Retrieving Black Carbon AAOD from refractive indices of AERONET retrievals

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Extension of
Schuster, G., Dubovik, O., and Arola, A.:
Remote sensing of soot carbon – Part 1: Distinguishing different absorbing aerosol species
Atmos. Chem. Phys., 16, 1565–1585
https://doi.org/10.5194/acp-16-1565-2016, 2016.

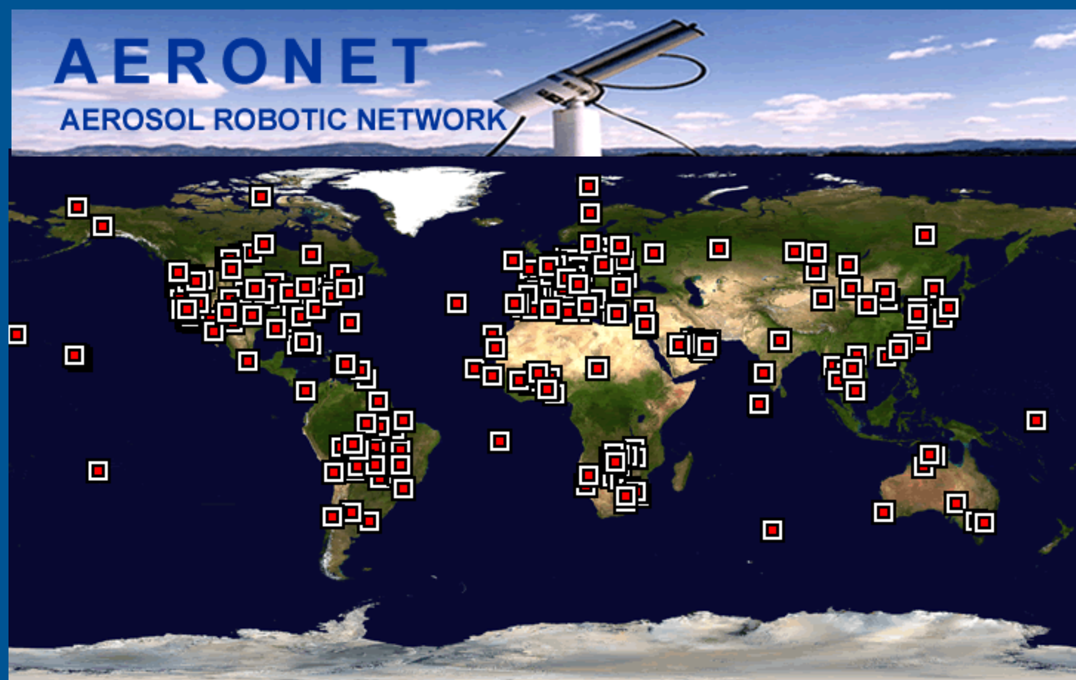
Data through Feb 11, 2017 publicly available at
https://science.larc.nasa.gov/personal-pages/gregs/data/2019-08-26/

Acknowledgements
This work was supported by NASA's Science Mission Directorate, Earth Science Division, Glory Science Team. We appreciate the efforts of the AERONET and PHOTONS (Service d'Observation from LOA/USTL/CNRS) principal investigators and the entire AERONET/PHOTONS teams.

The AERONET Retrievals

Principal Investigator: Brent Holben, GSFC

Federation of sky-scanning sunphotometers

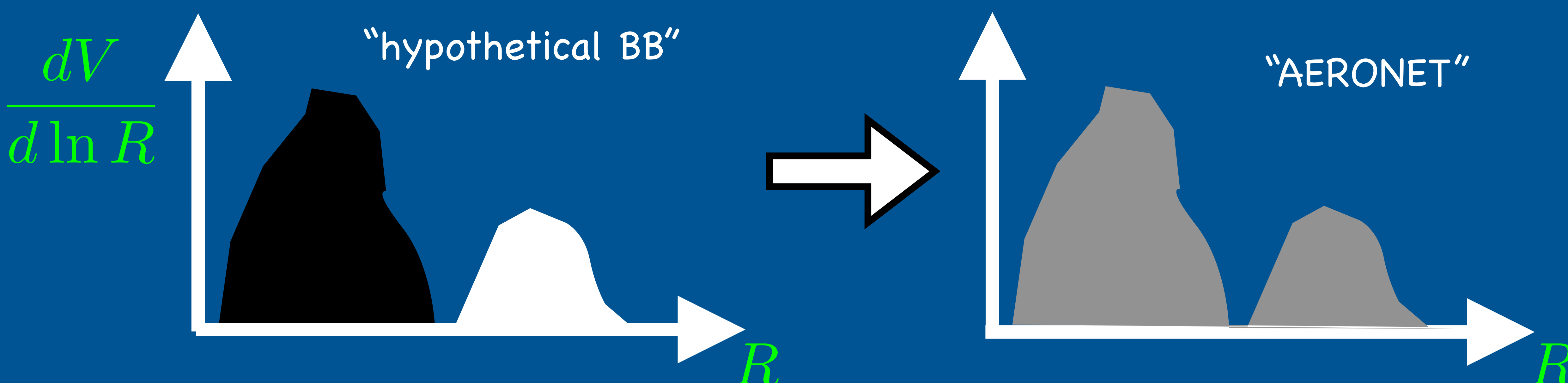


When AOT(440) > 0.4, AERONET provides:

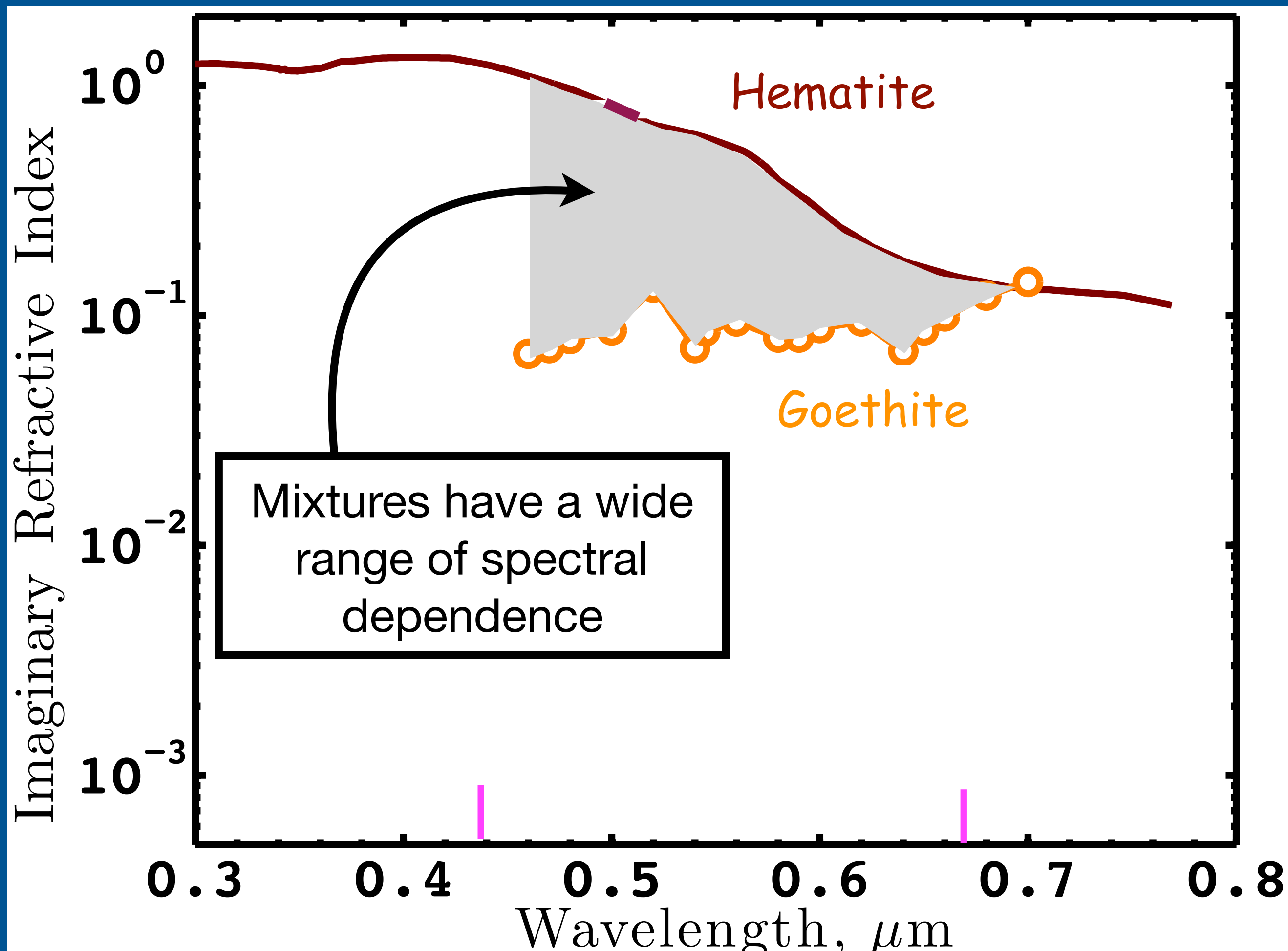
- Volume size distribution
- Aerosol complex refractive index $n(\lambda), k(\lambda)$;

