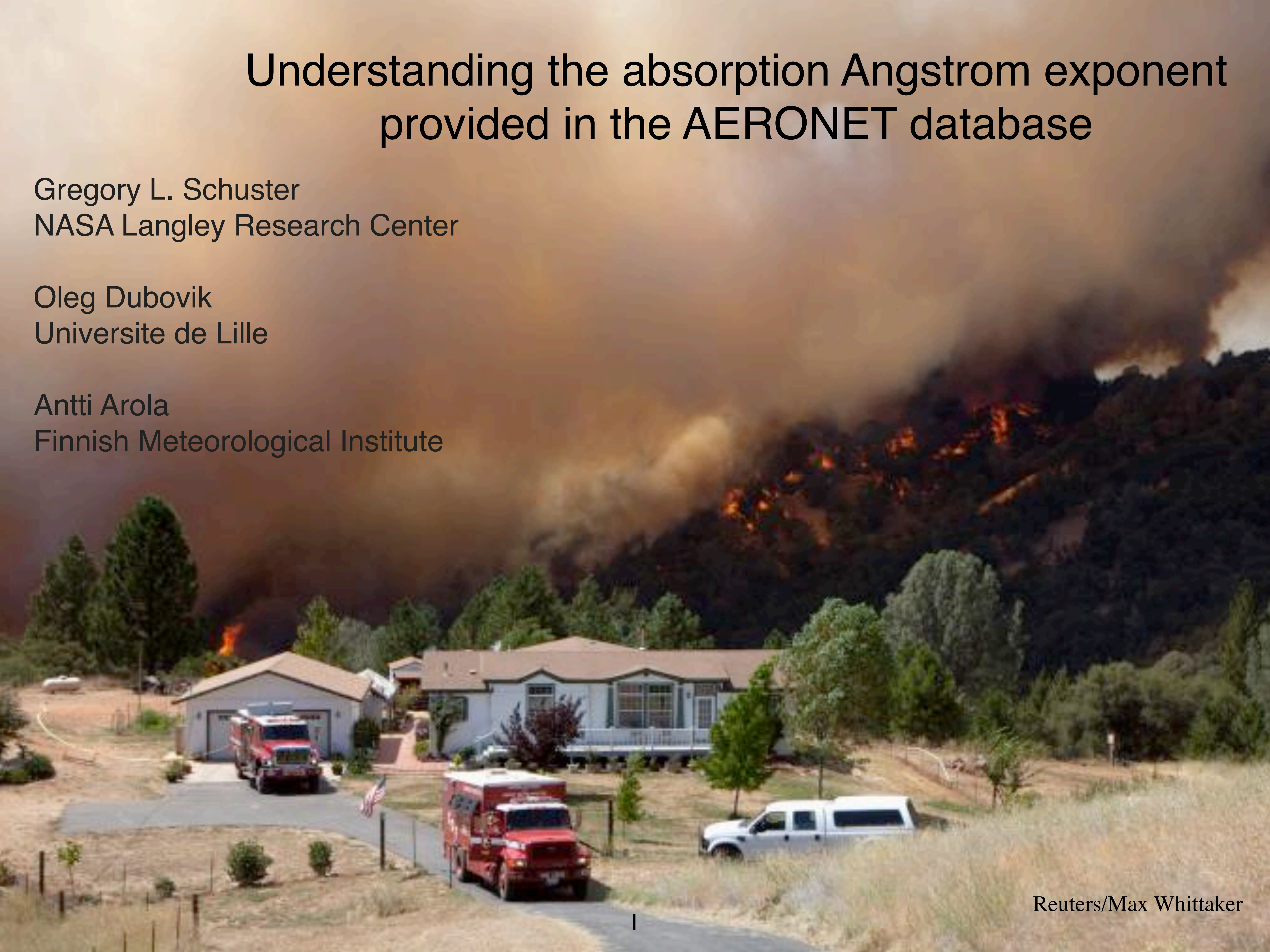
Understanding the absorption Angstrom exponent provided in the AERONET database

Gregory L. Schuster
NASA Langley Research Center

Oleg Dubovik
Universite de Lille

Antti Arola
Finnish Meteorological Institute



Reuters/Max Whittaker

Motivation: The AAE approach for speciating absorbers

PNAS (2012)

Observationally constrained estimates of carbonaceous aerosol radiative forcing

Chul E. Chung[a,1], V. Ramanathan[b], and Damien Decremer[a]

[a]School of Environmental Science and Engineering, Gwangju Institute of Science and Technology, Gwangju 500-712, Korea; and [b]Scripps Institution of Oceanography, University of California at San Diego, La Jolla, CA 92093

Edited by Mark H. Thiemens, University of California San Diego, La Jolla, CA, and approved May 30, 2012 (received for review March 5, 2012)

Separate absorption AOD into carbon and dust components:

$$AAOD = \xi(\lambda) = \xi_d(1)\lambda^{-AAE_d} + \xi_{BC}(1)\lambda^{-AAE_{BC}} + \xi_{BrC}(1)\lambda^{-AAE_{BrC}}$$

where:

- $AAE_{dust} = 2.4$ Dust
- $AAE_{carbon} \simeq 1$ Carbonaceous (0.84 to 1.16, depending upon region)
- $AAE_{BC} = 0.5$ Black Carbon
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Problems with the AAE approach:

1. Assumes that all absorbers are externally mixed.
2. Uses AAE for BC is much lower than our traditional value of AAE_{BC} = 1.
3. It does not account for the variability in the AAE of dust (0 to 3.5).

Main Points

1. All aerosols are ***always*** internally mixed in the AERONET retrieval.
2. AAE = 0.5 can not represent BC in the AERONET database, unless $dk/d\lambda > 0$ for BC.
3. The AAE of dust can be anything (~0 to 3.5).

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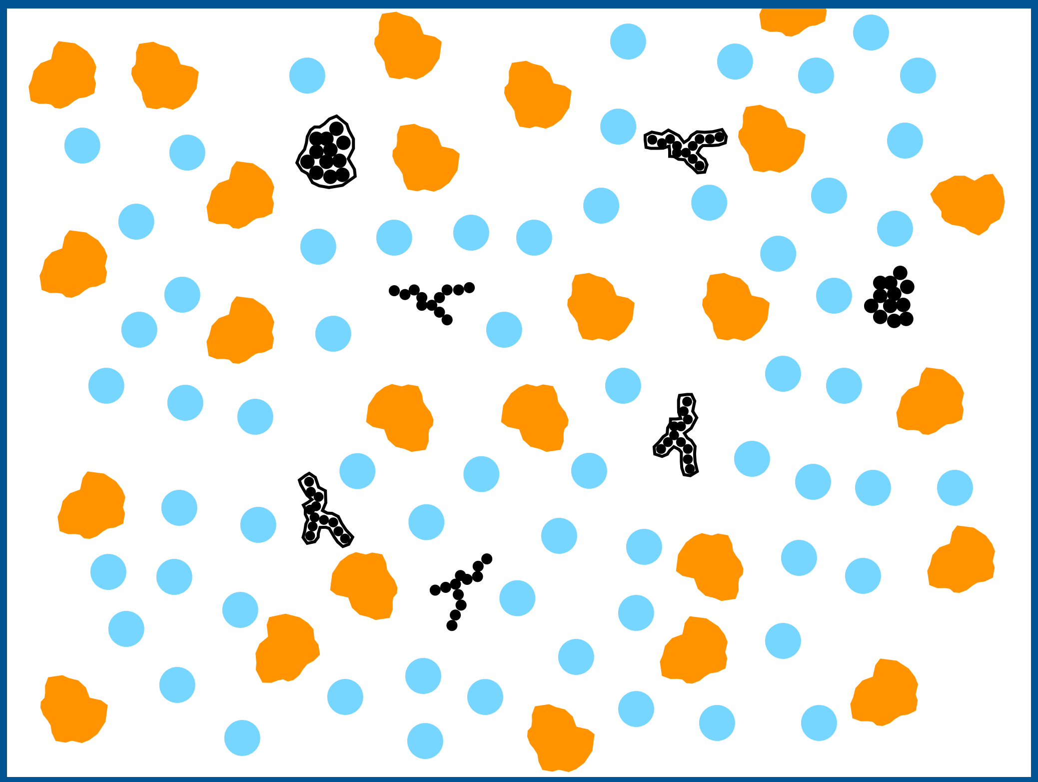
AERONET World

If the atmosphere looks like this...



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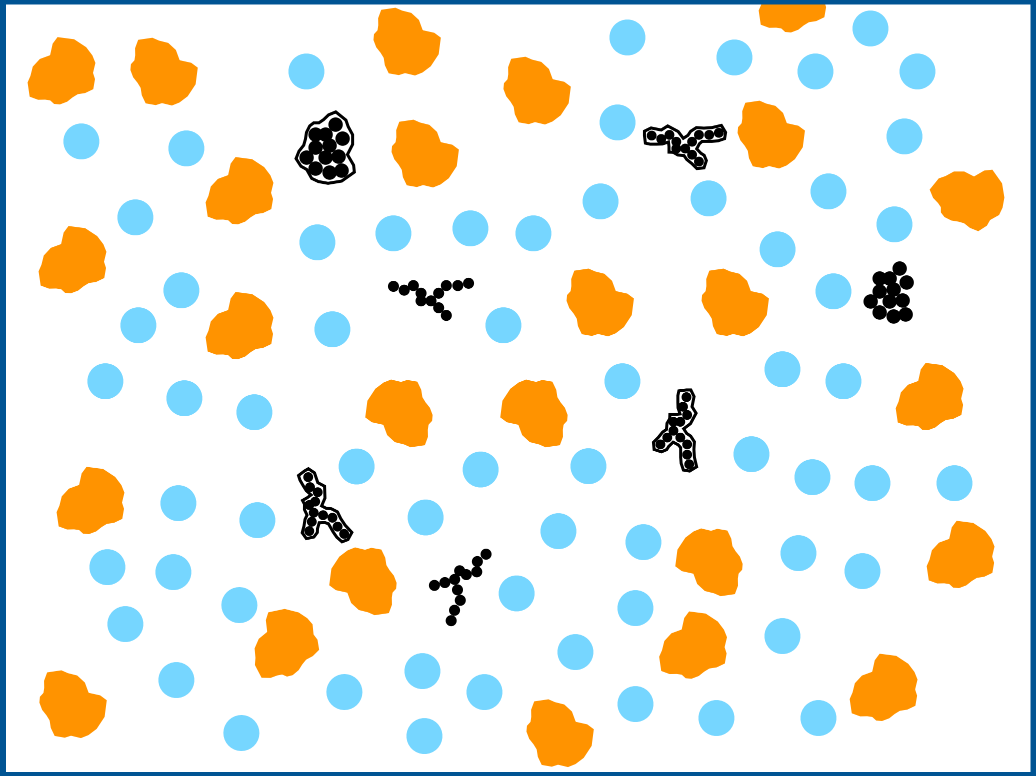
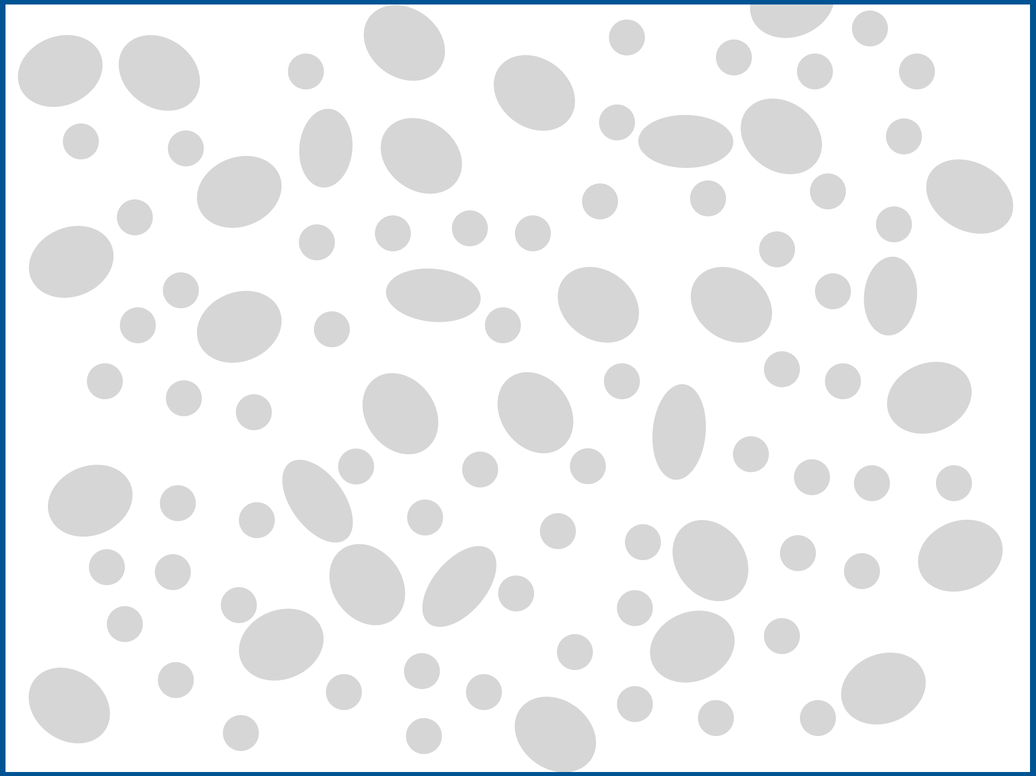


