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

A New Working Group

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Clip art in this talk is from
https://publicdomainvectors.org/

Send email to calipso_v5alr-join@lists.nasa.gov with the word `subscribe' in the subject line to join MIRA.

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

- Purpose of today's talk:
  - Introduction of an international working group called MIRA that will operate under the umbrella of the International Global Atmospheric Chemistry (IGAC) project.

Creating a diverse audience

- 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.

We are better together

- 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.

Time is running out for CALIPSO; current optics tables are based upon very old data.

- 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, the single-scatter aerosol optical models that many of them use are based upon data that is 40+ years old (i.e., traces back to Shettle and Fenn, 1979).

Clear near-term goals

- 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

Important!

- New leadership with new topics in ~3 years.

Two immediate areas of focus for MIRA

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

But, these are near-term goals (~3 years)…

MIRA will also pursue new leadership and new goals, such as:

- PM2.5 / air quality?
- Aerosol assimilation advancements?
- OSSEs?

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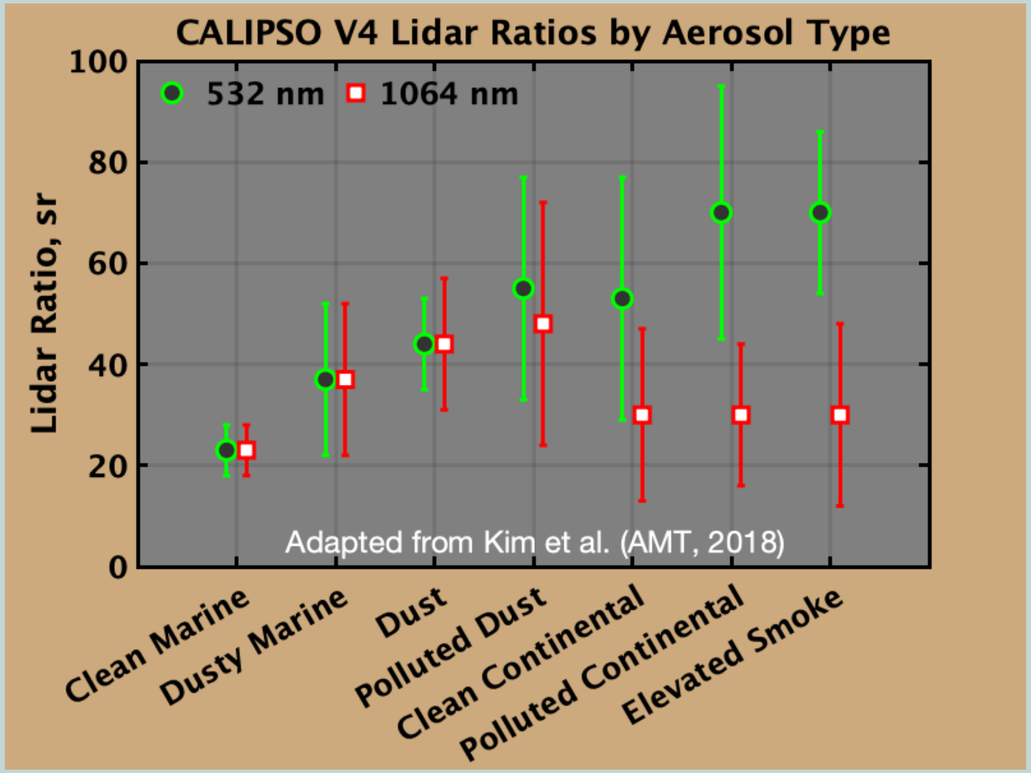
The Cloud-Aerosol and Infrared Pathfinder Satellite Observation (CALIPSO) Mission

- 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).
- Unfortunately, backscatter lidars require additional assumptions (or constraints) to produce extinction profiles.
- Thus, CALIPSO categorizes aerosol layers within a framework of seven aerosol types (Marine, Dust, etc; see Kim AMT 2018), based upon:
  1. Linear depolarization ratio (indicator of sphericity).
  2. Surface scene type (ocean, land, desert)
  3. Signal strength
  4. Layer Altitude
- Once an aerosol type has been defined, a lidar ratio and uncertainty is assigned.
- Uncertainty is large, **so improved methods are needed**.