Dubovik & King (JGR, 2000),
Dubovik et al (JGR 2000, GRL 2002, JGR 2006)

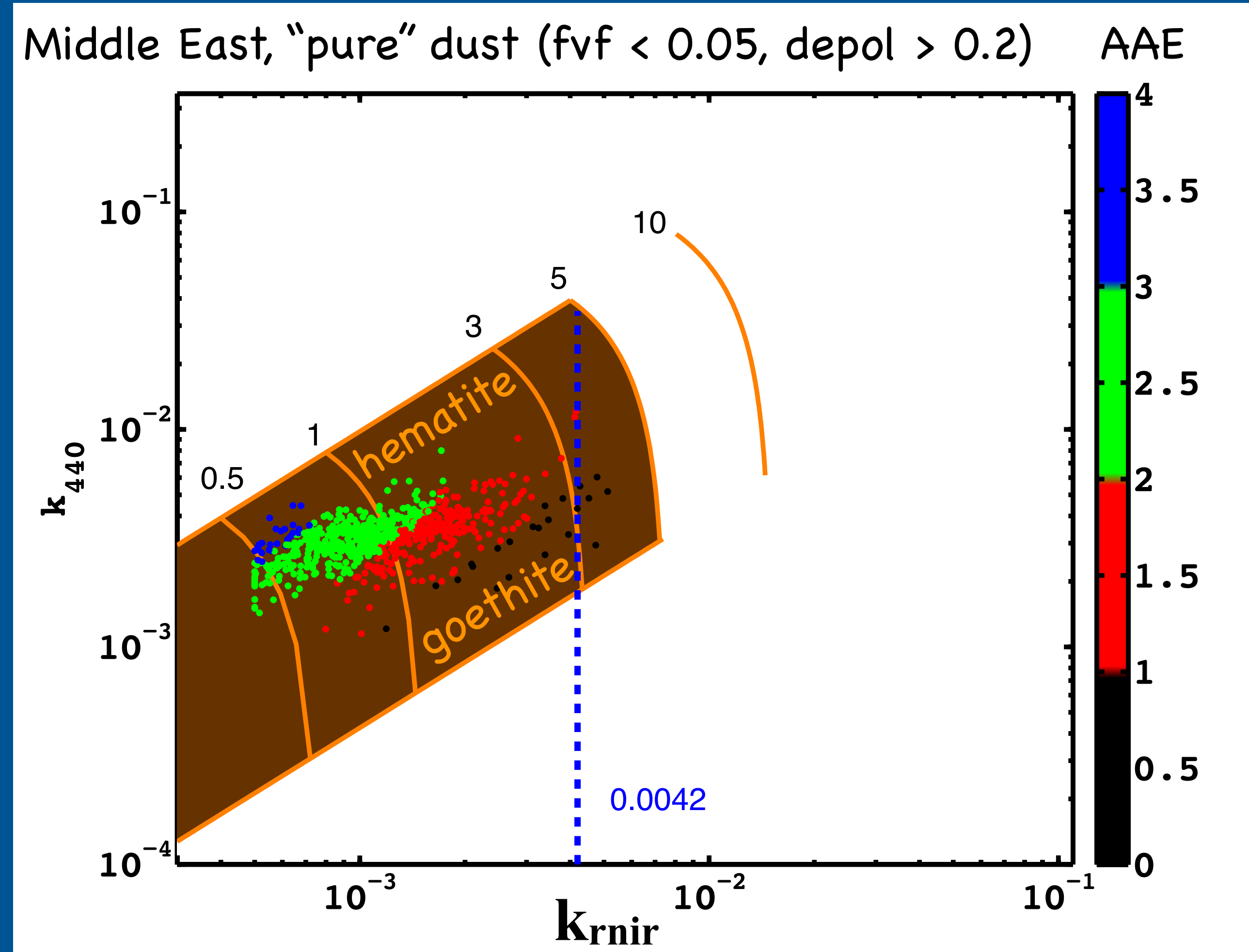
Retrieval assumes that all aerosols are internally mixed (i.e., refractive index independent of particle size), which results in **crosstalk** between the size modes.

