U.S. DEPARTMENT OF ENERGY | Office of Science

Pacific Northwest NATIONAL LABORATORY

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A Modeling Perspective on Absorption

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- Absorption is a **key parameter** that contributes to aerosol direct and semi-direct effects
- Aerosol optical parameters can be **computed in several ways**, and we need to know which is the **most appropriate method** for climate model predictions
- Therefore, modelers need to have a **high confidence in the absorption measurements** used for model evaluation

Model Treatments of Optical Properties

Current Assumptions in CAM

- Internal mixtures for computation of optical properties for 3-mode aerosol; some external mixing for 4 and 7 mode aerosols
- No BC absorption in water droplets

Treatments in Being Tested CAM

- Separate organic aerosol species (anthropogenic, biogenic, biomass burning)
- Brown carbon absorption for primary emissions of biomass burning
- Speciation of dust – primarily for ice nucleation, but could also account for variable refractive indices for dust

Other 0-D and regional-scale models often have more complex treatments, but they are also computationally more demanding

size and number distribution, composition (with aerosol water) → refractive indices → (*mixing rules*) Mie theory → (*scattering absorption*) layer optical depth, τ_λ single scattering albedo, ω_o asymmetry factor, g → radiation calculations

τ_λ *evaluated most often*

Challenges in Simulating SSA

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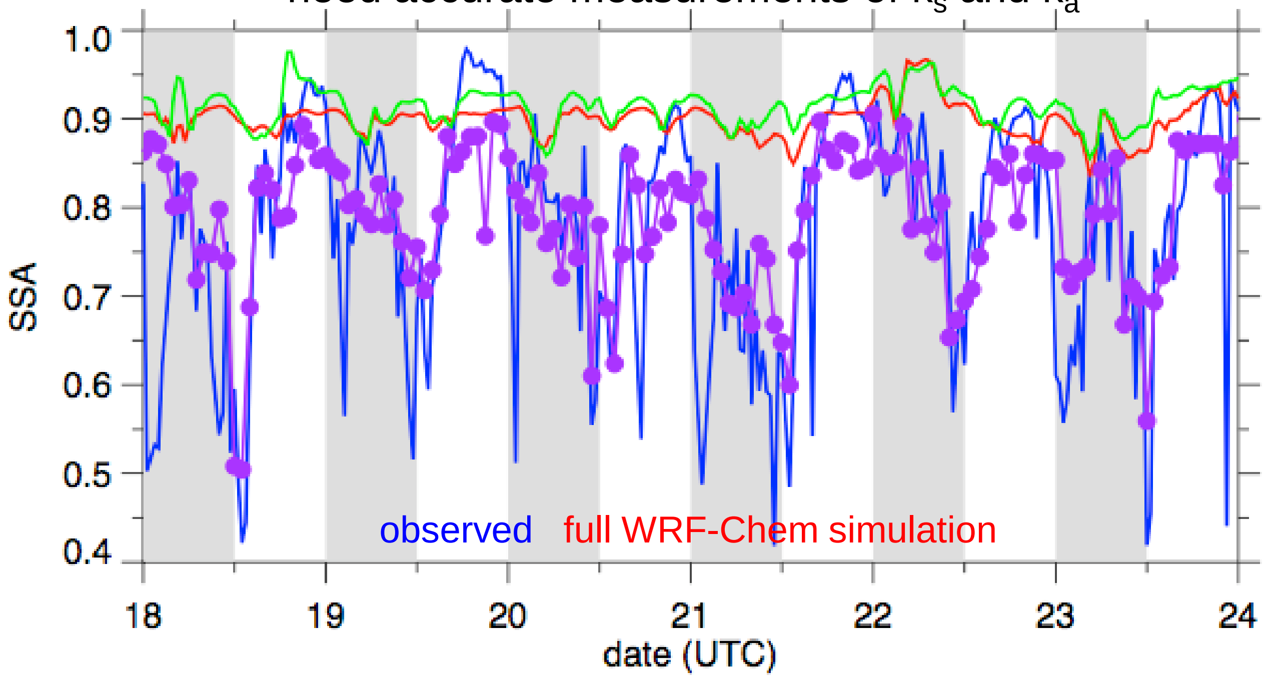
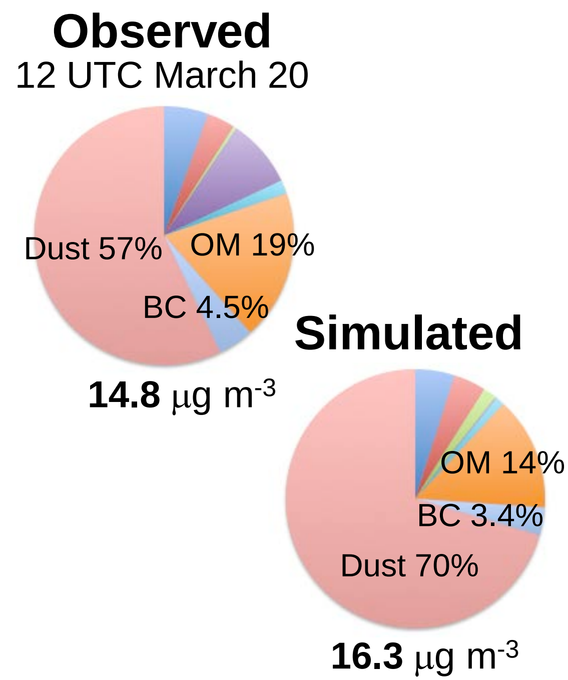
$$SSA_{870nm}\ (\omega_o) = k_s / (k_a + k_s)$$