AERONET uses an internal mixture like this to COMPUTE AAOD and AAE



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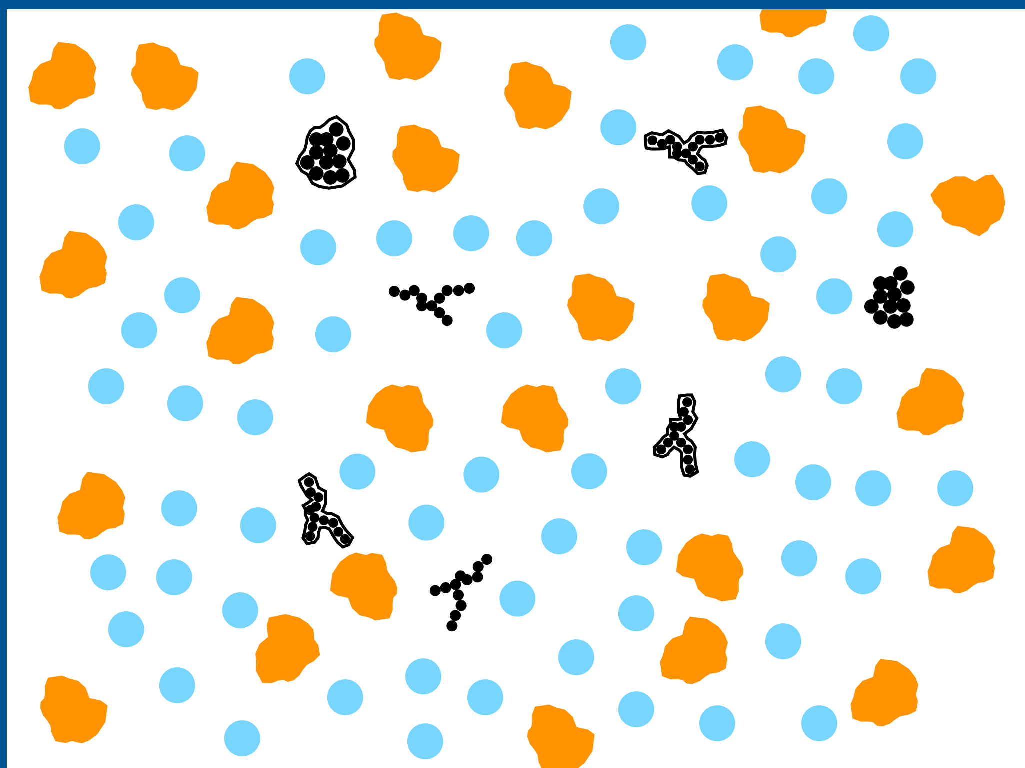

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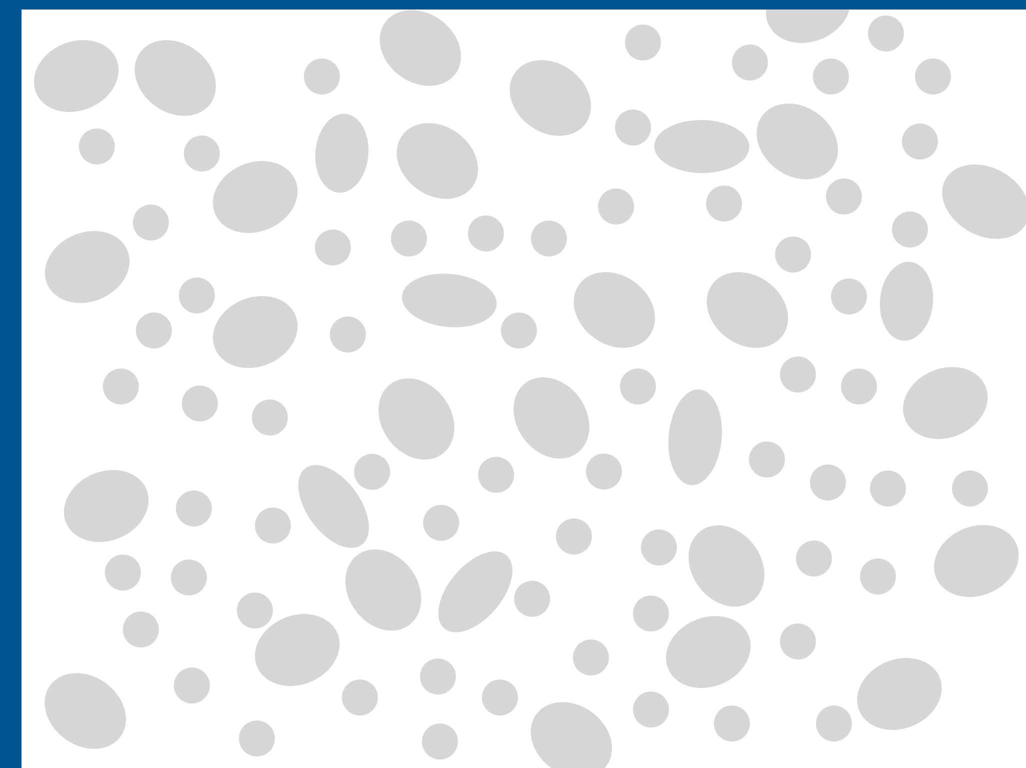
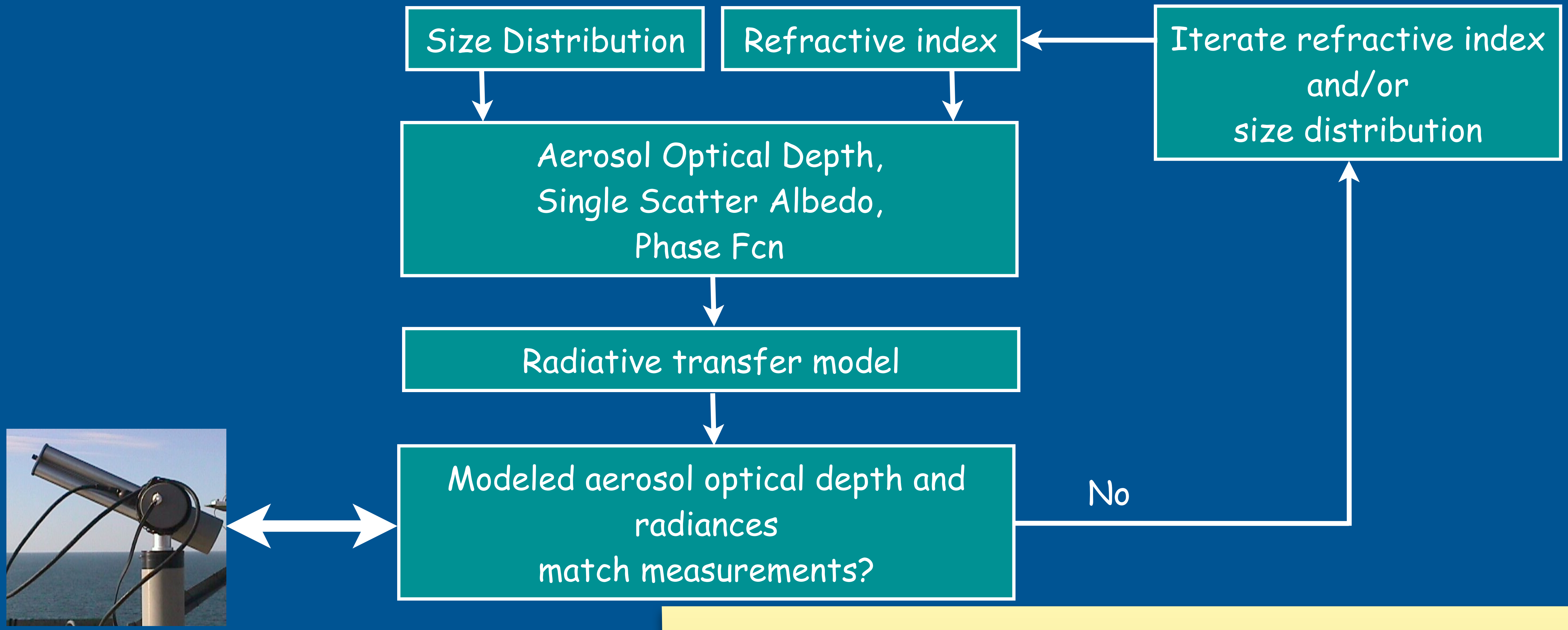


Repurcussions:

- All BC is internally mixed. Always!
- BC absorption contained in a small percentage of particles is redistributed to **all** particles in both fine and coarse modes.
- We can't use complicated morphologies to explain AERONET AAE (i.e, fractals, or even core-shell).
- Single scatter albedo ≤ 1. Always!

AERONET Retrieval Schematic



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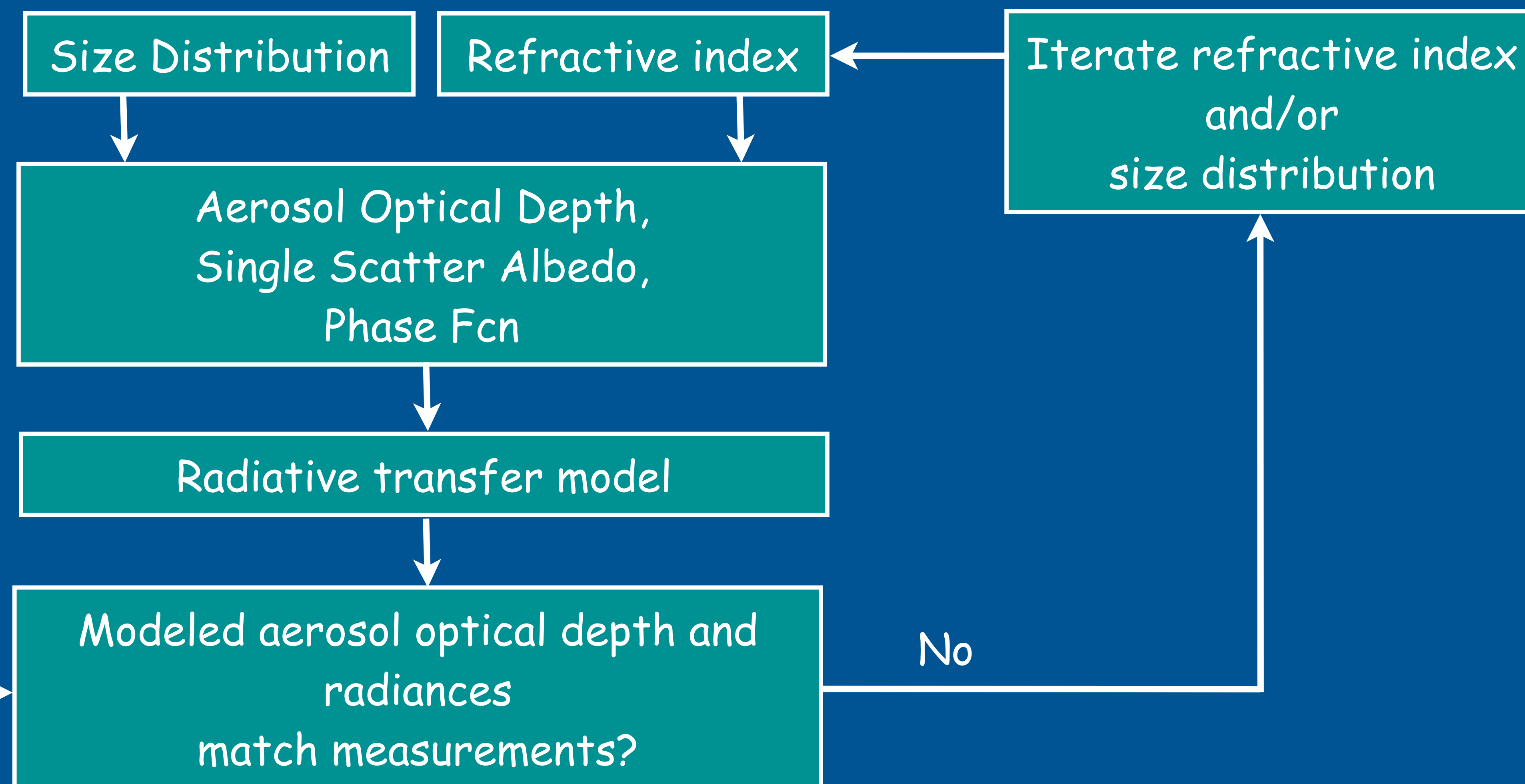

