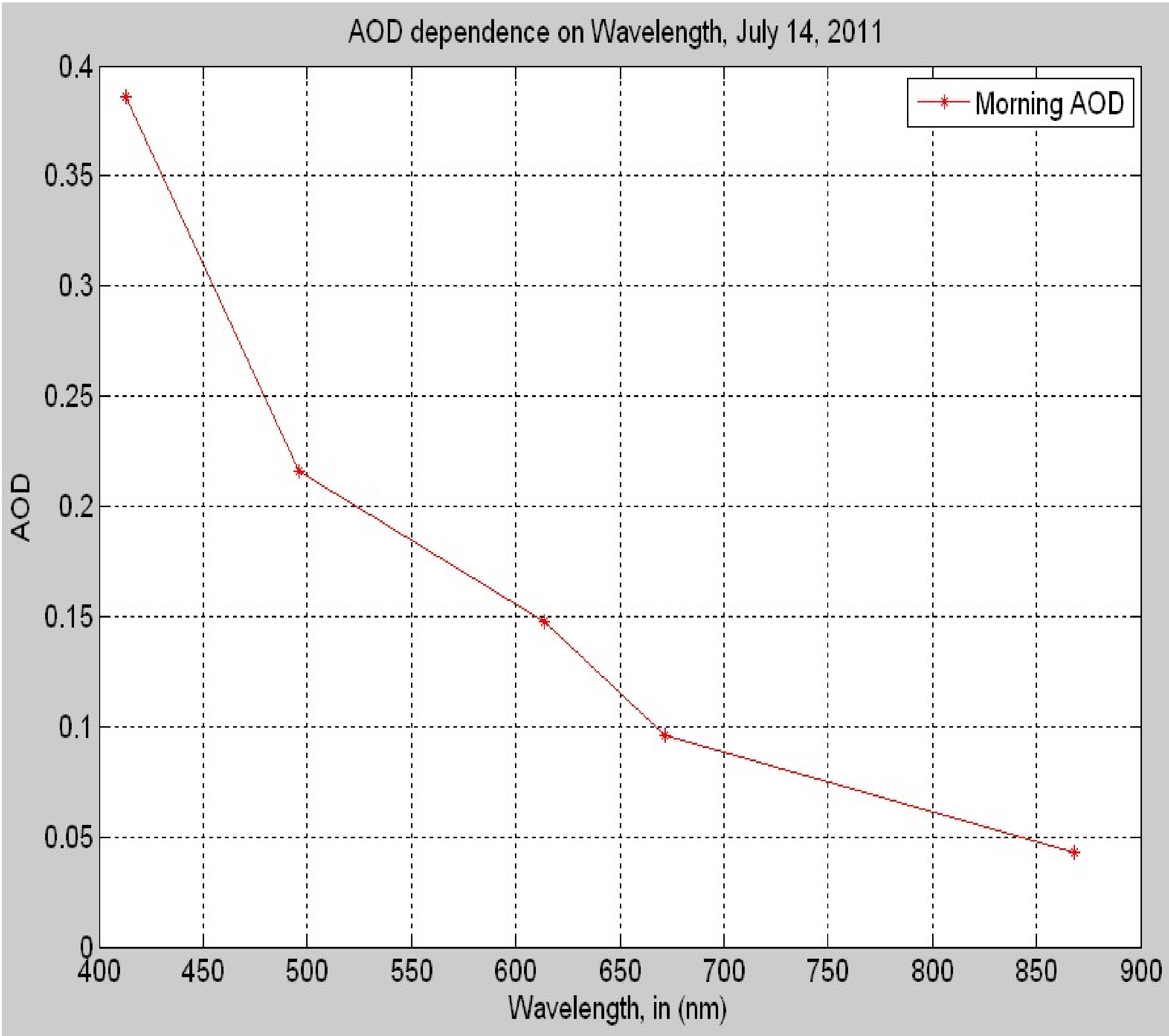

Figure 2. Dependence of aerosol optical depth on wavelength.

Figures 3 below shows inter-comparisons between each of the three instruments' AOD values for various days. For July 20, 2011 there is no comparison to the MICROTOPS II Sun photometer due to the fact that it does not have a 672nm channel. The best agreement lies between the MFRSR and the CIMEL Sun photometer, while the MICROTOPS II provides a greater value for the AOD.