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



Thus, we are exploring the possibility of including ***regional and seasonal dependencies*** in the 7 CALIPSO aerosol types.

But CALIPSO measures globally: How do we characterize regional and seasonal lidar ratios over the whole Earth?

Special case: Determine a single effective lidar ratio for the column when the transmittance is known and the laser beam reaches the surface

The lidar equation simplifies to (e.g., Fernald et al., JAM, 1972):

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

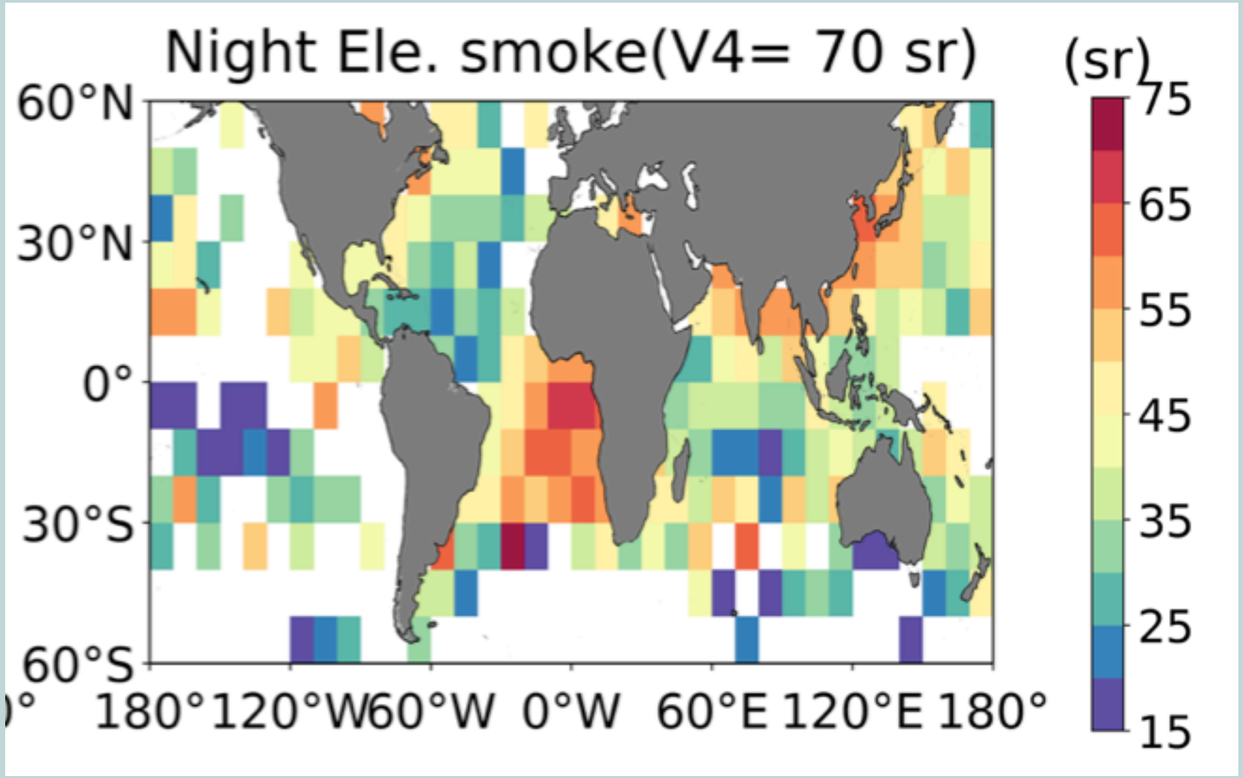
Thus, we can use constrained retrievals to evaluate the CALIPSO lidar ratios (Li et al, in preparation).