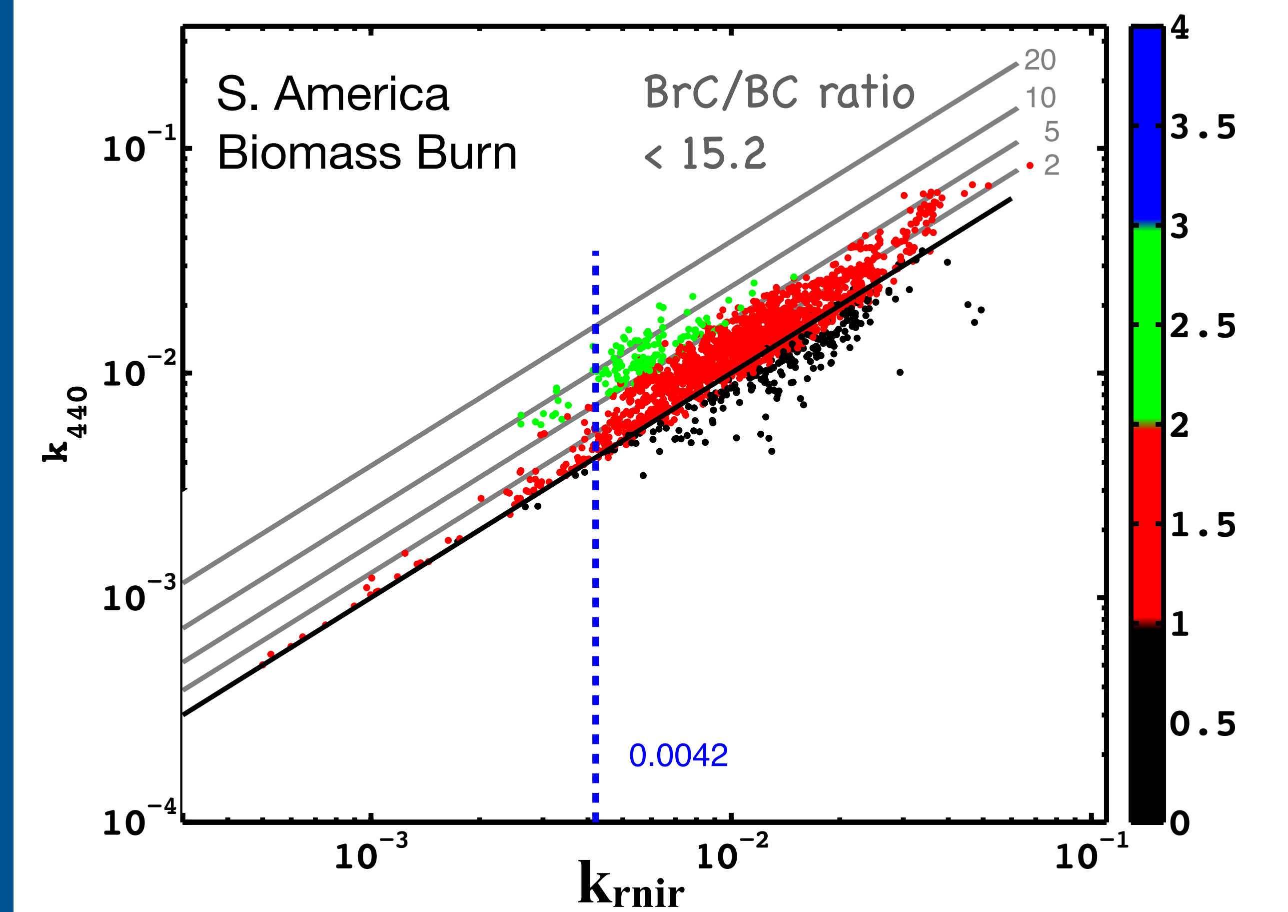


Mixtures of Components for “pure” Species in Imaginary Index Space

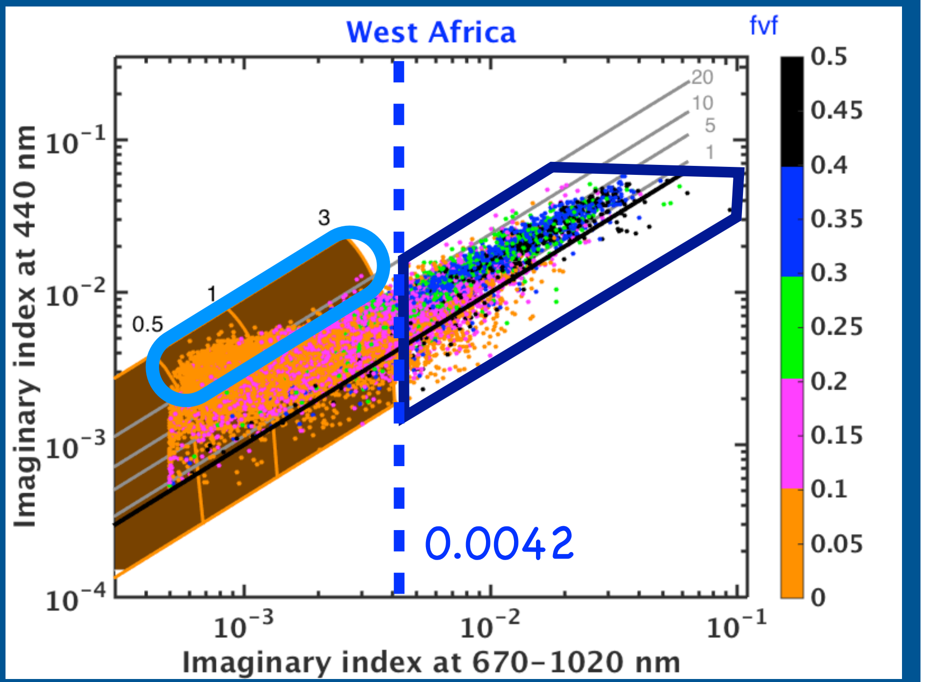


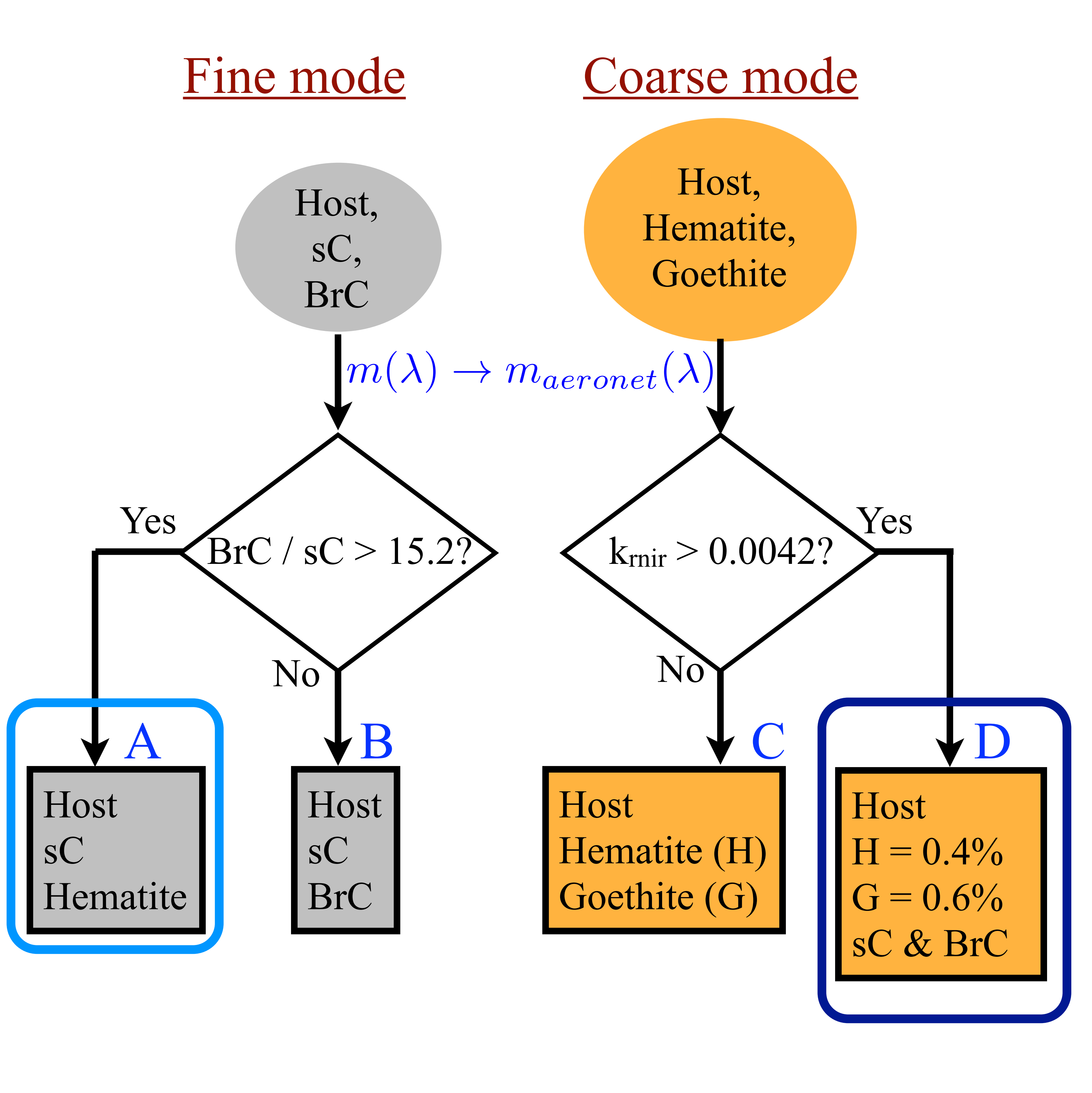
The goethite fraction of iron oxide in dust varies from 0.4 to 0.7 (Lafon, JGR 2006; Shi, Aeolian Res, 2012).





Use thresholds determined from imaginary index space to constrain absorbing species concentrations





Branch A:
Called for 12–14% of retrievals in W. Africa and M. East, but never for S. America or S. Africa

Branch D:
Called for 17% of retrievals in M. East, 24% W. Africa, and 96–98% of retrievals in S. America and S. Africa.

Sensitivity of Component Fractions to Component Refractive Indices

Repeated retrieval with 24 combinations of component refractive indices:

- Two values of sC: k = 0.63 and k = 0.79 (Bond and Bergstrom, 2006).
- Three values of hematite (from Chen81 Gillespi92, and Hsu85).
- Four values of BrC (from Kirchstetter04, Sun07, and Chen10).

Tested at 15 West Africa sites with seasonal carbonaceous and dust loadings:

- Agoufou, Banizoumbou, IER_Cinzana, DMN_Maine_Soroa, Ouagadougou, Djougou, Saada, Capo_Verde, Dahkla, Dakar, Ilorin, Quarzazate, Santa_Cruz_Tenerife, Tamanrasset_INM, Tamanrasset_TMP.

