Welcome to the IGAC Side Meeting on Models, In situ, and Remote sensing of Aerosols (MIRA)

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September 17, 2021

- Thank-you for tuning in, especially if this time slot is challenging for your location.
- Your audio travels 2-3 chairlengths, so be cognizant of typing near your neighbors (i.e., mute).
- The virtual microphone is near the podium (anywhere between small bushes) for questions.
- Roundtable discussion, so feel free to interrupt by raising your hand or walking to the 'microphone.'
- Use headphones (if you have them) during group discussion to reduce echos.

Models, In situ, and Remote sensing of Aerosols (MIRA)

- Purpose of today's meeting:
  - Roundtable discussion of how to form an international MIRA Working Group.
- What is MIRA?
  - MIRA provides a new forum that fosters collaborations across regional boundaries amongst aerosol modeling, in situ, and remote sensing specialties, with the purpose of advancing knowledge about aerosol properties to improve understanding of air quality, weather, and climate.
- Why?
  - Bridging across aerosol science disciplines and interests offers opportunities to gain new insights and help address gaps in understanding that can aid in the interpretation of observations and model simulations.
    - For example, there is a long-standing need to improve linkages between aerosol optical properties and chemical speciation for model simulations.
- Why now?
  - The CALIPSO satellite mission is expected to reach its end of lifetime in the next 2 years. The mission has acquired > 15 years of aerosol profile observations over the globe. There is a narrow window of opportunity to improve the quality of its aerosol retrievals by advancing knowledge of optical properties for aerosols of different compositions (lidar ratio).
  - Aerosol models have also advanced significantly in the past decade and their ability to compute aerosol impacts on climate will benefit from improvements to aerosol optical models for different aerosol compositions.
- Propose emphasis for the MIRA WG on two topics (although there could be others):
  - Refine survey of global aerosol optical properties (lidar ratio) to support lidar algorithm retrievals and data interpretation (satellite and ground-based lidar networks)
  - Creation of a new generation of Tables of Aerosol Optics (TAO) for model simulations

Two immediate areas of focus (and more) for MIRA

1.) Improve *a priori* lidar ratios for space-based lidars
2.) Create community Tables of Aerosol Optics (TAO)

and more… PM2.5, air quality, and other topics

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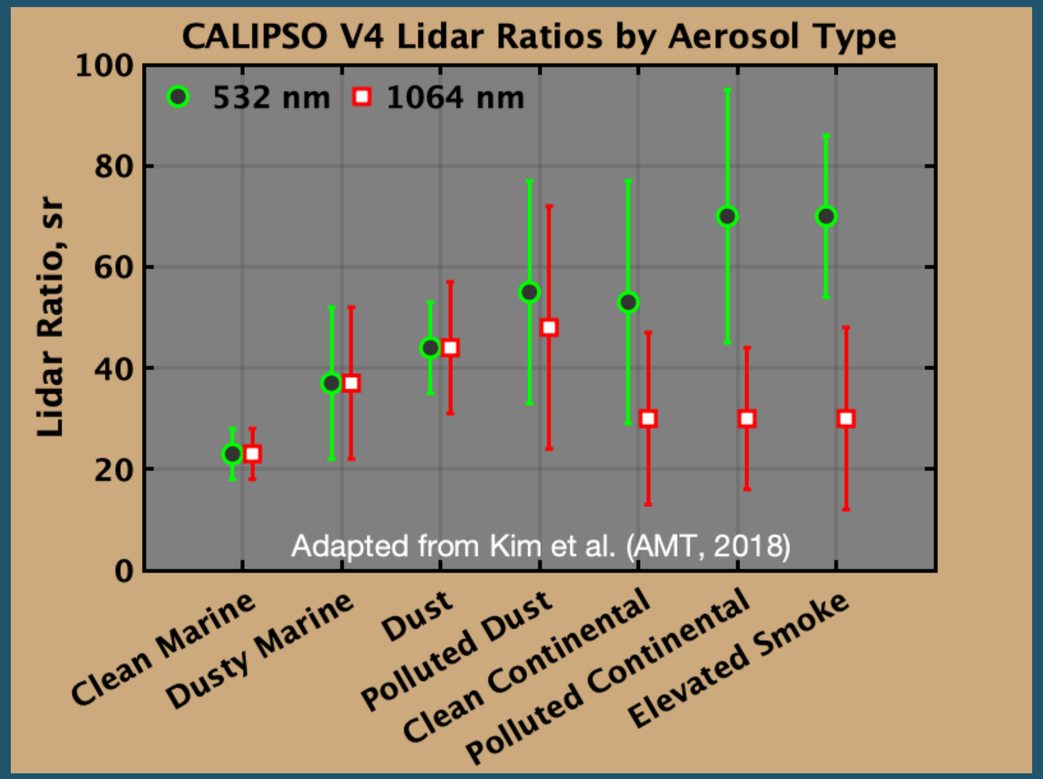
The Cloud-Aerosol and Infrared Pathfinder Satellite Observation (CALIPSO) Mission

