

Enhanced Aerosol Measurements at NOAA's Baseline Observatory at Barrow, Alaska

J. A. Ogren

NOAA-Climate Monitoring and Diagnostics Laboratory
Boulder, Colorado

Introduction

As a result of collaboration with the U.S. Department of Energy's (DOE's) Atmospheric Radiation Measurement (ARM) Program, the National Oceanic and Atmospheric Administration's (NOAA's) aerosol measurement system at the Barrow, Alaska, observatory was modernized and upgraded in September 1997. The original four-wavelength nephelometer was replaced with a modern, high-sensitivity, three-wavelength nephelometer that additionally determines the backwards-hemispheric component of aerosol light scattering (TSI model 3563). A continuous light absorption photometer [Radiance Research PSAP (Particle/Soot Absorption Photometer)], calibrated in terms of aerosol light absorption coefficient, replaced the original aethalometer. The aerosol inlet system was also upgraded to provide careful control of relative humidity (RH) and particle size, and uses real-time wind speed and direction measurements at the top of the inlet to exclude data from the locally polluted sector (130° to 360°). These upgrades were performed to meet the data requirements of the ARM Program, to provide measurements that are quantitatively comparable with those at the ARM Southern Great Plains (SGP) site, and to provide additional parameters needed to evaluate the direct radiative forcing of climate by aerosols.

Aerosols extracted from the base of the main stack are heated gently to maintain an RH of no more than 40%, which minimizes the effects of hygroscopic growth on the measured aerosol properties. Sample air passes through inertial impactors to provide separate measurements on particles smaller than $1\ \mu\text{m}$ and $10\ \mu\text{m}$ diameter. The new system includes provisions for automated filter sampling for later chemical analysis, with all sample handling being done in a glove box. In order to maintain continuity of the measurements, the new system will be operated in parallel with the old system until it has been proven that the results from the two systems are quantitatively comparable.

Historical Record

NOAA began aerosol observations at Barrow in 1976 with the deployment of an integrating nephelometer operating at wavelengths of 450 nm, 550 nm, 700 nm, and 850 nm, and a condensation nucleus (CN) counter. An aethalometer

was added in 1988 to measure light-absorbing particles. These sensors allow determination of the aerosol light scattering coefficient σ_{sp} , the aerosol light absorption coefficient σ_{ap} (based on an assumed light absorption efficiency of $10\ \text{m}^2\ \text{g}^{-1}$), the Ångström exponent (defined as the negative slope of a log-log relationship between σ_{sp} and wavelength, reported here for the 550/700 nm wavelength pair), and the single-scattering albedo ω_0 at 550 nm.

The annual cycles of selected aerosol properties are illustrated in Figure 1. The data are presented in the form of box-whisker plots that summarize the distribution of values:

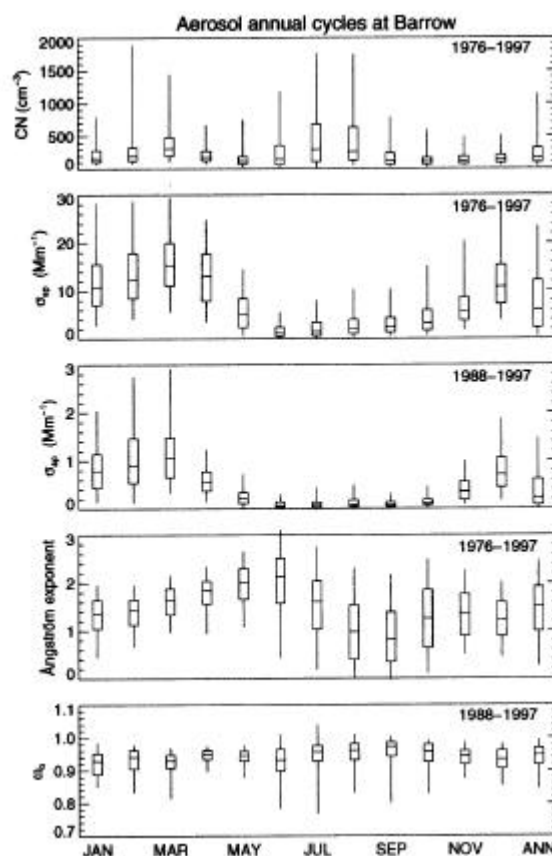


Figure 1. Seasonal cycle of aerosol properties.