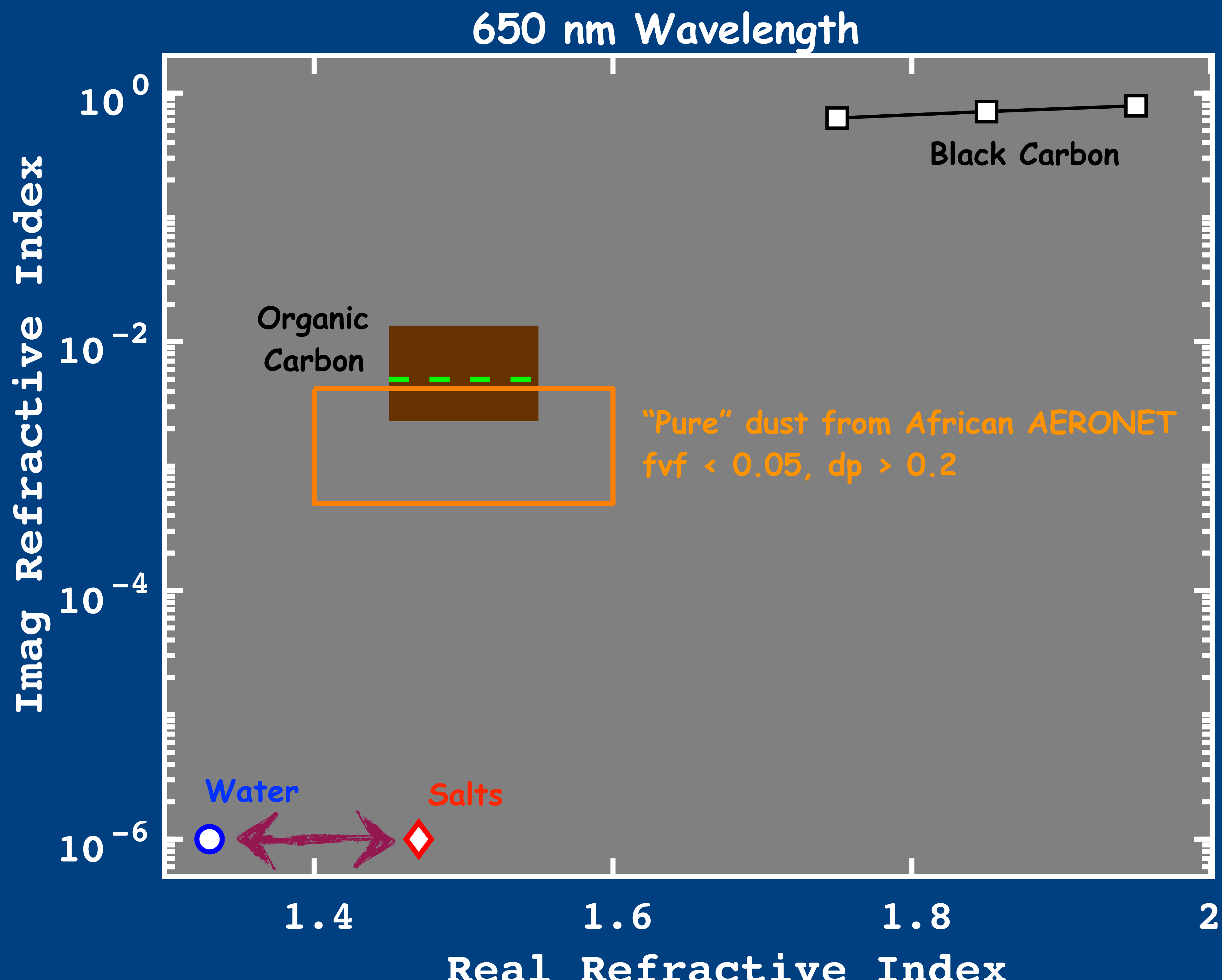
Results

- Less than 14.2% variability in sC.
- Up to 83% variability in free iron.
- Up to 440% variability in BrC.

Schuster et al, ACP 2016.

Why is the sC volume fraction unique?

- Soot carbon refractive index is two orders of magnitude higher than other atmospheric aerosols at red and infrared wavelengths.
- Uncertainty in sC refractive index is ~20%



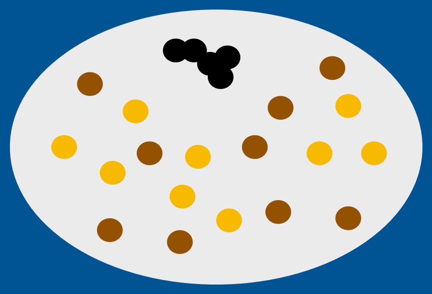
Bond & Bergstrom (2006)
Sun (2007)
Kirchstetter (2004)
Lacis, gacp.giss.nasa.gov

Onward to AAOD

For internal mixtures like AERONET:

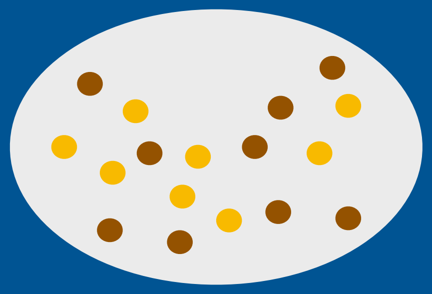
$$AAOD_{sC} \overset{?}{\Longleftrightarrow} \int Q^{sC}_{abs}\pi r^2 \frac{dN}{dr}\Big|_{sC} dr$$

Don't have size distributions for the absorbers

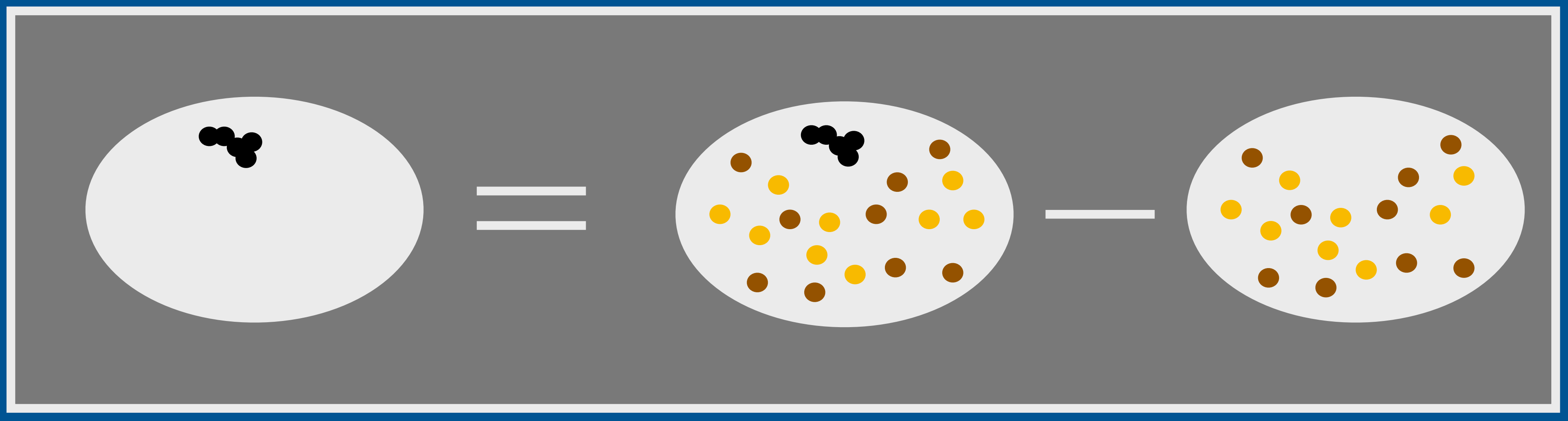


However:

$$AAOD_{\underline{no\,sC}} = (1-f_{sC})\int Q_{\underline{abs,\,no\,sC}}\,\pi r^2 n(r)dr$$

