

# A12M-1272 The Tables of Aerosol Optics (TAO) Project

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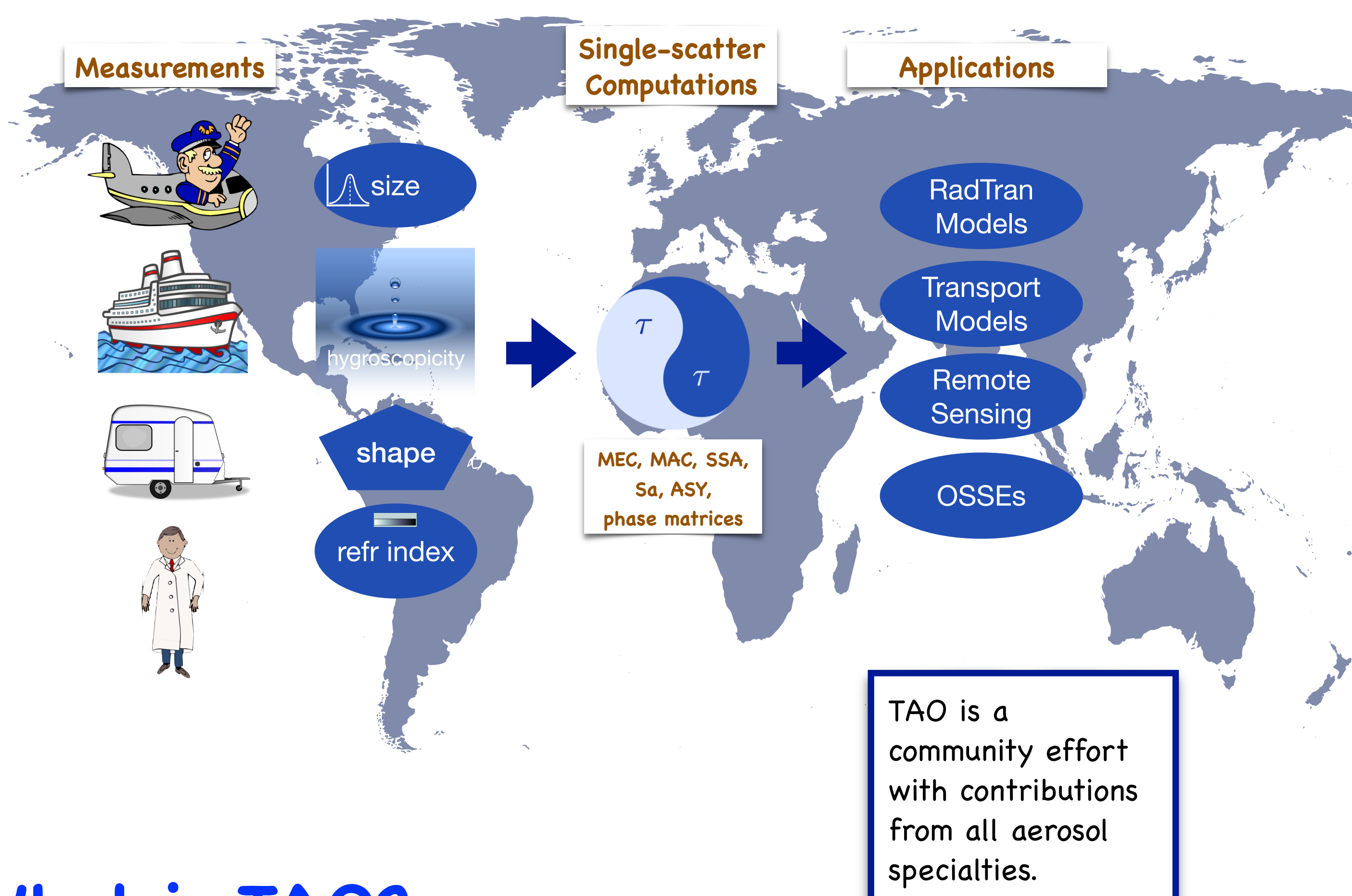
## What TAO has now, and how you can get it

We have created aerosol optical tables that include mass extinction, absorption, and backscatter coefficients, single-scatter albedos, asymmetry parameters, lidar ratios, etc. But we are still building, and we seek your help in establishing a community database.