- CALIPSO is a joint U.S. (NASA) and French (CNES) satellite mission.
- It is a backscatter lidar in space that was originally part of the A-Train, and it is still collecting data! (since mid-June, 2006).
- One of the many CALIPSO products are aerosol extinction profiles, but backscatter lidars require a priori knowledge about the lidar ratio to retrieve extinction profiles.

$$\text{Lidar Ratio} \equiv \frac{(\text{ext coeff})}{(\text{backscatt coeff at } 180^\circ)}$$

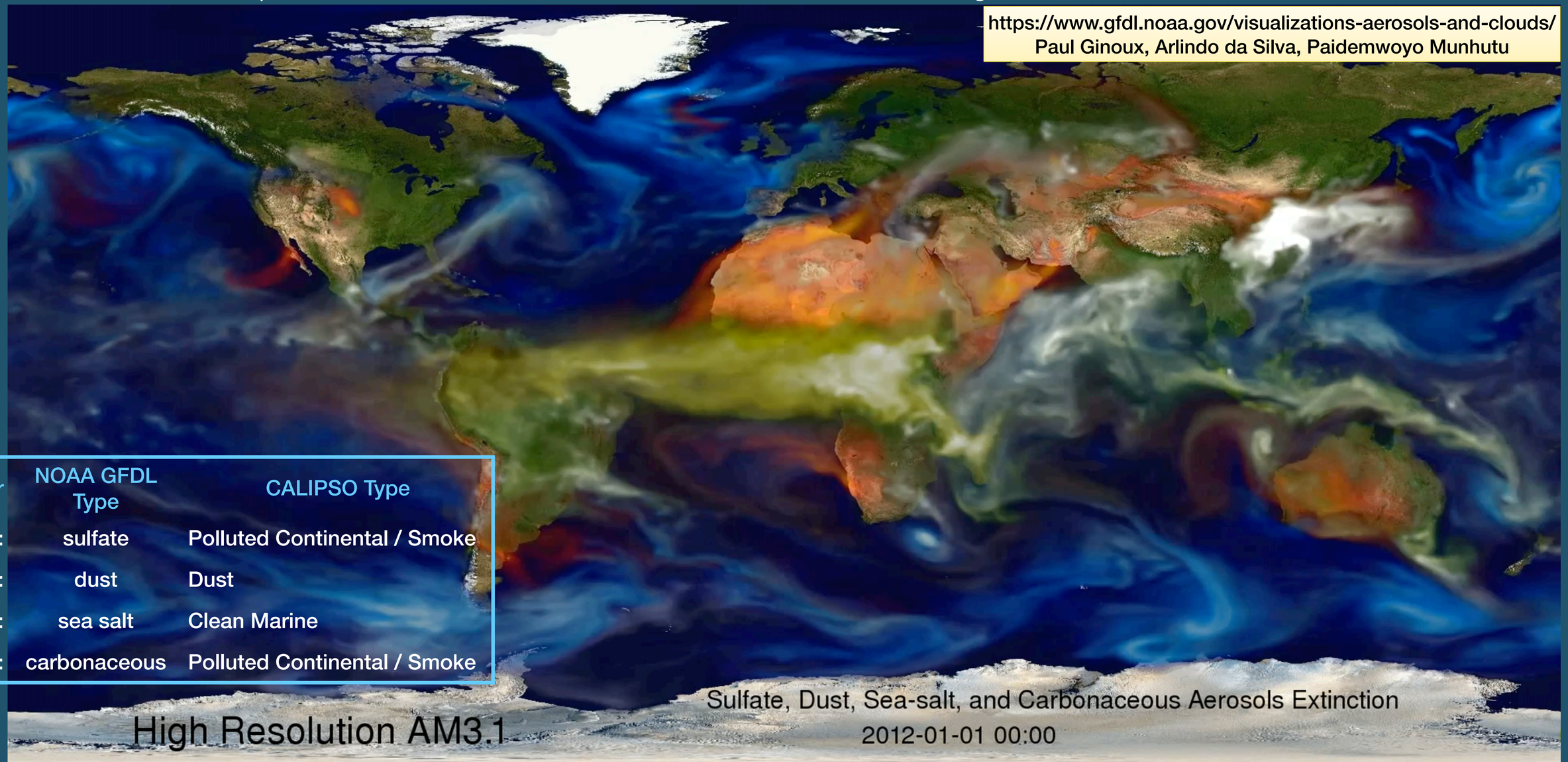
- Lidar ratio at a particular wavelength is a pseudo-intrinsic parameter that is sensitive to aerosol composition (or type), size, and shape.
- The current aerosol data products (Version 4) uses the lidar signal (linear depolarization ratio and integrated attenuated backscatter) along with the surface scene (ocean/land/desert) and altitude to define 7 aerosol 'types' in the detected layers.
- Once aerosol type has been defined, a lidar ratio and uncertianty is assigned.
- Uncertainty is large, so improved methods are needed.