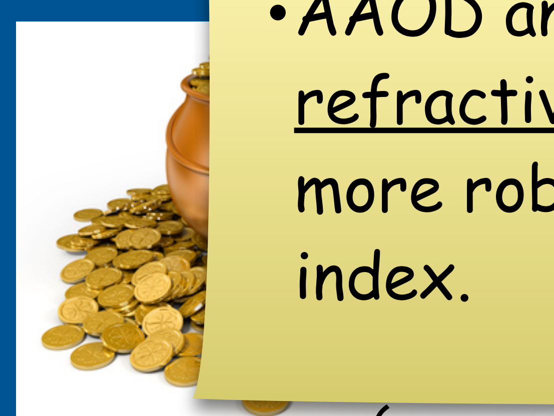

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AERONET Retrieval Schematic

Size Distribution

Refractive index

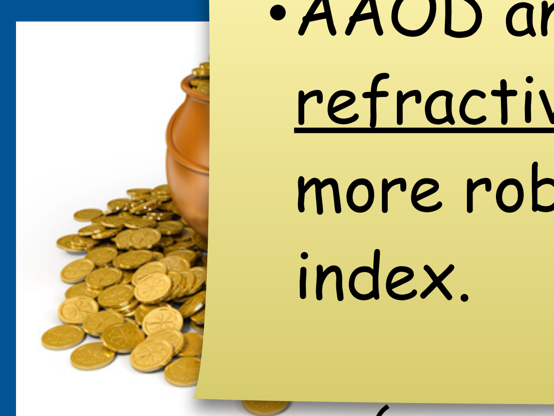
Iterate refractive index and/or size distribution

Aerosol Optical Depth, Single Scatter Albedo, Phase Fcn

Radiative transfer model

Modeled aerosol optical depth and radiances match measurements?

No



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AERONET Retrieval Schematic

Absorption Angstrom Exponent (AAE) and AAOD

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Refractive index

Iterate refractive index and/or size distribution

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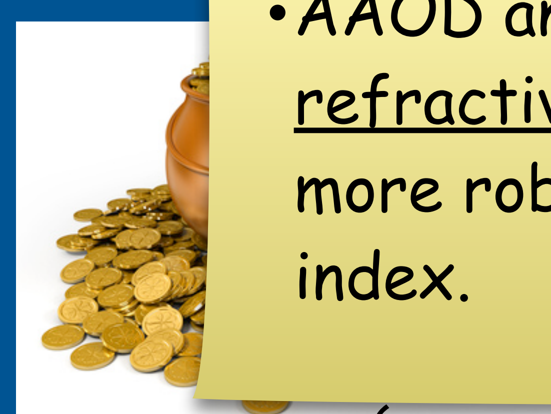

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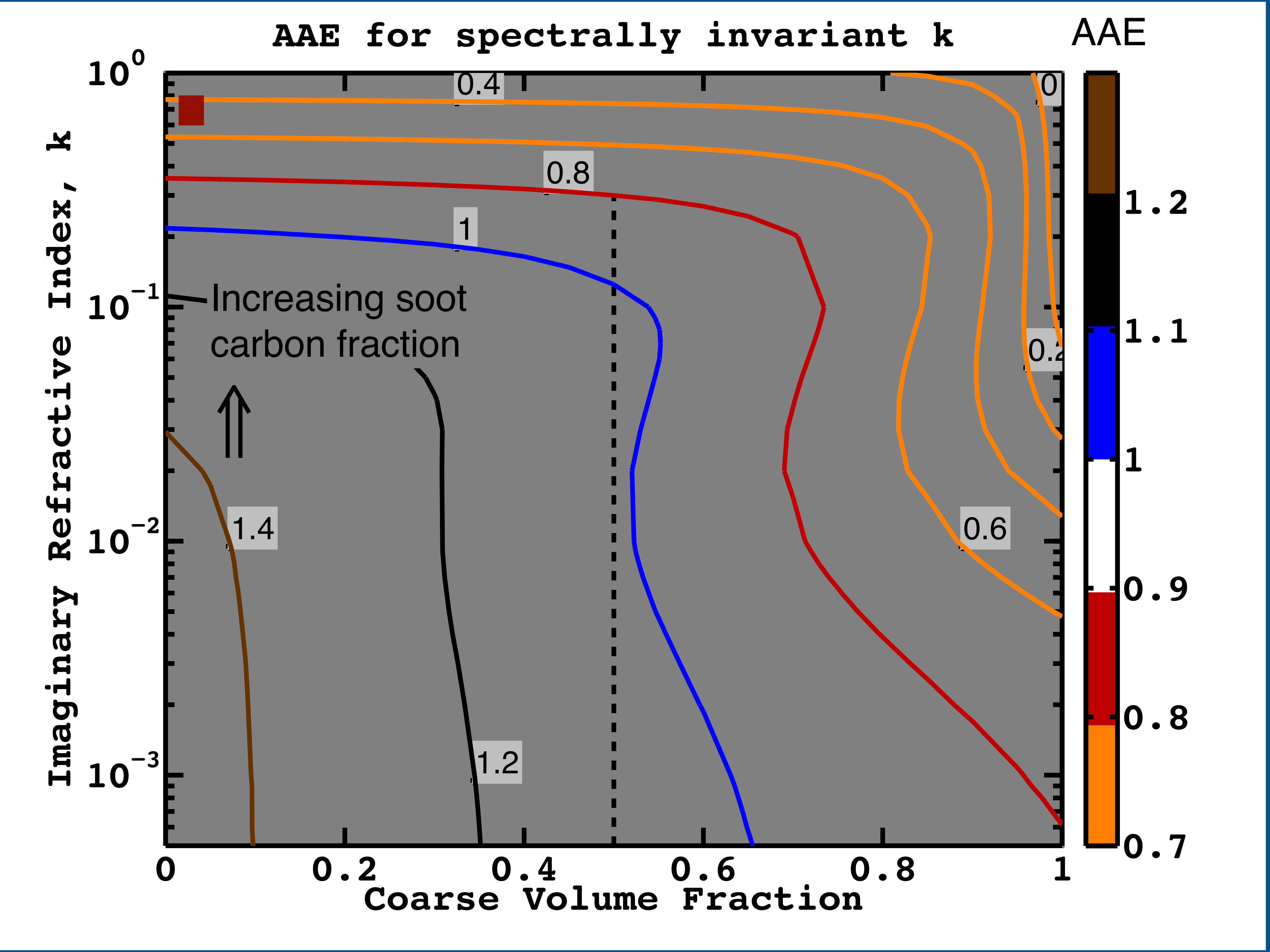
3. The AAE of dust can be anything (~0 to 3.5).

AAE calculations for bimodal lognormals with spectrally invariant k (i.e., $dk/d\lambda = 0$)

See also
Bond, GRL (2001),
Gyawali ACP (2009) ,
Lack and Langridge,
ACP (2013)



$$\frac{dV}{d\ln r} \propto \sum_{i=1,2} \exp\left[-\frac{(\ln r - \ln R_i)^2}{2\sigma_i^2}\right]$$

$R_{fin} = 0.12\,\mu m,\ R_{crs} = 3.2\,\mu m,\ \sigma_{fin} = 0.38,\ \sigma_{crs} = 0.75$

$n = 1.49$

West Africa: Agoufou, Banizoumbou, IER_Cinzana, Capo_Verde, Dahkla, Dakar, Ilorin, Quarzazete, Santa Cruz Tenerife, Tamanrasset

Middle East: Solar Village, Nes Ziona, Sede Boker, Dhabi, Hamin

South Africa: Mongu, Skukuza

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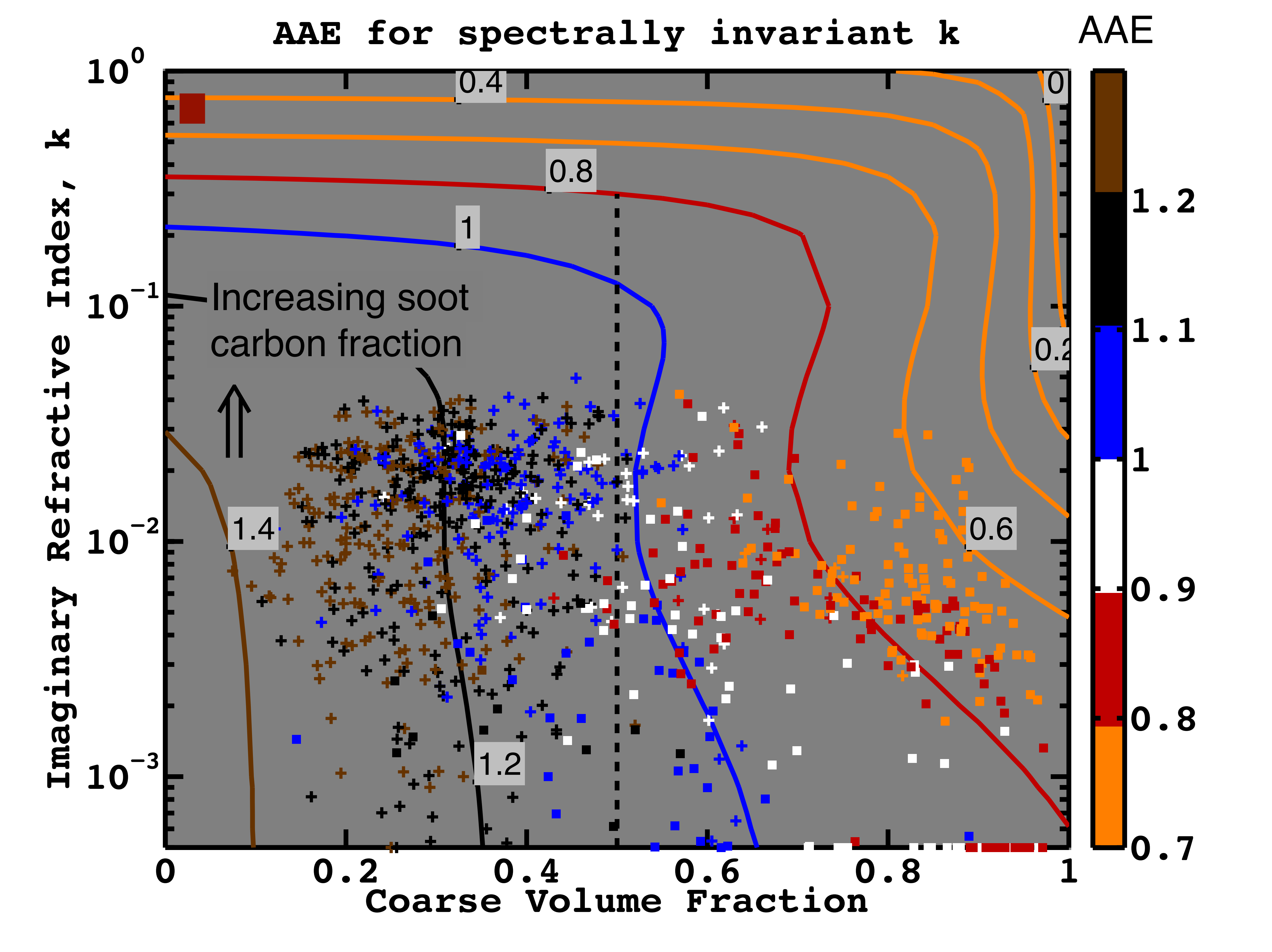
AERONET AAE, filtered for $\delta k \leq 10\%$



