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

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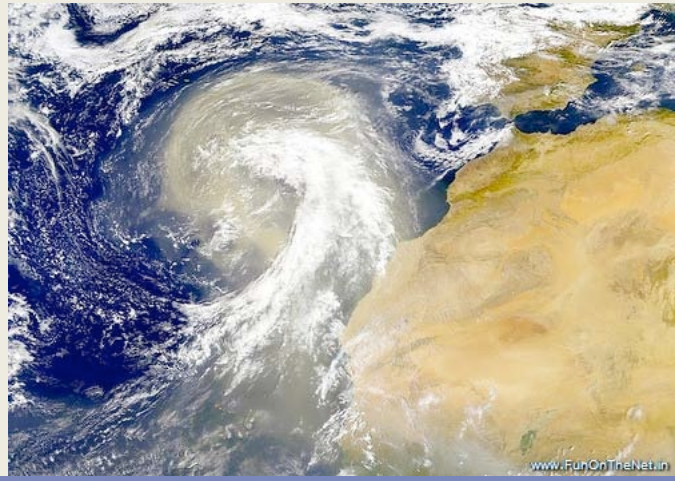
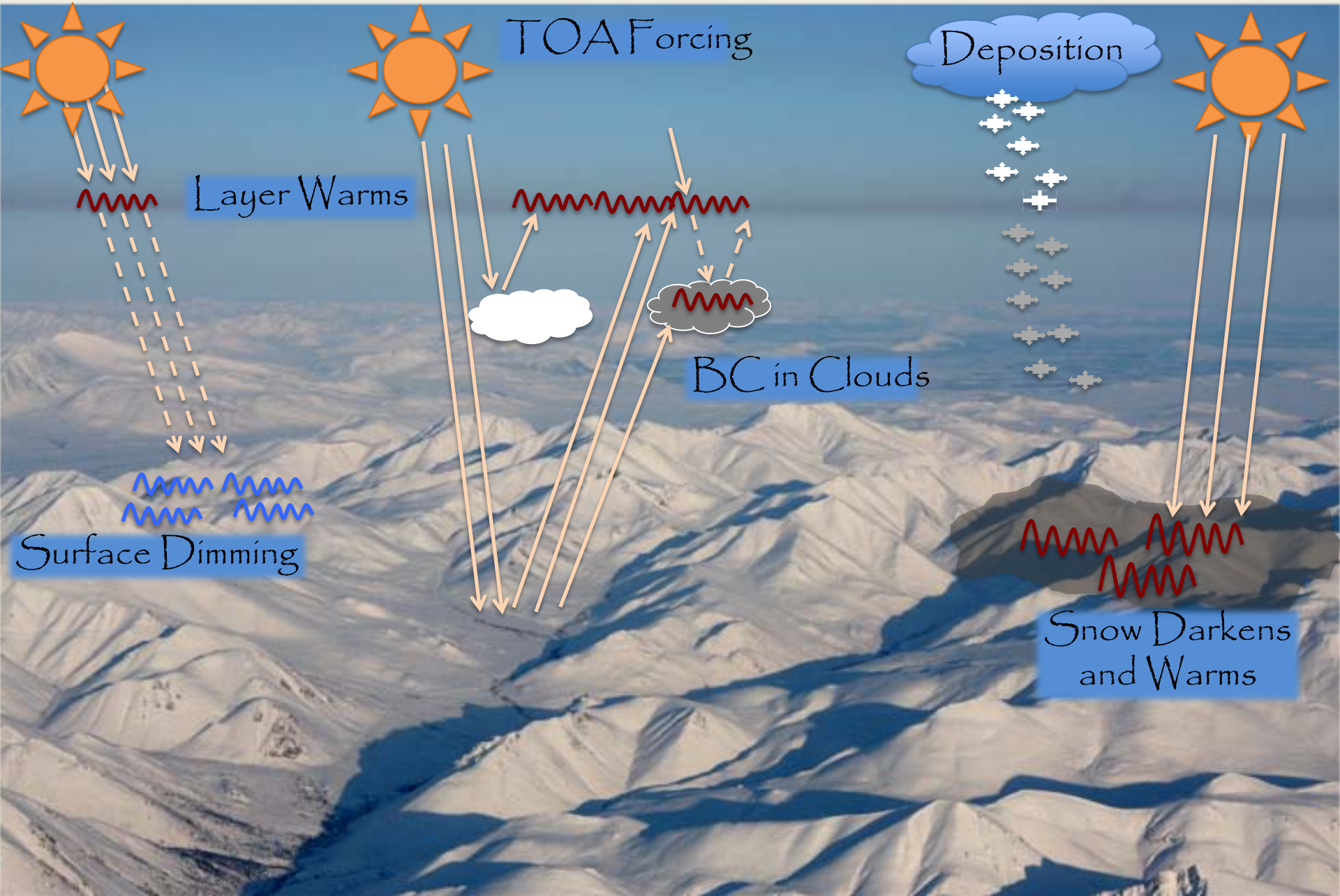


Absorbing Aerosols and Climate



Forcing

$$\Delta_a F\uparrow = 1/2 F_T T^2 (1-A_C) \times [SSA\beta_a (1-R_S)^2 - 2(1-SSA)R_S] AOD$$