How can we improve upon the current lidar ratio selection scheme?

Known issues:

- Aerosols don't respect CALIPSO's land/ocean demarcations
- Mixtures are everywhere! — Forward models better than backtractories for understanding mixtures.



Color	NOAA GFDL Type	CALIPSO Type
grey:	sulfate	Polluted Continental / Smoke
red:	dust	Dust
blue:	sea salt	Clean Marine
green:	carbonaceous	Polluted Continental / Smoke

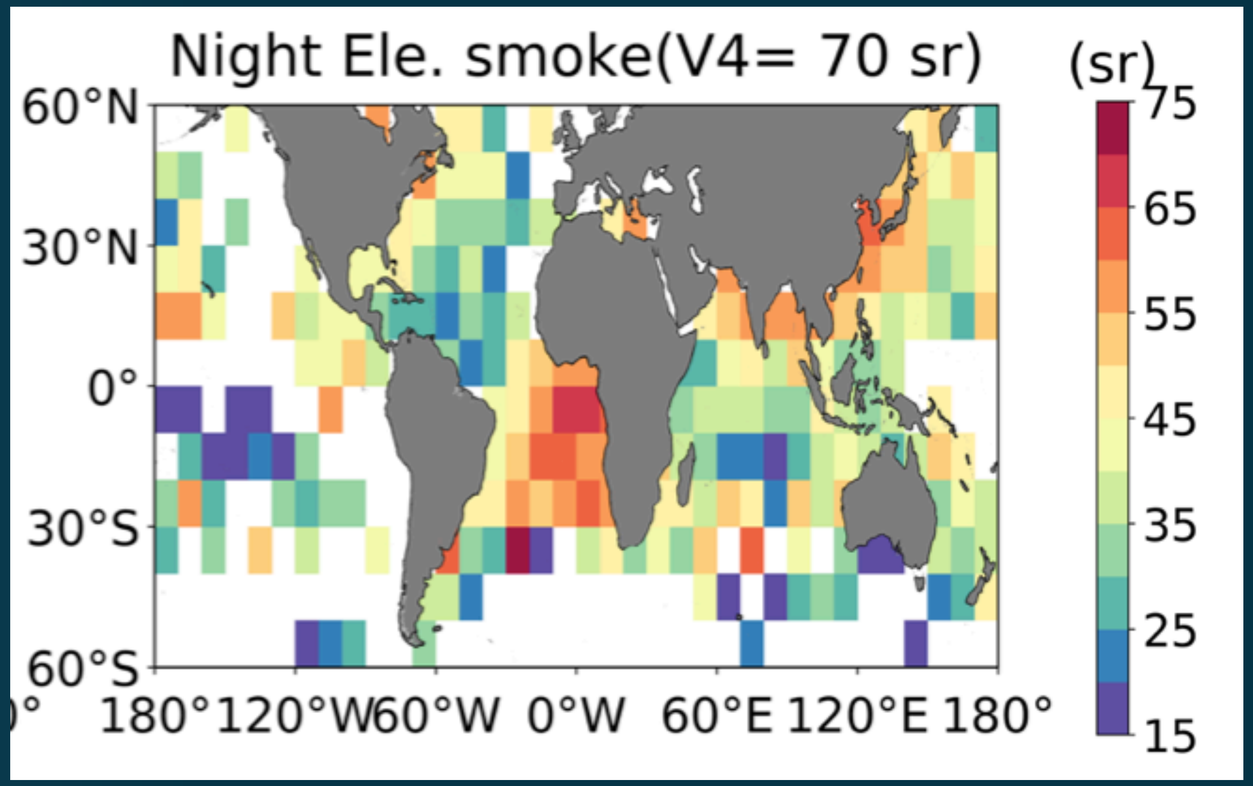
Special case: Determining lidar ratio when transmittance is known