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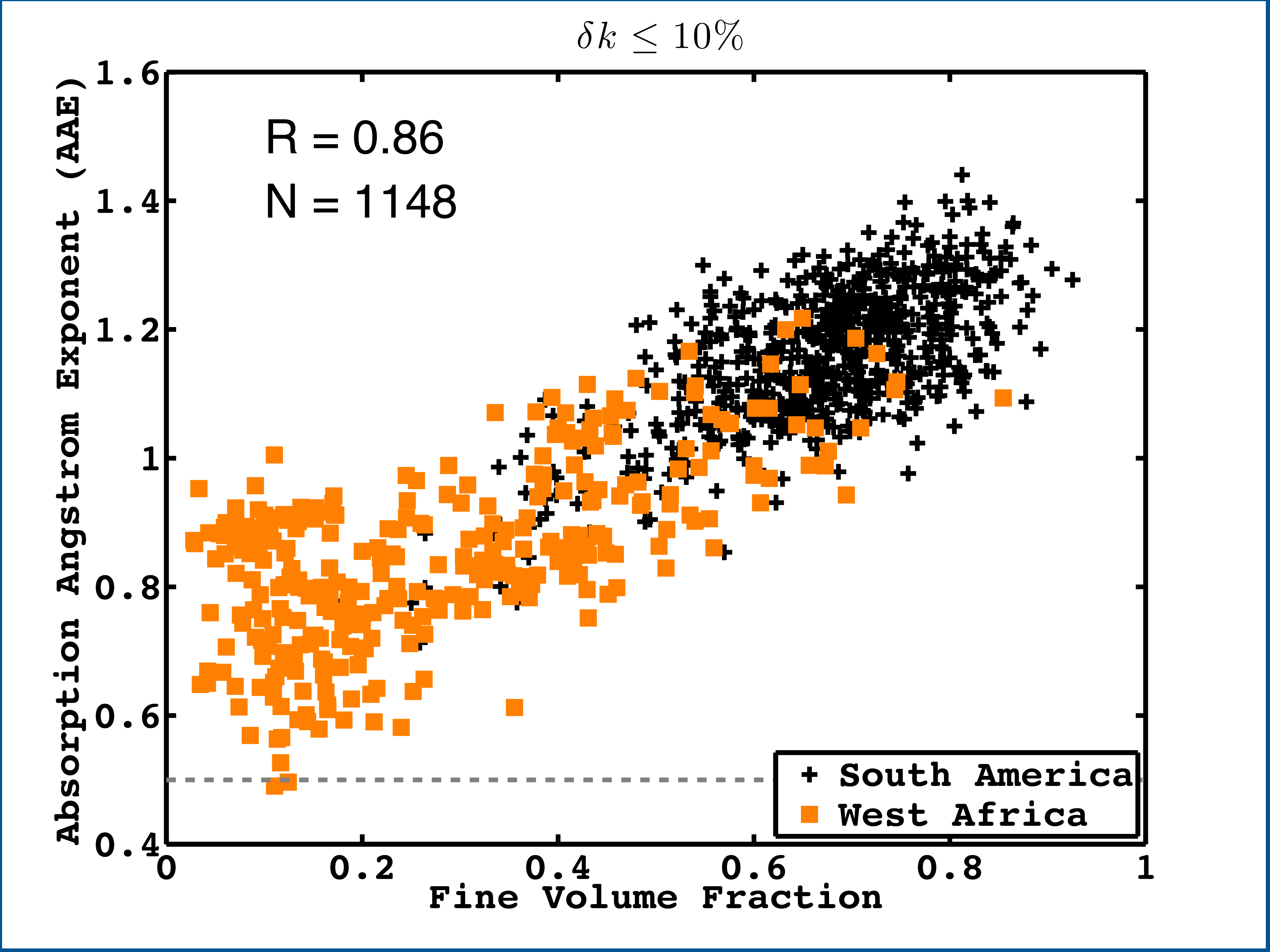
AERONET AAE (L2), filtered for $\delta k \leq 10\%$



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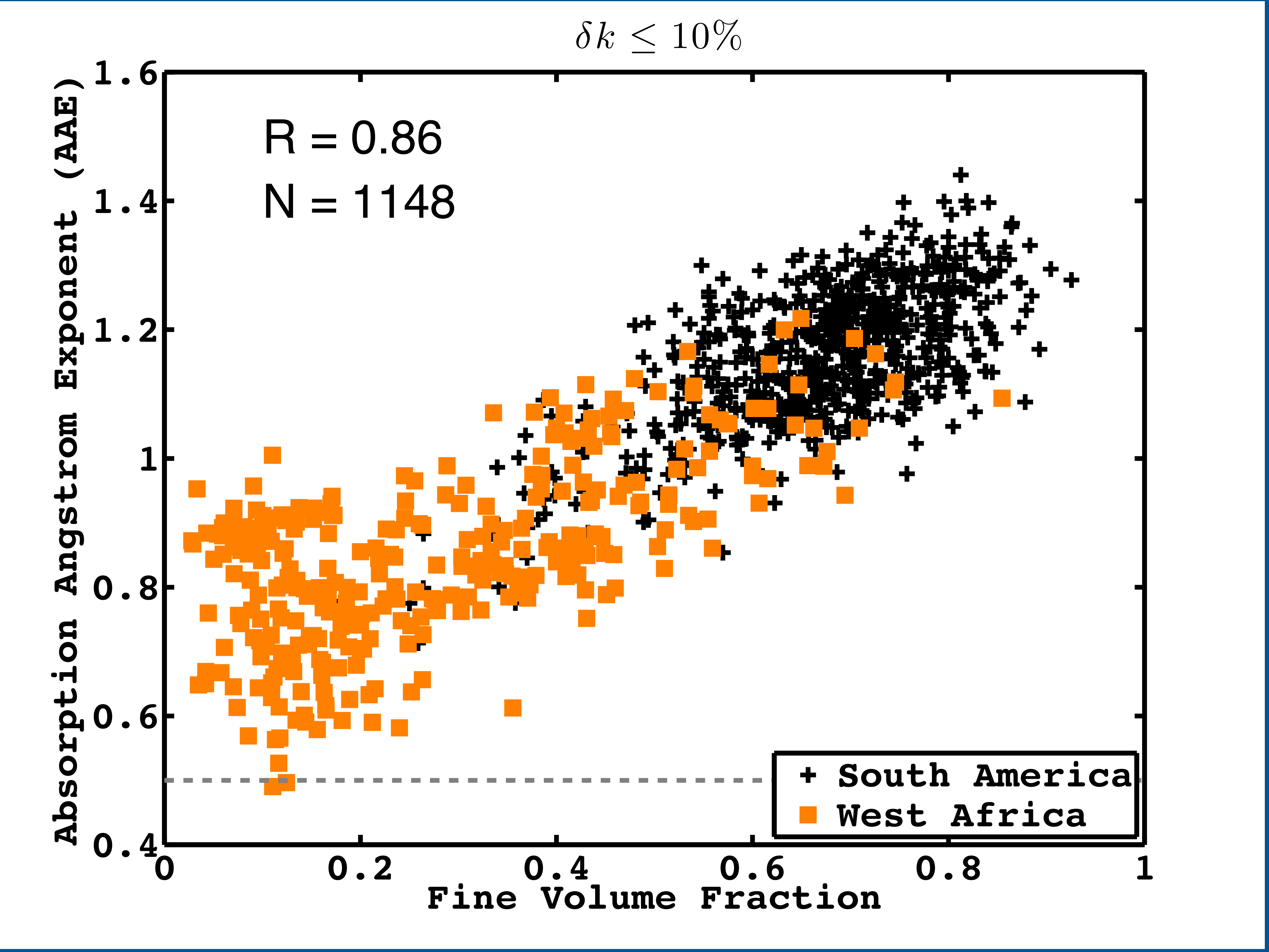
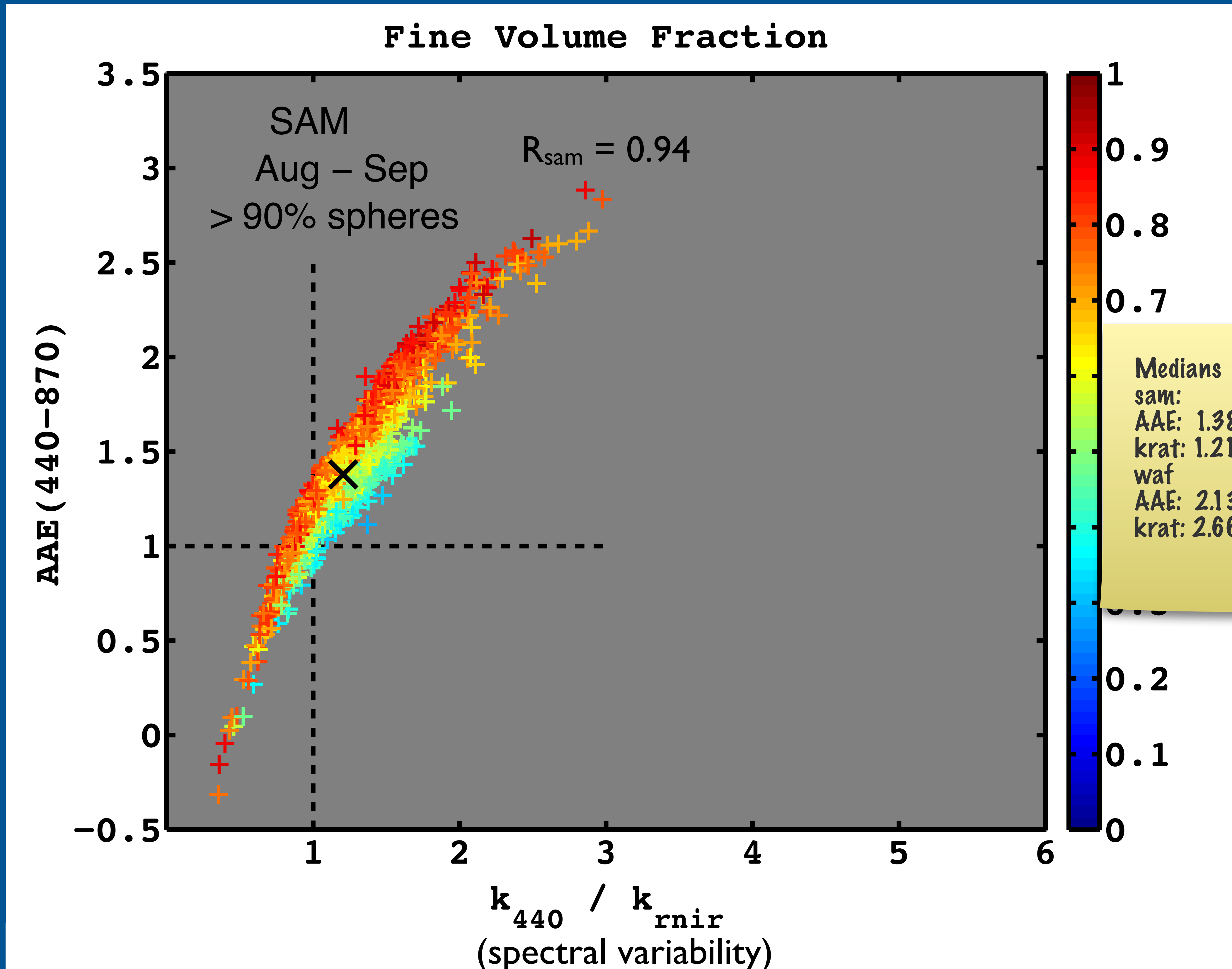


