Measuring Aerosol Optical Properties Using CAPS

Timothy B. Onasch, Paola Massoli, Paul L. Kebabian, Frank B. Hills and Andrew Freedman

Center for Sensor Systems and Technology
Aerodyne Research, Inc.

45 Manning Road
Billerica, MA 01821
www.aerodyne.com

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Critical Aerosol Optical Parameters for Climate Change Modeling

• Optical Extinction (Visibility$^{-1}$)
  Total Attenuation of Light
  Extinction = Scattering + Absorption

• Single Scattering Albedo (SSA)
  Partitioning Between Scattering and Absorption
  SSA = Scattering/Extinction

• Asymmetry Parameter
  Directionality of Scattering Component
  Optics Letters 37:3654 (2012)
Measuring Extinction with CAPS PM\textsubscript{ex}

Exactly Like Laser Cavity Ringdown
No Laser
Don’t Measure the Ringdown Time

- Cavity Enhanced Technique
- LED Light Source
- Detection of Phase Shift

$$\text{Ext} = [2\pi f/c][\cot \phi - \cot \phi_0]$$
A. Petzold, T. Onasch, P. Kebabian, and A. Freedman
SSA Monitor Approach
Measure Scattering and Extinction on the Same Sample Volume

• Scattering Is Self Calibrating
  Scattering is Ratioed to Extinction
  Absolute Accuracy is Not an Issue
  Lack of Suitable Standards for Absorption

• Minimal Sampling Artifacts Compared to 2 Instruments
  Inlet Issues – Unequal Flow Rates
  Time Response

• No Wavelength Correction Required
Measuring Scattering Using An Internal Nephelometer

Collimated Light Source

- Integrating Sphere \((d = 10 \text{ cm})\) to Collect Scattered Light
- Lambertian Surface
  Photons Are Randomly Scattered (Cosine Distribution)
  No Bias with Respect to Initial Scattering Angle
- Photomultiplier Tube Measures Scattered Light
- Scattered Light Calibrated Using White Particles \((SSA=1.0)\)
  Ratioed to Measured Extinction
Calibration

Linearity

\( \lambda = 630 \text{ nm} \)

Intercept = 0.15 ± 0.2
Slope = 1.00 ± 0.0004

Ammonium Sulfate
Precision

Allan Analysis (630 nm)
Truncation

**Monodisperse**

- 630 nm (RED)
- 450 nm (BLUE)

**Polydisperse**

\[ \lambda = 530-550 \text{ nm} \]

Refractive Index = 1.46

Lognormal Particle Size Distribution (\(\sigma = 1.8\))


Typical Accumulation Mode Correction 2-6%
Ambient Monitoring
Comparison with MAAP/CAPS

- PM 2.5 Cutoff Located on Roof
- 17 lpm Sample Flow
- PM$_{ssa}$ Sampled Through Isokinetic Probe
- SSA Derived from PM$_{ssa}$ and MAAP/CAPS Combination
- Truncation Correction 1.025
Absorption Measurement
At Low SSA
$PM_{ssa}$ Preferred Way to Measure Absorption

- Extinction is the Most Accurate Optical Measurement
- Error in Scattering Contributes Little to Accuracy of Absorption Determination
Absorption Measurement At High SSA
Accuracy is the Issue

NCSR- Demokritos, Athens, Greece

$<BC> = 375 \text{ ng m}^{-3}$

$<SSA> = 0.90$

$\lambda = 630 \text{ nm}$

Courtesy of Kostas Eleftheriadis
Conclusion

- CAPS PM_{ssa}
  Autonomous Operation
  Fast Time Response ~1 second
  Rugged

- Precision  <1 Mm^{-1} (1s) in Both Channels

- Accuracy  SSA  \pm 2\% (dependent on truncation)
  Extinction  \pm 5\% (?)

Tim Onasch
Multi-Wavelength Measurement of Soot Optical Properties:
Influence of Non-Absorbing Coatings
Saturday, 12:15 OP22-3 Room B (104+105)

Andy Freedman
Optical Measurements of Aircraft Engine Soot Emissions
Saturday, 14:45 OP49-2, Room D (109-110)