

Analysis of Aerosol Data Collected by Atmospheric Radiation Measurement Aerosol Observing System at Southern Great Plains Cloud and Radiation Testbed Site

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Introduction

The Aerosol Observing System (AOS) is the primary Atmospheric Radiation Measurement (ARM) platform for in-situ aerosol measurements at 10-m above the ground surface. It has been operational since the beginning of April 1996. The relative humidity of the sample stream is conditioned to <40% and the temperature is maintained at < 40°C before aerosol measurements are taken. Aerosol instruments consist of

- two integrating nephelometers (one 1-wavelength [λ at 530 nm] and the other 3-wavelength [450, 550, and 700 NM]) for light scattering and backscattering measurements
- one photometer for light absorption at $\lambda = 550$ NM
- one condensation nuclei counter for measuring the total number of concentration of condensable particles ranging from 10 NM to 3 μ m in diameter
- one optical particle counter measuring the number of particles in 31 size channels from 0.1 to 10 μ m and one channel for particles with diameters >10 μ m.

Throughout the system (except for the optical counter) a 10 μ m cut-size impactor was installed in front of the integrating nephelometers and photometer. The sampling interval for all aerosol measurements is 1 minute.

We have analyzed AOS data taken from April 1, 1996, to January 31, 1997. We have also derived and analyzed a number of aerosol properties based on the measurements obtained during this period. These properties include extinction coefficient, single scatter albedo, Angstrom coefficient, and hemispheric backscatter fraction. Results for

single scattering albedo and Angstrom coefficient are presented here. More results will be presented in the ARM Science Team meeting and in this proceeding. An earlier version of this paper that used a subset of the data from mid-September to October 1996 was presented at the Second ARM aerosol workshop (Cheng 1996). This workshop paper can be found on the web at the following Uniform Resource Locator (URL):

<http://www.archive.armgov/research/2ndworkshop/abstracts/cheng.html>

The means for retrieving the aerosol data is also described on that webpage. The summary report for the second aerosol workshop can be found at

<http://www.archive.arm.gov/research/2ndworkshop/report.html>

Description Data

One-minute observations taken by instruments of the ARM aerosol observing system from April 1, 1996, to January 31, 1997, were quality controlled before the analysis. The quality control was done in the following manner. Raw data obtained from the Southern Great Plains (SGP) site computer data system were processed to remove any spiky data points. Diagnostic graphs were made using the raw data obtained from the past 24 hours. The graphs were updated every day. The graphics can be found at URL

http://data.archive.arm.gov/research/aerosols/dayshow/aerosol_dayshow.html

A quick check on raw data was made daily by both a manual and an automatic quality control script. Spikes whose values exceeded the second maximum and minimum of the day by

3 orders of magnitude were identified by the script and flagged. If this identification was confirmed by the analysis, the data points were edited and a value of NaN (Not a Number) was used to substitute the outlying spikes.

A second qualifier to confirm the identification was that the “outlying segment” had to be shorter than 5 min (i.e., five 1-min data points). If the segment was longer than 5 min, a system upset case was possible. Cross validation among AOS variables was also conducted to verify the identification and check if the data perturbation had occurred to one instrument or the entire AOS system. Other data quality report information (e.g., system operation log) was searched to confirm the outlier identification. (The raw data, however, were untouched and are currently stored at <http://www.archive.arm.gov/> waiting to be processed into a netCDF format that can be retrieved through the Archive User Interface.)

Generally, we found one spike per day for each AOS variable, although there were days when more than one spike as well as days with no spikes found. Figure 1 shows an example of such a spike. The data were scattering coefficients obtained by the 1-wavelength radiance nephelometer. The spike was measurement noise, and should not be interpreted as real data. Data from two days (8/9) in April ‘96 and the first 16 days in September ‘96 were not used in the analysis because they were not available either because of system upset/shutdown or upgrade and maintenance.

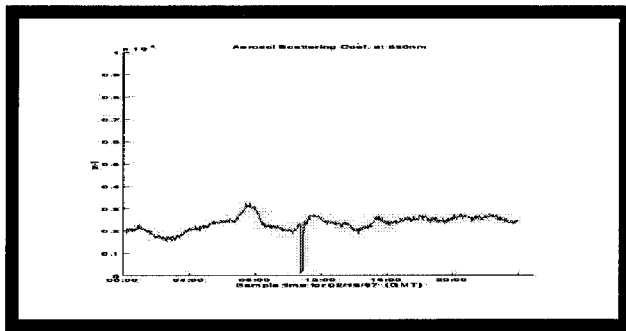


Figure 1. Example spike for AOS variable.