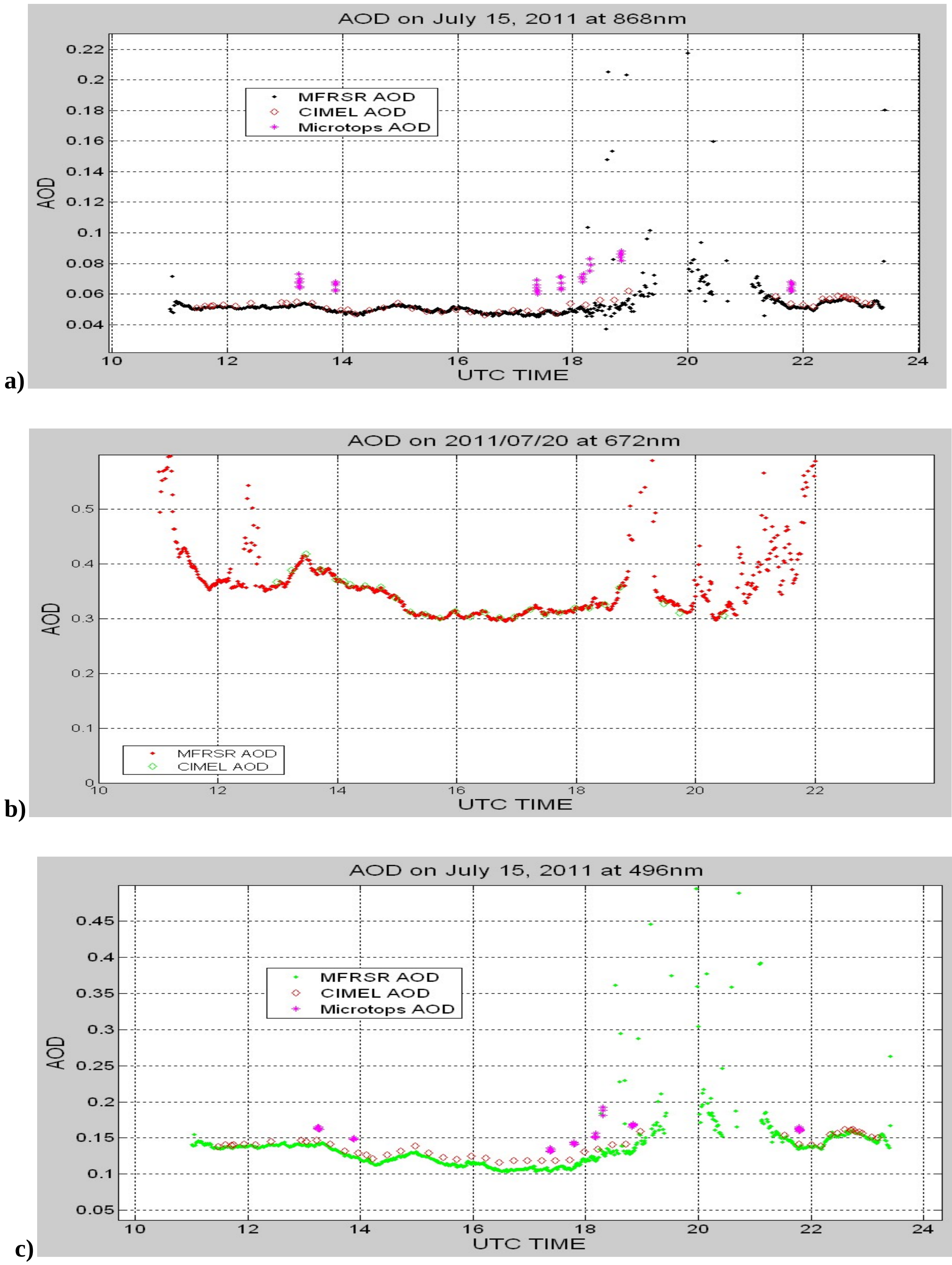

Figure 3. Inter-comparison of AODs for each of the instruments.

