Retrieval of Optical And Size Parameters of Aerosols Utilizing a Multi-Filter Rotating Shadowband Radiometer and Inter-Comparison with CIMEL Sun Photometer and MICROTOPS Sun Photometer

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Abstract

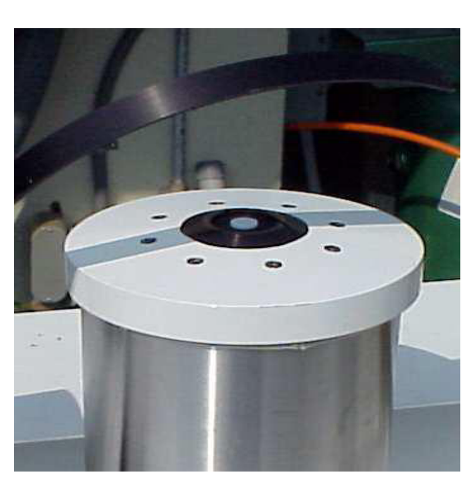
Aerosols are liquid or solid particles suspended in the air. The presence of aerosols in the atmosphere contributes to the total optical depth, which is a measure of the transparency of the atmosphere due to the extinction of solar radiation. The amount of solar radiation extinction relates to the number of aerosols in the atmosphere. The presence of aerosols affects the transparency of the atmosphere which is referred to as aerosol optical depth (AOD), the major contributor to the extinction of solar radiation. Hence, environmental scientists are concerned about the effects of aerosols due to their capacity to warm and/or cool the planet. The focus here is to calculate optical and size parameters of aerosols by measuring the radiation at the surface (direct irradiance) with respect to time and wavelength using a Multi-Filter Rotating Shadowband Radiometer (MFRSR) and comparing with data from a CIMEL Sun Photometer and a MICROTOPS Sun Photometer. Using multiple instruments to determine the same quantity allows for comparison and aids in determining if the instruments were functioning properly. To derive AOD we use Langley plots to find the total optical depth by plotting the natural logarithm of the direct normal radiation as a function of wavelength versus the inverse cosine of the angle between the sun and the vertical. A Langley plot provides a linear regression which is fitted with a best-fit line whose slope is the total optical depth. The AOD is derived from a Langley analysis by means of removing Rayleigh scattering, ozone absorption, and nitrogen dioxide absorption optical depths from the slope. Data retrieval and analysis was conducted daily by a source code written and executed in MATLAB. The code reduced the data producing Langley plots for each wavelength, the AOD of each wavelength, and the Ångström coefficient at the 415/870nm ratio. Experimentally, we found excellent agreement between the MFRSR and CIMEL Sun Photometer AODs , with less agreement of these two instruments AOD and Microtops retrieved AOD. To conclude, by measuring the direct solar irradiance from the sun using a MFRSR we are able to determine the size of particles that are scattering and absorbing radiation, calculate the AOD for daytime and clear sunny potions of the day, and that AOD is typically inversely proportional to wavelength. The performance of the instruments are based on the inter-comparisons and uncertainties of Rayleigh scattering, ozone absorption, and nitrogen dioxide absorption.

Introduction

The MFRSR is a field instrument which was used in the intensive observational period of the optical, chemical, and microphysical properties of aerosols at Brookhaven National Laboratory from June 5, 2011 to August 12, 2011.