If the transmittance (T) or aerosol optical depth is known and the lidar ratio is assumed to be constant wrt altitude (z), the lidar equation simplifies to (e.g., Fernald et al., JAM, 1972):

$$S_a \propto \frac{1 - T^2(Z^*)}{\int_0^{Z^*} P(z) z^2 dz}$$

Thus, we can use constrained retrievals to evaluate the CALIPSO lidar ratios (Li et al, in preparation).

- Lidar ratio climatology (2006-2011) for elevated smoke using the Synergized Optical Depth for Aerosols (SODA) product to constrain the CALIPSO backscatter measurements.
- Regional variations are significant and unaccounted for in Version 4.
- SODA uses CloudSat, which had a battery failure in 2011 and ended nighttime data collection.
- Additionally, SODA does not work over land.
- So we'll repeat this study, using other AOD retrievals (e.g., ODCOD, MODIS) and the entire data record.



Painemal et al., CALIPSO Version 5 Aerosol Lidar Ratio Workshop, March 2021

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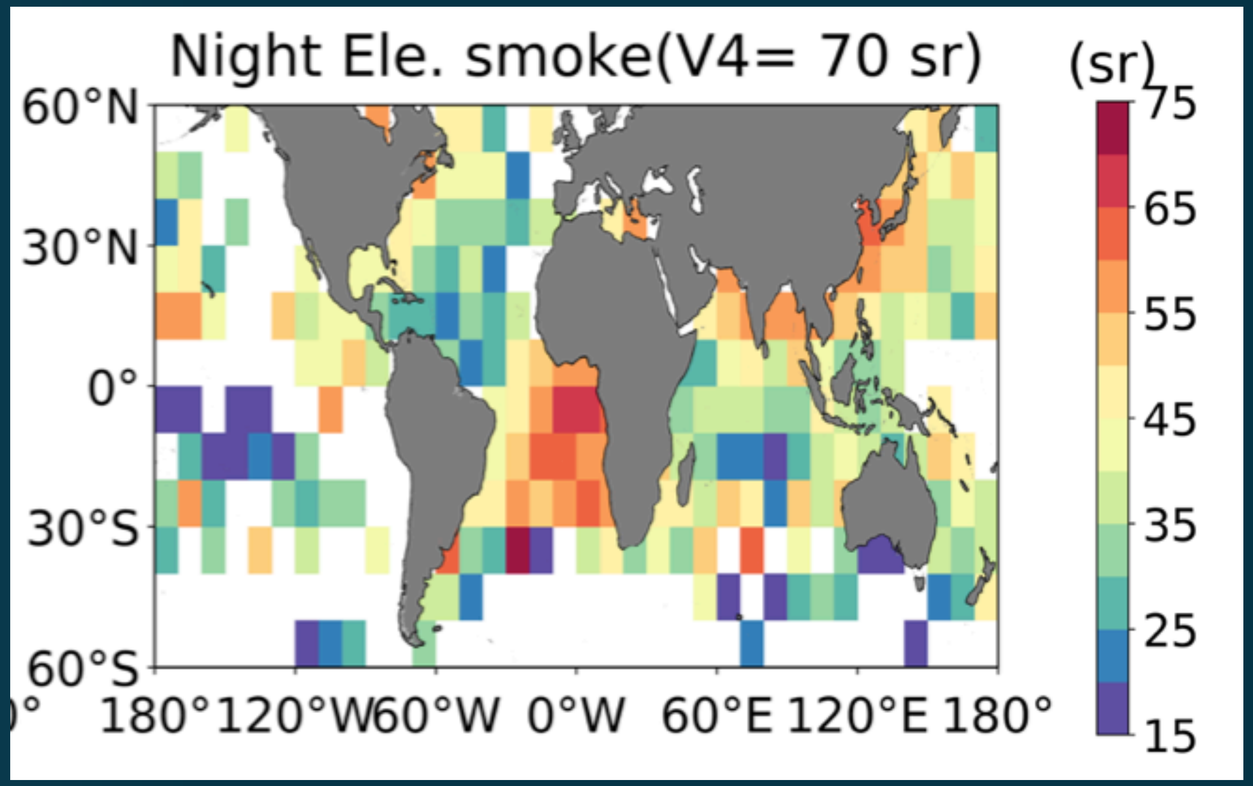
- So this is an example of how we can create a catalogue of lidar ratios that vary regionally and seasonally for each of the existing CALIPSO types.
- But, we need to verify the methodology.