The Ångström values over the summer are shown in Figure 6. Lower Ångström values indicate larger particles

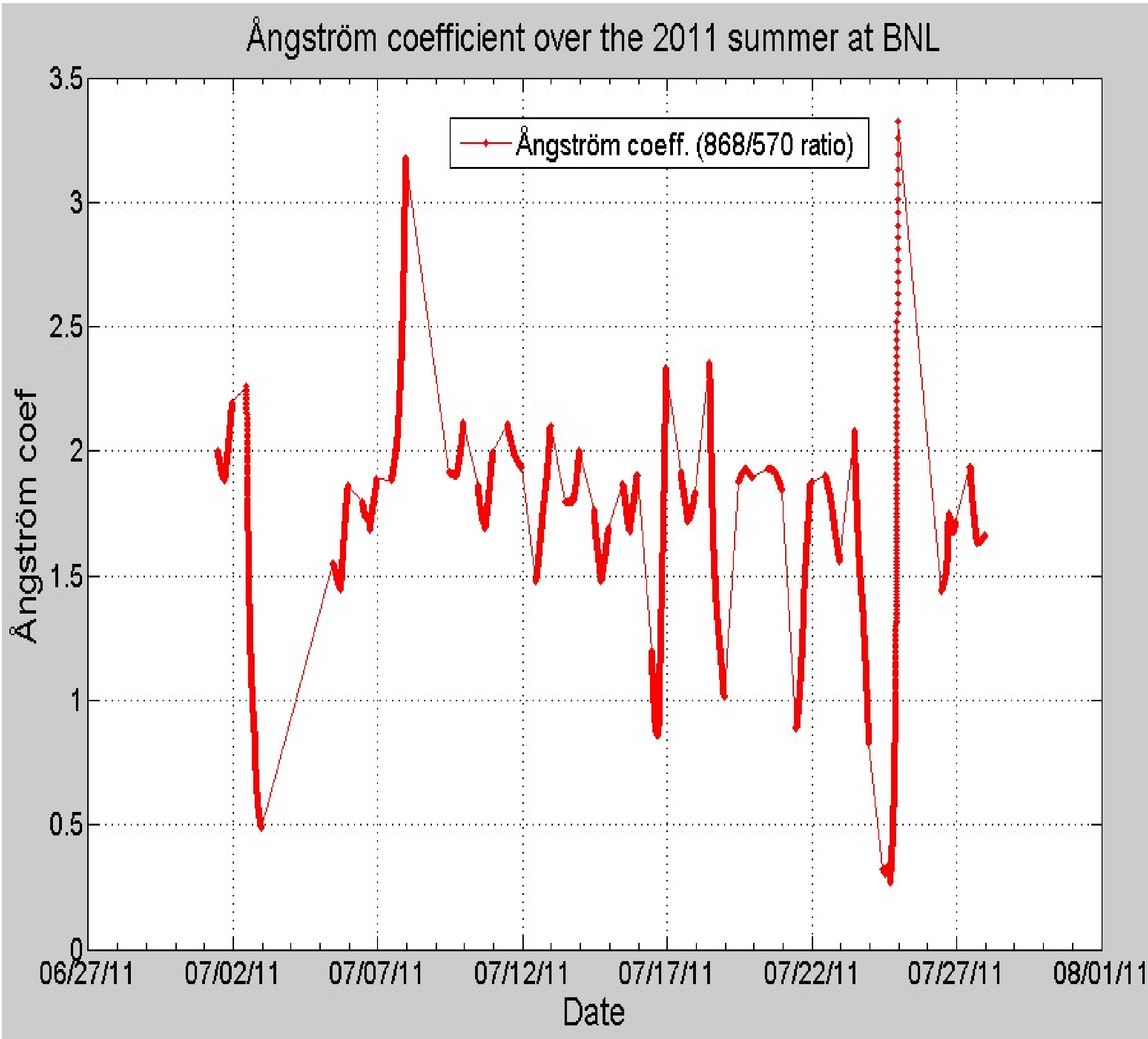

Figure 6. Ångström coefficients over the summer determined from aerosol optical depths at wavelengths 868 and 500 nm. Thin interconnecting lines indicate no data.

Figure 7 shows the aerosol optical depths over the summer, which ranged from approximately 0.1 to greater than 1.0. Extremely high values may be artifacts of clouds.