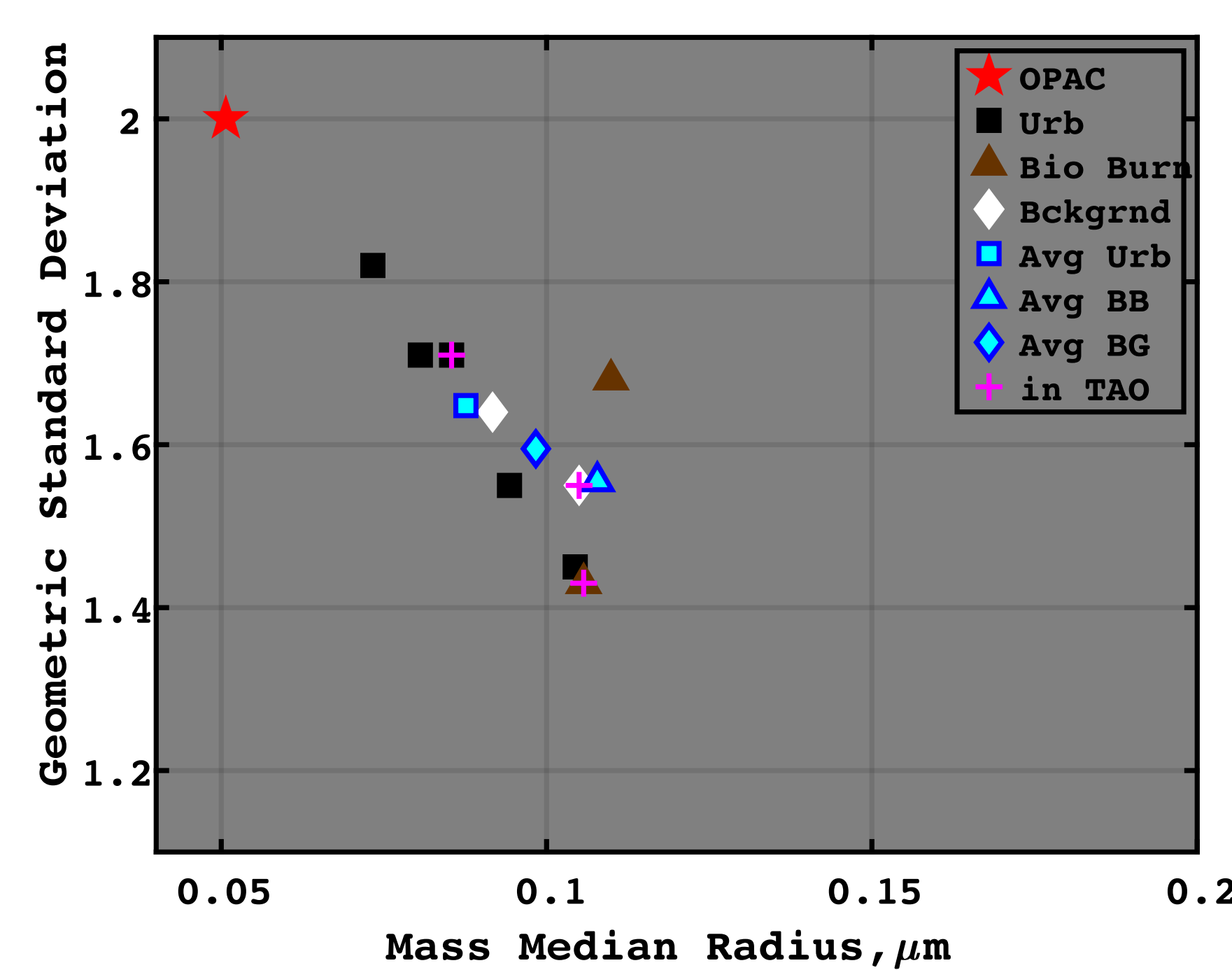
- Computations at 61 OPAC wavelengths from 0.25 to 40  $\mu\text{m}$  and 12 common remote sensing wavelengths.
- We will eventually make recommendations about how to proportion species for the different aerosol types.
- TAO is located on a NASA google drive while we get started. Contact [gregory.l.schuster@nasa.gov](mailto:gregory.l.schuster@nasa.gov) or [mira\\_crew@lists.nasa.gov](mailto:mira_crew@lists.nasa.gov) for access.

TAO Aerosol Species	Aerosol Type					Citations
	Bio Burn	Urban	Dust	Marine	Bckgrnd	
Externally-mixed Black Carbon	✓	✓			✓	3 BC SDs & 1 BC Complex RI: Schwarz (GRL, 2008), Bond & Bergstrom (AST, 2006)
Internally-mixed Black Carbon	✓	✓			✓	
Water-insoluble Brown Carbon	✓				✓	36 SDs & hygroscopicities: Rissler (ACP 2006)
Water-insoluble White Carbon	✓	✓		x	✓	
Water-soluble Brown Carbon	✓				✓	4 complex refractive indices: Sun (GRL 2007), Sutherland and Khanna (AST 1991) Dick (JGR 2000; AST 2007), Dinar (Faraday Discuss. 2008)
Water-soluble White Carbon	✓	✓		x	✓	
Sulfates		x		x	x	Gosse (Appl Opt, 1997)
Nitrates		x		x	x	
Sodium Chloride				x	x	Gosse (Appl Opt, 1997), Jarzembki (Appl Opt, 2003) Irshad (ACP, 2009)
Internal mix of clays + FeO <sub>x</sub>			✓			8 GEOS-GOCART SDs: Chin (Ann Geophys, 2009) 2 Complex RI and Hexahedras: Saito (JAS, 2021)

✓ symbols — at least one calculation available in TAO; X symbols — species that still need to be calculated.