Measuring Total Irradiance


MFRSR

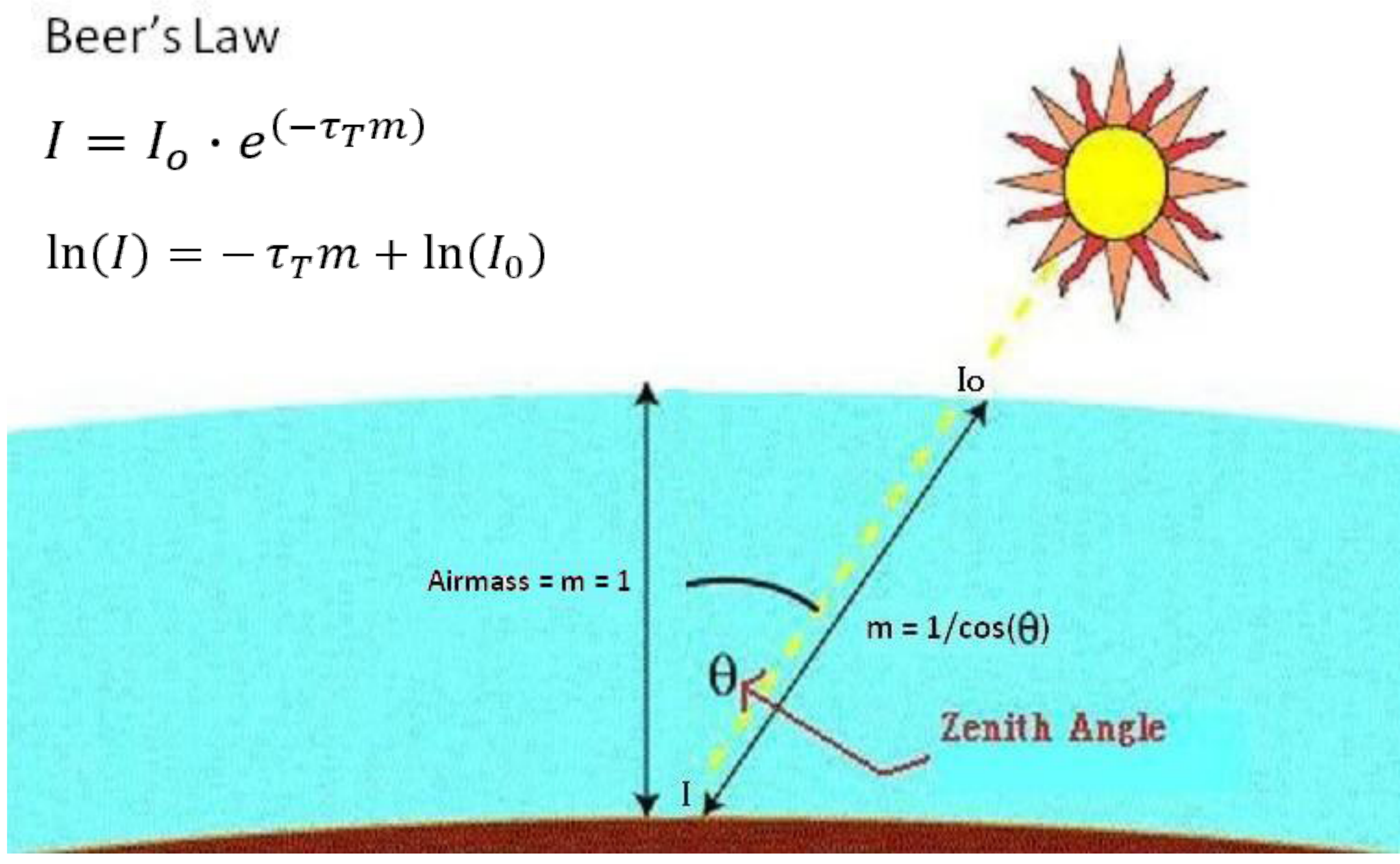

Measuring Diffuse Irradiance

- MFRSR measures total and global irradiance at: 415nm, 500 nm , 615nm , 675nm , 870nm (10nm FWHM)
- Direct Irradiance is calculated by the MFRSR as : Direct Irradiance = Total Irradiance – Diffuse Irradiance
- The CIMEL and MICROTOP II Sun photometers were co-located at BNL. Both of the sun photometers internally process the data, whereas MFRSR data was processed by MATLAB.

Beer's Law

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

$$\ln(I) = -\tau_T m + \ln(I_0)$$



- Total Optical Depth (τ_T) is a measure of the extinction (scattering and absorption) of solar radiation along a path in the atmosphere.

$$\tau_T(\lambda) = \tau_{Ray}(\lambda) + \tau_{O_3}(\lambda) + \tau_{NO_2}(\lambda) + \tau_{aer}(\lambda)$$