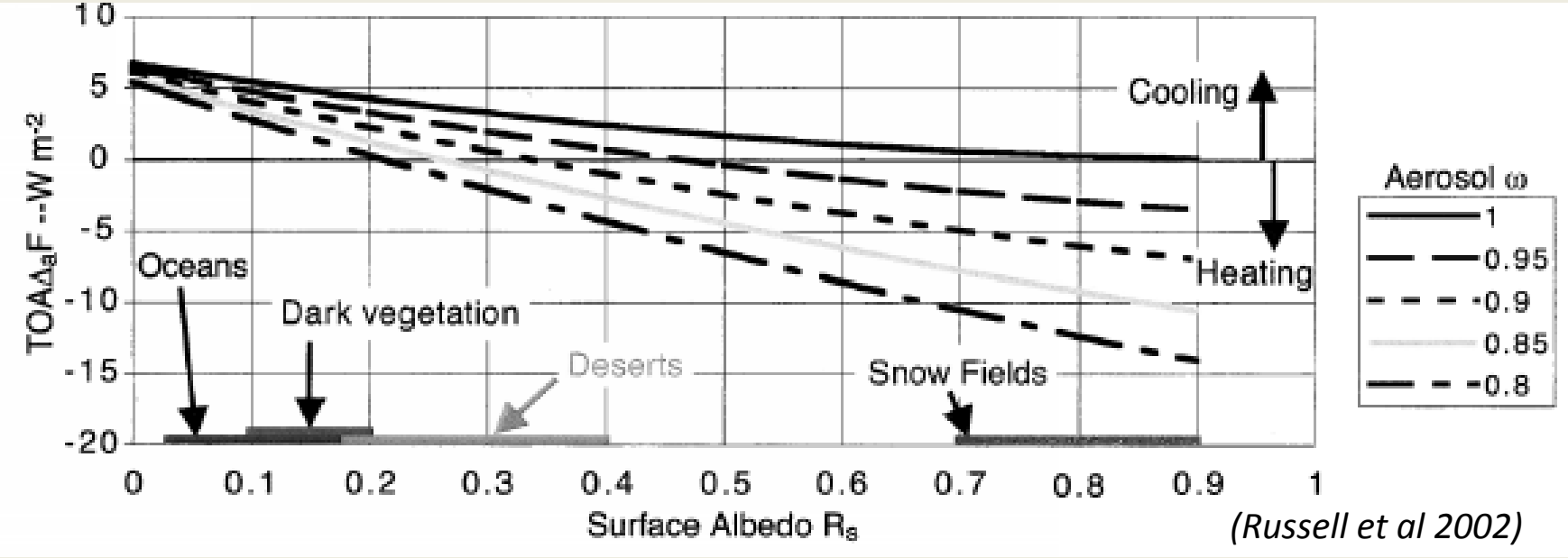
- *SSA – Aerosol single scatter albedo*
- *β_a – Aerosol upscatter fraction*
- *AOD – Aerosol optical depth*
- *A_C – Cloud Fraction*
- *R_S – Surface Albedo*

Forcing Uncertainties

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

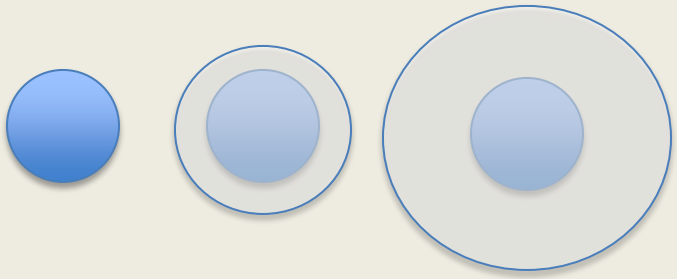
(Ramanathan and Carmichael 2008)

SSA Evolution

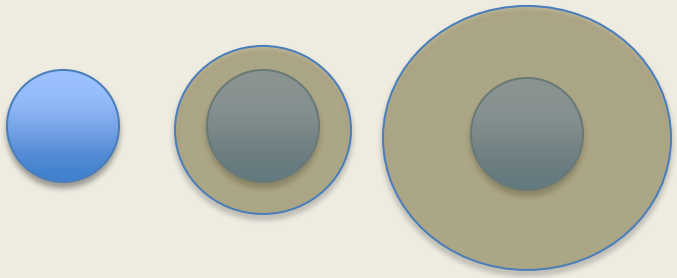


(Russell et al 2002)

