bulk versus single-particle analysis

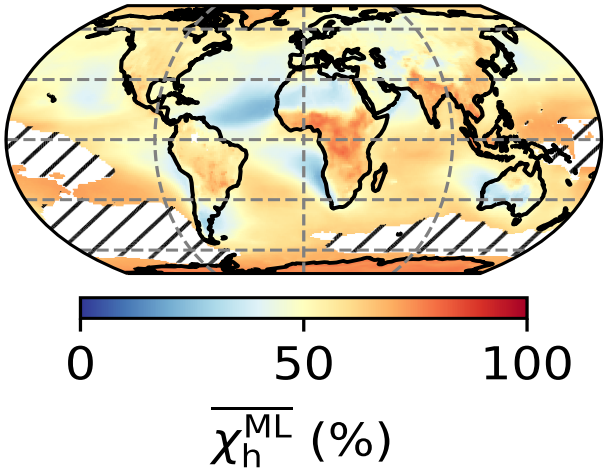
Nicole Riemer

What IS the aerosol mixing state?

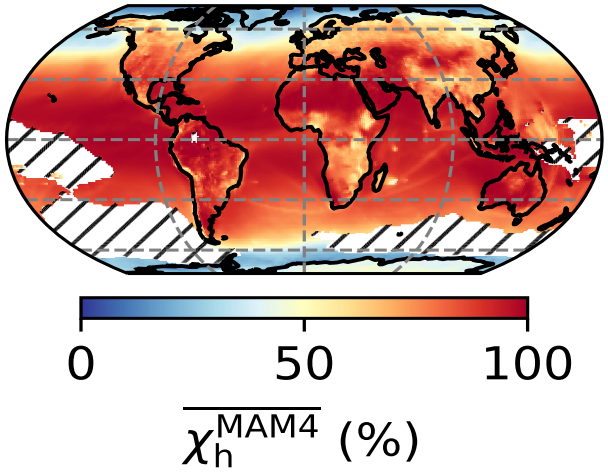
Bridging the chasm between particle-based measurements and models

What IS the aerosol mixing state?

Simulated mixing state index from PartMC model result



Simulated mixing state index from MAM4



Who is right?