- An example that uses the Synergized Optical Depth for Aerosols (SODA) product as a constraint is provided at right.
- Regional variations are significant and unaccounted for in Version 4.
- We are currently exploring other AOD products (e.g., ODCOD, MODIS) to complete the data record.
- 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 input and verification.
- We also seek transport model analysis for context and extrapolation to other regions and possibly Level 4 products.

Lidar ratio climatology (2006-2011) for elevated smoke



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

SODA methodology: Josset (GRL, 2008; Opt Express, 2011)

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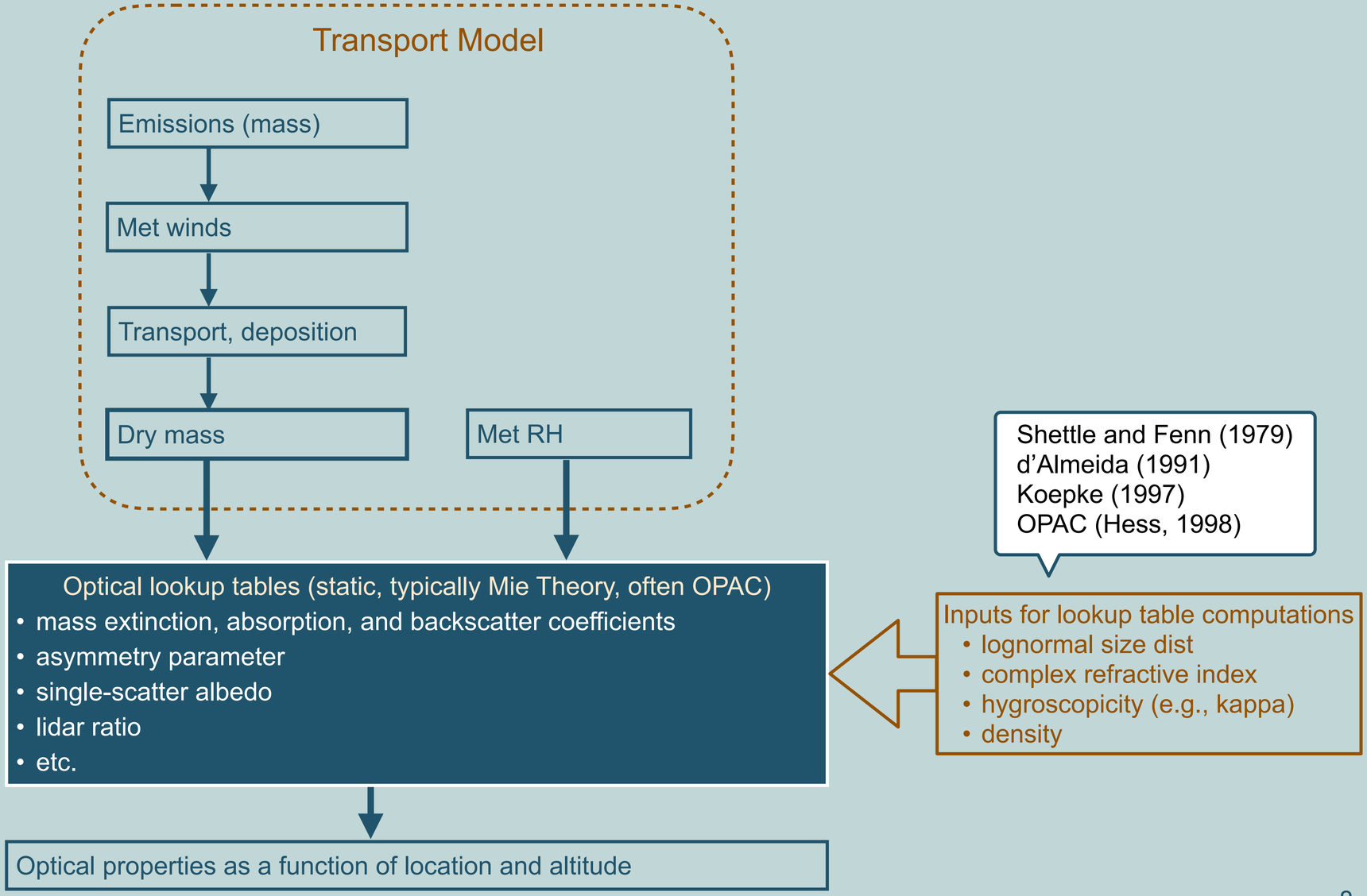
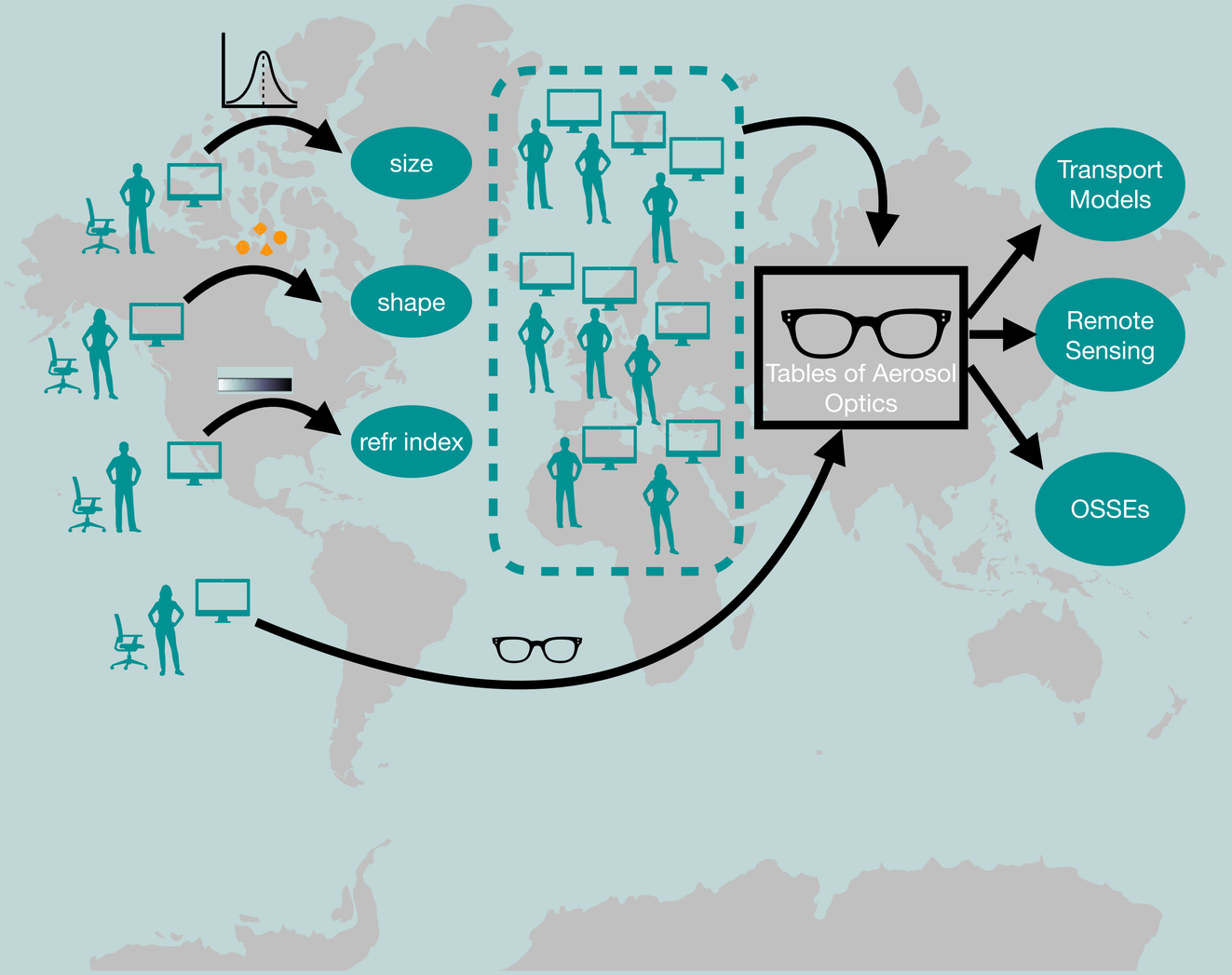
Pedestrian Guide to Offline Optical Calculations in Aerosol Transport Models