SSA Evolution

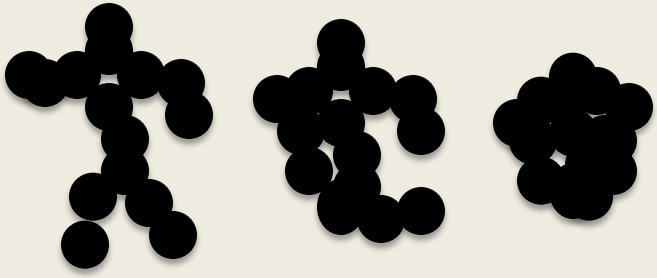


Coating Evolution
Absorbing Core / Clear Coat



Coating Evolution
Absorbing Core / Absorbing Coat

Absorption Evolution
Absorbing Organic Particles



Density Evolution
BC Fractal Dimension

SSA

1

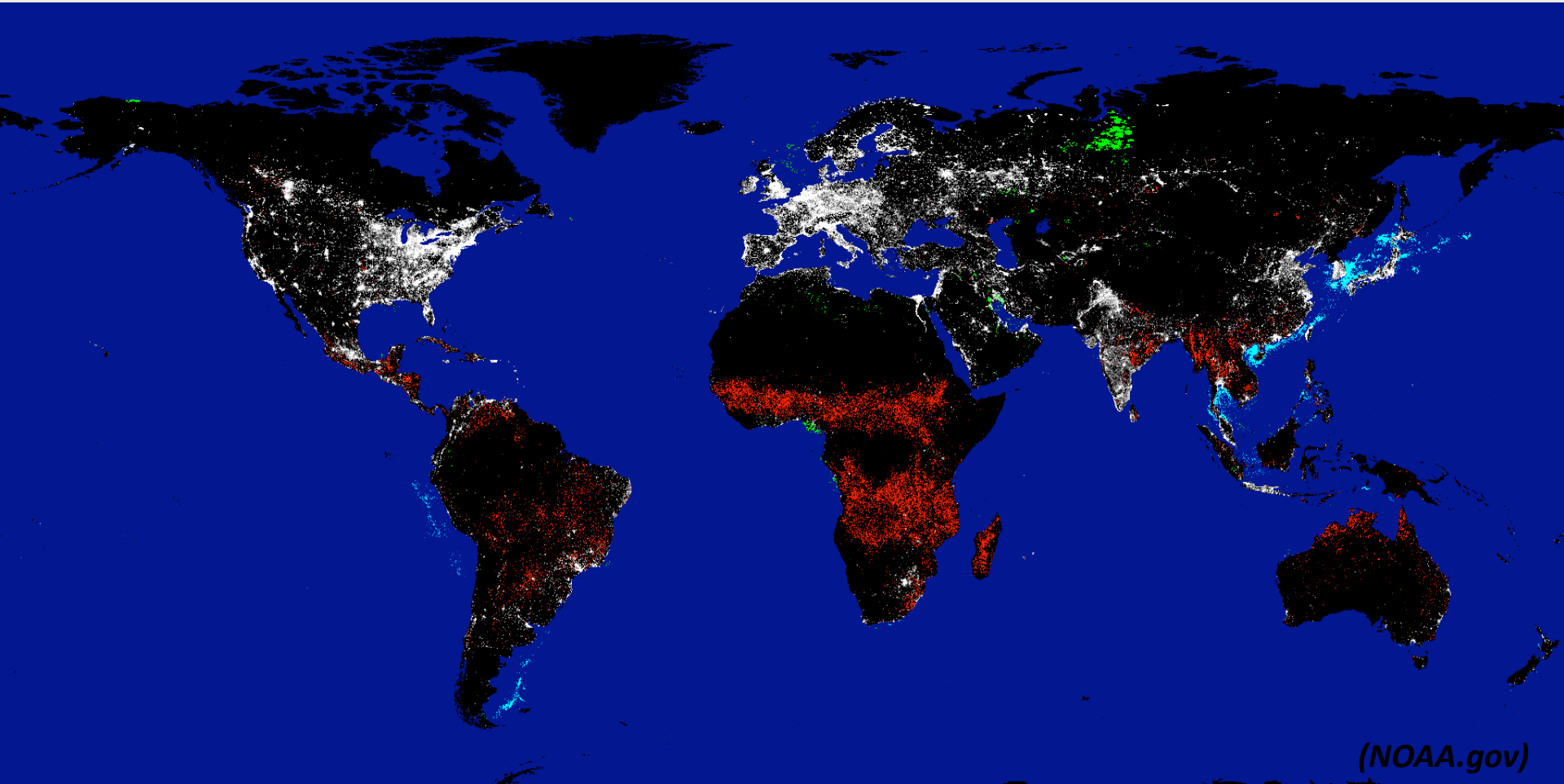
0.2

Global Distributions of Variations in Absorbing Material/Effects (simplified look)

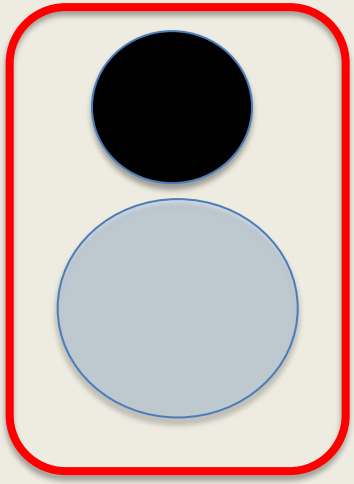
Fractal BC, Clear Coatings, Evolving BC shape, evolving BrC

Non-Fractal BC, BrC Coatings

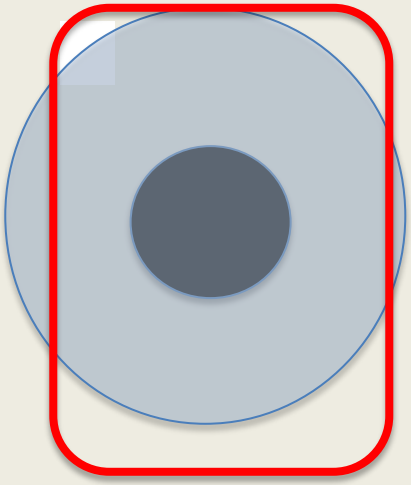
Sub-Equatorial: Dust



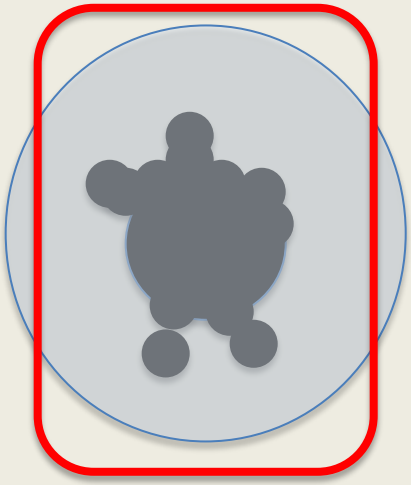
Remote Sensing and Models



Models until recently



Most models now



Satellite/radiometer retrievals

In-Situ Measurements

In-Situ Measurements:

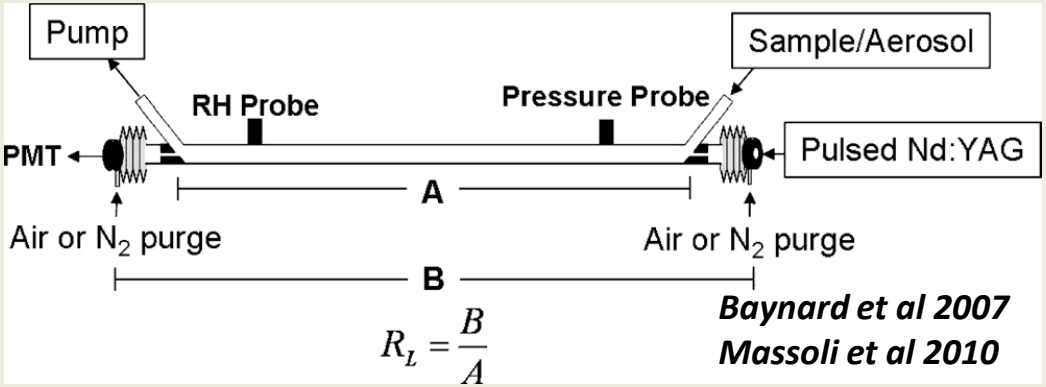
1. BC mixing state.
2. BC vertical distributions.
3. Inventories.
4. Indirect effect.