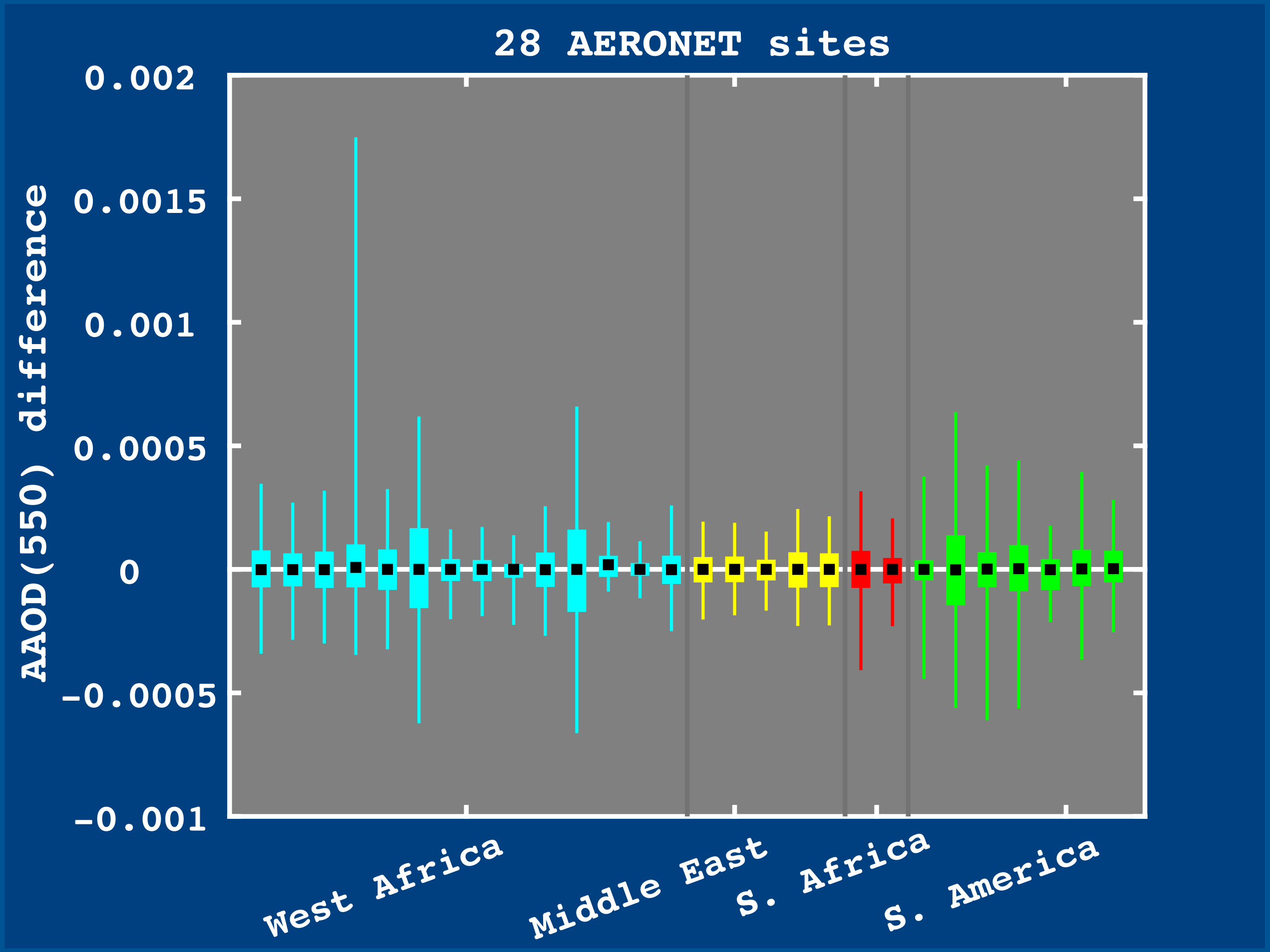


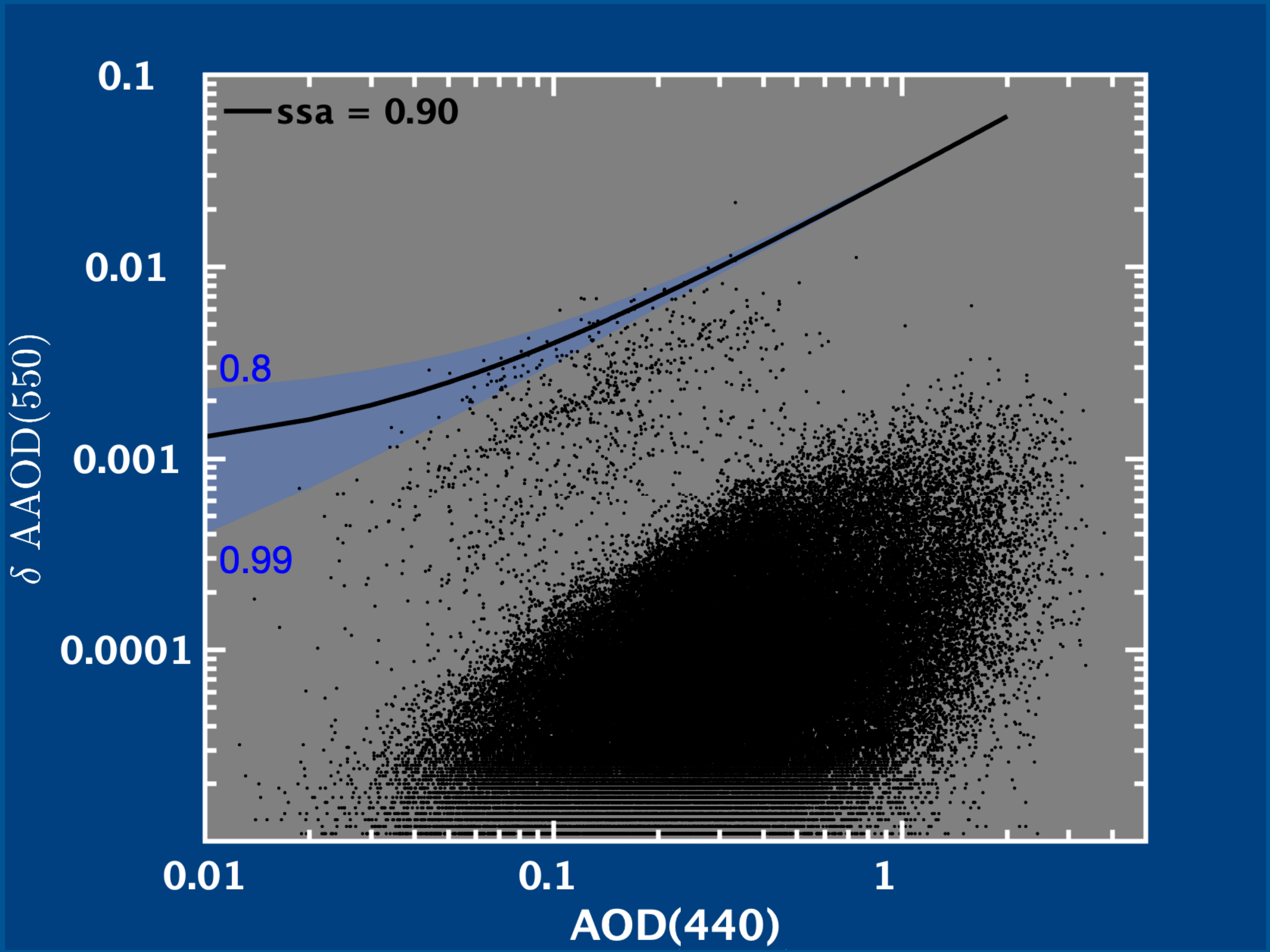
$$AAOD_{sC} = AAOD - AAOD_{\underline{no\quad sC}}$$



Sensitivity of sC AAOD to sC Refractive Index

- Run retrieval twice with different sC refractive indices:
  1. $m_{sC} = 1.95 - 0.79i$ (baseline, high end of BB06 and Bond13 recommendation)
  2. $m_{sC} = 1.75 - 0.63i$ (low end of BB06)
- Difference 2.) - 1.)





N:	117461
Median:	0.0
Mean:	6.0E-06
σ_{67}:	0.0003
σ_{98}:	0.0005

$$AAOD = (1 - \omega) \times AOD$$

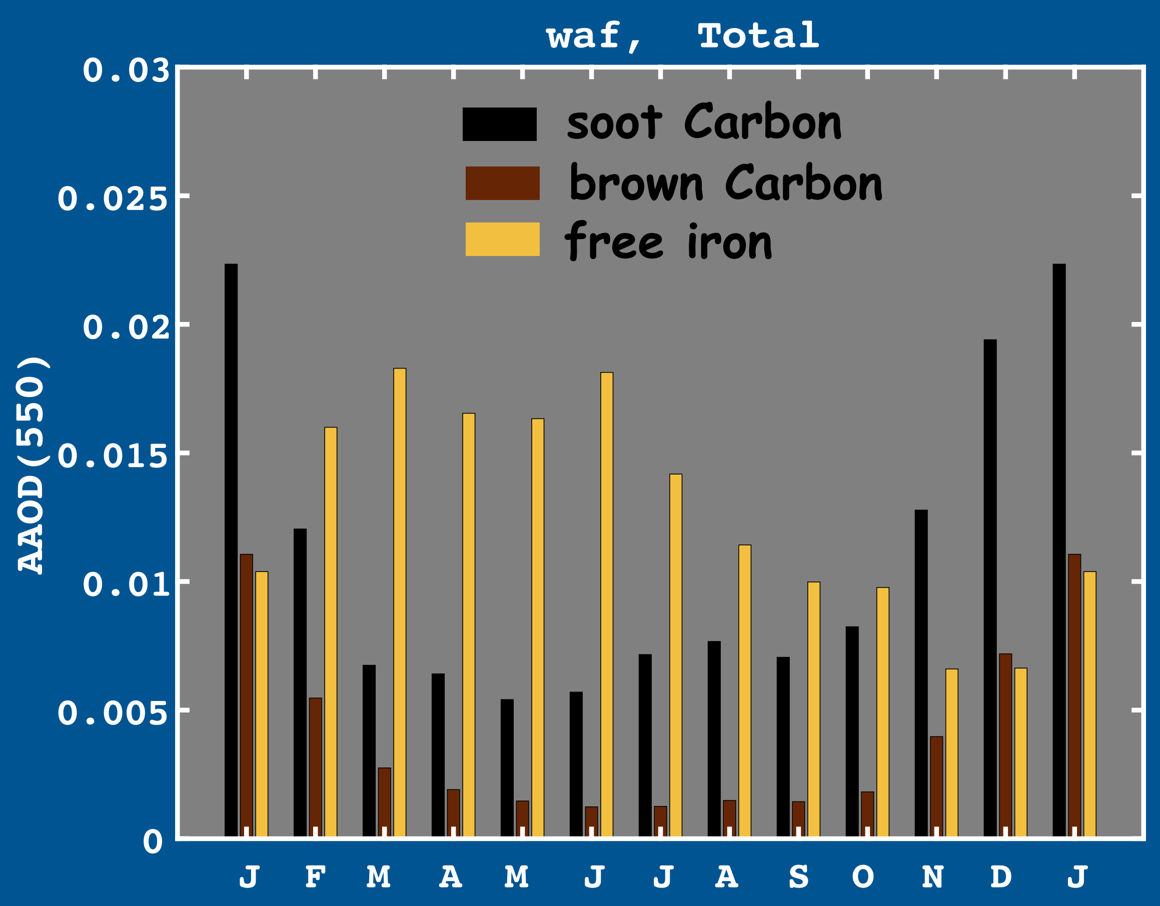
$$\delta AAOD = AOD \times \delta\omega + (1 - \omega) \times \delta AOD$$