the box ranges from the lower to upper quartiles, with a central bar at the median value, while the whiskers extend to the 5th and 95th percentiles. The statistics are based on daily averages of each parameter for each month of the year, as well as for the entire year (“ANN”). In general, changes in long-range transport patterns dominate the annual cycles. The highest values of σ_{sp} and σ_{ap} are observed during the spring, due to the long-range transport of pollution into the Arctic from lower latitudes (“Arctic haze”). The CN record shows a more variable semiannual cycle, with a maximum that usually coincides with the maximum in σ_{sp} and a secondary maximum in late summer or early fall. The secondary maximum in late summer is thought to be caused by local oceanic emissions of dimethylsulfide (DMS) gas that are eventually converted to sulfate aerosol.

Long-term trends for these aerosol properties are shown in Figure 2 for March, at the peak of the Arctic haze season, for June (the month with the lowest light-scattering levels),

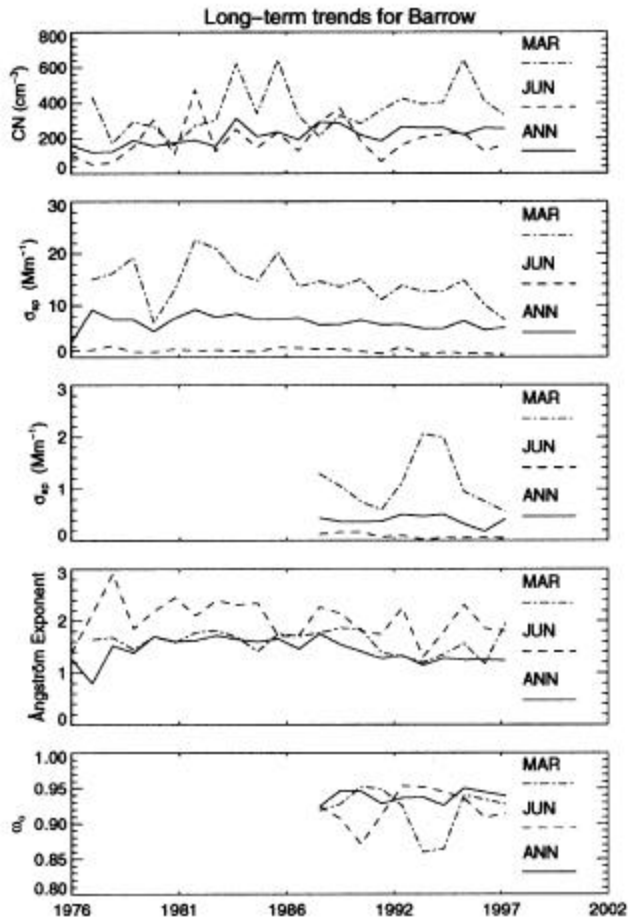


Figure 2. Long-term trends for aerosol properties.

and for the annual average. No pronounced long-term trends in aerosols are seen at Barrow, although the cause of the decrease in σ_{sp} during the 1980s in March is unknown. These data, and results from the NOAA Climate Monitoring and Diagnostics Laboratory’s (CMDL’s) other aerosol monitoring stations, are available at CMDL’s web site <http://www.cmdl.noaa.gov/aerosol/>.