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

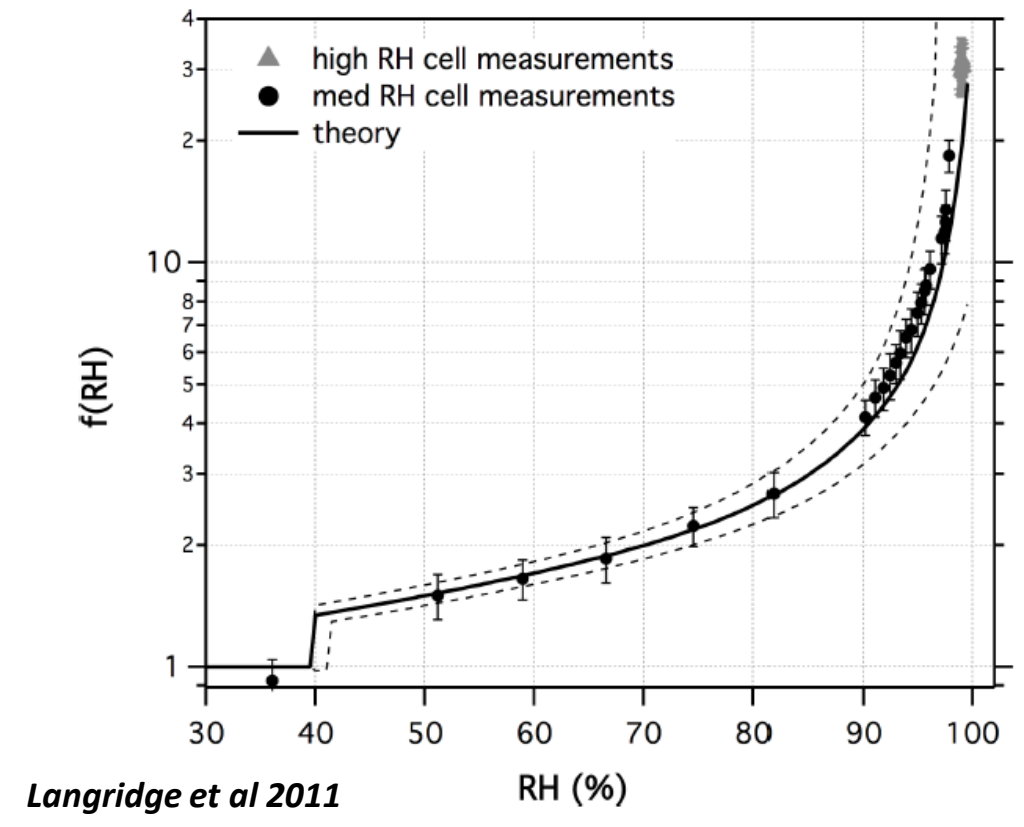
- Extinction (± 1 - 10%)
- Scattering (& backscatter) (± 3 - 10%)
- Absorption (± 5 - 50%)