TAO Scheme

- **The Table of Aerosol Optics is a community repository** of optics computations that are useful for models and remote sensing (extinction, absorption, SSA, Lidar Ratio, etc).
- **Expands upon historical efforts (Shettle and Fenn, d'Almeida, GADS, OPAC,** etc) by building a database that includes recent measurements and new computational techniques for non-spherical particles.
- TAO will also provide links to other repositories, e.g.:
  - http://aram.ess.sunysb.edu/tglotch/optical_constants.html,
  - http://www.astro.uni-jena.de/Laboratory/OCDB/carbon.html
- It is expected that TAO will include computations for traditional aerosol species (amm sulfate, amm nitrate, organics, etc.), but **TAO will also accept computations for aerosol 'type.'**
- Presently, TAO is highly fluid and located on my NASA google drive. **This is not permanent.** TAO will establish a new home (e.g., GitHub) within about 1 year.



Send email to aerosol-optics-join@lists.nasa.gov with the word 'subscribe' in the subject line to join TAO and receive email updates.

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

Example: processed 52 lognormals so far:

- We have created aerosol optical tables that include mass extinction, absorption, and backscatter coefficients, single-scatter albedos, etc.,

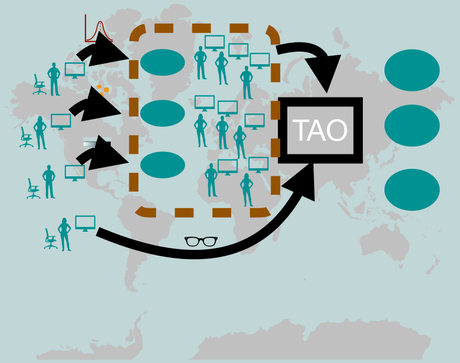
✓Water-insoluble Brown Carbon
✓Water-soluble Brown Carbon
✓Water-insoluble "White" Carbon
✓Water-soluble "White" Carbon

} 36 SDs, CRIs, & kappas
Amazon (Rissler, ACP, 2006)

- Externally-mixed Black Carbon
- Internally-mixed Black Carbon
- Multi-mineral dust mixtures (non-spheres) Saito (JAS, 2021), Chin (Ann Geophys, 2009)
- Sulfates
- Nitrates
- Sea salt (some RRI issues) Brock (ACP, 2021)

What we seek from the community:

- Existing tables that modelers are using
- Measurements (firsthand or from the literature)
- Additional single-scatter computations (spheres, irregular dust, fractal BC, internal mixtures, etc.).
- Customers and "Special orders."