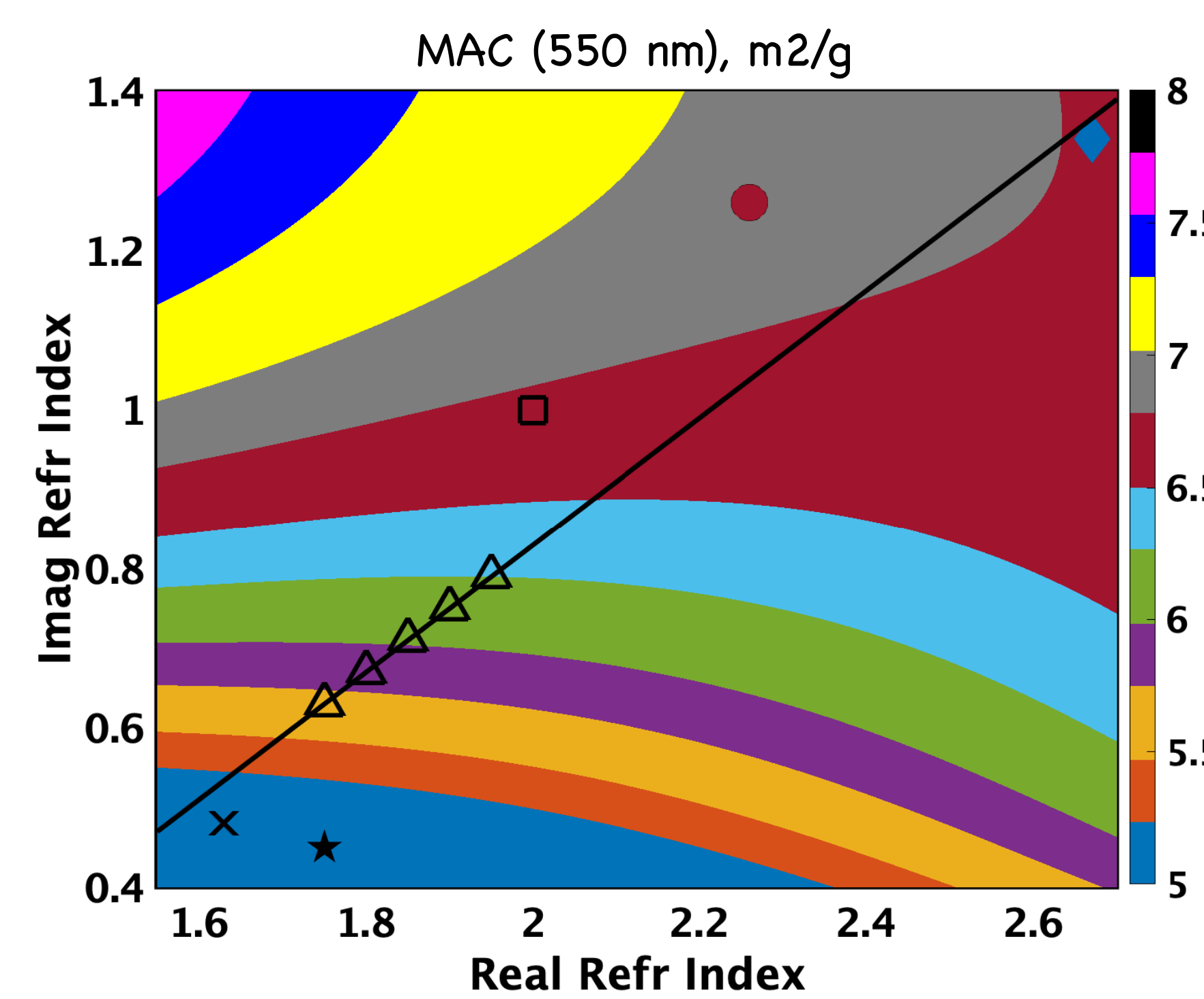


## Black Carbon Issues in OPAC



OPAC size distributions for black carbon are smaller and wider than modern SP2 measurements and do not differentiate between urban, biomass burning, and background conditions.  
 Data from Hess (BAMS 1998; OPAC), Moteki (GRL 2007), Schwarz (GRL 2008, 2010; + used for TAO), Kondo (Aer Sci Tech 2011)