Extinction

- Cavity Ring Down
- Extinction cells
- CAPS Extinction



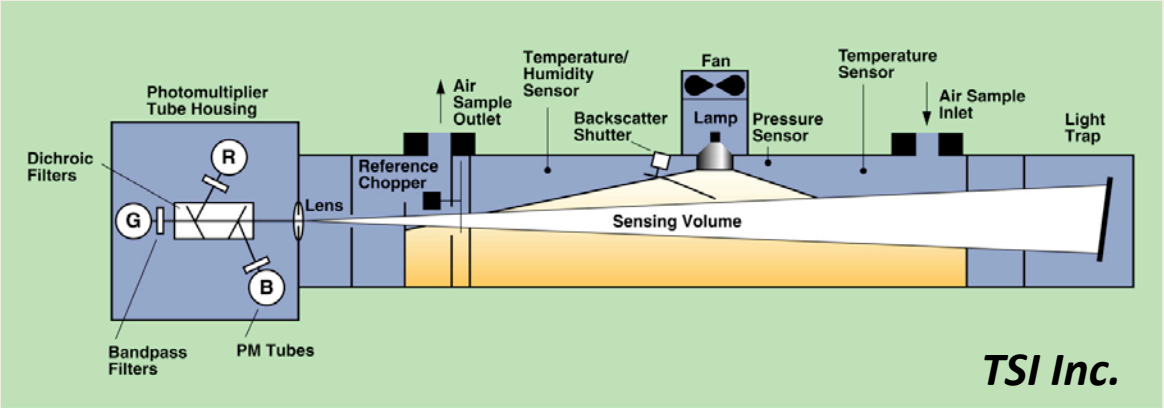
Baynard et al 2007
Massoli et al 2010



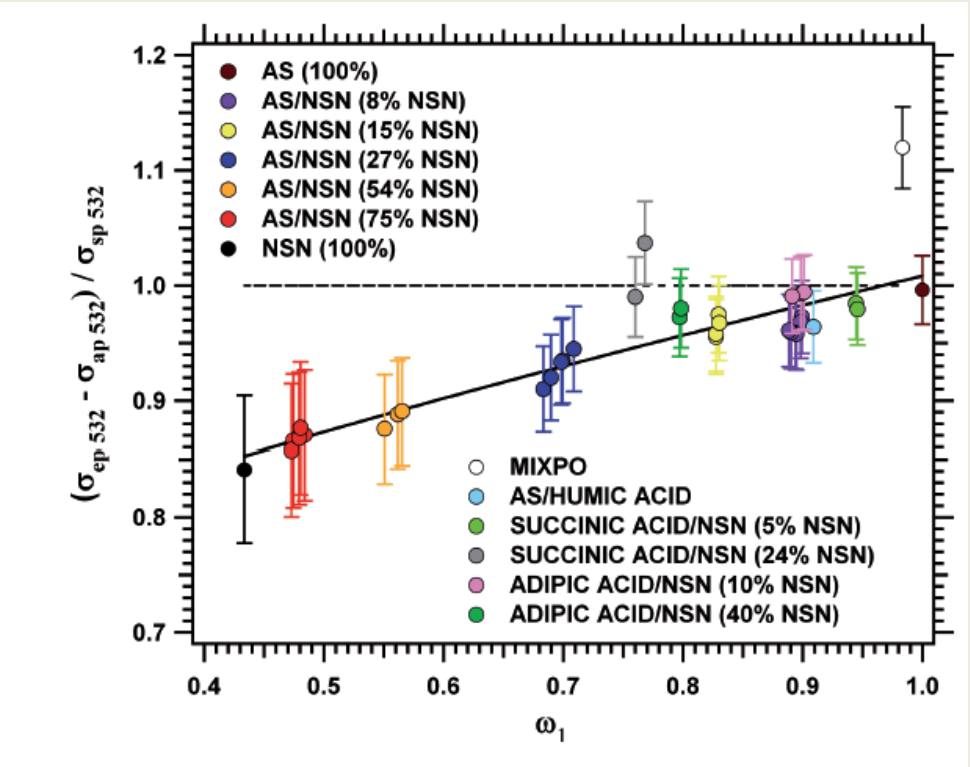
Langridge et al 2011

Scattering

- Nephelometers
- Integrating spheres



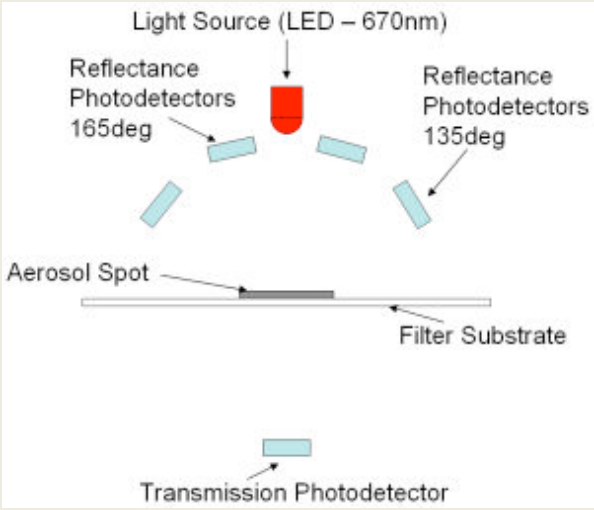
Absorbing Aerosol Biases



Massoli et al 2009

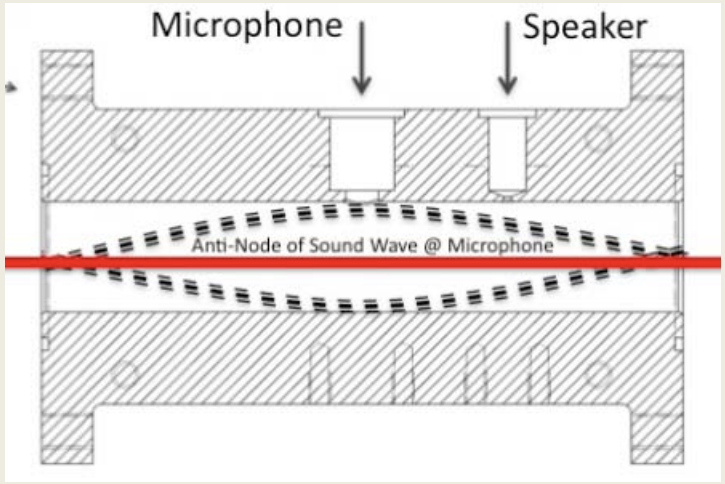
Absorption

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

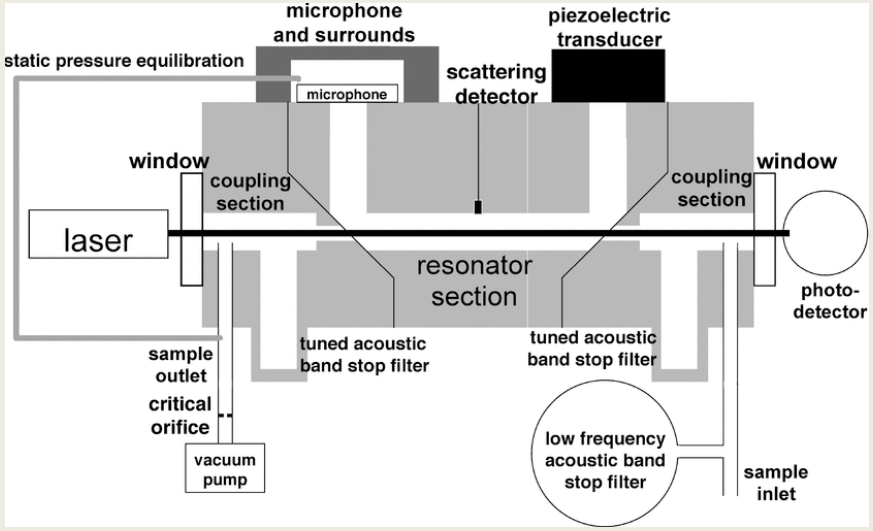


Petzold & Schonlinner 2004

- Photo-Acoustic Spectroscopy (PAS)



