A CAPS-Based Single Scattering Albedo Monitor

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We present data detailing the performance of a particle single scattering albedo (SSA) monitor that incorporates both a CAPS (Cavity Attenuated Phase Shift)-based optical extinction measurement [Massoli, et al., 2010] and an inverse nephelometer in the same measurement volume. Since an absolute extinction measurement is provided, the scattering channel can be calibrated with any non-absorbing particle (e.g., a PSL) or gas (other than air). The monitor demonstrates noise levels of less than 1 Mm^{-1} (1σ, 1 s) in both channels while providing 1 s response time (10-90%).

The aerosol extinction measurement is identical to that of the CAPS PM_{ex} monitor. However, the middle portion of the optical path incorporates a 10 cm i.d. sphere. The sphere walls are coated with Avian-D paint which provides a water-proof surface with >98% diffuse reflectance over the visible light range. Within the sphere region, the aerosol flow is contained within a transparent tube to prevent the particles from contaminating the sphere.

As with all instruments employing a nephelometer to measure scattering, the CAPS PM_{SSA} demonstrates a measurement bias as a function of particle size. The larger the particle, the more the differential scattering cross section grows in the forward and backward directions at the expense of sideways scattering. As there must be apertures for the probe light to enter and leave the measurement volume, less scattered light is thus captured for large particles compared to smaller ones. This 'truncation' error was measured using PSLs of varying diameter by measuring the apparent SSA compared to a value of unity expected for the non-absorbing particles. Virtually no truncation error is measured out to a diameter of ~500 nm. (See Fig. 1.) The response falls to 90% at 1 micron and to 80% at 2..5 micron diameter. While this level of error is not insignificant at large particle diameters, it is substantially smaller than commercially available nephelometers.

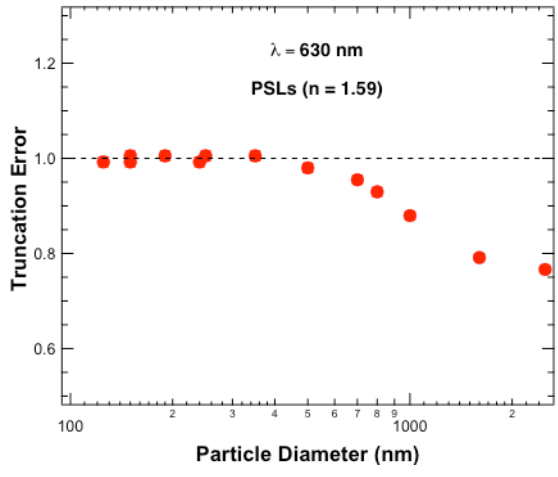

Fig. 1 Truncation error of CAPS PM_{SSA} at 630 nm measured using non-absorbing PSLs.

We have tested the CAPS PM_{SSA} monitor extensively in the laboratory. For example, SSA measurements of nascent and organic and sulfuric acid coated soot particles using a CAPS PM_{SSA} at 630 nm and a cavity ring down-based extinction monitor coupled to a photoacoustic particle absorption spectrometer at 532 nm, courtesy of C. Cappa, U.C. Davis, showed excellent agreement between the two over a wide range of SSA values. (See Figure 2.) The soot particles were generated using a methane diffusion flame, coated via gas-to-particle condensation, and size selected at 350 nm mobility diameter, small enough to eliminate the effects of scattering truncation.

The CAPS PM_{SSA} monitor can be operated in any wavelength region compatible with the availability of high reflectivity mirrors, LEDs and photomultiplier tube (PMT) photocathodes. At present, the available wavelength band is restricted to the 400-700 nm region because of the lack of suitable high reflectivity mirrors in the UV and of photocathode mateials in the near-IR.

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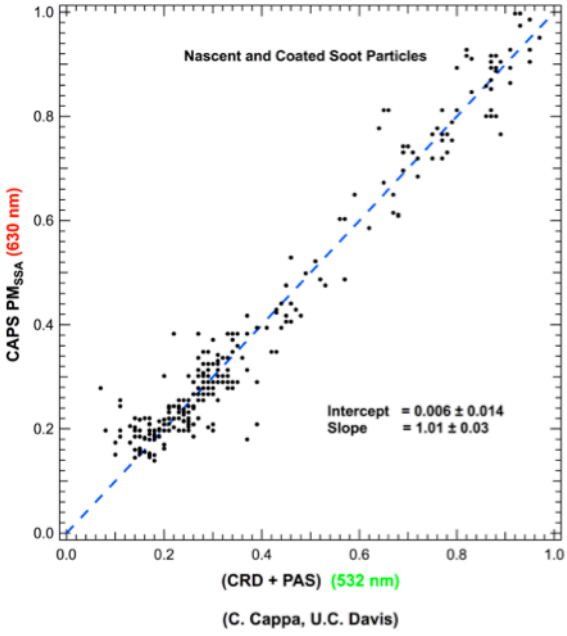

Figure 2. Comparison of measured SSA using CAPS PM_{SSA} (630 nm) and CRD Extinction+Photoacoustic Absorption Spectrometer (courtesy of C. Cappa, U.C. Davis) operating at 532 nm.