Zheng, West, Zhao, Ma, Liu, Riemer, *ACP*, 2021

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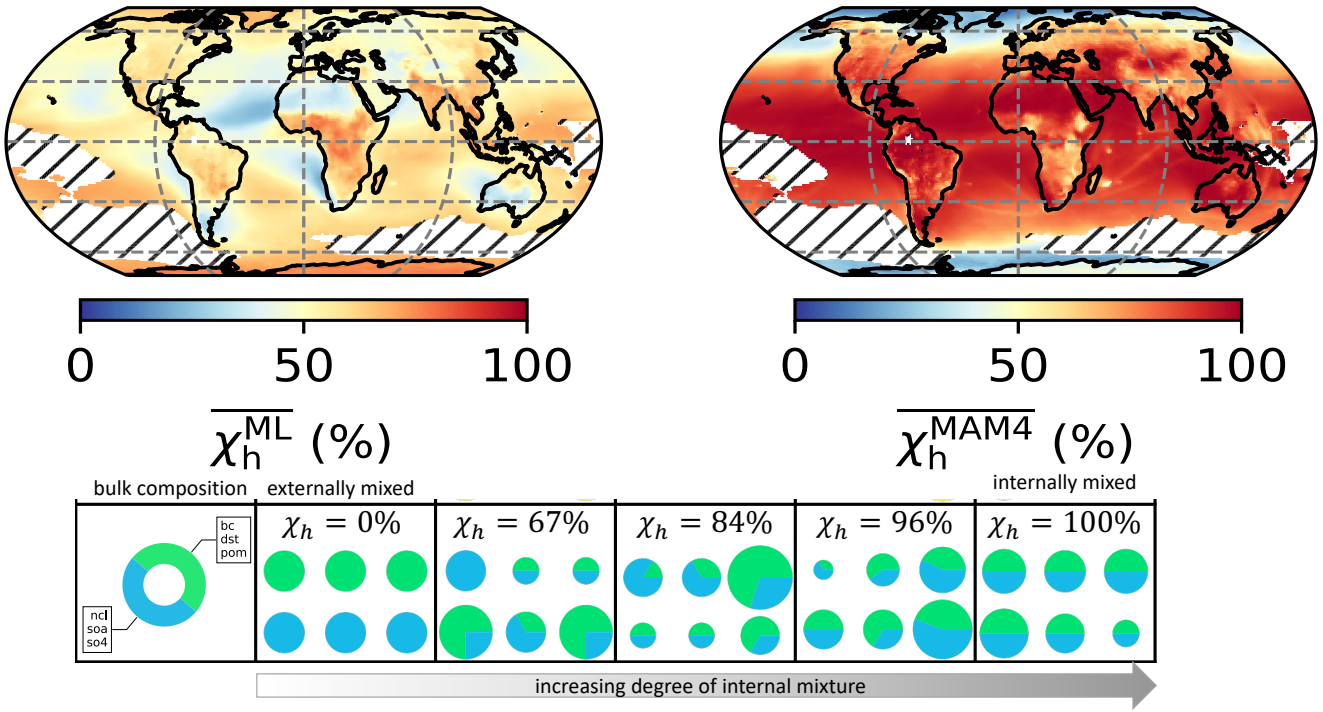
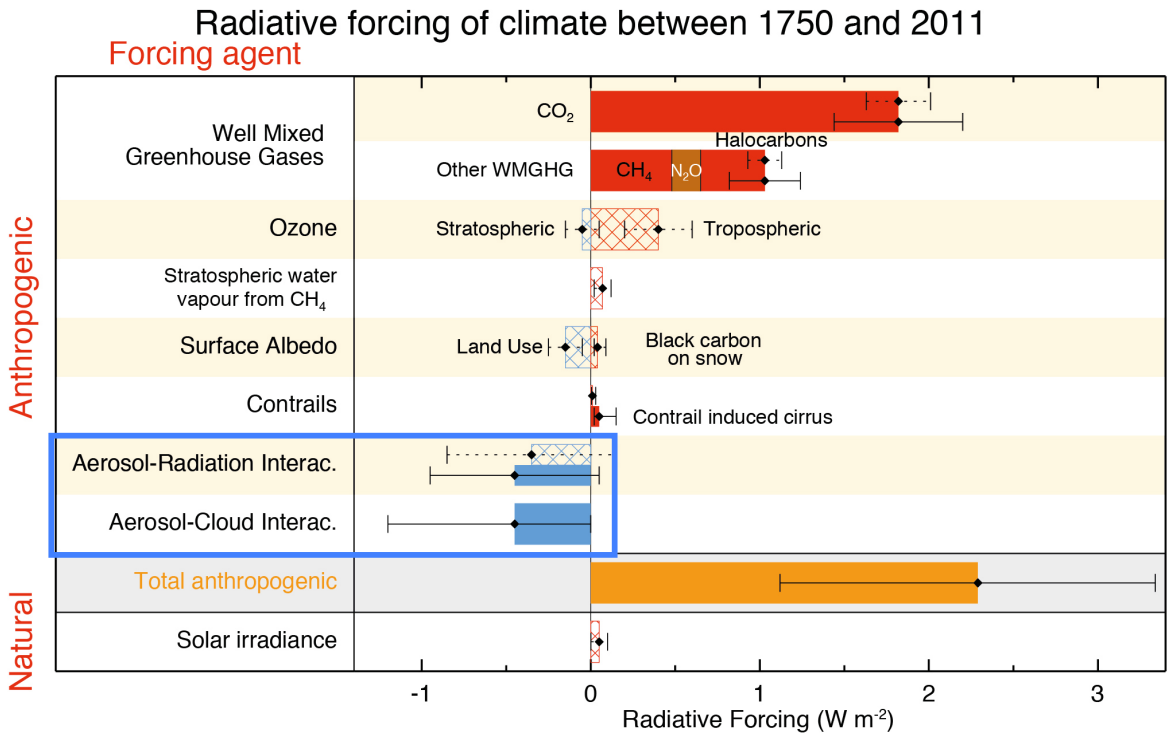
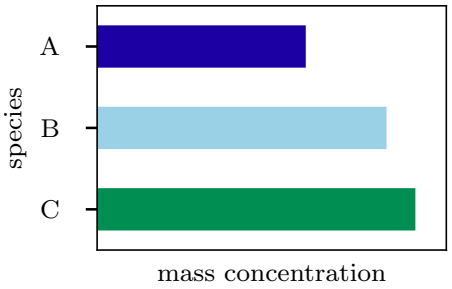


