Aerosol Radiative Properties in the Southern Great Plains of the United States

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Background

Data collection began at the Southern Great Plains (SGP) Atmospheric Radiation Measurement (ARM) site Aerosol Observation System (AOS) in April 1996. The final installation of the AOS took place during June 1996 and was conducted by the U.S. Department of Energy's (DOE's) Environmental Measurements Laboratory (EML). The National Oceanic and Atmospheric Administration (NOAA) Climate Monitoring and Diagnostics Laboratory (CMDL) began mentorship of the AOS in January 1997.

Aerosol samples are drawn through a 10-m stack, and conditioned with gentle heating to maintain a sample relative humidity (RH) of ~ 40%. This is done in order to measure properties that are intrinsic to the aerosol and not dependent on relative humidity. The aerosol then passes through an impactor to remove coarse aerosol ($D < 10$ µm) particles. In addition, a switched impactor system was added in April 1997 that provides measurements of smaller aerosol particles ($D < 1$ µm) as well as larger particles ($D < 10$ µm). The system alternates between the two modes in 5-minute time increments.

The aerosol measurements being made at the AOS include multiwavelength aerosol scattering and hemispheric backscattering coefficients (TSI Inc., model 3563 nephelometer), single wavelength scattering coefficient (Radiance Inc., nephelometer), absorption coefficient (Radiance Inc., PSAP), condensation nuclei (TSI Inc., Model 3010 CNC), and particle size distribution from 0.10 µm to 10.0 µm (PMS Inc., PCASP).

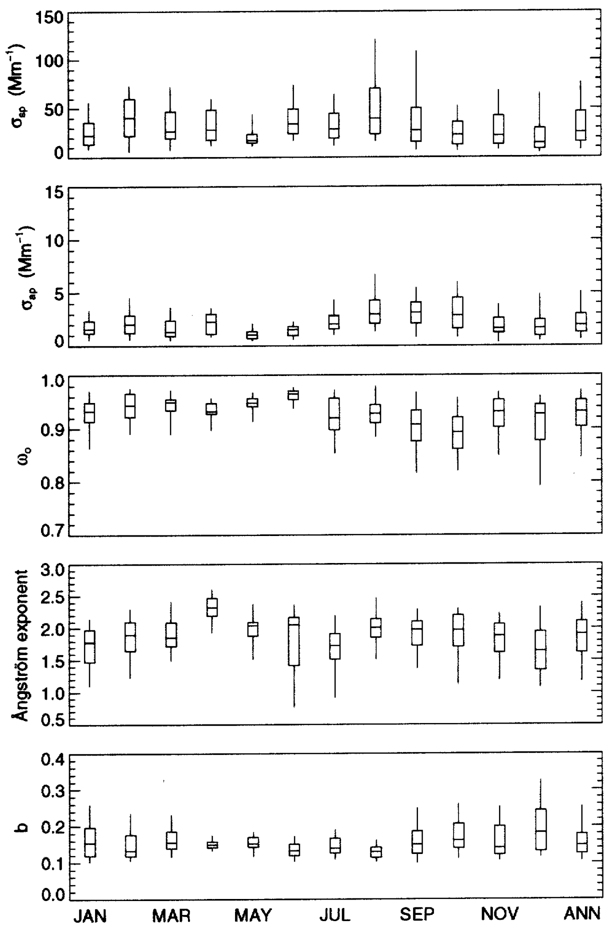

Figure 1. Seasonal cycle of total aerosol properties.

Total Aerosol (D < 10 µM) Seasonal Cycles

Figure 1 shows the seasonal cycles in aerosol radiative properties measured by the AOS for the total aerosol for the period from July 1996 to March 1998. The aerosol scattering coefficient, σ_{sp}, and hemispheric backscatter fraction (hemispheric backscatter/total scatter), b, and single scatter albedo (total scatter/extinction), ω_o, are reported at 550 nm. The Ångström exponent (negative slope of the scattering coefficient versus wavelength curve when plotted on a log-log scale), å, is estimated using aerosol scattering coefficients measured at 700 nm and 550 nm. The boxes in Figure 1 represent quartiles and median values with whiskers extending to the 5th and 95th percentiles of daily mean values. Daily mean values are used to estimate annual statistics (ANN). Both σ_{sp} and σ_{ap} are generally lowest in May. The single scatter albedo, ω_o, is lowest during October.

Submicron Aerosol (D < 1 μm) Seasonal Cycles

Figure 2 shows seasonal trends in submicron aerosol radiative properties covering the period from April 1997 to March 1998. The ratio of the submicron to total light scattering coefficients, $\sigma_{sp}1/\sigma_{sp}10$, single scatter albedo, ω_o, and hemispheric backscatter fraction are for data obtained at 550 nm. The Ångström exponent, , is estimated using scattering coefficient data at 700 nm and 550 nm. The box and whisker statistics are the same as described in the previous section. The results show that aerosol light