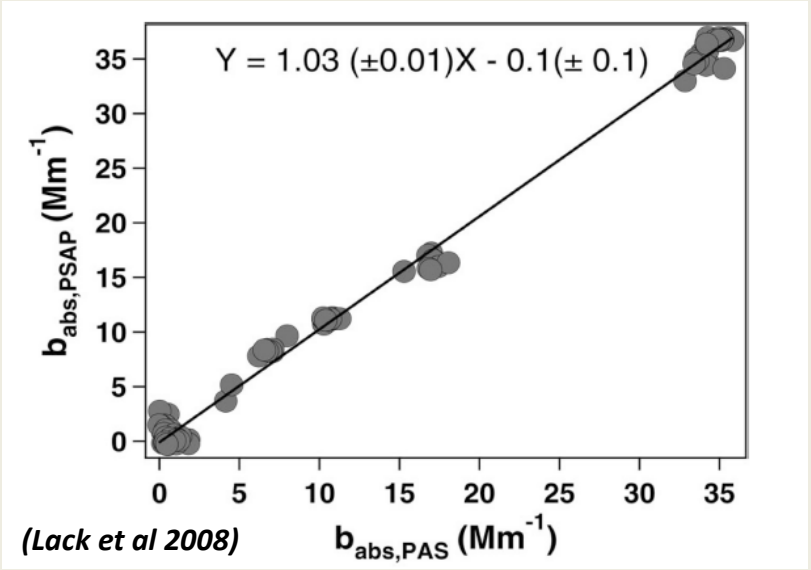
Lack et al, 2011



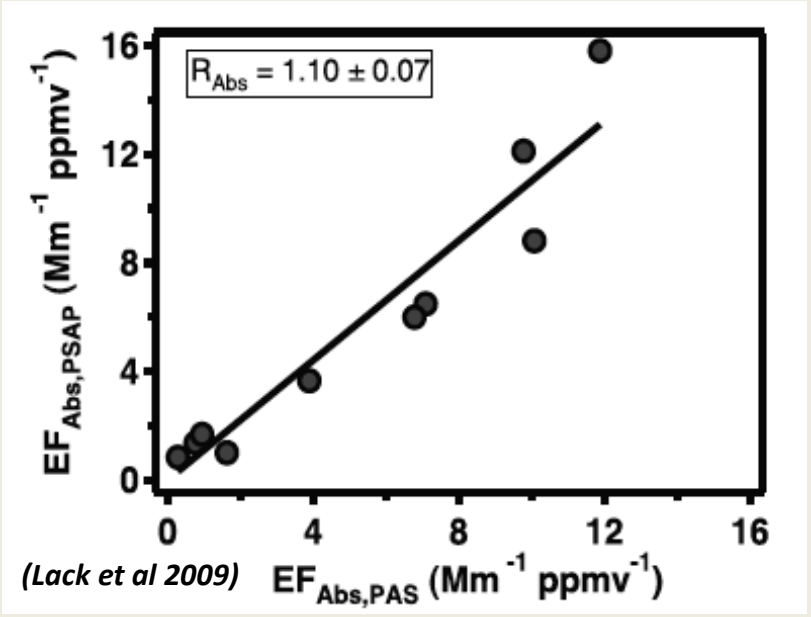
Tian et al, 2009

Simple absorbing systems (filter vs PAS):

Absorbing Mono-Disperse Spheres

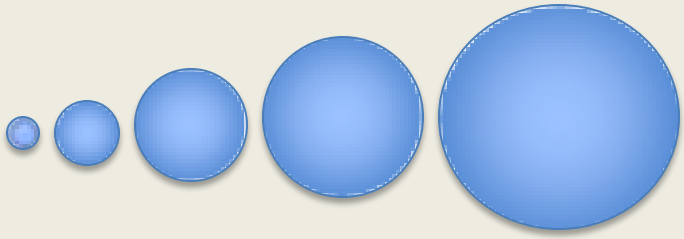


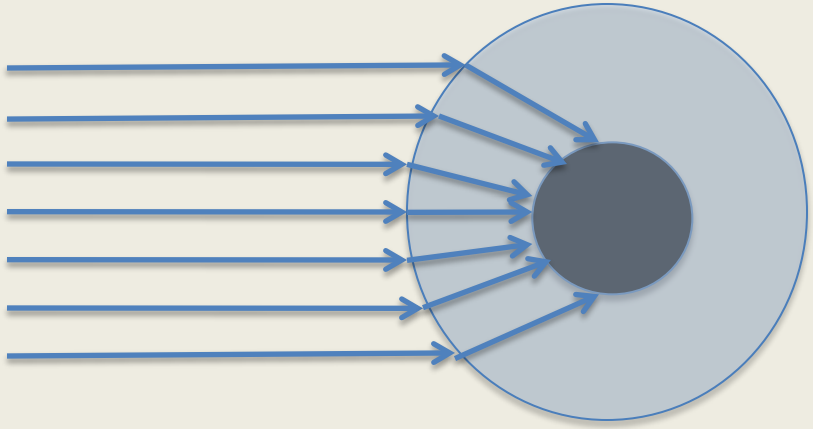
(Lack et al 2008)