need accurate measurements of k_s and k_a

from Barnard et al. ACP (2010)





- aerosol optical properties driven by data (volume-averaging and shell-core similar)

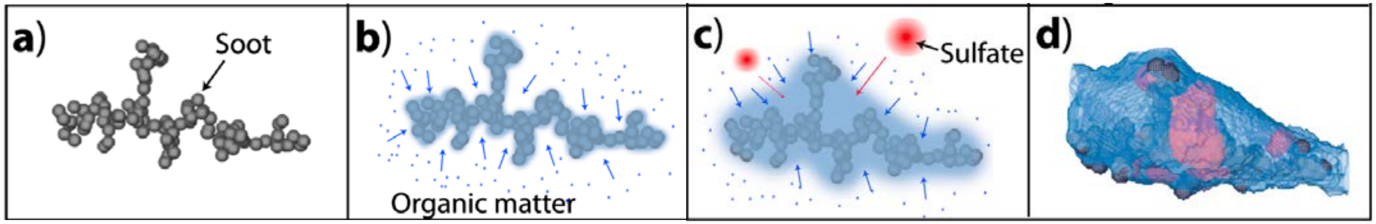
- Primary reason for error in simulated SSA is prediction of particulate composition (especially BC), rather than assumptions in aerosol optical properties
- This study did not evaluate optical properties at lower wavelengths, since a lack of dust and organic data (size, composition) would be an issue for absorption

Refractive Indices

Refractive indices employed by models are a function of composition and obtained from laboratory studies.

- **"Black Carbon"**
  - Range of values reported in the literature, for example *Bond and Bergstrom* (2006) report 1.75 – 1.95 for real part and 0.63 – 0.79 for complex part at 550 nm
- **Organics:**
  - In the past, one refractive index usually used, but …
  - Models are now speciating organics (POA, SOA, biogenic, biomass burning) so it is possible to account for different types of organics
  - "Brown carbon" is an obvious example, but data is limited – mostly to biomass burning
- **Dust:**
  - An important absorber for λ less than about 500 nm
  - Range of values reported in the literature, dependent upon composition but speciated dust source datasets just now being developed

Aerosol Morphology

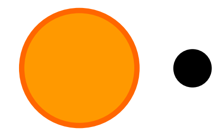


real world soot coating

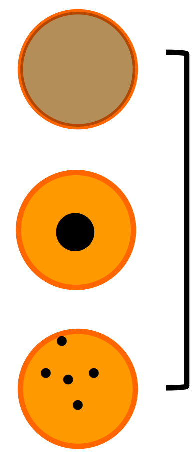
Adachi et al., 2010

model's treatment of soot

- Mixing rules applied to account (crudely) for morphology
  - **External Mixing:** assume single composition for each particle