$$\delta\omega = 0.03$$

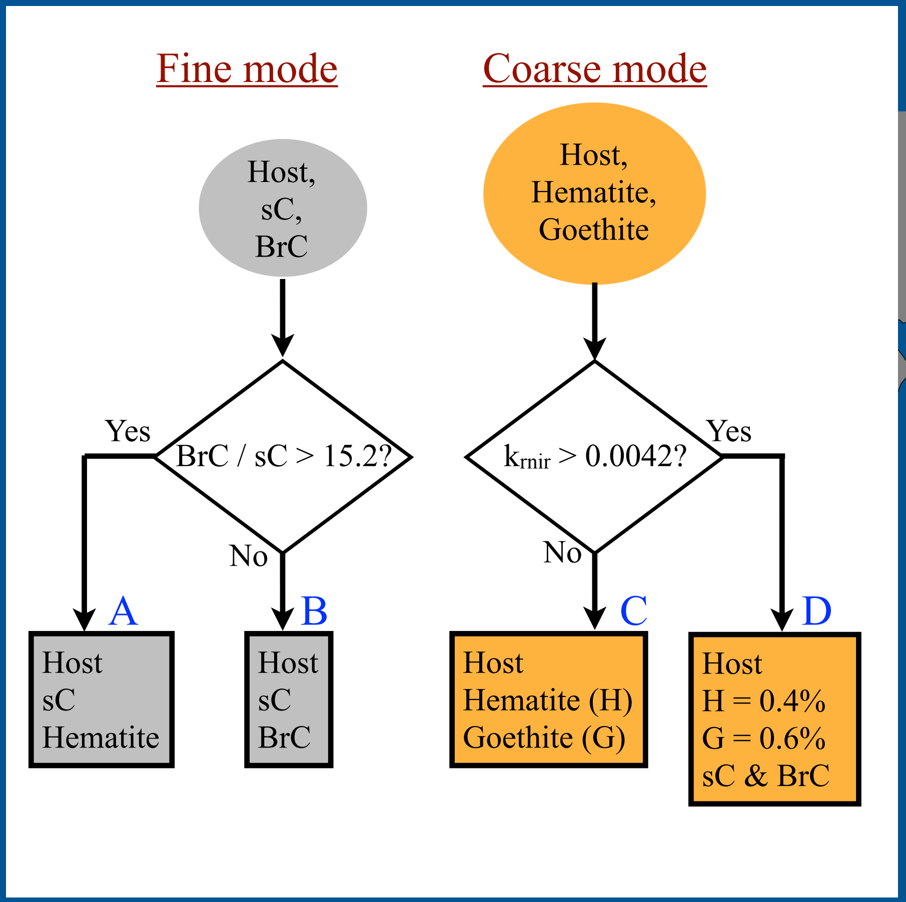
$$\delta AOD = 0.01$$

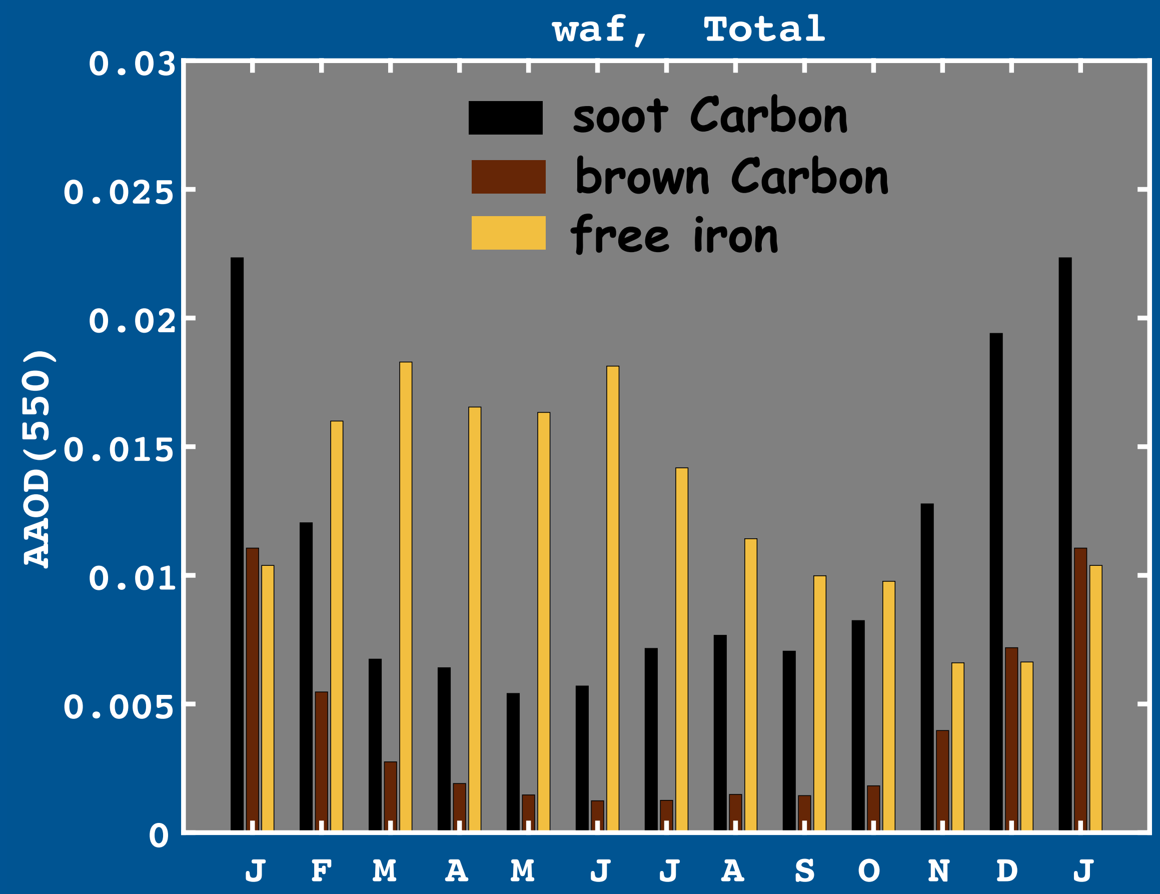
BB06: Bond and Bergstrom, AST (2006); Bond13: JGR (2013)