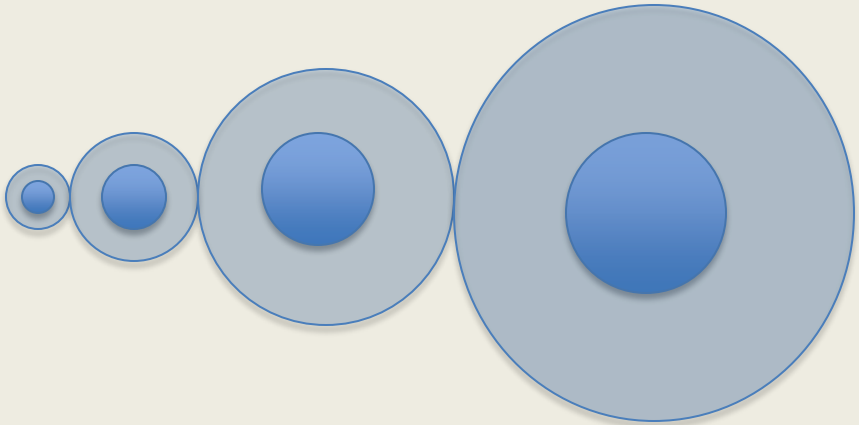


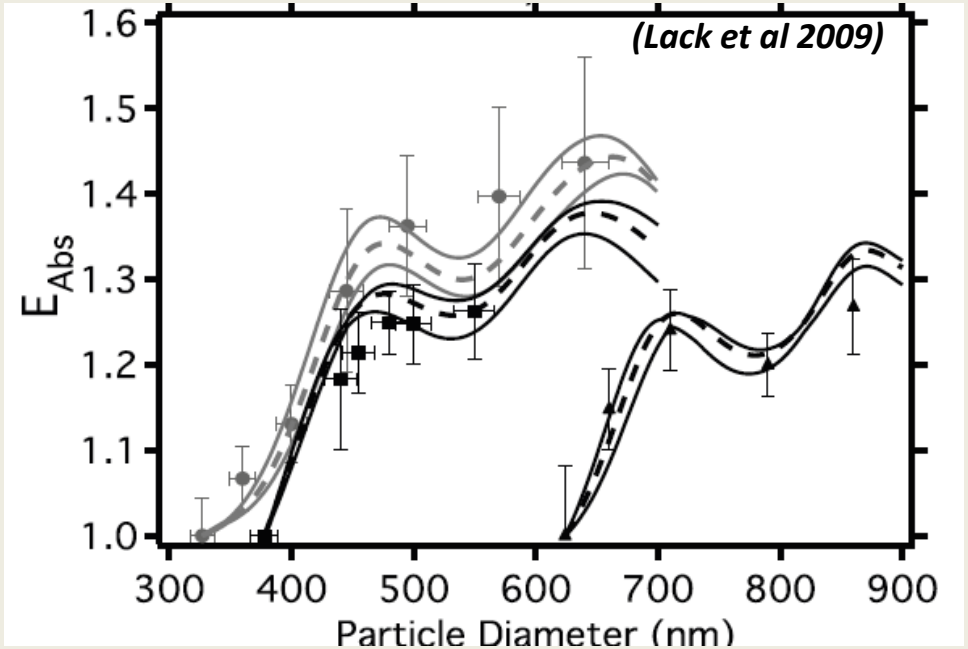
(Lack et al 2009)

Coated Absorbing Systems

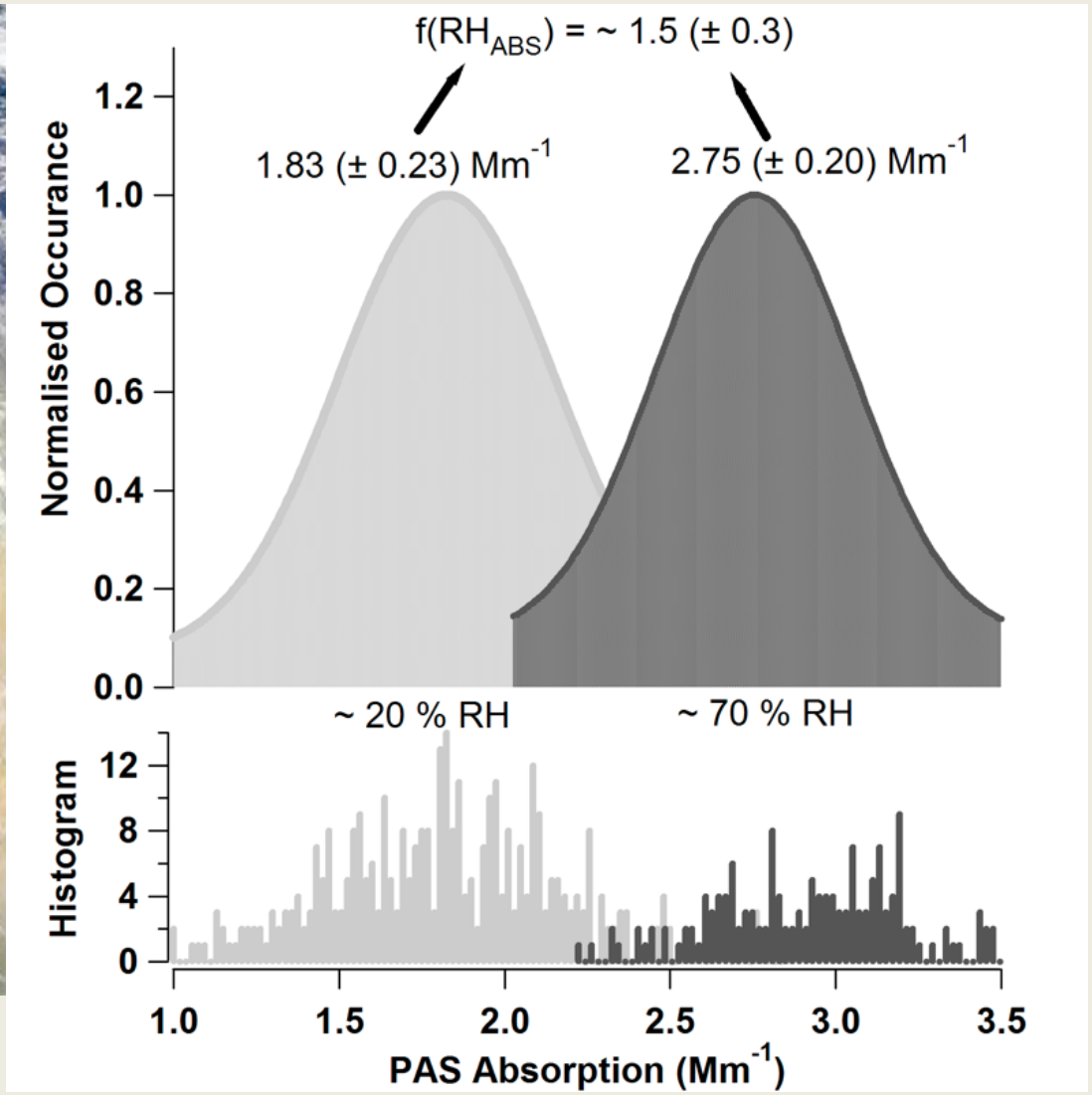








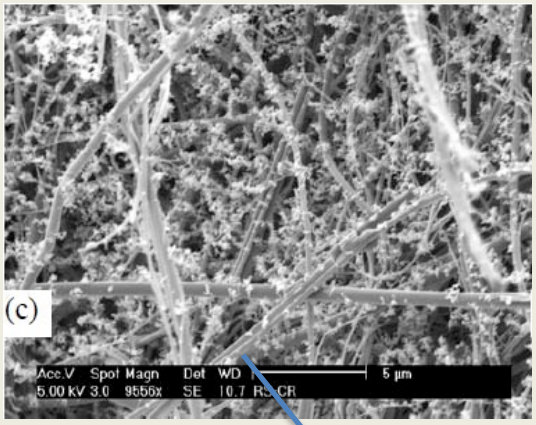
Water Uptake and Absorption



(Lack et al 2009) (Zhang et al 2008)