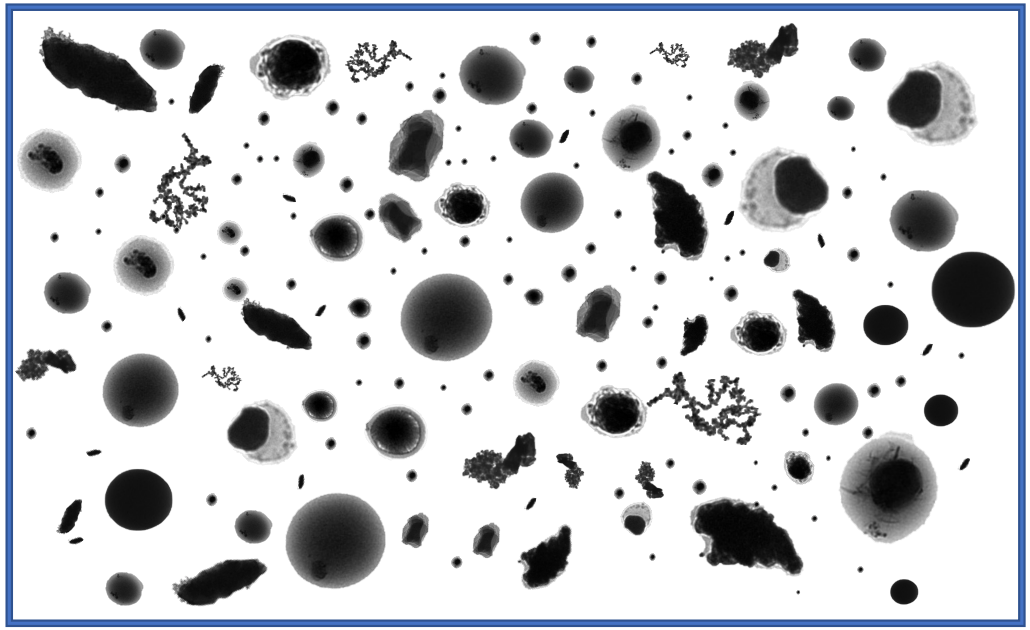
The large “error bar” on aerosol climate impacts in the IPCC figure is a manifestation of structural uncertainty in aerosol models