**MAC and Complex Refractive Index**  
 Mie theory computations of the Mass Absorption Coefficient (MAC) using Schwarz (GRL 2008) BC size distributions. Newer complex refractive index measurements for black carbon result in much higher MACs than OPAC when reasonable BC densities are used. Recall that the BB06\* recommends 6.5-8.5 m<sup>2</sup>/g.  
 Contour parameters:  
 Count Median Radius (CMR) = 0.072, Geometric Std. Dev = 1.430  
 BC density = 1.7 g/cm<sup>3</sup>

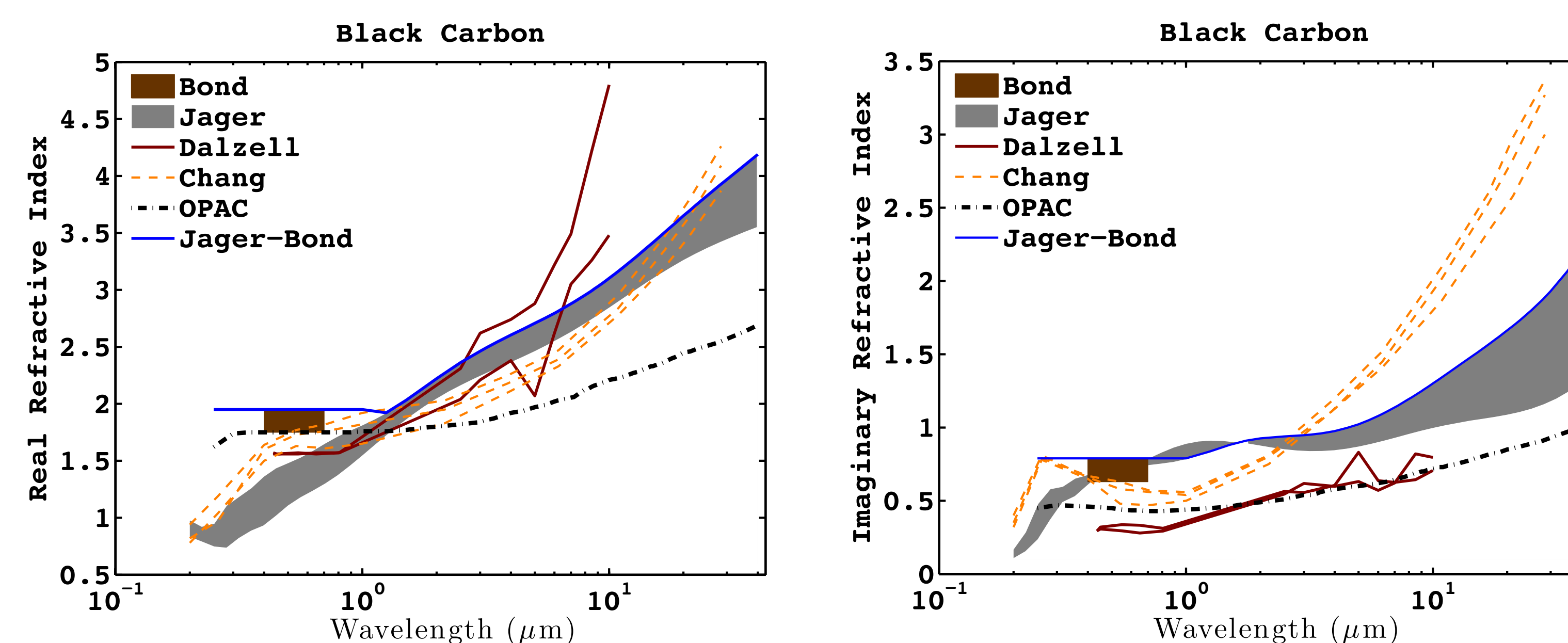


### Symbol Key

Symbol	Source	Density (g/cm <sup>3</sup> )	n - ki	Comment
◇	Borghesi and Guizzetti (1991)	2.26	2.67 - 1.34i	Graphite
○	Moteki et al (2010)	1.8	2.26 - 1.26i	Technique sensitive to density. Measured CRI at 1064 nm, but applied here at 550 nm
□	Janzen (1979)	1.7	2 - 1i	Carbon Blacks
△	* Bond and Bergstrom (2006)	1.7	1.96 - 0.79i	Literature review.
*	Hess et al. (1998)	1.0	1.75 - 0.44i	OPAC; density is unrealistic
x	Chang and Charalampopoulos (1990)	1.7	1.63 - 0.48i	

## Finding complex refractive index spectrums for black carbon remains a challenge

TAO uses the blue Jager-Bond line below, given the limited options.



Bond and Bergstrom (AST 2006), Jager et al (Astron. Astrophys 1998), Dalzell and Sarofim (J. Heat Trans 1969), Chang and Charalampopoulos (Proc. Roy. Soc. London 1990), OPAC (Hess, BAMS 1998).