AAE < 1 requires spectrally variable k for small particles



Medians
sam:
AAE: 1.38
krat: 1.21
waf
AAE: 2.13
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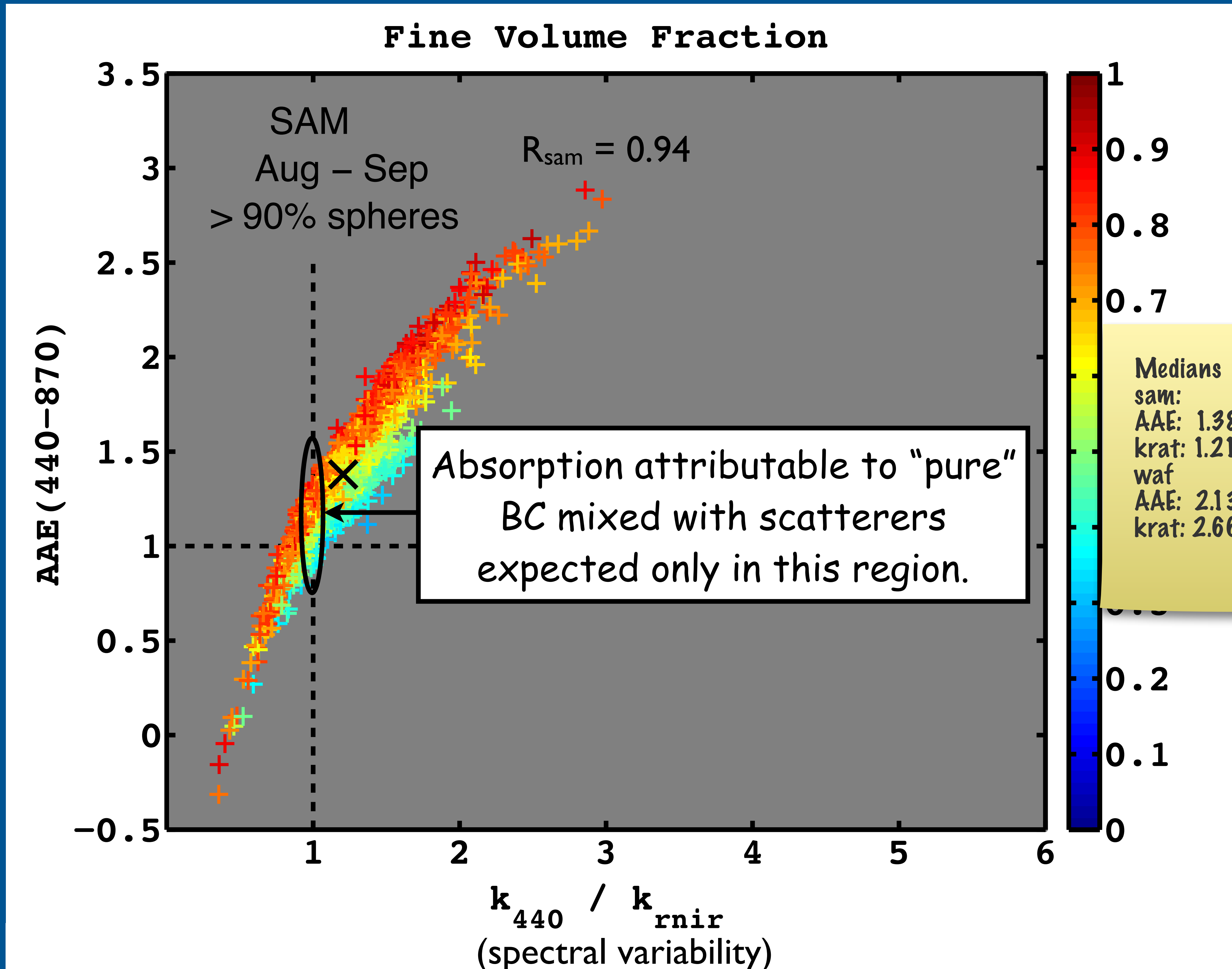

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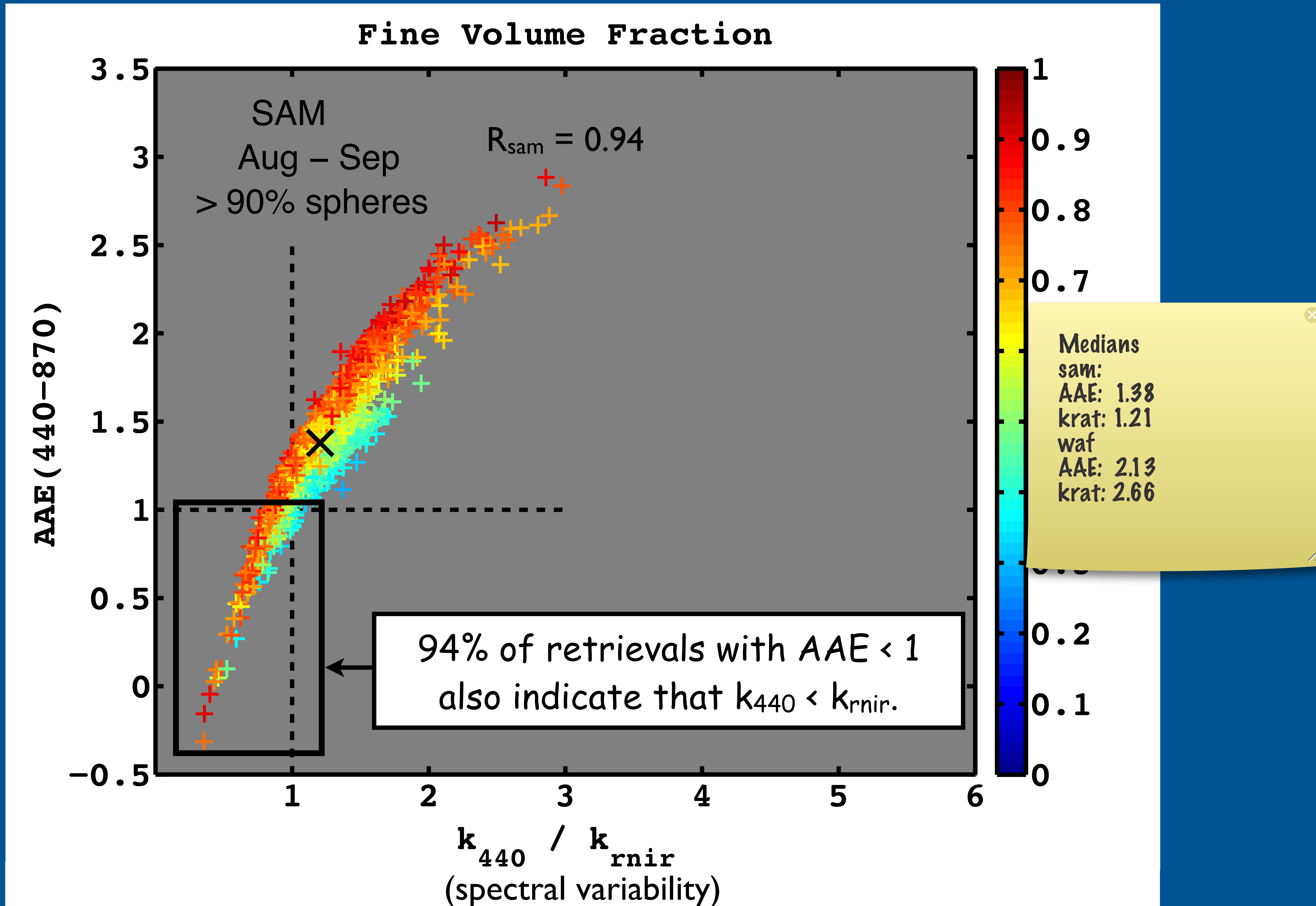

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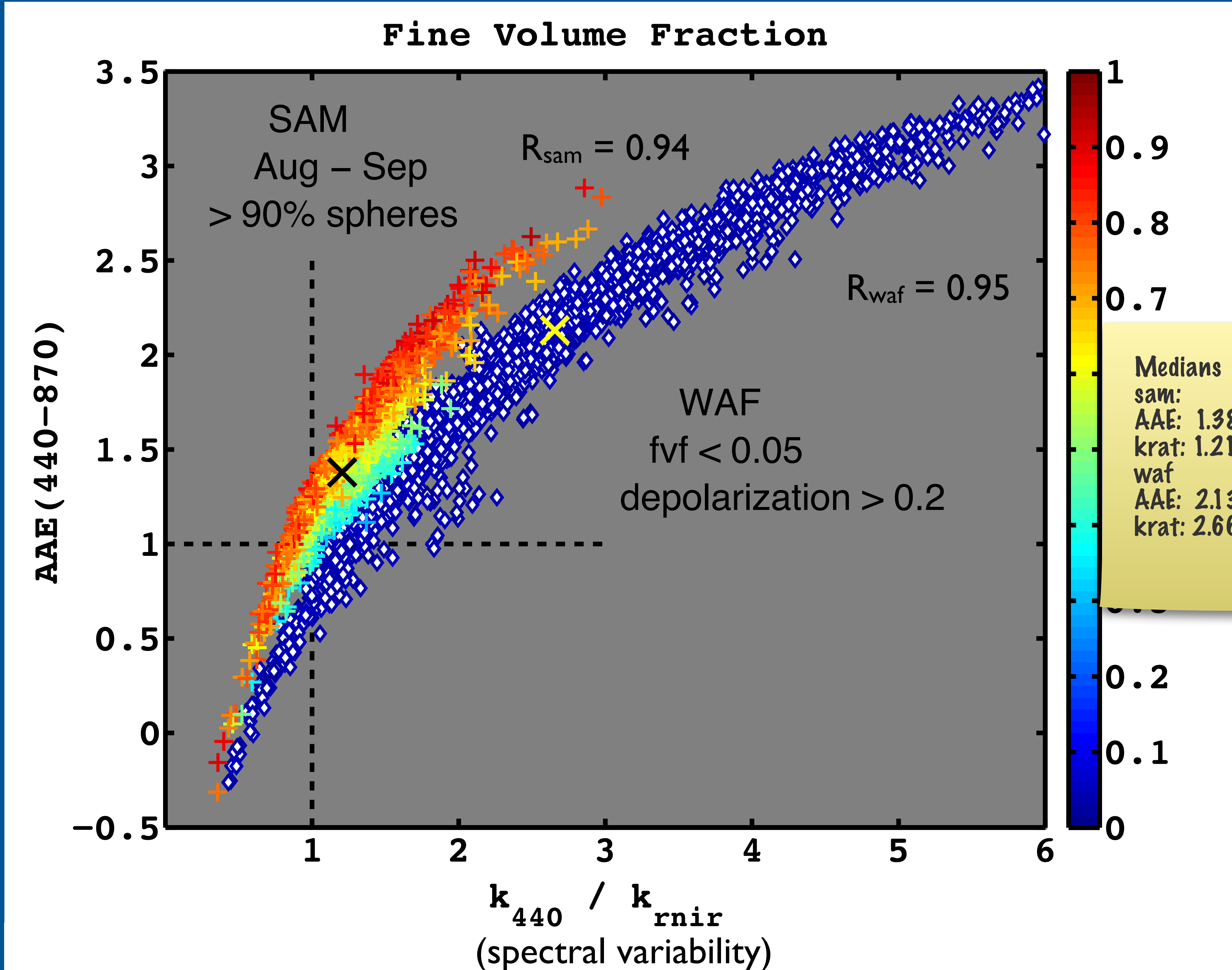