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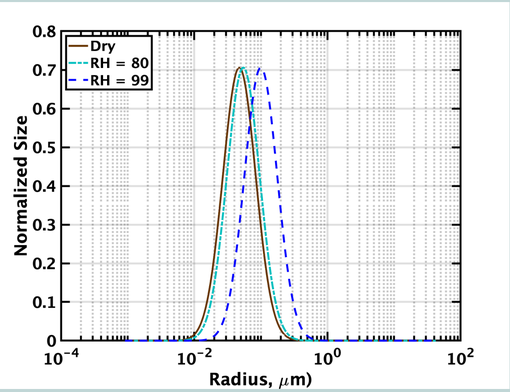
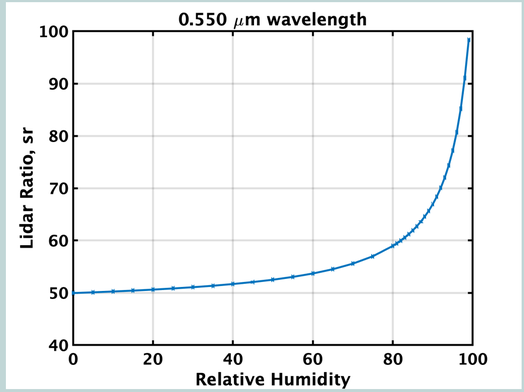
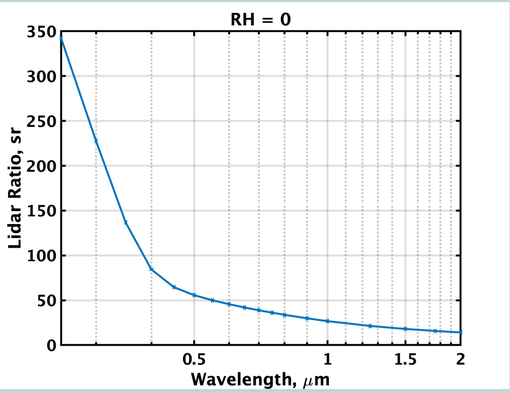
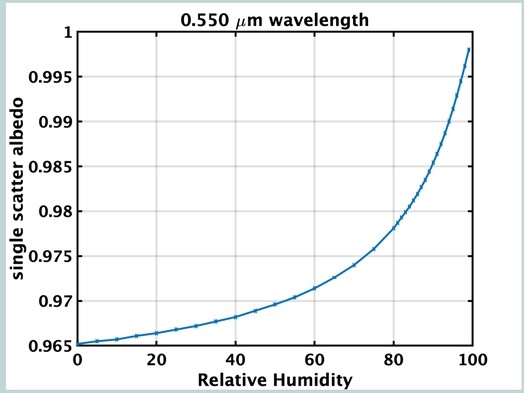
Example

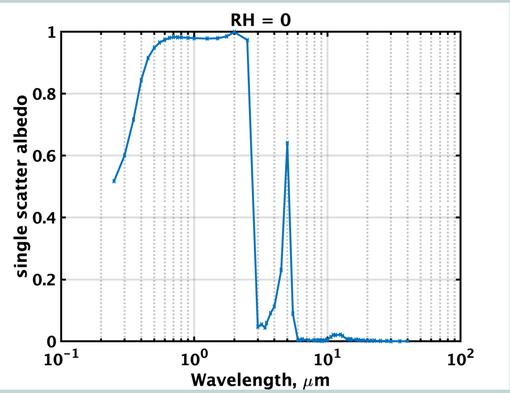
Water-soluble Brown Carbon











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Summary of 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 IGAC (International Global Atmospheric Chemistry), Gordon Research Conferences, and at other meetings (e.g., EGU 2023+, AGU 2022+, virtual?).
- Establish initial project plan (e.g., global survey of aerosol lidar ratios and development of improved aerosol optical models).
- Public Webpage and Newsletters for MIRA coming **soon!** (initially on a NASA domain, but we are seeking a different host).
- Seek sponsorship under IGAC as MIRA WG.

Quick! Get a screenshot

- **Important Links**
  - Check out the CALIPSO V5 Aerosol Lidar Ratio Workshop talks:

    https://science.larc.nasa.gov/calipso/2021-calipso-version-5-aerosol-lidar-ratio-workshop/
  - Join our email distributions to receive our newsletters and other information about MIRA:

    Send email to calipso_v5alr-join@lists.nasa.gov with the word 'subscribe' in the subject line to join MIRA.
    Send email to aerosol-optics-join@lists.nasa.gov with the word 'subscribe' in the subject line to join TAO.
  - Take our Survey:

    https://forms.gle/5ttmqWP4C4VQNo5dA

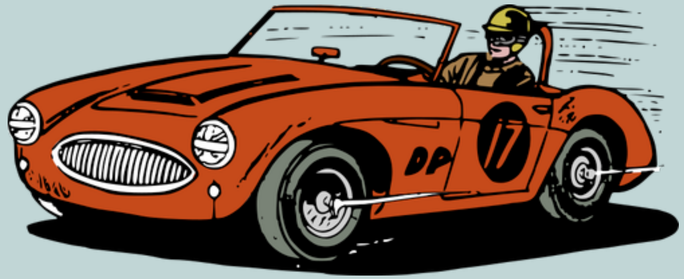
CALIPSO Version 5 Aerosol Lidar Ratio Workshop