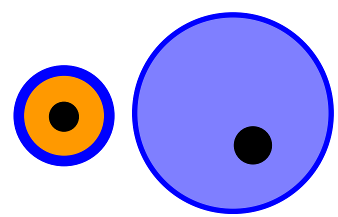


  - **Volume Averaging:** averaging of refractive indices based on composition
  - **Shell-Core:** BC core and average of other compositions in shell; *Ackermann and Toon* (1983), *Bohren and Huffman* (1983)
  - **Maxwell-Garnett:** small spherical BC cores randomly distributed in particle; *Bohren and Huffman* (1983)



internal mixing

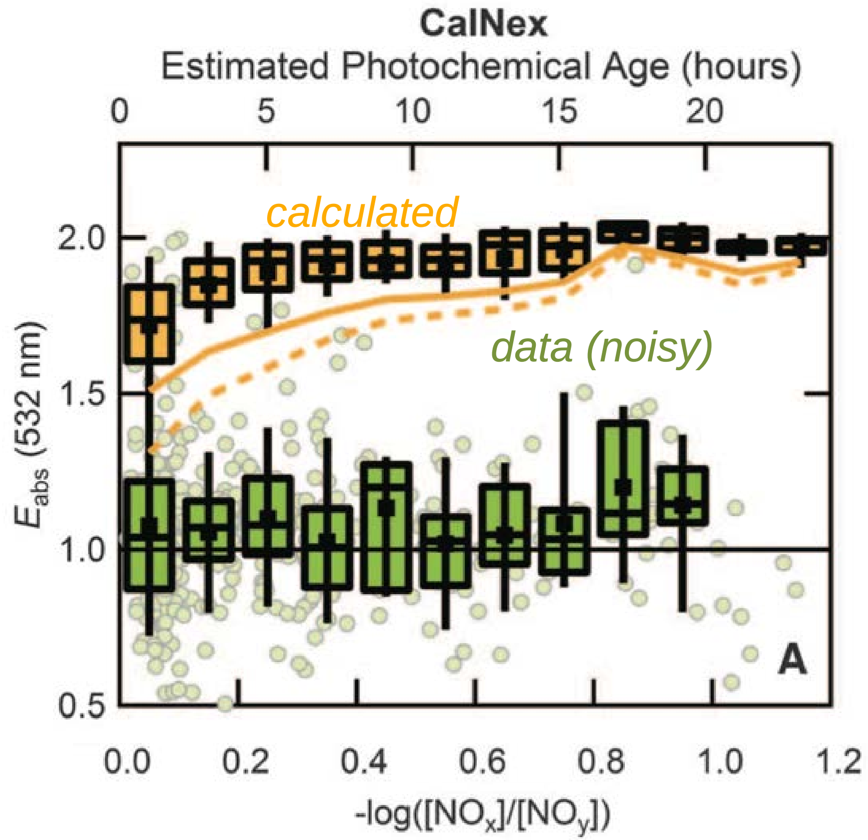
  - BC forcing for internal mixing > for external mixing
- What about effect of water uptake and aerosols in clouds (both cloud-borne and interstitial aerosols)?



Model Evaluation: Measurements

- **Black Carbon:** SP2 a critical instrument
- **Organics:** Need speciated organic information which is possible to derive from AMS data
- **Coarse Mode:** Need size distribution of composition > 1 μm (*Kassianov et al., GRL, 2012*)
- **Mixing State:** Now have instruments (e.g. SPLAT) and lab analysis techniques to provide this information
- **Absorption:**
  - PSAP (traditional)
  - Photoacoustic systems
  - AERONET AOD_{abs}, (derived)
  - Models need to be evaluated more frequently at more than one wavelength

uncertainties?