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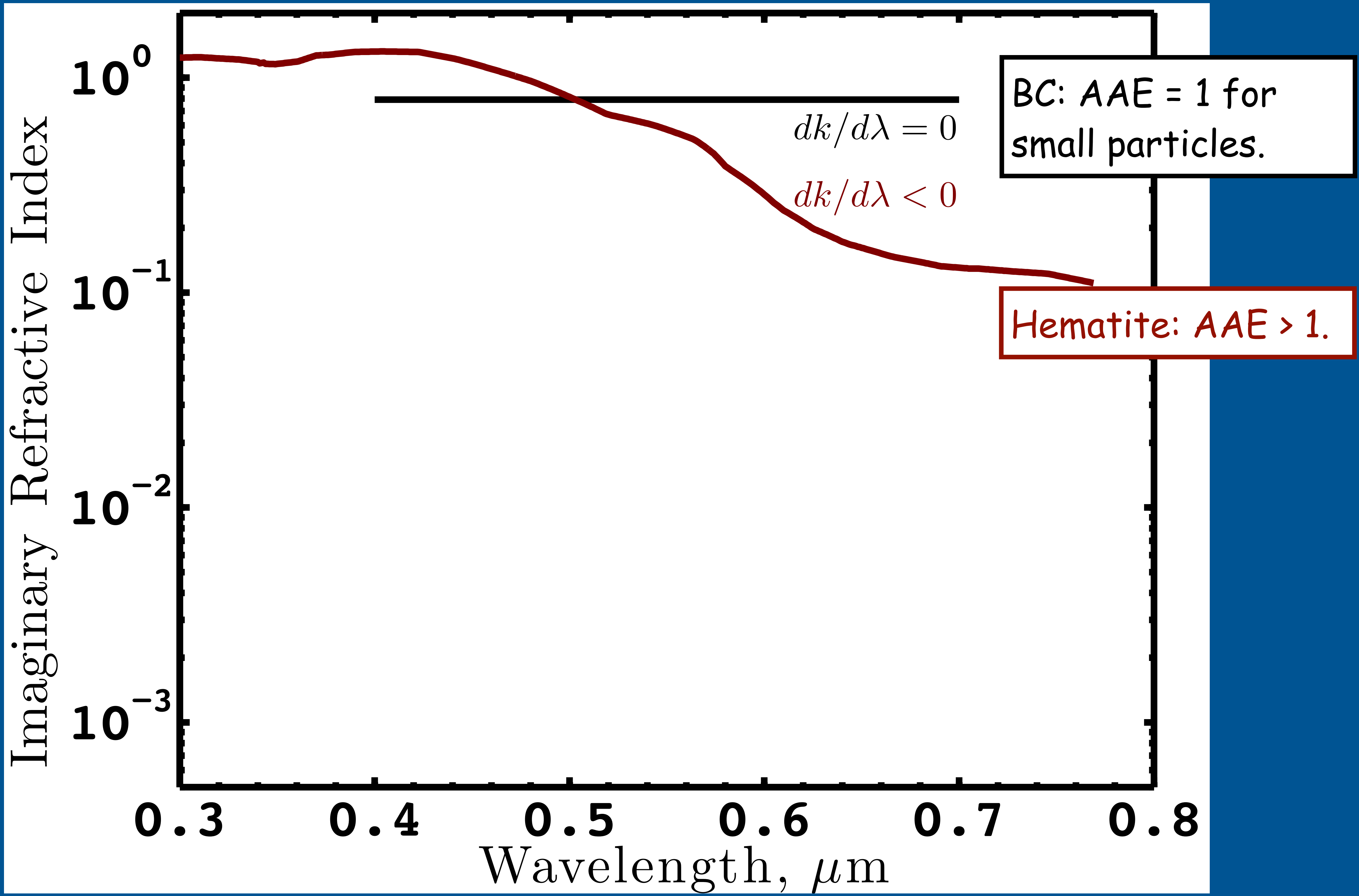

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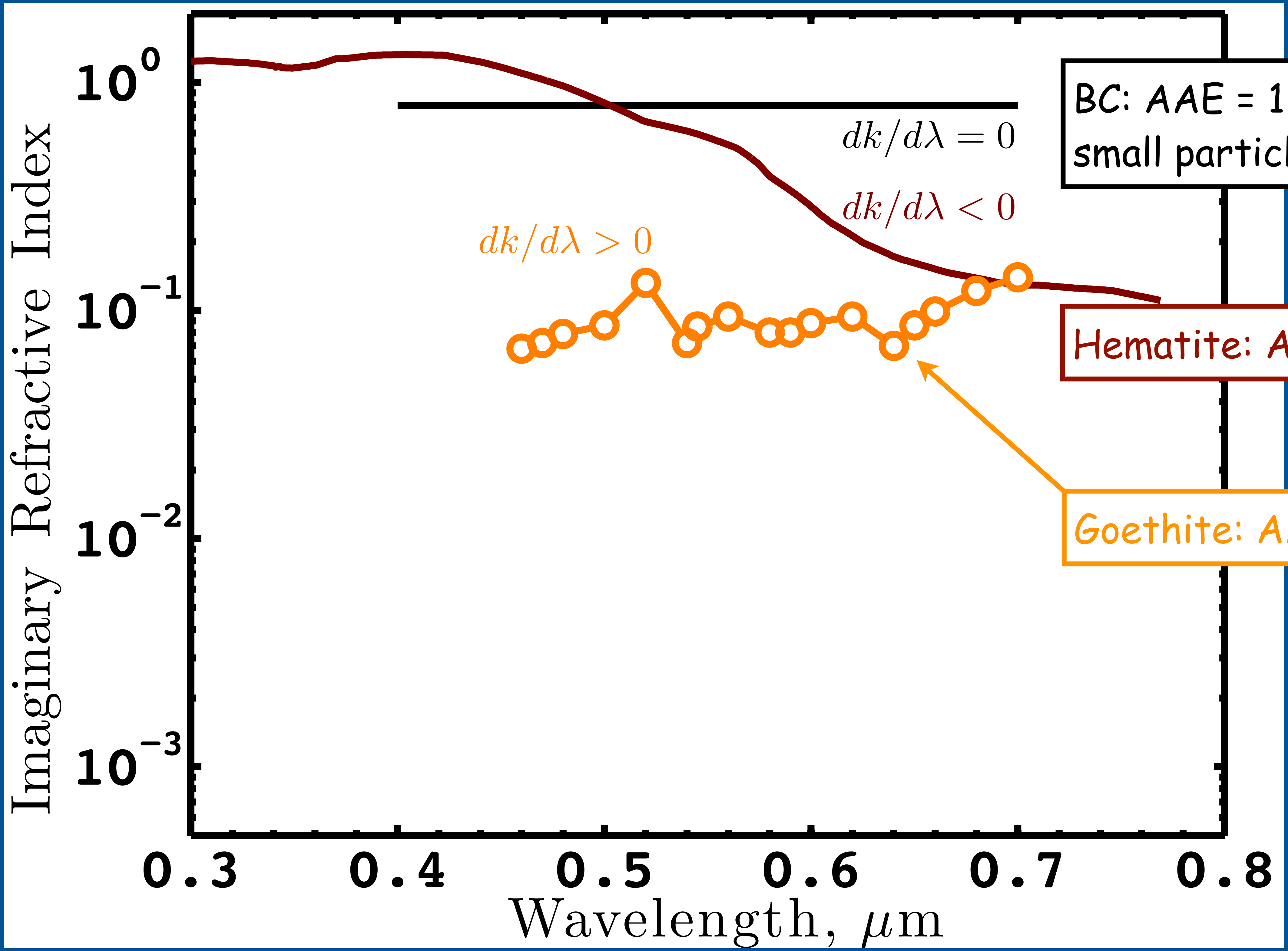

BC: AAE = 1 for small particles.

Hematite: AAE > 1.

Goethite: AAE < 1.

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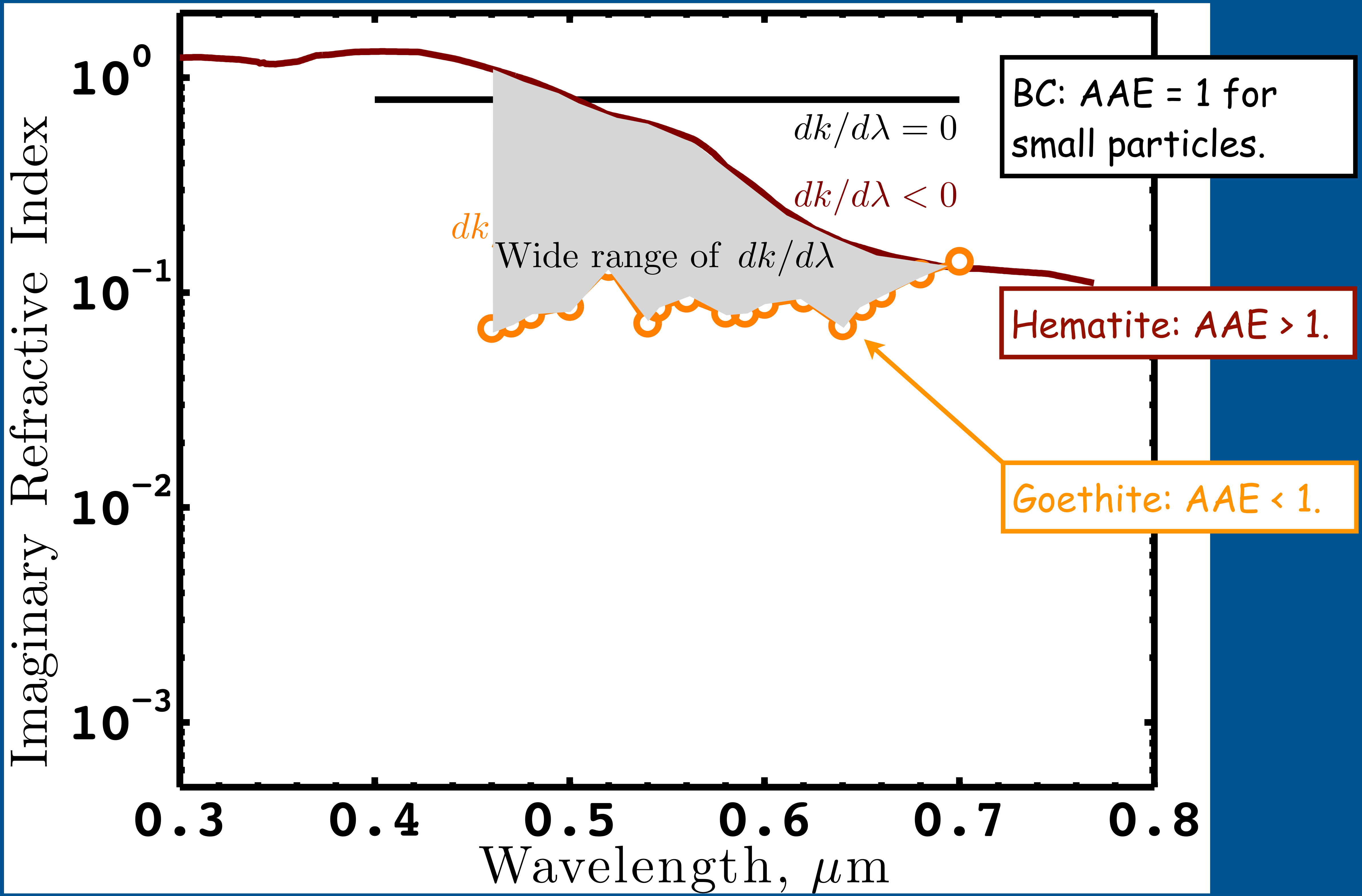
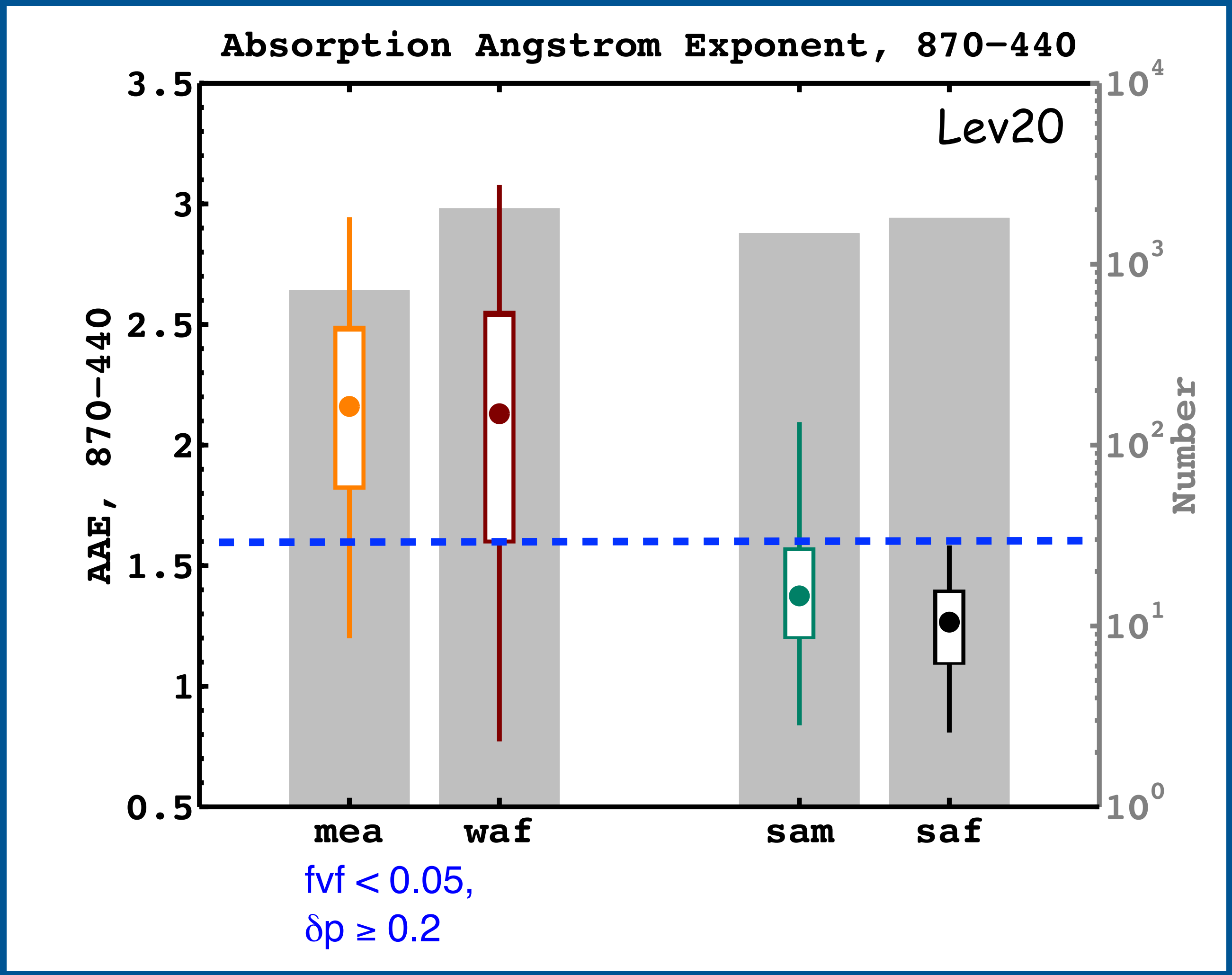