## What is TAO?

- TAO is an extensive set of aerosol single-scatter computations (e.g., Mie theory) that transform particle size and composition into mass-normalized optical properties like extinction, absorption, and angular scattering.
- Global models use such tables to quickly compute upwelling and downwelling radiative flux at wavelengths that range from ~0.25 to 40  $\mu\text{m}$ .
- These optical tables must also accommodate the full range of relative humidities for hygroscopic particles.
- The most common optical tables used by modelers today are the Optical Properties of Aerosols and Clouds, or OPAC (Hess et al, BAMS 1993).
- TAO is an update to OPAC.

## Why we need TAO

- OPAC was published more than two decades ago, so it pre-dates all of the atmospheric measurements obtained in this century.
- These early datasets were sparse, so OPAC was unable to account for regional variations of intrinsic aerosol properties (i.e., the composition of smoke, dust, and pollution are considered as identical everywhere).
- Measurement and retrieval techniques have advanced significantly since OPAC (e.g., AERONET SSA, SP2 rBC mass, and Cavity Ringdown extinctions, to name a few).
- Single-scatter computations for complex (non-spherical) shapes have advanced significantly in recent years.

## What TAO seeks from the community

- Measurements of aerosol size distributions and complex refractive indices that are regionally representative.
- Single-scatter computations, especially for complex shapes.
- Special orders — if your favorite global model needs something and it is missing in TAO, please let us know!

## TAO is part of MIRA Models, In situ, and Remote sensing of Aerosols



Come to our MIRA sessions  
 Tuesday, December 13  
 1445-1815  
 McCormick Place  
 E350 (Lakeside, Level 3)



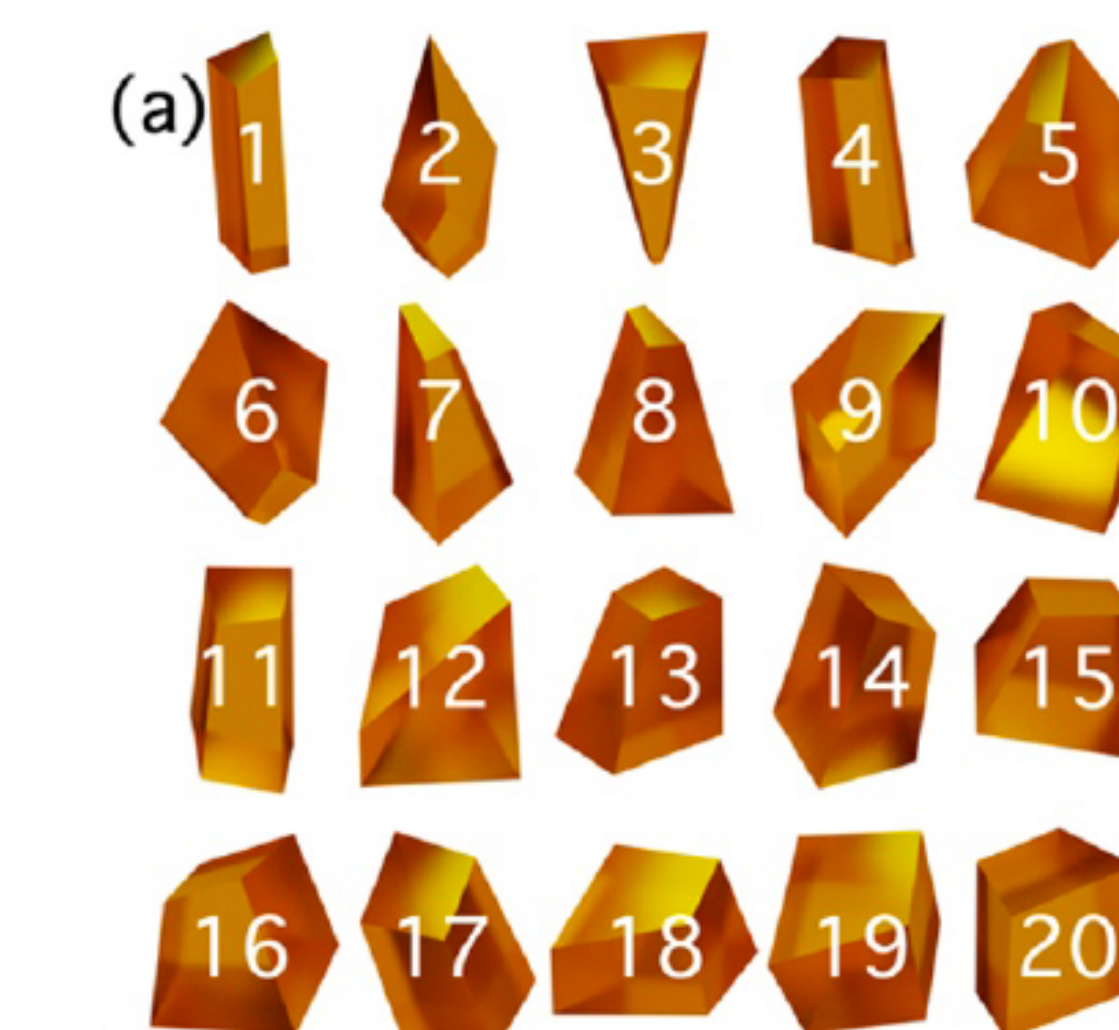
<https://science.larc.nasa.gov/mira-wg/>