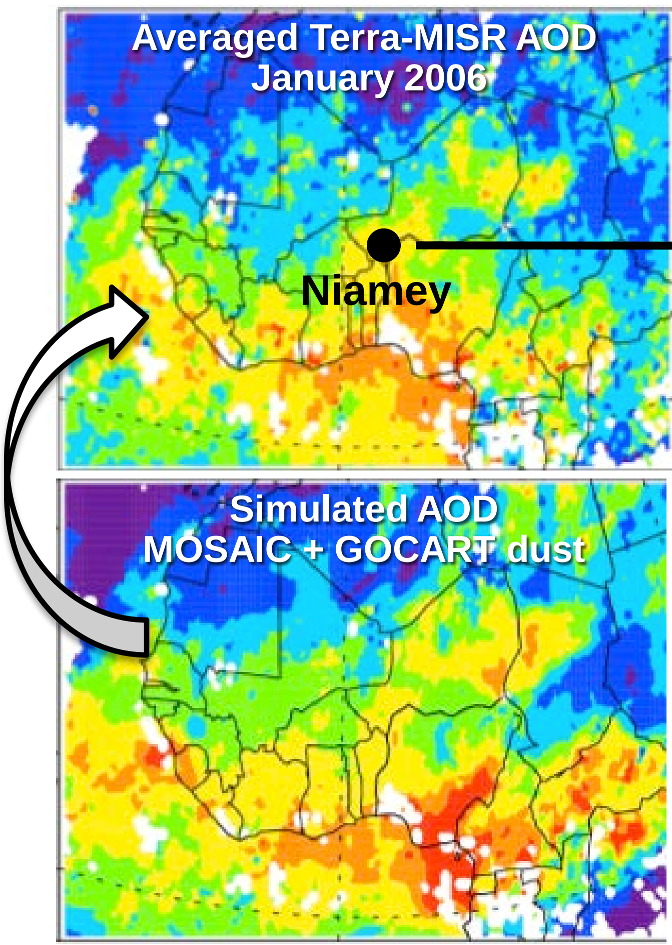


Similar results for CARES

Cappa et al., Science, (2012) found little enhancement in absorption with aging in contrast with model representation, but this result is only for low RH