What we seek from the community:

- We seek lidar ratio measurements/retrievals from suborbital instrumentation throughout the world for verification.
- We also seek transport model analysis for context and extrapolation to other regions and possibly Level 4 products.



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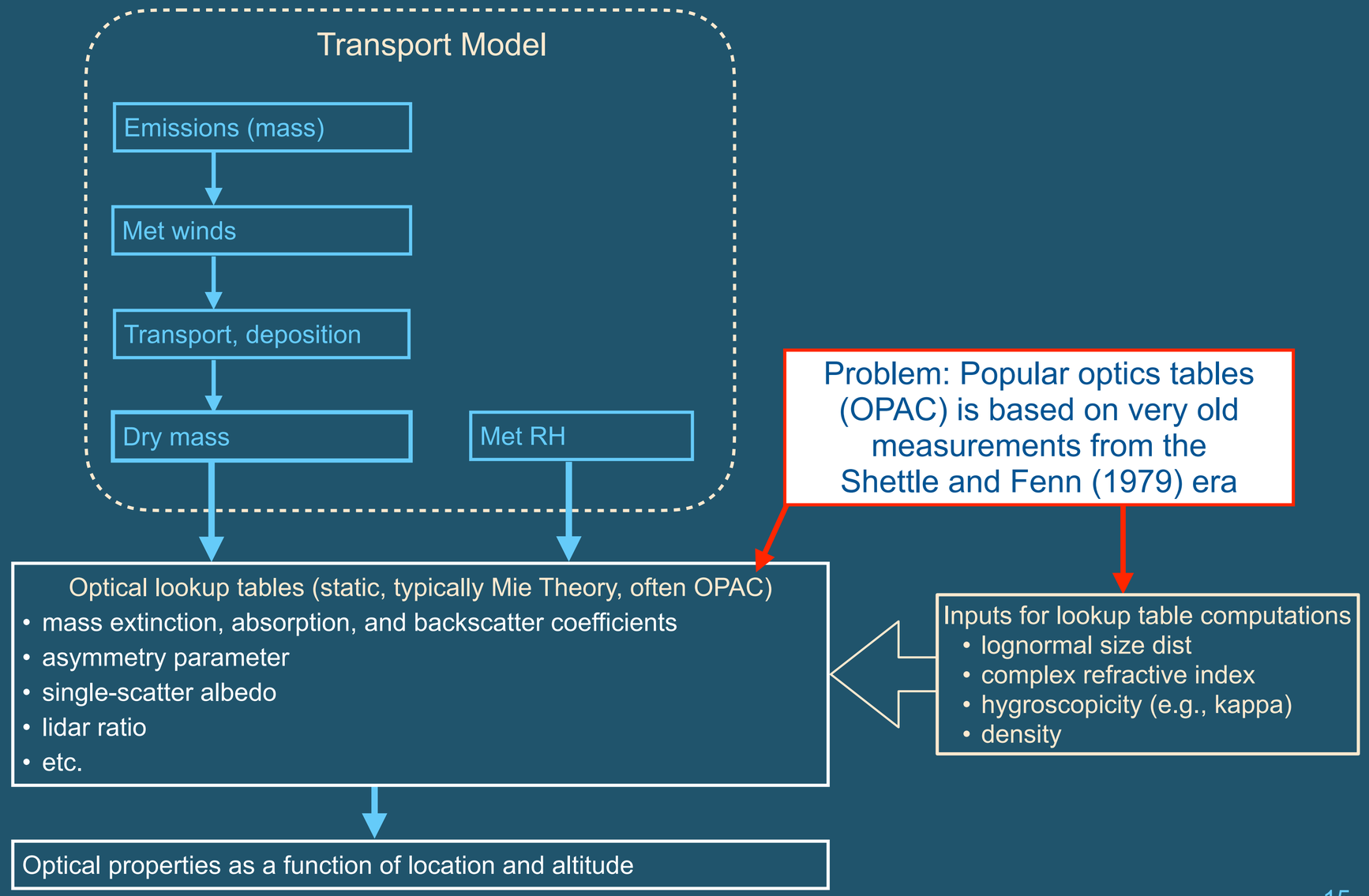
Pedestrian Guide to Offline Optical Calculations in Aerosol Transport Models