Contributions to Total Optical Depth

Rayleigh Scattering

- Scattering by air molecules $= \tau_{Ray}(\lambda)$
- Why sky is blue

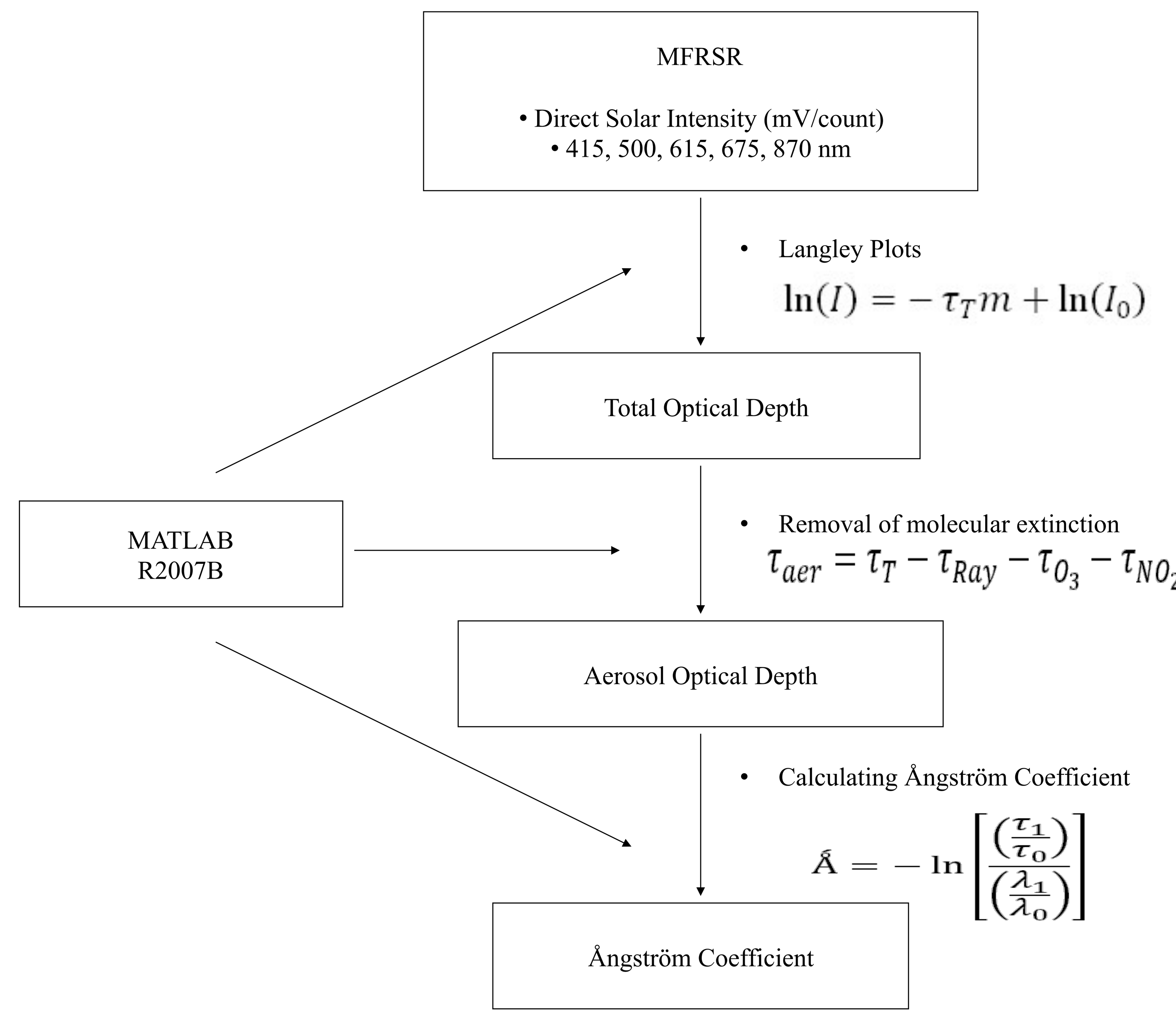
Gaseous Absorption

- $\tau_{NO_2}(\lambda)$ = NO_2
- $\tau_{O_3}(\lambda)$ = O_3

Aerosols

- Aerosol Optical Depth ($\tau_{aer}(\lambda)$) is the contribution of aerosols to the total optical depth.

Methods & Materials



Results

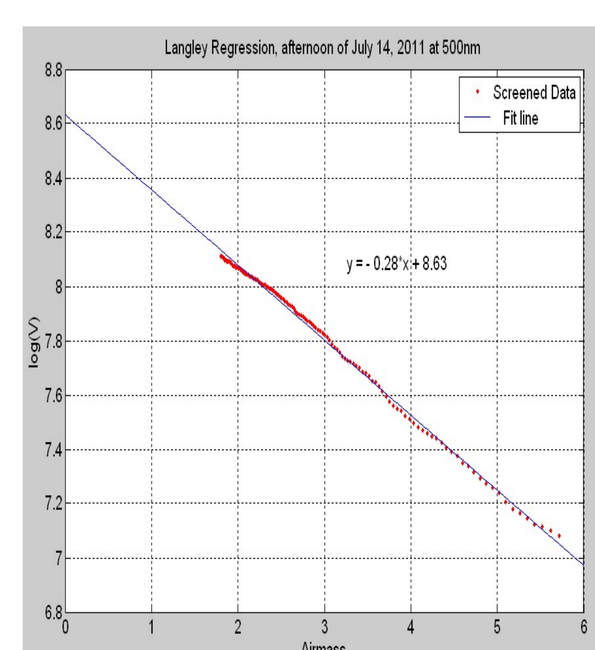


Fig.1. A Langley plot showing the negative slope which is the Total Optical Depth and the approximate extraterrestrial solar constant (y-int.) .