Model Evaluation: Profiles

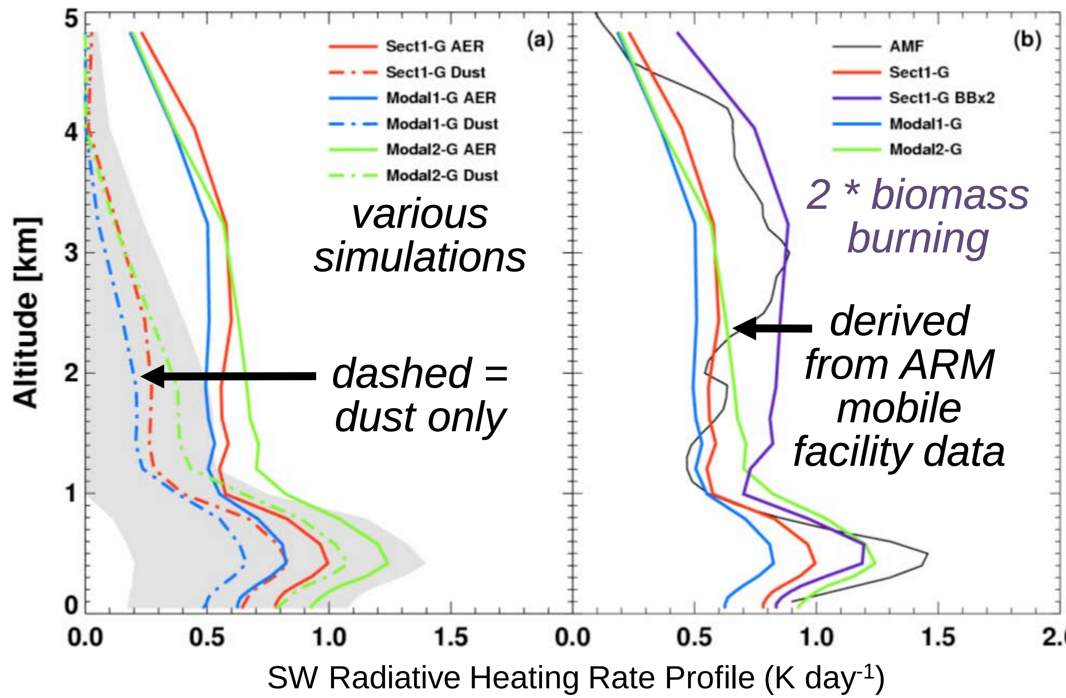
Common Type of Evaluation



from *Zhao et al.*, ACP, 2010

necessary, but not sufficient type of evaluation

Uncommon Type of Evaluation



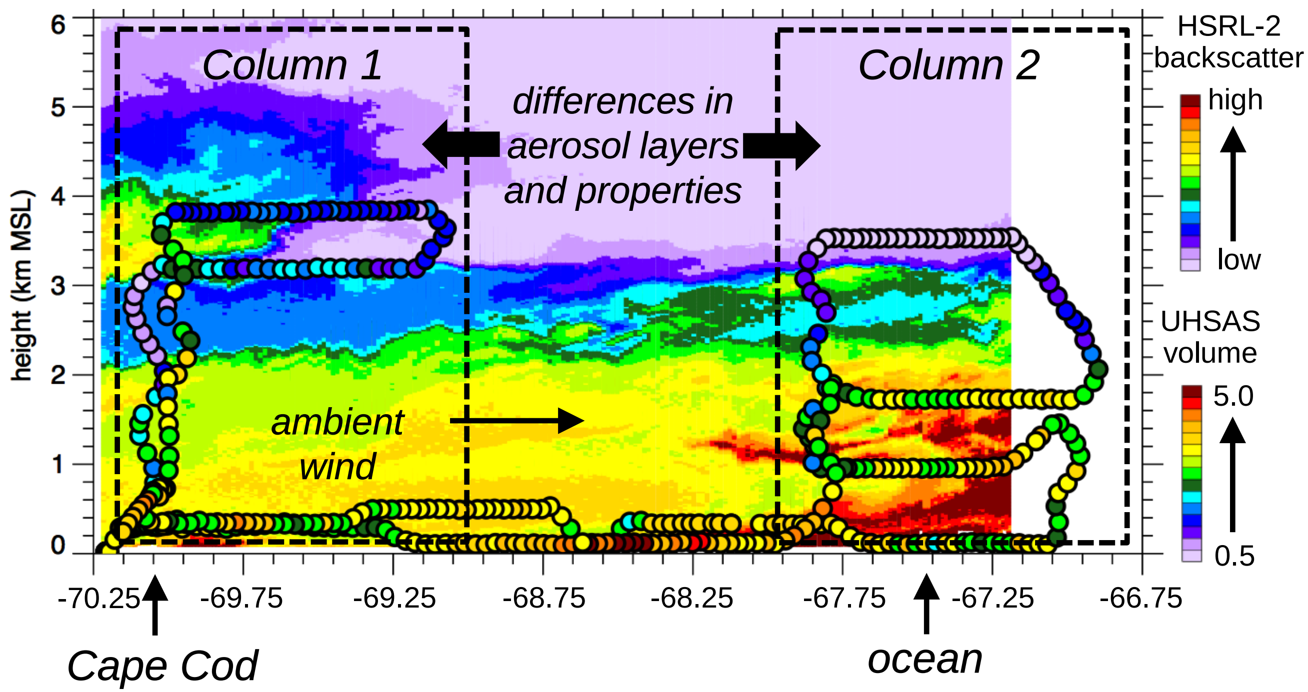
- We have vertical profiles of a range of aerosol parameters from aircraft and remote sensing (e.g. Lidar) platforms, but …
- Coincident measurements of BC (and other absorbing aerosols) and absorption profiles are more limited

Measurement Strategies

Are there enough measurements to verify simulated absorption?

- Are measurements at long-term ARM sites (SGP, TWP, NSA) sufficient?
- Are measurements from multiple platforms (e.g. aircraft, mobile facilities) during ARM IOPs sufficient?

Use TCAP Closure Studies to Examine Uncertainties in Absorption Profiles



- HSRL-2 obtained extinction profiles, profiles of aerosol composition, scattering, and absorption from G-1
- Evaluate single-column CAM (constrained) and unconstrained 3-D CAM simulations
- Test model treatments of aerosol optical properties