There is a need to create new Tables of Aerosol Optics (TAO) from existing measurements

We have begun creating a repository of aerosol optical tables.

- We have created aerosol optical tables that include mass extinction, absorption, and backscatter coefficients, single-scatter albedos, etc.,
- Based upon Brock (ACPD, 2021), Rissler (ACP, 2006), and Mie Theory.

Other species (processed 100 lognormals so far):

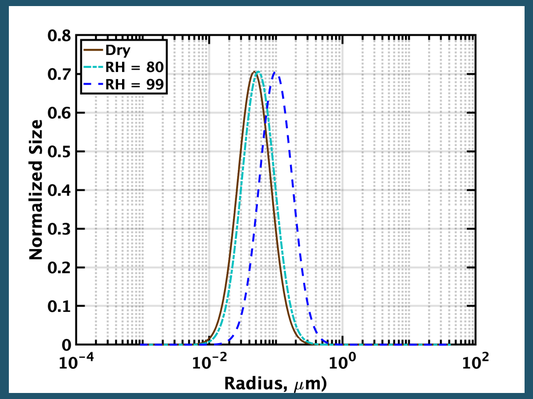
✓Water-insoluble Brown Carbon
✓Water-soluble Organic Carbon
✓Water-insoluble Organic Carbon
• Externally-mixed Black Carbon
• Internally-mixed Black Carbon
• Multi-mineral dust mixtures (non-spheres)
✓Sulfates
✓Sea salt

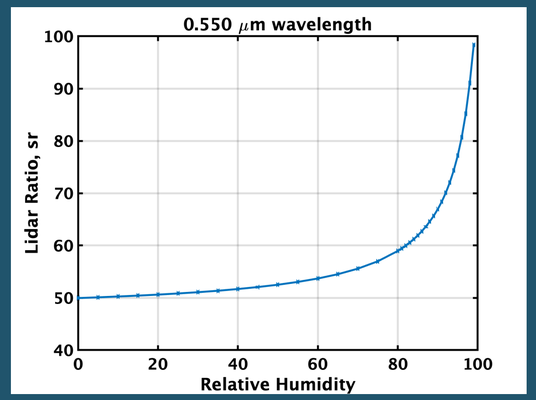
What we seek from the community:

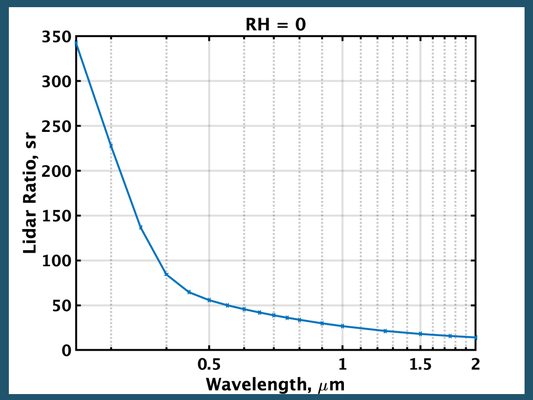
- We invite others to contribute their ideas, favorite measurements (firsthand or from the literature), and documentation.