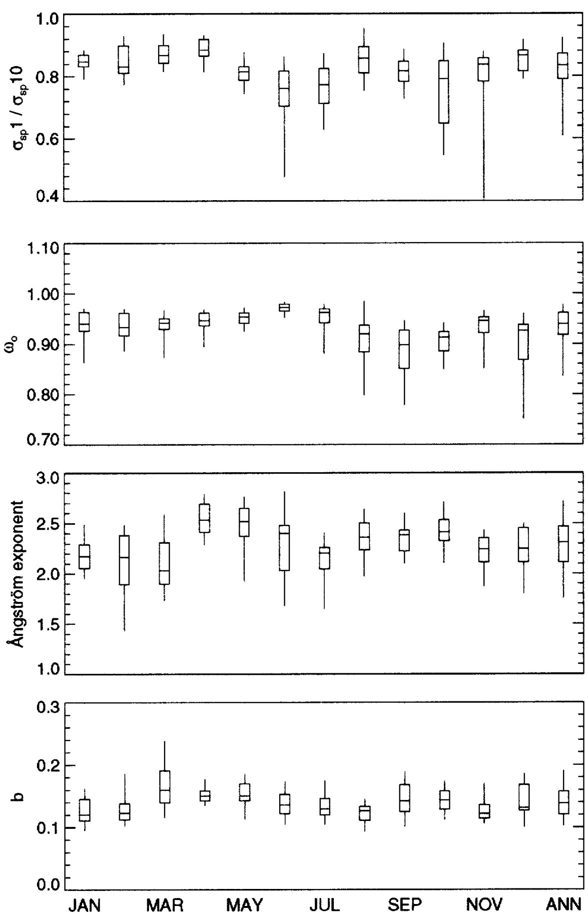

Figure 2. Seasonal cycle of submicron aerosol properties.

scattering is dominated by submicron particles. Minima in the $\sigma_{sp}1/\sigma_{sp}10$ ratio occur during June and July as well is in October. Interestingly, the October minimum corresponds to low values in ω_o for the total aerosol. The submicron, ω_o, is generally lowest during September.

Estimating Direct Shortwave Aerosol Radiative Forcing per Unit Optical Depth

The direct shortwave aerosol radiative forcing at the top of the atmosphere ($\Delta F/\tau$) can be estimated as follows (Haywood and Shine 1995).

$$\frac{\Delta F}{\tau} = -DSoT_{at}^2(1-A_c)(1-R_s)^2\omega_0\,\beta\left(1-\frac{2R_s}{(1-R_s)^2\beta}\left(\frac{1}{\omega_0}-1\right)\right)$$

where D is the fractional daylength (0.5), S_o the solar constant (1370 Wm^{-2}), T_{at} the atmospheric transmittance (0.76), A_c the fractional cloud cover (0.60), R_s the surface reflectance (0.15), and β the upscatter fraction (estimated from the hemispheric backscatter fraction). Figure 3 shows the frequency distribution of annual averaged estimates of $\Delta F/\tau$ based on daily mean total aerosol (D < 10 μm)

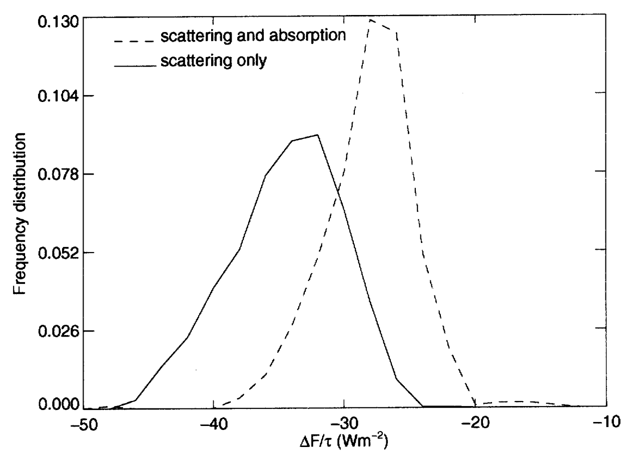

Figure 3. Annual averaged direct shortwave forcing per unit optical depth (RH < 40%).

radiative properties. The figure shows distributions estimated when both aerosol absorption and scattering properties are considered and with aerosol scattering properties only (i.e. ω_o =1.0). For the scattering only case there is a considerable amount of variability that results from the variance in the measured aerosol hemispheric backscatter ratio. When aerosol absorption is considered, the peak in the distribution shifts to the right by 25%. The results suggest that variability in both the aerosol hemispheric backscatter as well as single scatter albedo must be considered when estimating the direct shortwave radiative forcing at the SGP site.

Conclusions

Measurements of aerosol radiative properties at the SGP site show that light scattering is dominated by submicron aerosol particles. Light scattering and absorption have highest values in August with lowest values occurring in May. The minimum in the submicron to total aerosol scattering fraction occurs in October and corresponds to low values in the total aerosol single scatter albedo. In addition, frequency distributions of the direct forcing per unit optical depth, $\Delta F/\tau$, suggest that both the aerosol hemispheric backscatter as well as single scatter albedo must be considered when estimating the direct shortwave radiative forcing at the SGP site.

Acknowledgments

Robert Leifer at DOE/EML was responsible for installation and operation of the initial AOS. Richard Eagan was involved in many aspects of data acquisition and the troubleshooting of the AOS. Mijke Doorenbosch and Wen Huang were involved in data editing and manipulation.

References

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