<https://espo.nasa.gov/lists/listinfo/mira>

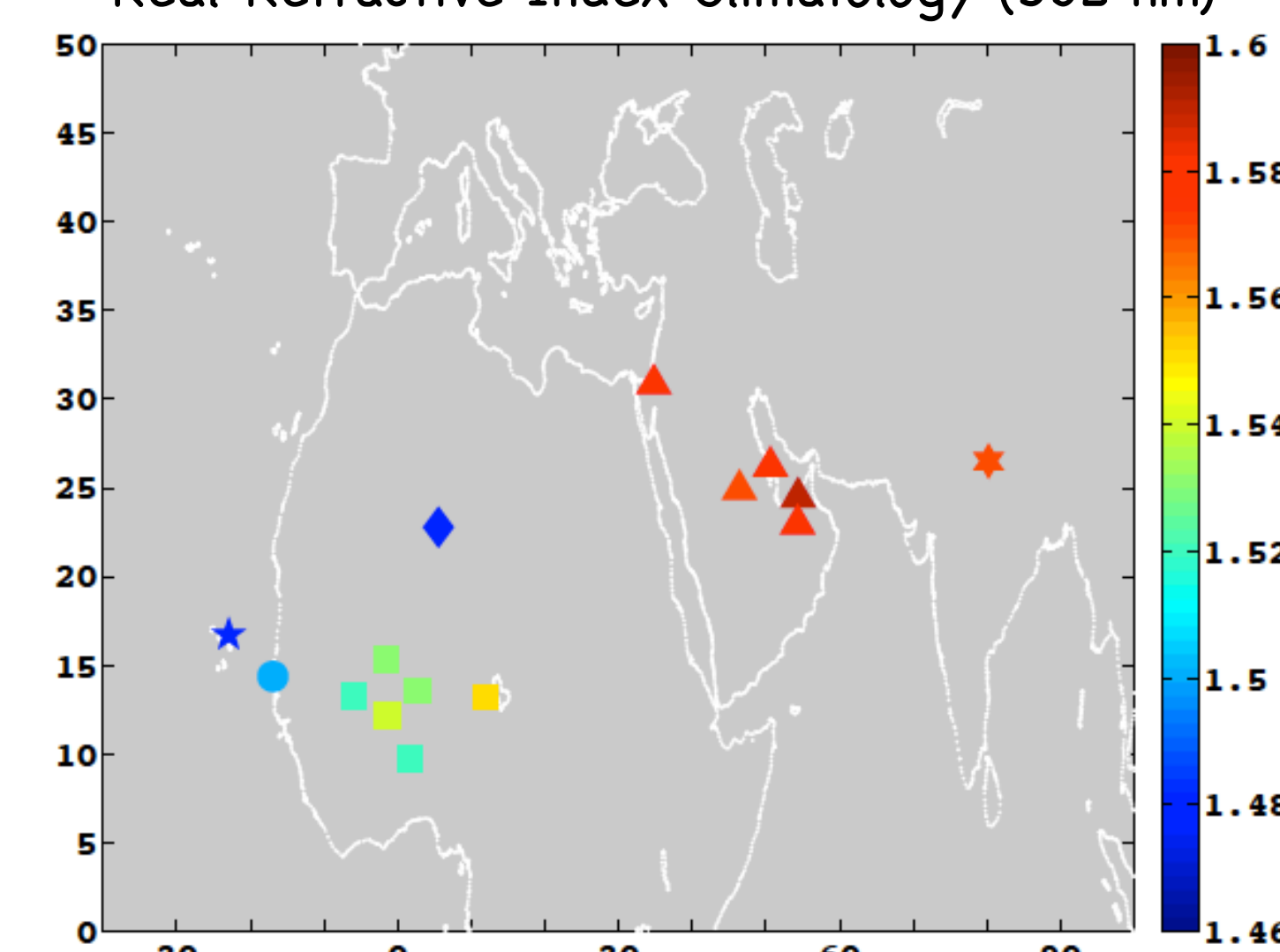
## Texas A&M Hexahedrals

### First Irregular Shapes for TAO

8 lognormals (GEOS-GOCART) and 2 sets of complex refractive indices to differentiate W African and Middle East dust.