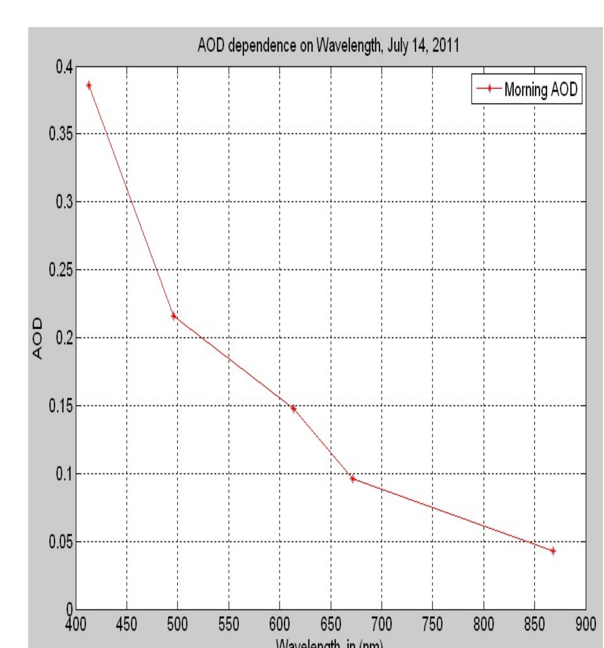


Fig.2. Illustrates our findings that AOD is inversely proportional to wavelength.

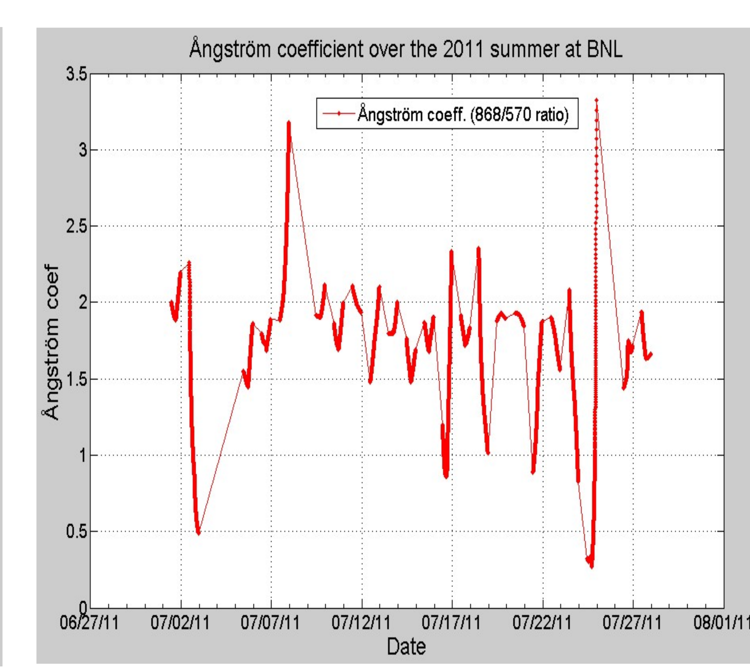
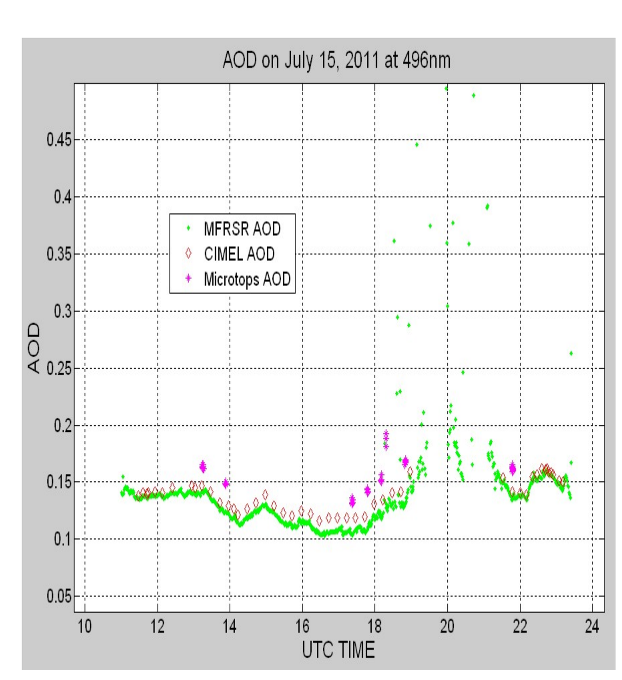


Fig.3. Illustrates the average size of aerosols in the atmosphere contributing to solar radiation extinction for the summer.. Thin interconnecting lines indicate no data.