Old Versus New Aerosol Sampling Systems

There are several fundamental differences between the old and new aerosol sampling systems that may yield different results. Differences in flow rates, tubing diameters, and tubing bends may lead to differences in particle sampling efficiency, particularly for super-micrometer particles. The old sampling system included no provisions for sample RH or size control. Comparison of the results from the first 21 weeks (October 1997 to February 1998) of side-by-side operation of the old and new nephelometers (Table 1) shows that the two systems produce nearly identical results for two of the three common wavelengths, demonstrating that particle losses in the two inlet systems are not significantly different. The very low sample RHs encountered in the Arctic winter do not allow evaluation of any differences introduced by the RH control in the new system. It is not known if the ~10% lower readings for the blue channel of the old nephelometer represent a recent change or the entire record.

	Blue	Green	Red
r^2	0.993	0.995	0.995
old ÷ new	0.907	1.007	0.975

The mass absorption efficiency of $10 \text{ m}^2 \text{ g}^{-1}$ assumed in calculating the absorption coefficient from the “black carbon” concentration reported by the aethalometer underestimates σ_{ap} by ~40% relative to the PSAP (Figure 3). The PSAP was calibrated by the manufacturer as the difference between light extinction and scattering (i.e., light absorption), whereas the manufacturer of the aethalometer calibrates the unit relative to the mass concentration of black carbon. Laboratory tests show that 1 to 3% of the scattering by non-absorbing particles appears as absorption in the PSAP and aethalometer (T. Bond, personal communication, 1998). After subtracting the estimated contribution by light scattering, and adjusting the aethalometer’s results upwards to compensate for its lower response relative to the PSAP (Figure 4), the quartiles of the historical annual distribution of single-scattering albedos (Figure 1) decrease from (0.92, 0.97) to (0.89, 0.97).

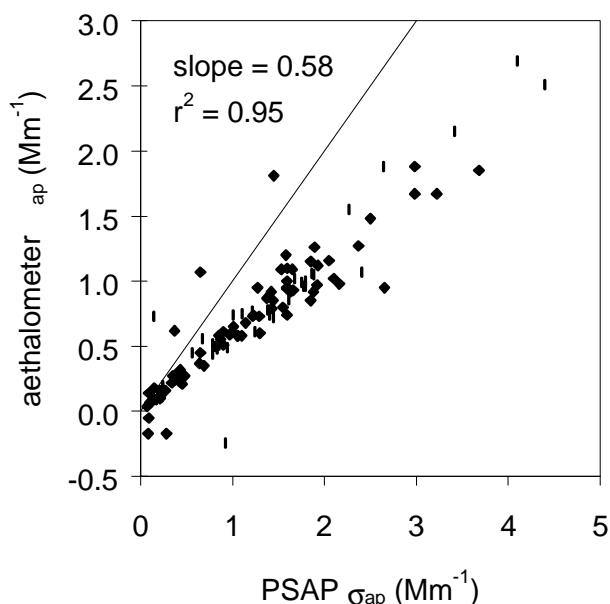


Figure 3. Comparison of light absorption photo-meters.

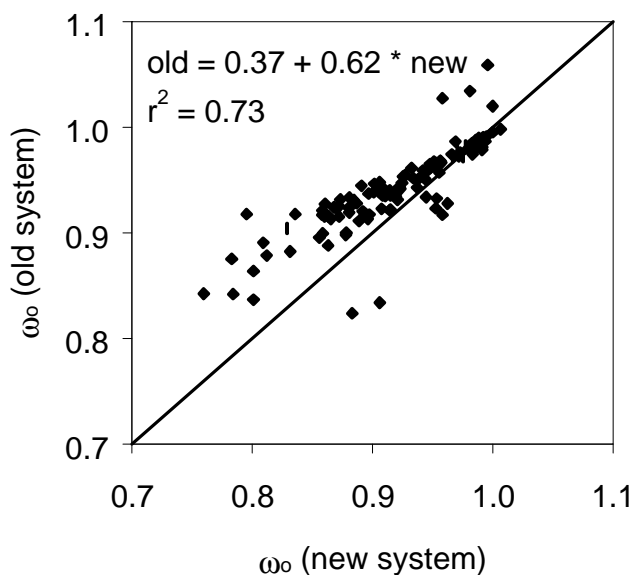


Figure 4. Comparison of single-scattering albedo.