The goethite fraction of iron oxide in dust varies from 0.4 to 0.7 (Lafon, JGR 2006; Shi, Aeolian Res, 2012).

AAE for dust can be anything!

Dust and carbonaceous aerosols can not be separated with confidence using AAE



were the biomass sites filtered for 90% spheres in these slides? YES!

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waf: West Afriaca

sam: South America

saf: Southern Africa

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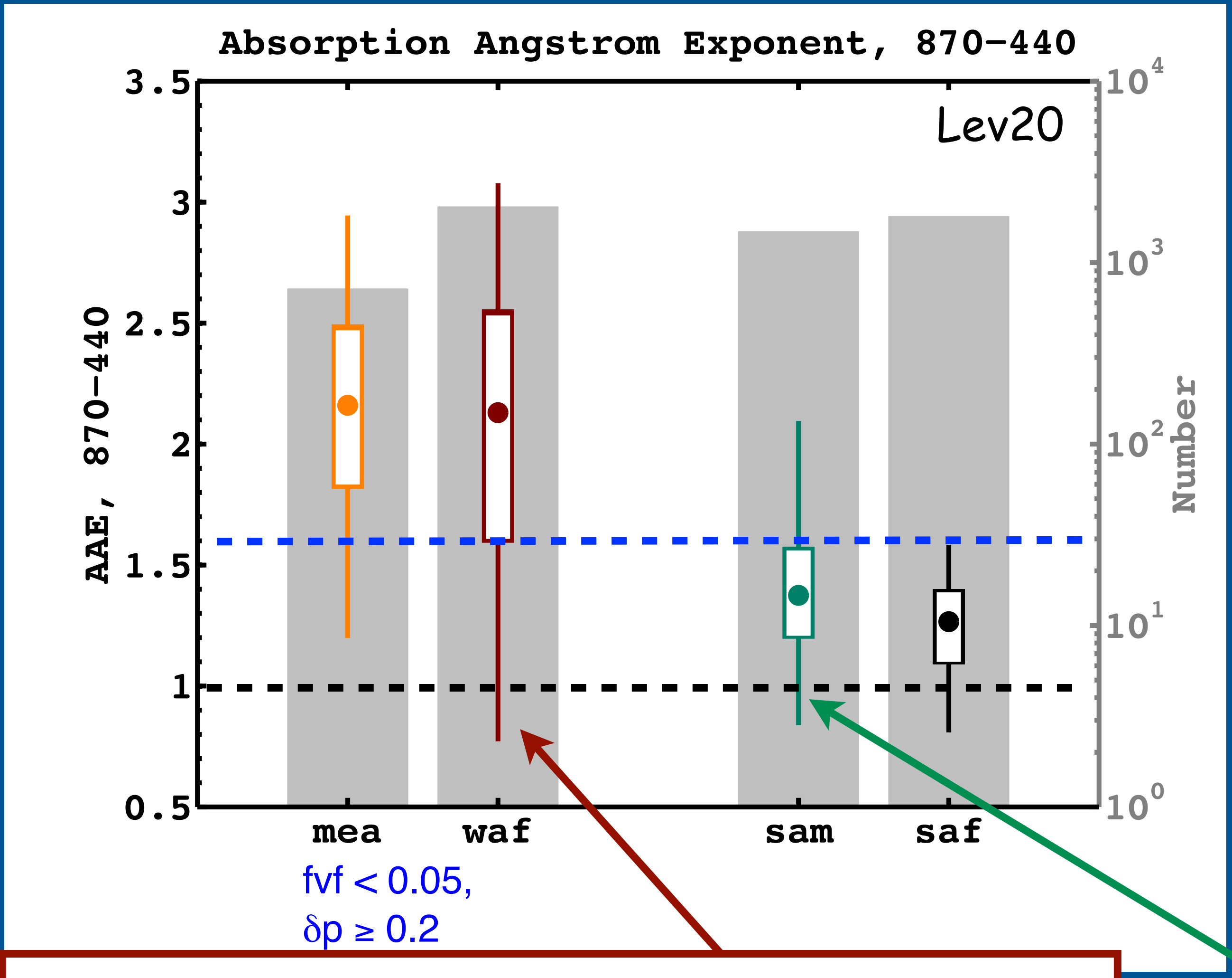

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13% of S. America smoke have AAE < 1

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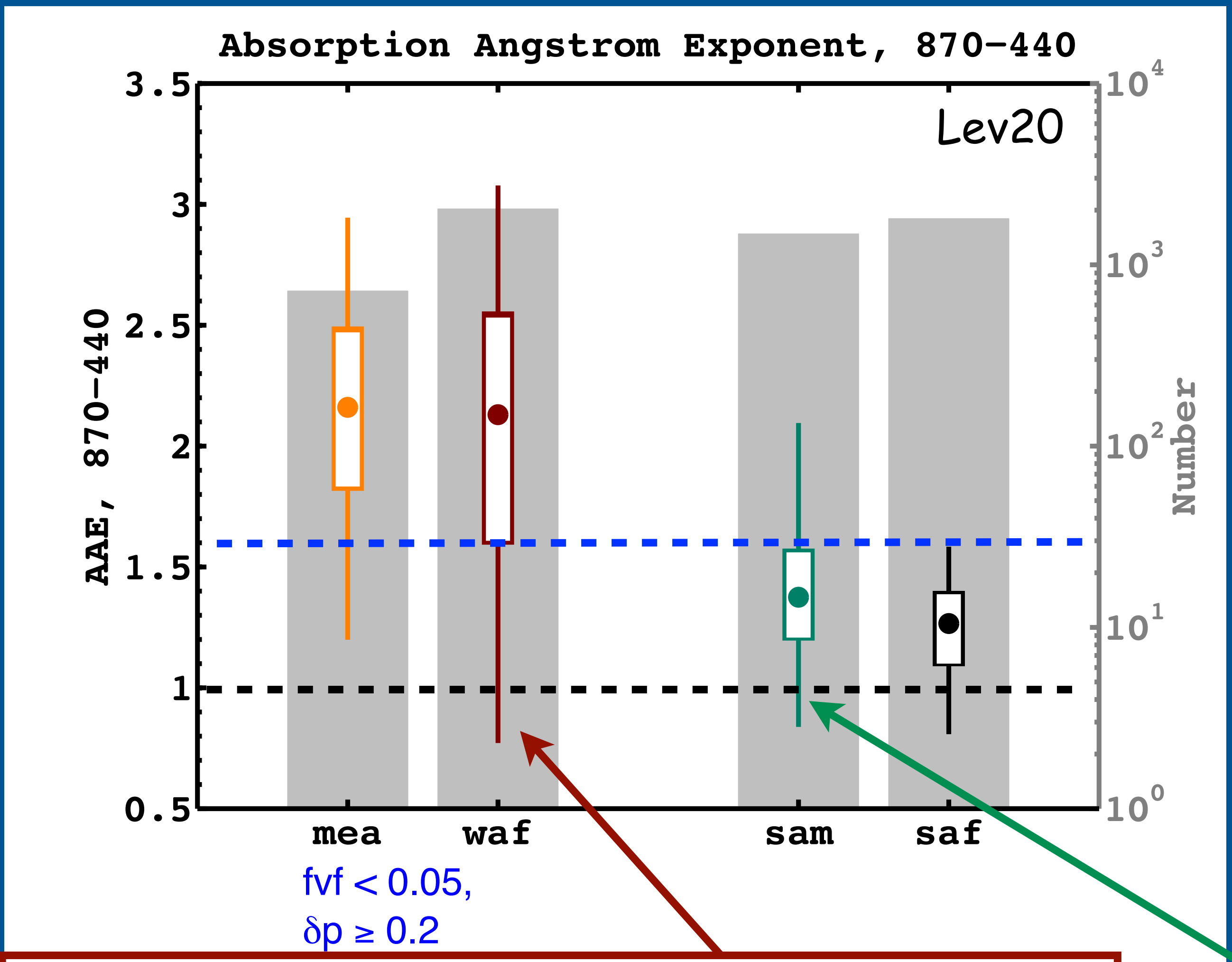
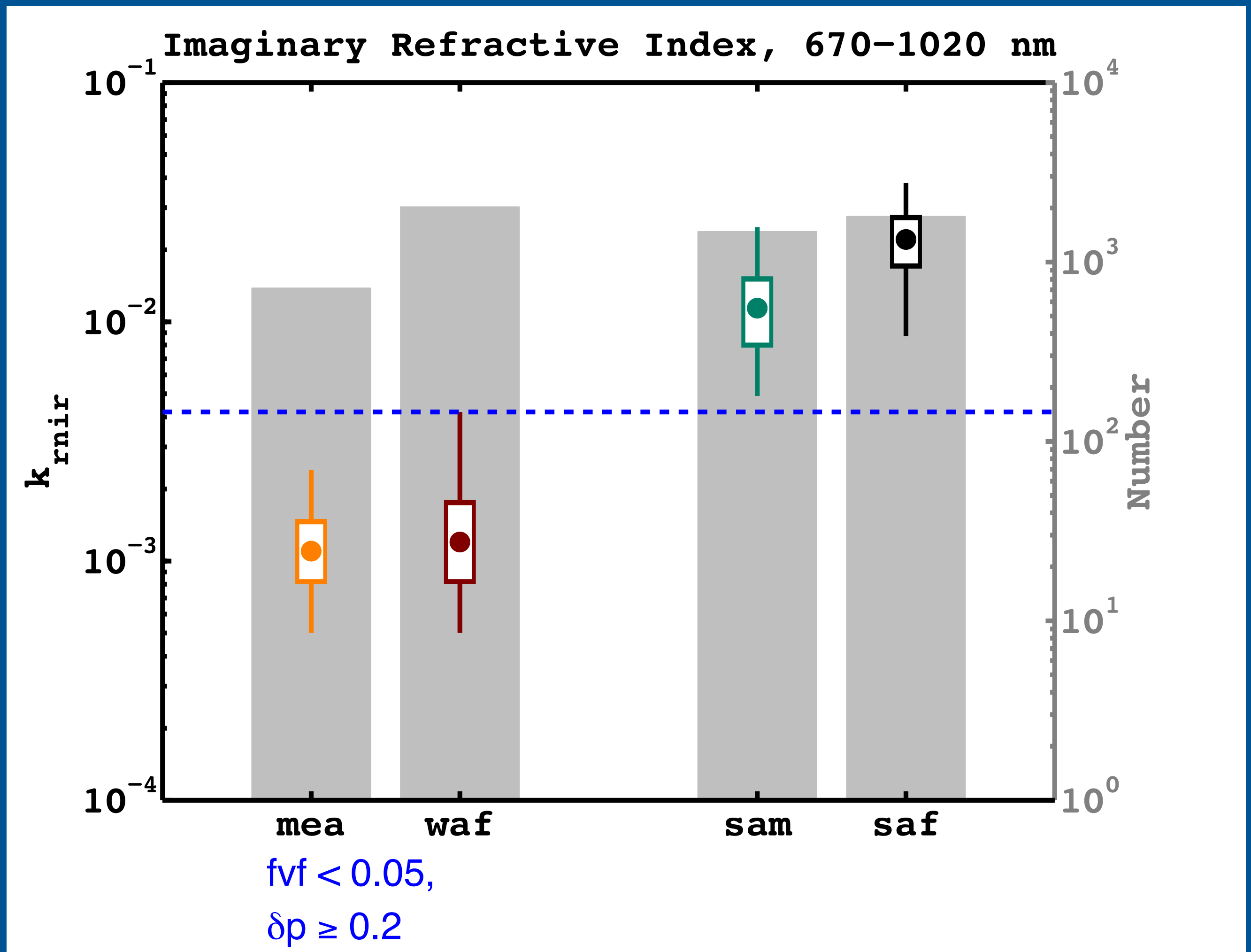