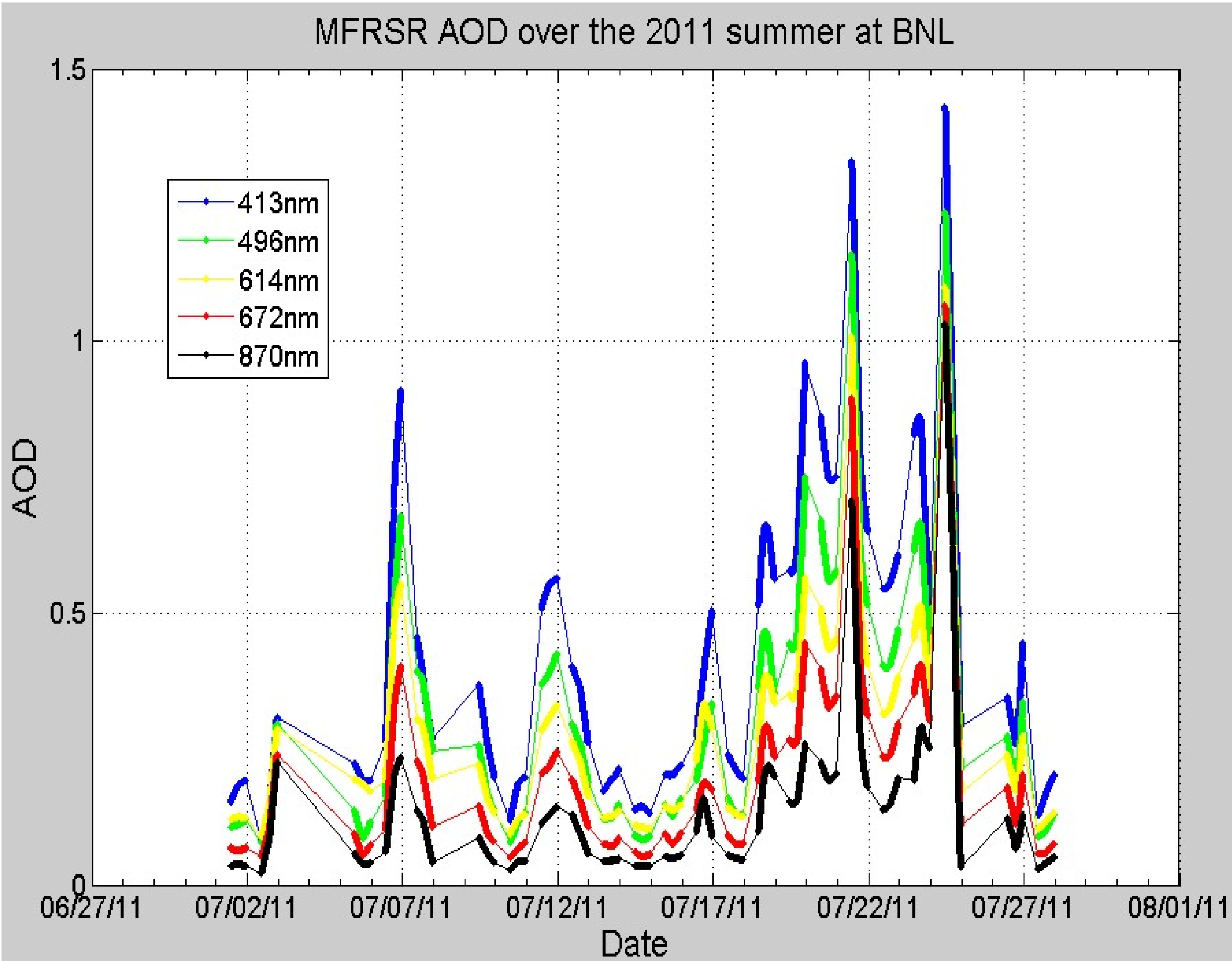

Figure 7. AOD variation over the summer. Thin interconnecting lines indicate no data.

Conclusions

Aerosol optical depths were determined from measurements with a Multi-Filter Rotating Shadowband Radiometer (MFRSR) at various wavelengths, and the Ångström coefficient was calculated. These results were compared with AODs determined from a co-located CIMEL sun photometer and a MICROTOPS II sun photometer. However, ~~F~~further investigation in to the confidence levels of our measurements with the MFRSR are need based on our uncertainties in atmospheric corrections relating to solar radiation extinction and uncertainties in the extraterrestrial solar constant for each wavelength at the top of the atmosphere. Understanding our level of uncertainty and to what we owe the uncertainty will assist us in finding better agreement with similar instruments. Also, investigation of cloud filtering algorithms is necessary to ensure that aerosol optical depth measurements were not affected by clouds. Investigation of wind trajectories might help explain extreme variability in AOD by providing information of aerosol sources.

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