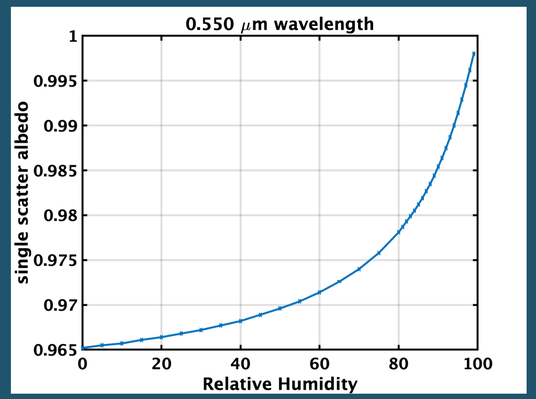
Example

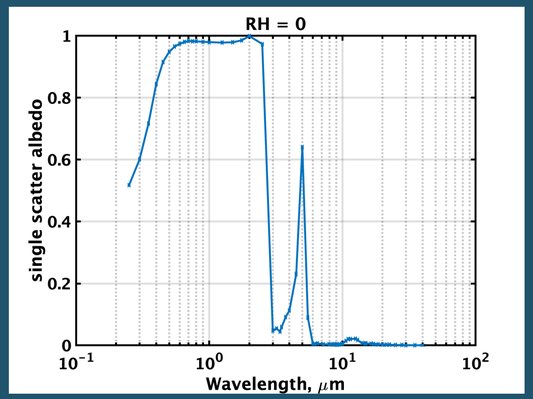
Water-soluble Brown Carbon











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- Seek appropriate leadership.
- New leadership presents roadmap at IGAC 2023?

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1.) Improve *a priori* lidar ratios for space-based lidars

- Develop a catalogue of lidar ratios for each CALIPSO aerosol type that accounts for location and season.
- Use surface measurements, aircraft measurements, and transport models to validate and verify the catalogue.
- Dedicated session at IGAC 2023 to present results and status.
- Special Issue

2.) Create Community Tables of Aerosol Optics (TAO)

- Goal is to incorporate all reasonable aerosol microphysical, optical, and hygroscopicity measurements into the new tables.
- The tables will also incorporate new irregular shapes for dust and black carbon.
- The community tables will be very large, so *we invite others to contribute* their ideas, favorite measurements (firsthand or from the literature), and documentation.
- Need in situ specialists to help us vet and summarize the measurement methods and techniques.
- Present results at IGAC 2023.
- Journal publication, possibly multiple articles.

and more… PM2.5, air quality, and other topics

- Seek appropriate leadership.
- New leadership presents roadmap at IGAC 2023.

MIRA Organizational Goals

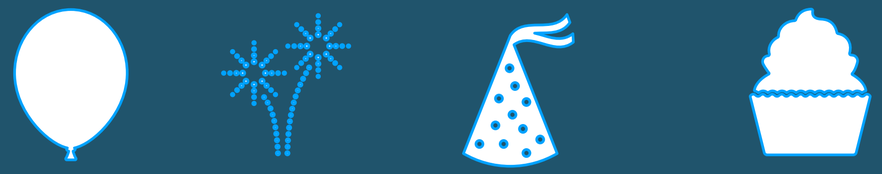
- Develop a framework that will grow in scope and adapt to new major aerosol measurement/modeling programs (e.g., NASA's Atmosphere Observing System (AOS) vision).
- Facilitate a forum that encourages international collaborations between aerosol modeling and measurement groups.
- Enable conversations through virtual meetings and bi-annual IGAC (hopefully, face-to-face) meetings.
- Establish initial project plan (e.g., global survey of aerosol lidar ratios and development of improved aerosol optical models).
- Seek sponsorship under IGAC as MIRA WG .

Ideas for Maintaining Communications

- Annual in-person meetings (IGAC bi-annually, but need another venue for in-between years).
- We propose to leverage the ‘new normal’ and meet virtually (in-between the annual meetings).
  - How often should we meet virtually, and for how long?
  - How many technical talks per meeting, and for how long?
  - Should we record presentations (or entire meetings) and store them on Google Drive for sharing exclusively with MIRA members?
- Public Webpage for MIRA
  - Collection of links to publicly available lidar data.
  - Public chat board that is NASA-OK? (not optimistic)
  - “Newsfeed” that chronicles email announcements.
  - Monthly newsletters, with short informal articles targeted to broad audiences
- Google Drive could also be used for sharing other material.