Strong separation exists in imaginary refractive index space.



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Conclusions

- AERONET AAE and AAOD are **computed** from size and refractive index!
- External mixture assumption of AAE approach is inconsistent with AERONET retrievals.
- The value of AAE_{BC} = 0.5 is inconsistent with the Bond (2013) definition of BC.
- AAE < 1 can be caused by coarse mode particles or $dk/d\lambda > 0$, but not carbon particles.
- Coming soon to ACPD!
- gregory.l.schuster@nasa.gov

Acknowledgements

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APPENDIX

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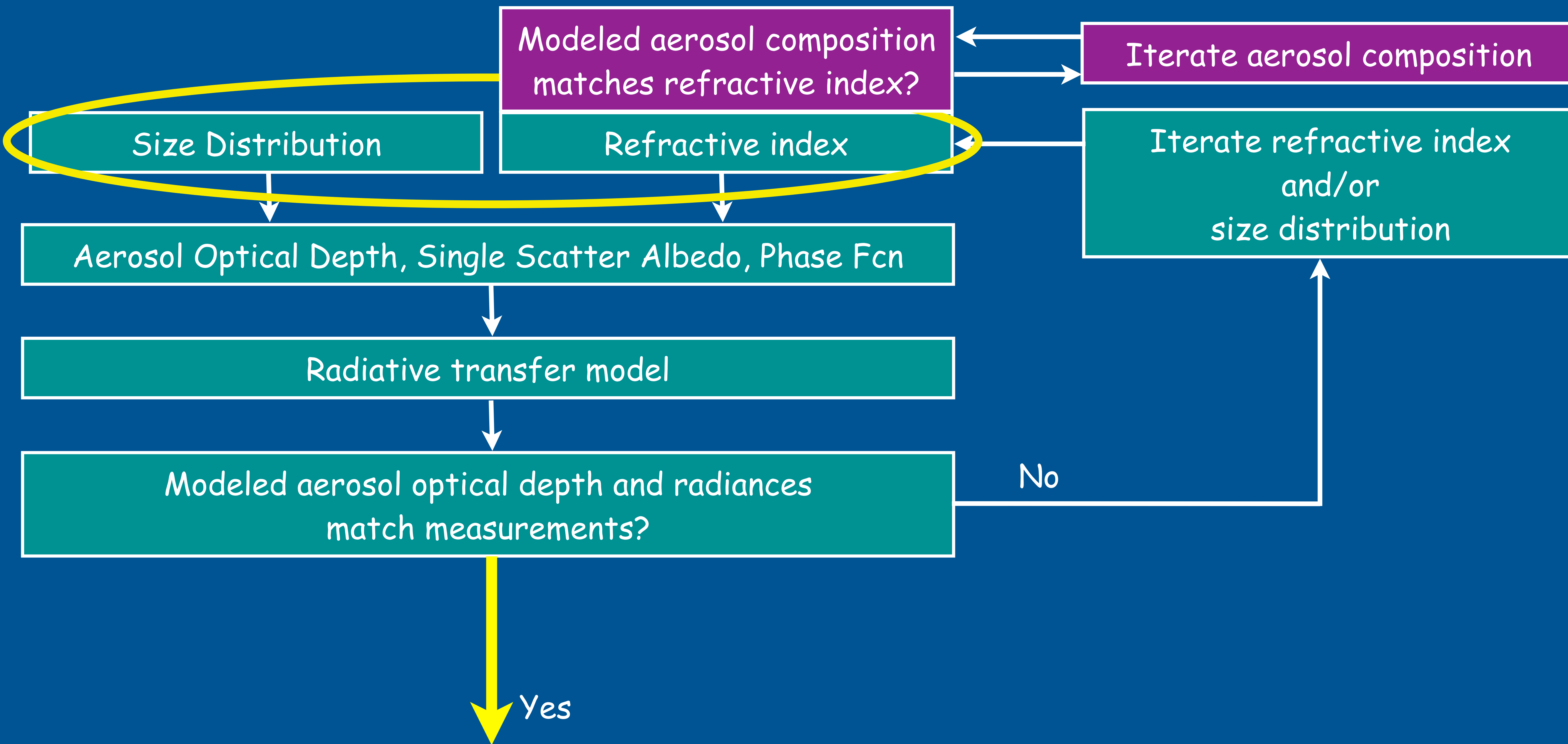

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AERONET — solve for component absorptions AODs

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AERONET

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Carbonaceous component is further separated into BC and BrC:

$$\xi_c(1)\lambda^{-AAE_c} = \xi_{BC}(1)\lambda^{-AAE_{BC}} + \xi_{BrC}(1)\lambda^{-AAE_{BrC}}$$

$$AAE_{BC} = 0.5$$

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Much lower than traditional value of AAE = 1

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Apply Angstrom Eq to each component:

$$\underbrace{\xi(1)\lambda^{-AAE}}_{\text{AERONET}} = \xi_c(1)\lambda^{-AAE_c} + \xi_d(1)\lambda^{-AAE_d}$$

But, the AAE of dust can be anything (< 0 to 3.5)

where:

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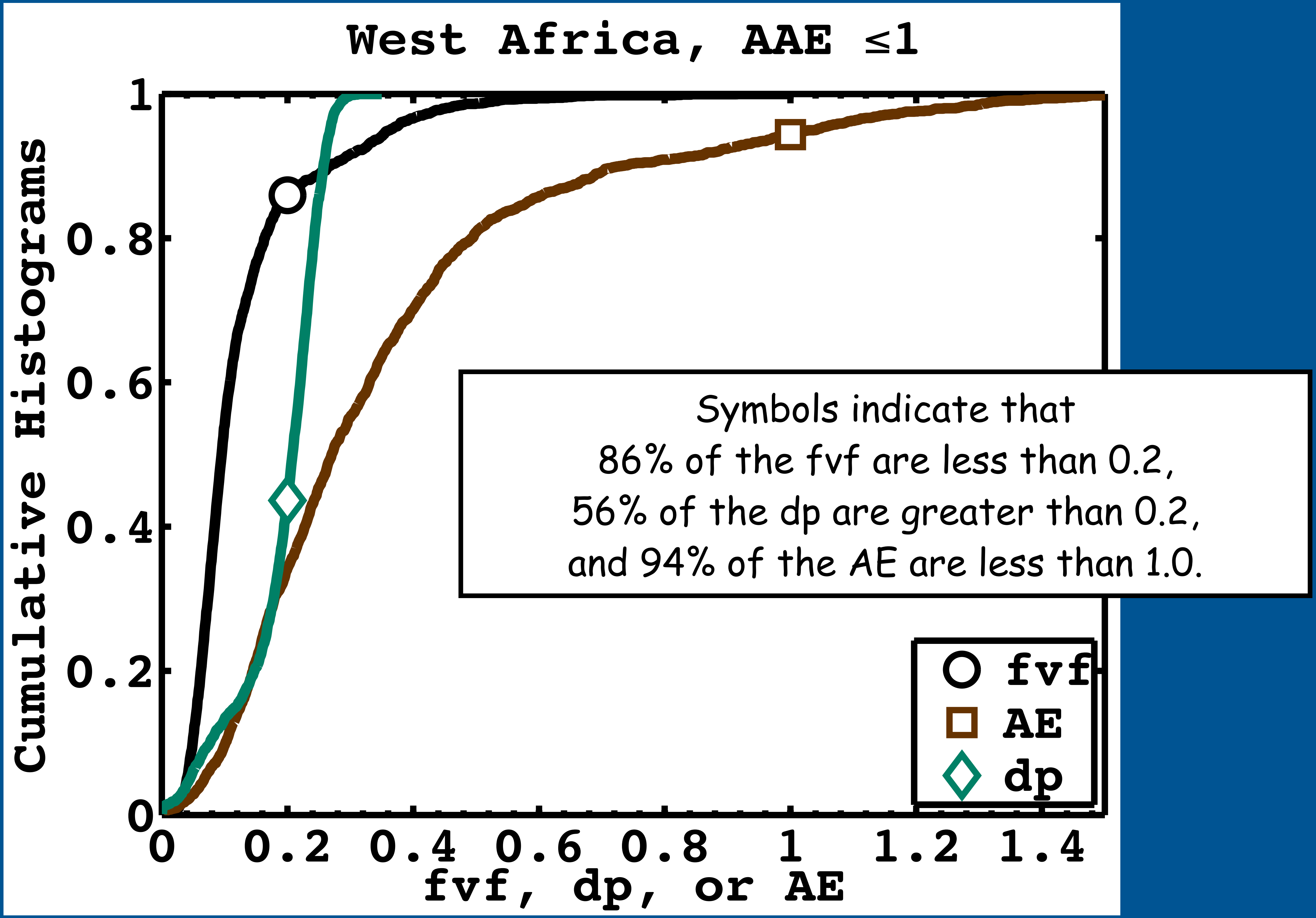
$$AAE_{BC} = 0.5$$

$$AAE_{BrC} = 4.8$$

Clearly, AAE < 1 does not represent carbonaceous aerosol in Africa



11 % of retrievals