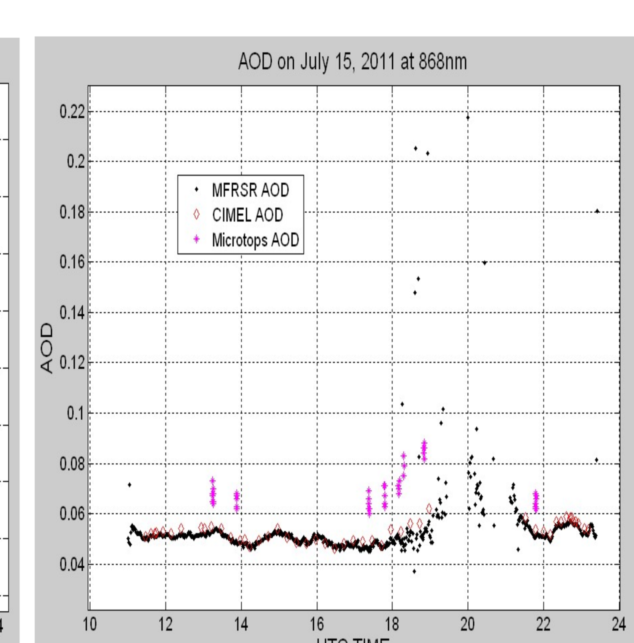


Fig.4,5 Inter-comparison of AODs for each of the instruments at various wavelengths. Disagreement maybe be attributed to uncertainty in atmospheric calibrations and cloud presence.

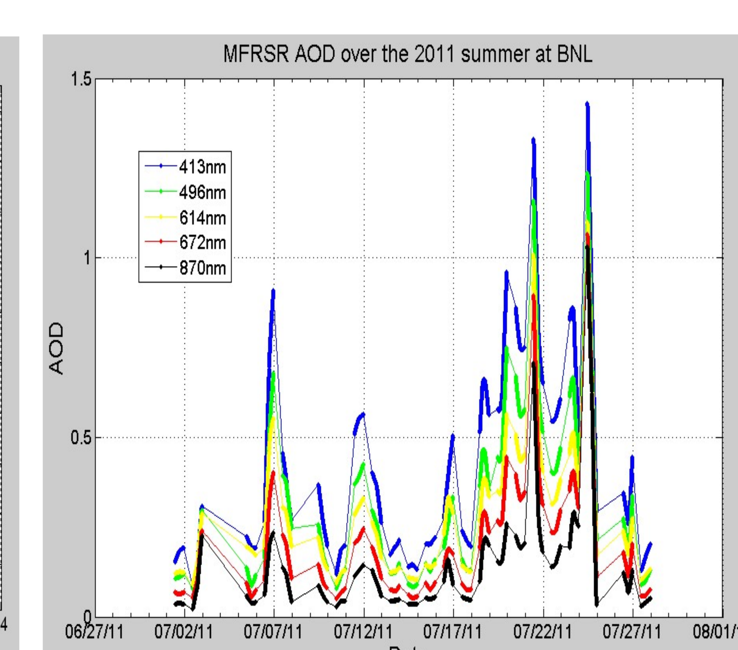


Fig.6. AOD variation over the summer. Thin interconnecting lines indicate no data.

Conclusions

- AOD is dependent on wavelength.
- AOD has been found to decrease with increasing wavelength.
- AOD can only be measured with certainty during clear sunny portions of the day.
- Wavelength dependence of AOD provides information on the sizes of aerosol particles responsible for the majority of the extinction.
- Further analysis is needed to explain large variations of AOD and Ångström values. Possible contributors are varying meteorological conditions (RH, air pressure), pollution transportation (wind trajectories) , and cloud presence.
- Future work entails: inter-comparison between the instruments over the summer, improving cloud screening techniques, establishing typical AOD and Ångström values at BNL for the summer, and establishing a confidence level in our measurements based on our uncertainties.

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References

[1] Michalsky, J. J., J. A. Schlemmer, W. E. Berkheiser, J. L. Berndt, L. C. Harrison, N. S. Laulainen, N. R. Larson, and J. C. Barnard. "Multiyear Measurements of Aerosol Optical Depth in the Atmospheric Radiation Measurement and Quantitative Links Programs." *Journal of Geophysical Research* 106.D11 (2001): 12099-2107..