Measurement Needs and Challenges for Absorbing Aerosol
Black Carbon, Brown Carbon, Dust and Coatings

Dan Lack
Daniel.lack@noaa.gov
Cloud & Aerosol Process Group
CSD/ESRL/NOAA

Presented at:
NIST Aerosol Metrology for Climate Workshop
15th March, 2011
Absorbing Aerosols and Climate

TOA Forcing

Layer Warms

BC in Clouds

Surface Dimming

Deposition

Snow Darkens and Warms
Forcing

\[ \Delta_a F^\uparrow = \frac{1}{2} F_T T^2 (1 - A_C) \times [SSA \beta_a (1 - R_s)^2 - 2(1 - SSA)R_s] AOD \]

- SSA – Aerosol single scatter albedo
- \( \beta_a \) – Aerosol upscatter fraction
- AOD – Aerosol optical depth
- \( A_C \) – Cloud Fraction
- \( R_s \) – Surface Albedo

Forcing Uncertainties

1. BC mixing state.
2. BC vertical distributions.
3. Inventories.
4. Indirect effect.
   - Precipitation patterns.

(Ramanathan and Carmichael 2008)
SSA Evolution

(Russell et al 2002)
SSA Evolution

Coating Evolution
Absorbing Core / Clear Coat

Coating Evolution
Absorbing Core / Absorbing Coat

Absorption Evolution
Absorbing Organic Particles

Density Evolution
BC Fractal Dimension
Global Distributions of Variations in Absorbing Material/Effects (simplified look)

- Fractal BC, Clear Coatings, Evolving BC shape, evolving BrC
- Non-Fractal BC, BrC Coatings
- Sub-Equatorial: Dust

(NOAA.gov)
Remote Sensing and Models

Models until recently

Satellite/radiometer retrievals

Most models now

In-Situ Measurements
In-Situ Measurements:

1. BC mixing state.
2. BC vertical distributions.
3. Inventories.
4. Indirect effect.

- Most information comes from mass measurements. Optics is inferred from in-situ laboratory or field studies.
  - Mass extinction, scattering, absorption efficiencies.

- Extinction (± 1 - 10%)
- Scattering (& backscatter) (± 3 - 10%)
- Absorption (± 5 - 50%)
Extinction

- Cavity Ring Down
- Extinction cells
- CAPS Extinction

Baynard et al 2007
Massoli et al 2010

Langridge et al 2011
Scattering

- Nephelometers
- Integrating spheres

Absorbing Aerosol Biases

Massoli et al 2009
Absorption

- **Filter-Based**
  - Corrections:
    - Scattering (size?, SSA?)
    - Flow
    - Filter spot size
    - Particle morphology
    - Particle phase?

- **Photo-Acoustic Spectroscopy (PAS)**
Simple absorbing systems (filter vs PAS):

Absorbing Mono-Disperse Spheres

(Lack et al 2008)

\[ Y = 1.03 (\pm 0.01)X - 0.1(\pm 0.1) \]

(Lack et al 2009)
Water Uptake and Absorption

$(Lack \ et \ al \ 2009) \ (Zhang \ et \ al \ 2008)$
Filter-Based Absorption: Organic Particles

Black Carbon

Organic + Black Carbon

(Subramanian et al. 2007)

(Lack et al. 2008)
Filter Based Absorption: Particle Size

(Lack et al 2009) (Nakayama et al 2010)
Filter Based: Variability

- Filter-based measurement has a number of issues.

Photo Acoustics (or PTI)

- Expensive, compared to filter methods.
- Can have biases at elevated RH or large particle sizes.
- Has yet to be widely deployed.
Long Term Monitoring

• Cannot spend $100’s K on state of the art.
  – Filter-based methods will continue to be used unless new inexpensive techniques are available.

• Require simple instruments to be:
  – Inexpensive
  – Robust
  – Simple operations
  – Well characterised
Characterisation Requires

• Simple Absorbing standard:
  – Spherical.
  – Monodisperse (known sizes)
  – Known refractive index (extinction, scattering, absorption at multiple wavelengths)

• More realistic absorbing standard (BC, soot)?

• RH Effects.

• Shape / Size Effects.

• Effects of OA.

• Effects of pressure.
Vertical Profiles

• Aircraft platforms require fast sampling.
• Alternative: instrument development for simpler platforms (balloons?).
• Require instruments to be:
  – Sensitive (immune to ambient and platform noise)
  – Probe relevant parameters
    • λ’s, coatings, BrC, RH
  – Well characterised
• Cavity Ring Down and PAS technologies have not yet common aircraft research tools.
References


Langridge, J. et al Aircraft instrument for comprehensive characterisation of aerosol optical properties, part 1: wavelength dependent optical extinction and its relative humidity dependence measured using cavity ringdown spectroscopy, submitted to AS&T, 2011