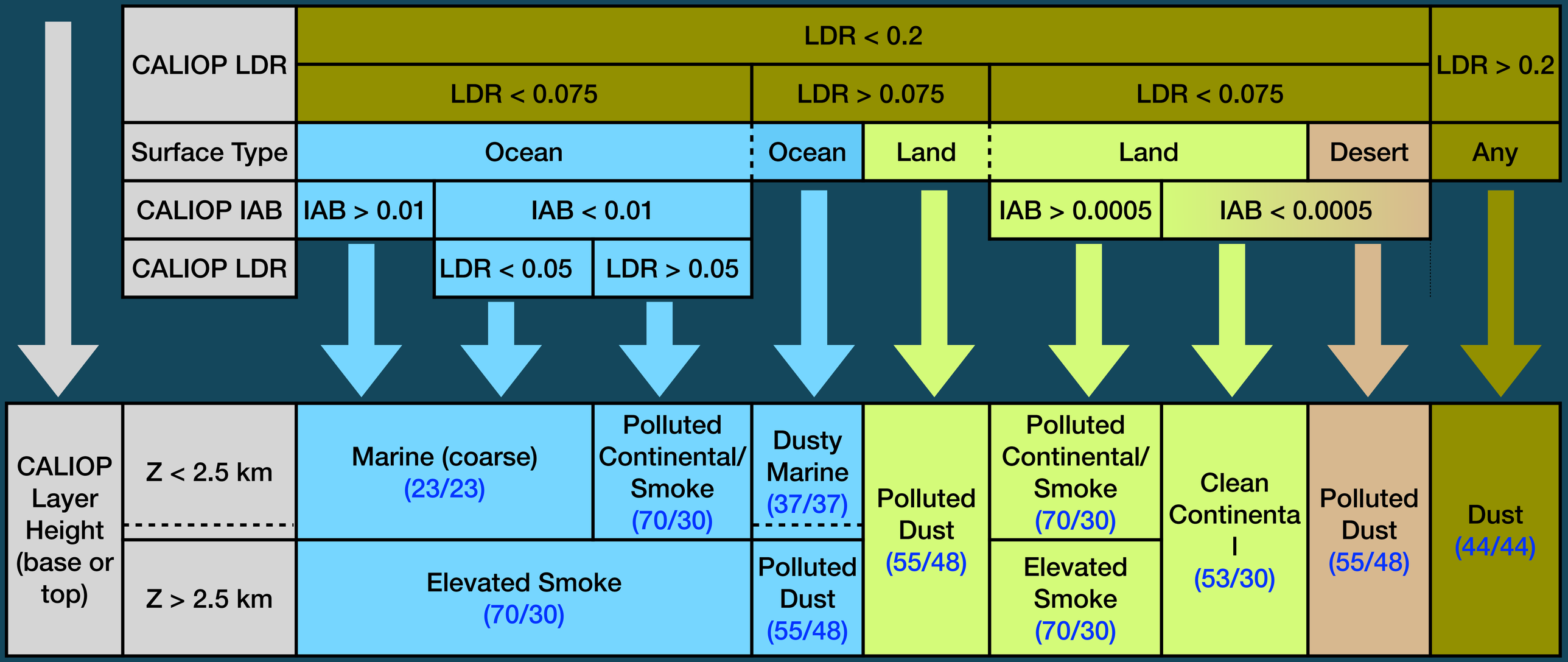
Next Steps

- Sign up at https://forms.gle/rtsbRRUNqN2ZH8r38 (paste to chat, Greg!) to get on email distribution.
- We'll send out a synopsis of this meeting in the next week or two.
- Synopsis will include a google questionnaire that is based upon today's discussion (e.g., some of the questions on the previous slide will likely be in the questionnaire).
- We want to reach everyone, including those who live in time zones unamenable to this particular meeting, so you might see redundant postings while we try to reach people who are unaware of the link above (sorry!).
- If there is enough interest after today, we will seek IGAC sponsorship to form a new working group.
- Next: build an international steering committee.
- Work with steering committee to outline a years worth of virtual meetings, including speakers and topics.
- Meet in-person around this time next year.



Questions?

BACKGROUND: CALIPSO Version 4 Lidar Ratio Selection Process



IAB: 532 nm integrated attenuated backscatter
LDR: 532 nm estimated linear depolarization ratio

(532/1064) lidar ratios

Adapted from Kim et al (AMT, 2018)