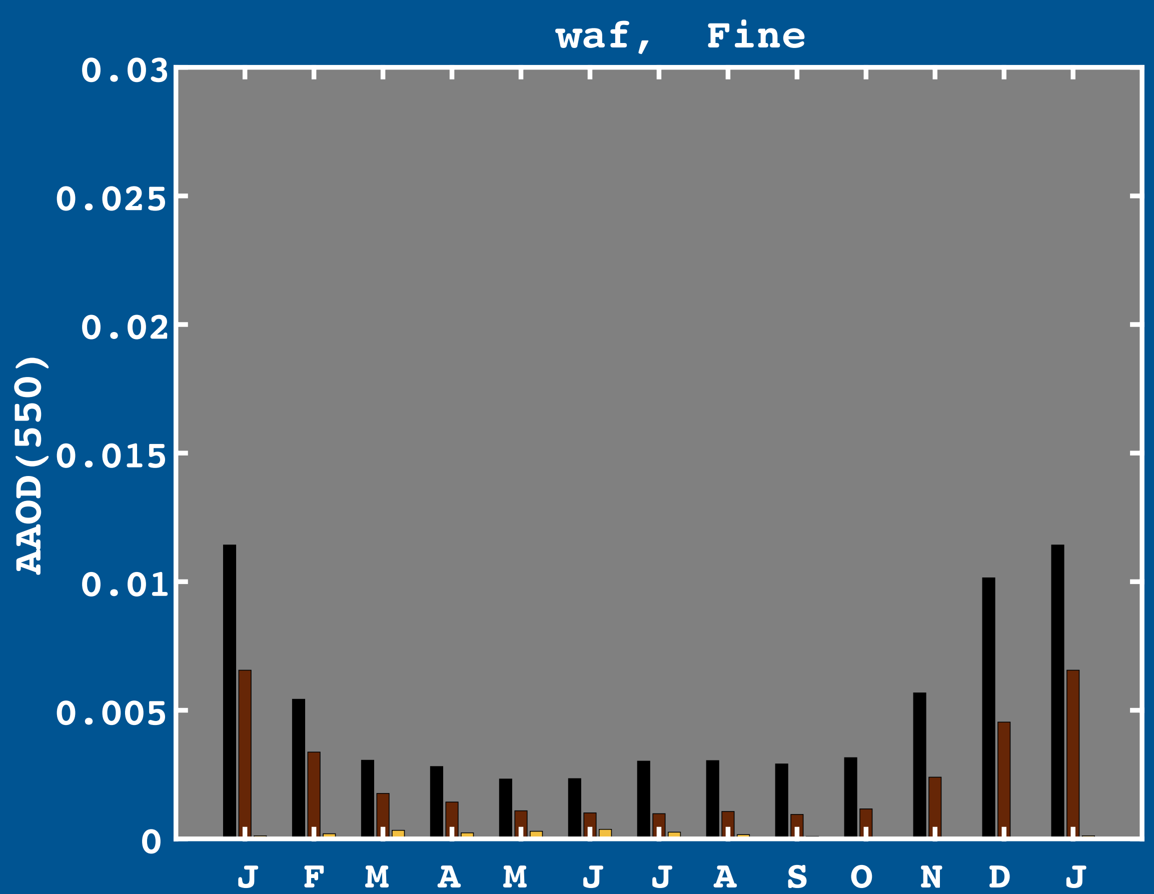
West Africa Dust and Biomass Burning Sites