### Real Refractive Index Climatology (532 nm)



The new Texas A&M kernel database for hexahedra.  
 Saito et al (JAS 2021), Saito and Yang (GRL 2021)

AERONET RRI varies because of regional mineralogy. Schuster et al (ACP 2012).

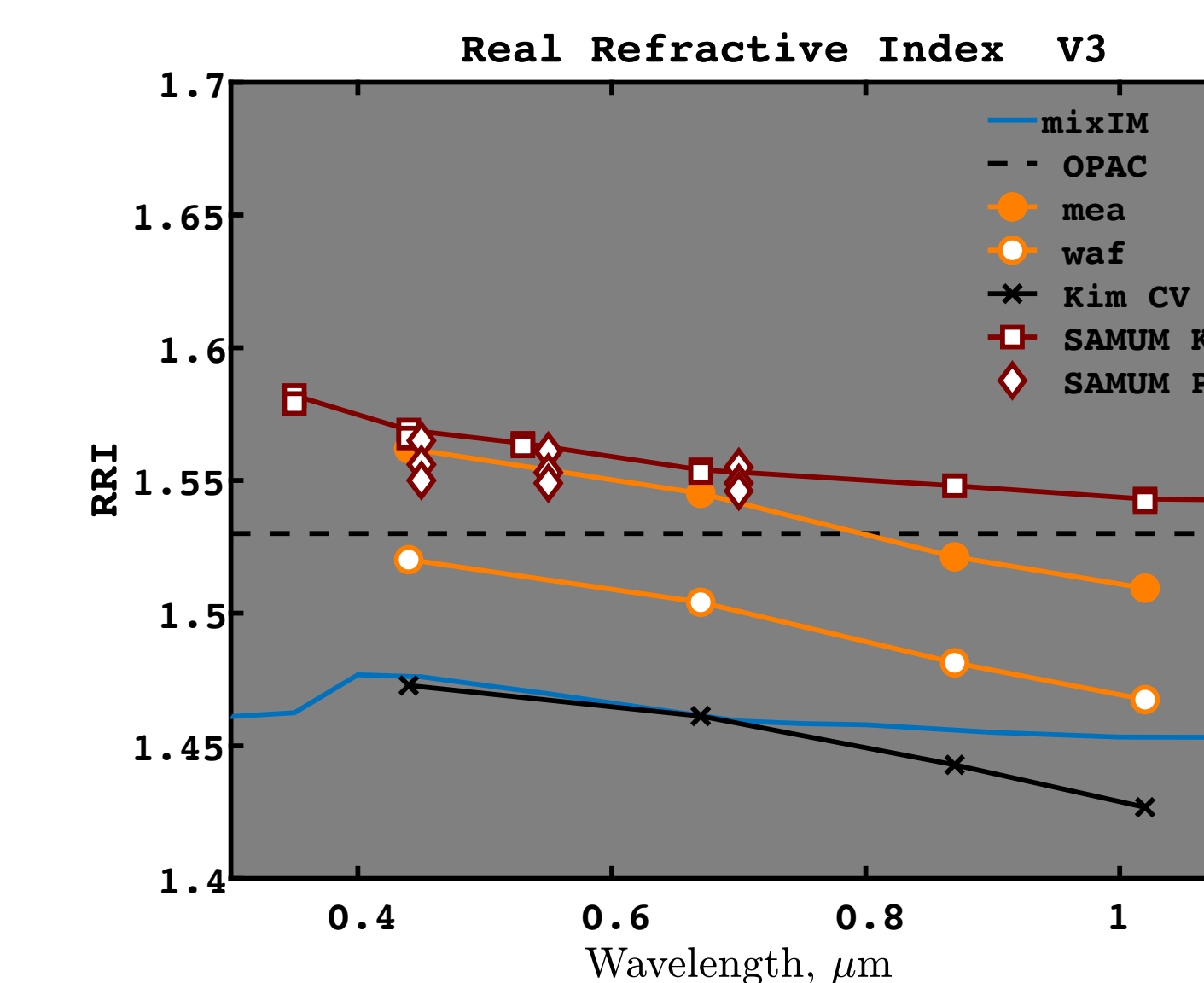
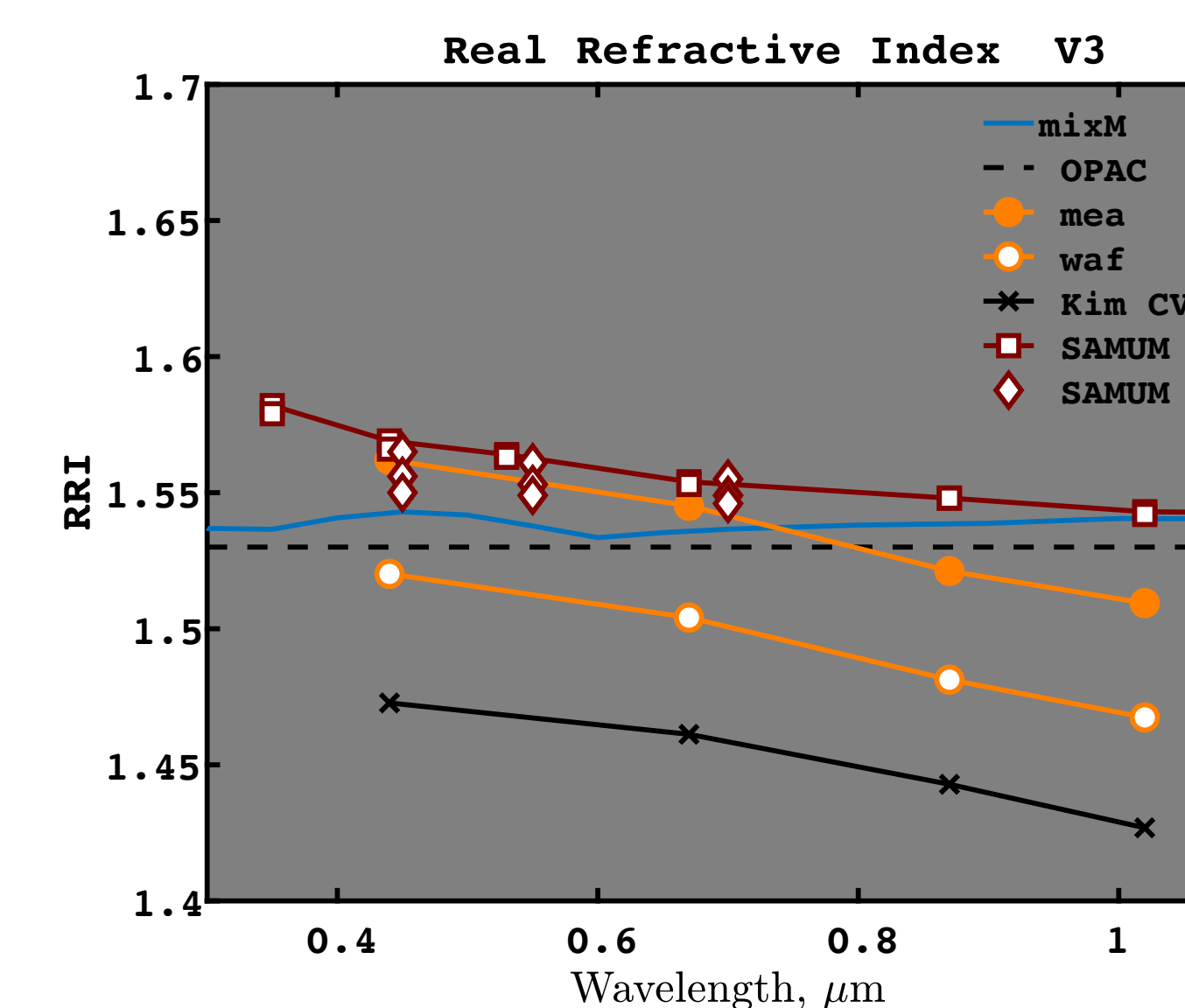
## Different mineral mixtures are required to simulate the range of dust real refractive index found in the literature.

### Montmorillonite (mixM)

98.8% Montmo., 0.7% Hematite, 0.5% Goethite by volume

### Illite & Montmorillonite (mixIM)

59.2% Illite, 40.0% Montmorillonite, 0.5% Hematite, 0.3% Goethite by volume



The blue line in the left panel is a simulated mixture dominated by montmorillonite and approximates the upper range of observations, whereas the blue line in the right panel contains a significant amount of illite as well as montmorillonite to approximate the lower range.

Mineral refractive indices from Egan and Hilgeman, 1979, Bedidi and Cervelle (JGR 1993), Chen and Cahan (JOSA 1981). Legend key — OPAC: Hess (BAMS, 1998); mea, waf: Schuster (ACP, 2012); Kim CV: Kim (ACP, 2011); SAMUM K: Kandler (Tellus, 2009); SAMUM P: Petzold (Tellus, 2009).

## Apply Texas A&M hexahedra calculations to the above mixtures:

Lognormal parameters:

Effective Radius,  $\mu\text{m}$ : 0.450 Geometric Standard Deviation: 2.0  
 Mode Radius,  $\mu\text{m}$ : 0.135 Mineral mass density (g/cm<sup>3</sup>): 2.6