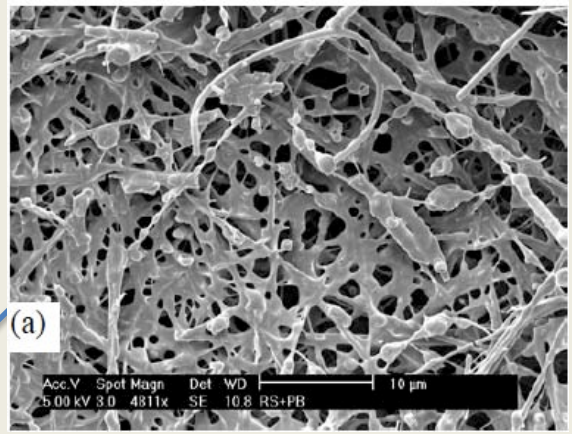
Filter-Based Absorption: Organic Particles

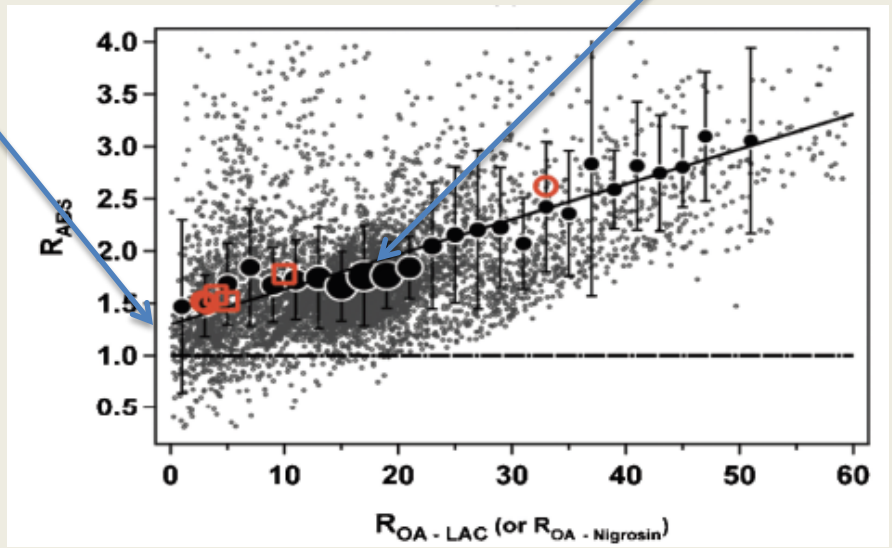
Black Carbon



(Subramanian et al. 2007)

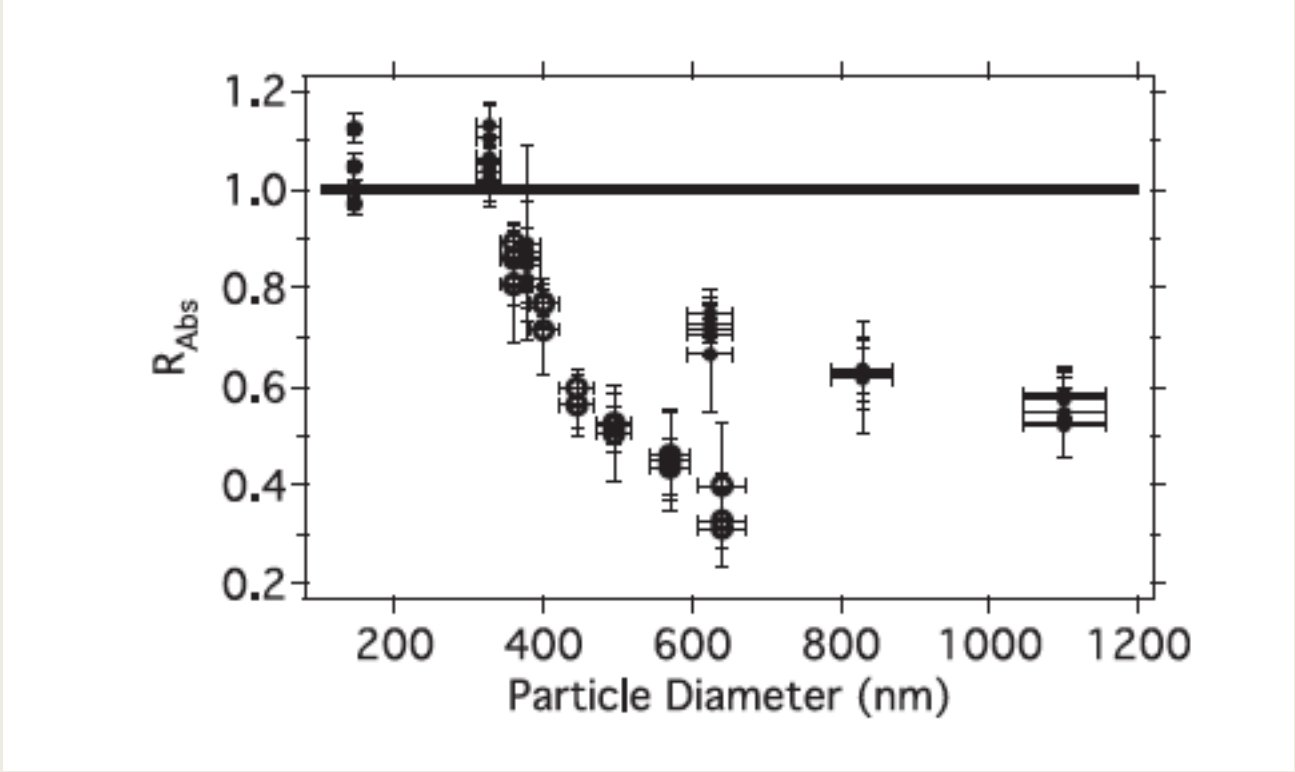
Organic + Black Carbon





(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.
- Muller et al, Characterization and intercomparison of aerosol absorption photometers: result of two intercomparison workshops. *Atmos. Meas. Tech.* ***2011, 4, (2), 245-268.***

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.

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