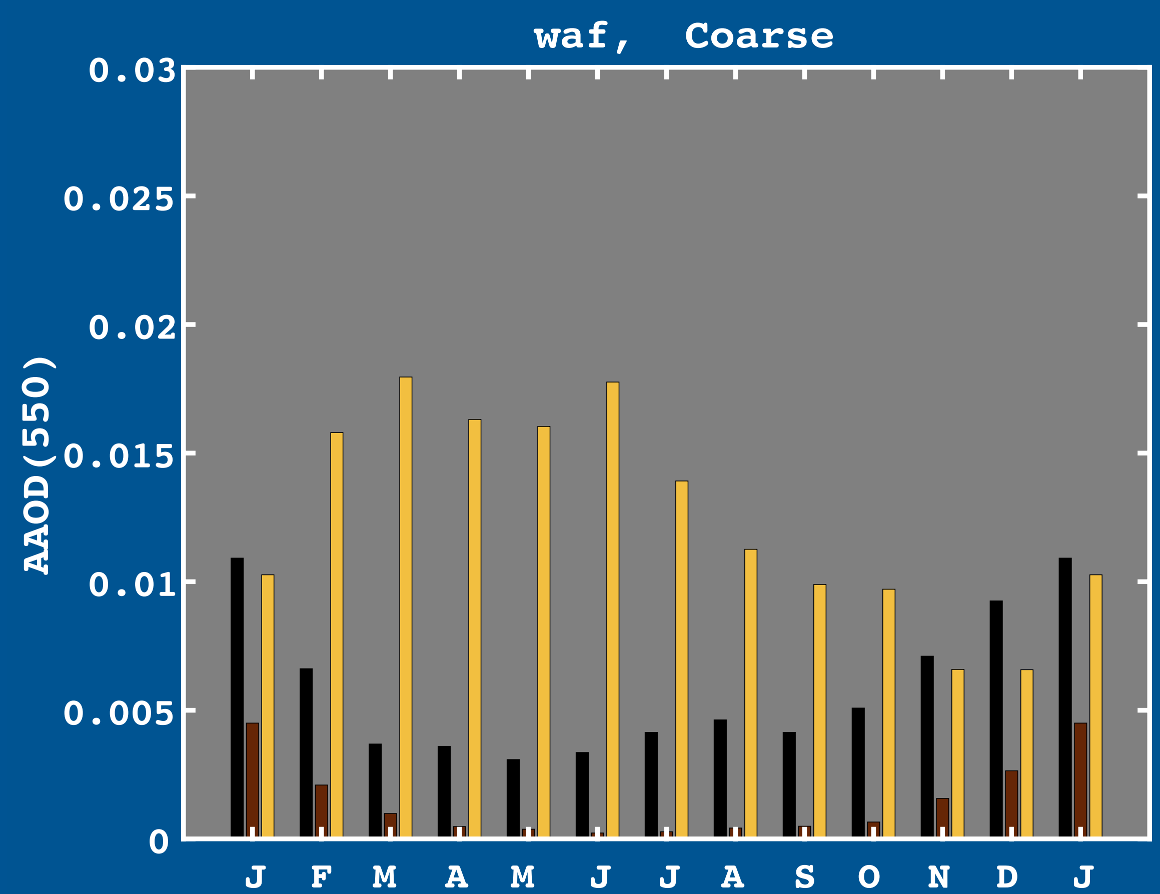


West Africa Dust and Biomass Burning Sites



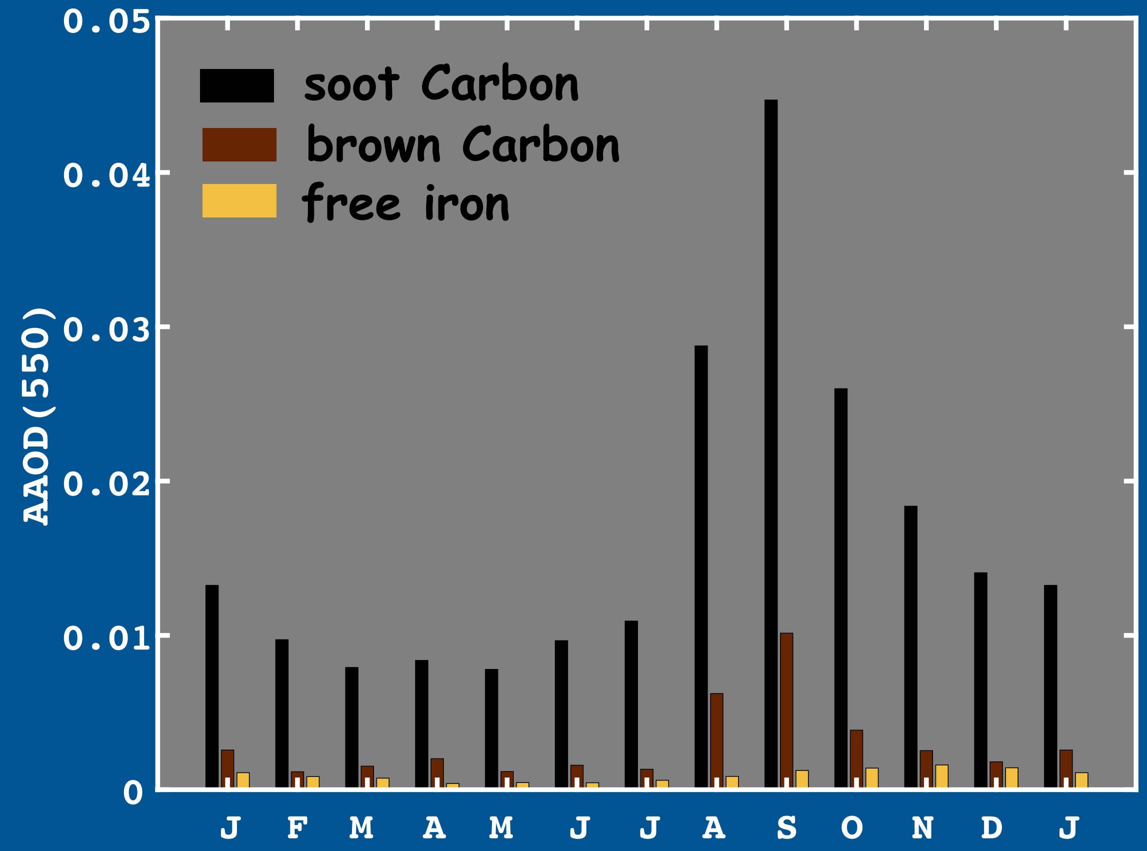




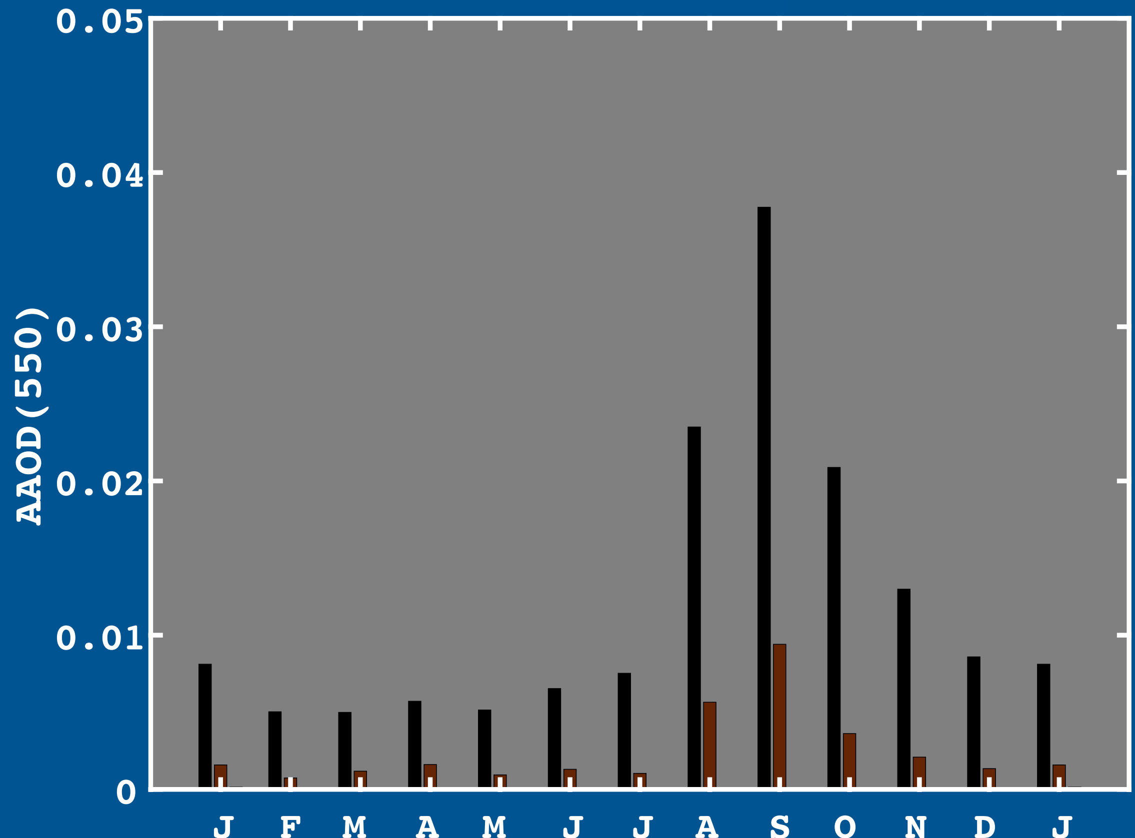


South America Biomass Burning Sites

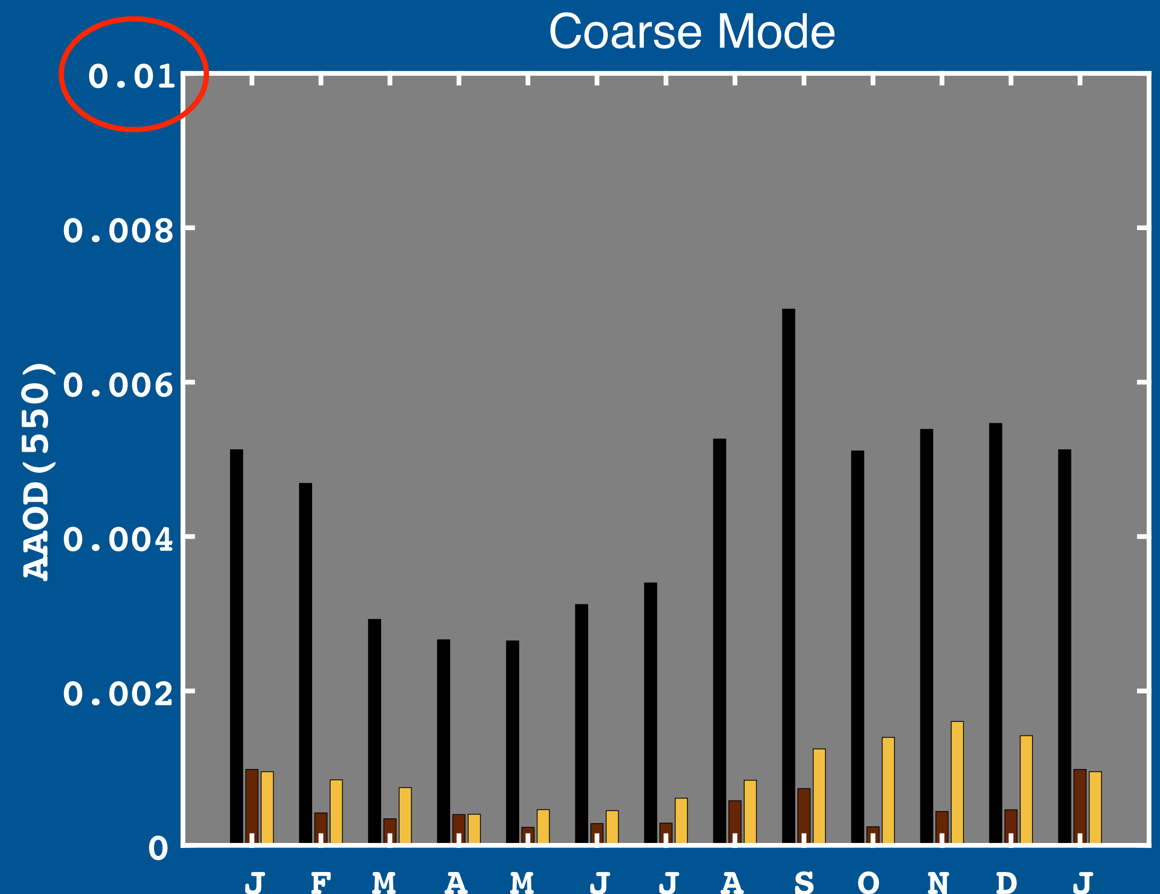
Fine and Coarse modes



Fine Mode



Coarse Mode



Recap

Fundamentals

- Cross-talk between fine and coarse modes of the AERONET retrievals artificially assigns some fine mode absorption to the coarse mode.
- Black carbon has an imaginary refractive index that is two orders of magnitude higher than dust or brown carbon.
- An imaginary refractive index of k = 0.0042 separates 95% of “pure” dust and “pure” biomass burning aerosols.

Retrieval

- ***Presented a technique for retrieving BC AAOD that removes crosstalk between aerosol modes while maintaining consistency with AERONET refractive indices and measured radiance fields.***
- Redistribution includes allowing carbonaceous aerosols in the coarse mode when $k > 0.0042$.
- Presented AAOD(550) results for Africa, and South America.
- Varying refractive index throughout the range of Bond and Bergstrom (AST, 2006) recommended values results in a 14.2% variability in the sC volume fraction.
- Also demonstrated that the AAOD retrieval is not sensitive to component refractive indices or densities.

- ***Processed all available AERONET (through Feb 11, 2017) and made publicly available at***

  https://science.larc.nasa.gov/personal-pages/gregs/data/2019-08-26/