The observables of this AOS system include

- light scattering coefficients (m^{-1}) at three wavelengths
- light absorption coefficient (m^{-1})
- total number concentration of condensable particles ($\# \text{cm}^{-3}$)

- number concentrations of aerosols at 31 particle size bins ($\# \text{cm}^{-3} \mu\text{m}^{-1}$) that were used to derive the particle size distribution.

The derived quantities based on these observations include

- light extinction coefficient, $b_e =$ light scattering coefficient, b_{sp} + wavelength adjusted light absorption coefficient, $a_p b$ (m^{-1})
- single scattering albedo, ($\omega = b_{sp}/b_e$, (no units)
- Angstrom coefficient, $A = d \ln(b_{sp}(\lambda))/d \ln(\lambda)$, (no units) based on scattering measurements
- hemispheric scattering coefficient (or upper scattering coefficient), $b = b_{bsp}/b_{sp}$ (no units).

Objectives

The objectives of the analysis performed on the first 10 months of data were to quality control the data, identify measurement errors, establish a reference baseline for future measurements, and determine the optical and microphysical characteristics of atmospheric aerosols observed at the ARM Cloud and Radiation Testbed (CART) site that can be used for further scientific investigations.

Results and Discussion

The ranges of aerosol microphysical properties based on measurement data taken from various locations around the world are summarized in Ogren (1995). We use them here for comparison only. We use non-parametric statistics (e.g., percentiles) of a measured or derived property to summarize the data for comparison instead of using the traditional mean and standard deviation. Table 1 shows the data from the literature and the ARM measurements. A cautionary note is added here to bring to the readers’ attention that the aerosol sampling and measurement techniques used by the literature studies differ from those used by ARM. So far there is no standard method for measuring these quantities.

Figure 2 shows the monthly ranges (from the 5th percentile to the 95th percentile) of single scattering albedo (ω) from April 1996 to January 1997. The overall median value of ω for these 10 months was around 0.91, ranging from 0.87 to 0.94. These values indicate that light extinction observed at the CART site over the past 10 months was generally caused by aerosol scattering, about 6% to 13% of the light

Table 1. Data from the literature and the ARM measurements.

Aerosol variable obtained based on the measurements of the ARM aerosol observing system	Polluted continental (nonurban)	Clean continental	Clean marine	Ranges of ARM 10-mo measurements (5% to 95%)
Scattering coefficient, $Mm^{-1(*)}$	50 - 300	5 - 300	5 - 20	4 - 170
Absorption coefficient, Mm^{-1}	5 - 50	1 - 10	0.01 - 0.05	0 - 8
Total condensable particle, $\# cm^{-3}$	1000 - 5000	100 - 1000	10 - 200	330 - 16,900
Single scattering albedo, ω	0.8 - 0.9	0.9 - 0.95	close to 1	0.7 - 1.0
Extinction coefficient, Mm^{-1}				3 - 180
Angstrom coefficient, A	1 - 2	1 - 2	-0.5 - 1.5	-0.9 - 2.7
Hemispheric backscatter coefficient, g in %				-2 - 80

* $Mm = 10^6$ meters. $Mm^{-1} = 1 \times 10^{-6} m^{-1}$.

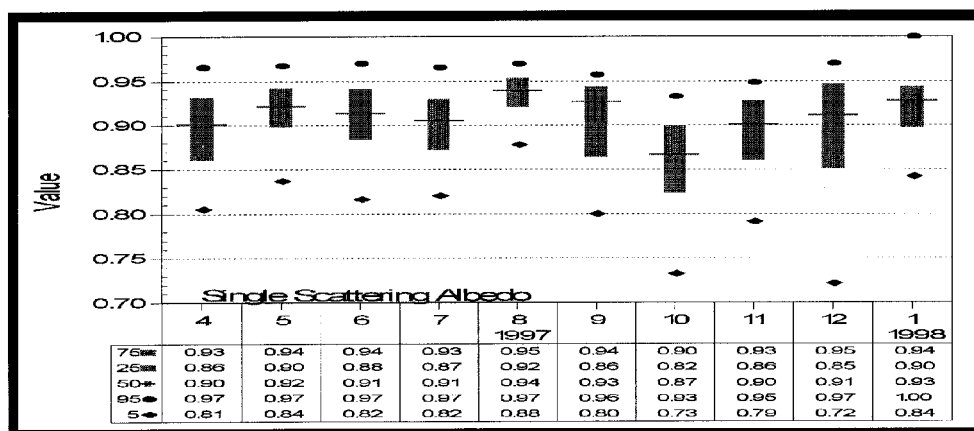


Figure 2. Monthly ranges (from the 5th percentile to the 95th percentile) of single scattering Albedo (ω) from April 1996 to January 1997.

extinction at CART was caused by aerosol absorption compared with the 20% to 40% range generally found in Europe (Horvath 1996).