New Measurement Results

The switched impactor in the new sampling system allows evaluation of size-dependencies of aerosol radiative properties. Supermicrometer particles near the ocean are generally composed of sea salt, while pollution-derived compounds are concentrated in the sub-micrometer fraction. These different sources produce differences in aerosol radiative properties for the two size ranges. Results from

the first 21 weeks of sampling (Figure 5) show that sub-micrometer particles generally control both light scattering and absorption, although at times supermicrometer particles can contribute as much as 50% to the total. Scattering into the backwards hemisphere is 10% to 15% of the total, for submicrometer particles. The Ångström exponent is seen to be strongly dependent on the relative amounts of submicrometer and supermicrometer particles (Figure 6).

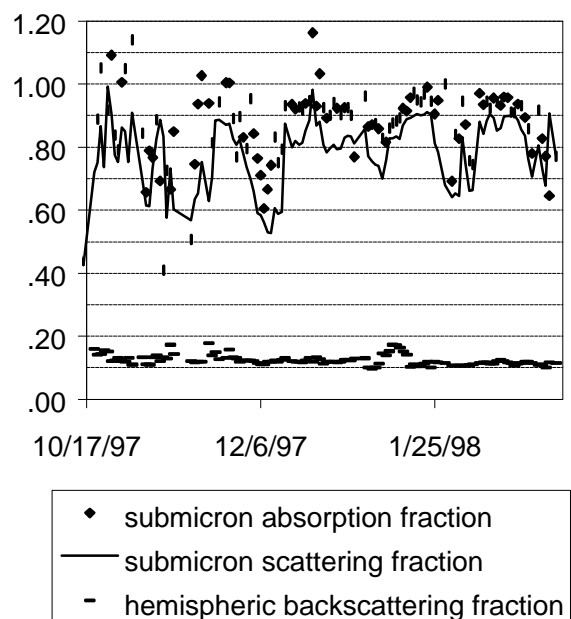


Figure 5: Time series of aerosol radiative properties

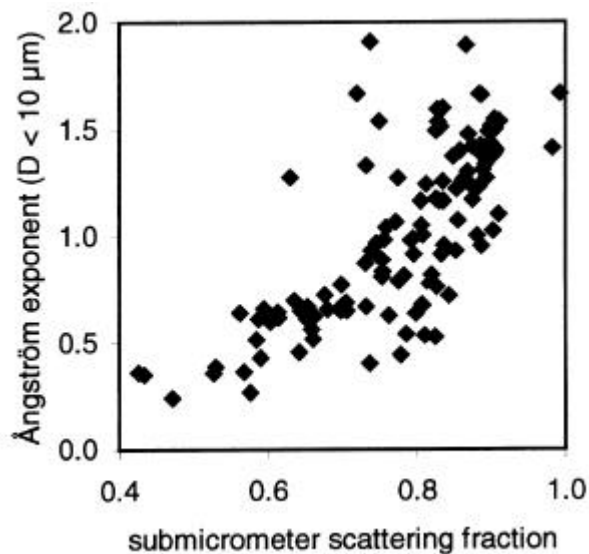


Figure 6. Ångström exponent vs. submicrometer scattering fraction.

Conclusions

The high degree of correlation in the light scattering and absorption results means that we will be able to connect the old and new data sets, but correction factors will be necessary. Results from the upgraded aerosol sampling system, together with results from operationally identical systems operating in Nova Scotia, Illinois, and Oklahoma, will be used to improve calculations of the direct aerosol radiative forcing of climate.

Acknowledgments

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