CALIPSO March 9-11, 2021

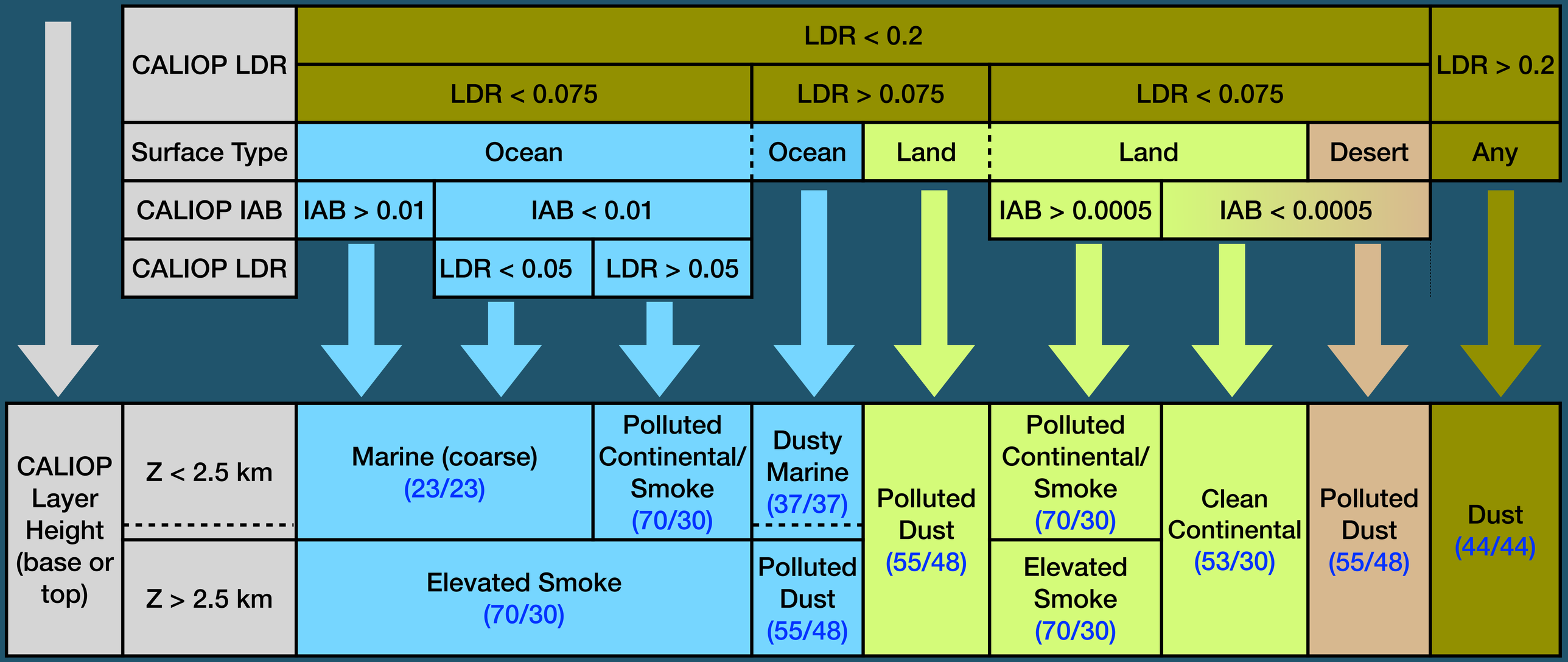
Presentation List

(arranged alphabetically by primary author last name)

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)