Figure 3 shows the range of Angstrom coefficients we have seen over the past 10 months at CART. The coefficient was derived based on the quality-controlled measurements taken by the 3 wavelength nephelometer. The overall 10-month median value for Angstrom coefficient was 1.74, from 1.56 to 2.01. This range corresponds to a Junge size parameter range from 3.1 to 4. The Junge size parameter is the slope of the Junge size distribution of a plot of $d n(r)/d \log(r)$ vs. $\log(r)$. Here, r is the particle radius and $n(r)$ is the aerosol number

density in a unit vertical column. Note that the Junge size distribution applies to a limited size range of about 0.1 to 1.0- μm radius.

Conclusions

Based on the results we summarized, our observations are that light extinction observed at the CART site at the 10-m height from April 1, 1996, through January 31, 1997, can be characterized as mostly aerosol light scattering. The 10-month median for ω was 0.91. Around 6% to 13% ($1-\omega$) of light extinction was attributed to aerosol absorption. That

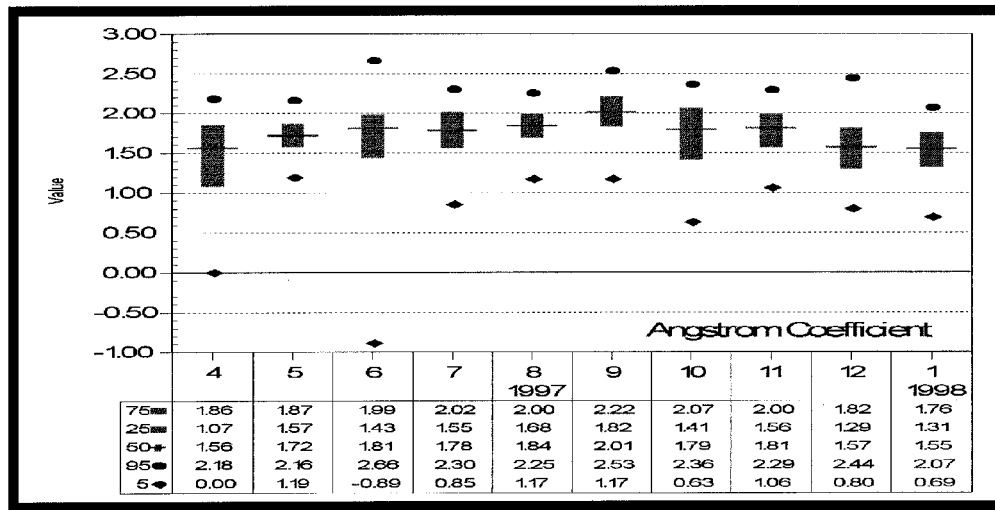


Figure 3. Range of Angstrom coefficients seen over past 10 months at CART.

percentage is relatively small compared with that of European aerosol, which is generally on the order of 20% to 40%.

However, this is not to say that all aerosol particles observed at CART are highly scattering at all times. The 1-minute value of ω is highly fluctuating and has dipped into the 0.4 - 0.6 range on occasions that are an indication of the presence of highly absorbing particles. These were rare events, however, and generally lasted for a few minutes. It is possible that these rare events were caused by either fluctuations in light scattering and absorption measurements, which should not be over-interpreted, or by anthropogenic aerosols emitted at nearby refinery sources.

The Angstrom coefficients derived indicate that most particles at CART may be fine ($r < \mu\text{m}$) particles. Measurements by the optical particle counter (OPC data not shown here) support this conclusion. This result is also indicative that the Junge size distribution may be suitable for deriving column particle size distribution based on spectrally resolved radiometric measurements at CART.

Future Work

Work on particle size distributions (PSD) as a function of time are being derived based on the OPC measurements. This PSD result is, however, for dry particles only, since AOS conditions relative humidity in its sampling stream to $< 40\%$ before OPC

data are taken. The vertical profiles of water vapor may be used to extrapolate the PSD result throughout entire columns under appropriate conditions and assumptions.

References

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