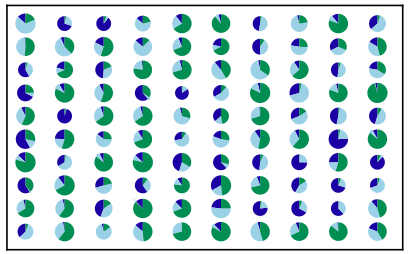
From aerosol state to model state

Bulk models

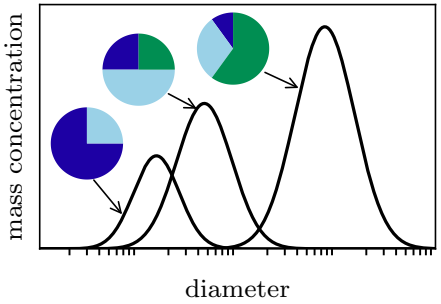




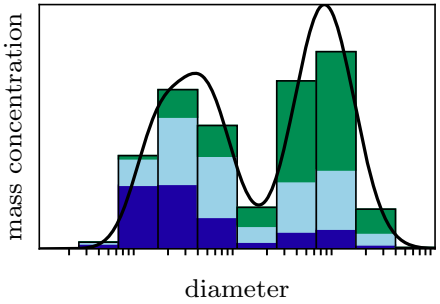
Particle-resolved models



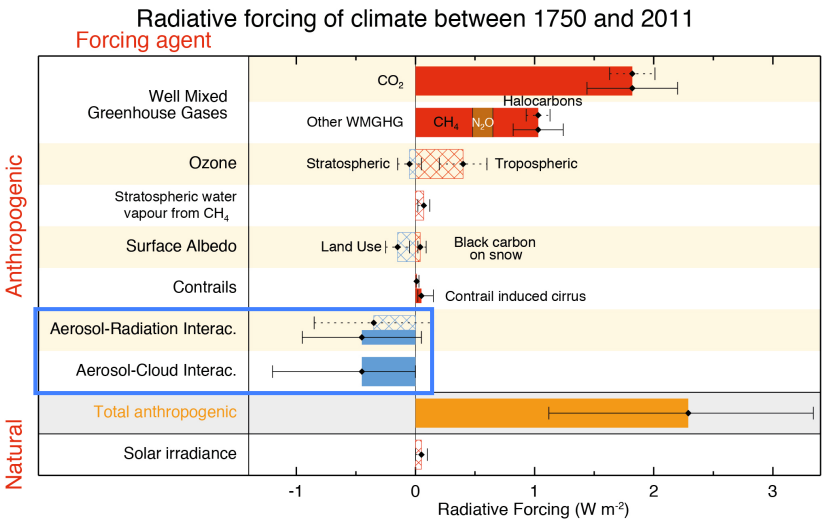
Modal models



Sectional models
Binned model



The large “error bar” on aerosol climate impacts in the IPCC figure is a manifestation of structural uncertainty in aerosol models

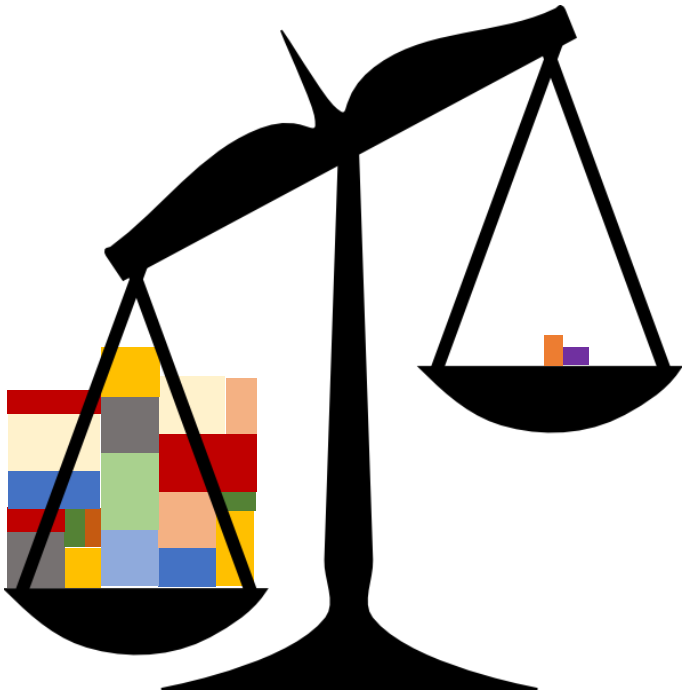


- How can this structural uncertainty be decreased?
- Our claim is that quantitative particle-level data is going to make a big difference to this.
- Creating a synthesized view of what the aerosol actually is, will provide strong constraints for models. (Currently we don’t have/don’t make use of these strong constraints.)

Single-particle aerosol measurements have been available for several decades, yet they are rarely used to compare to, let alone improve, models

Why?

Large amounts of existing data



Quantitative particle-scale data to *directly constrain* model state

What are we missing out on? Measuring prognostic quantities provides stronger constraints on model accuracy than measuring diagnostic quantities.

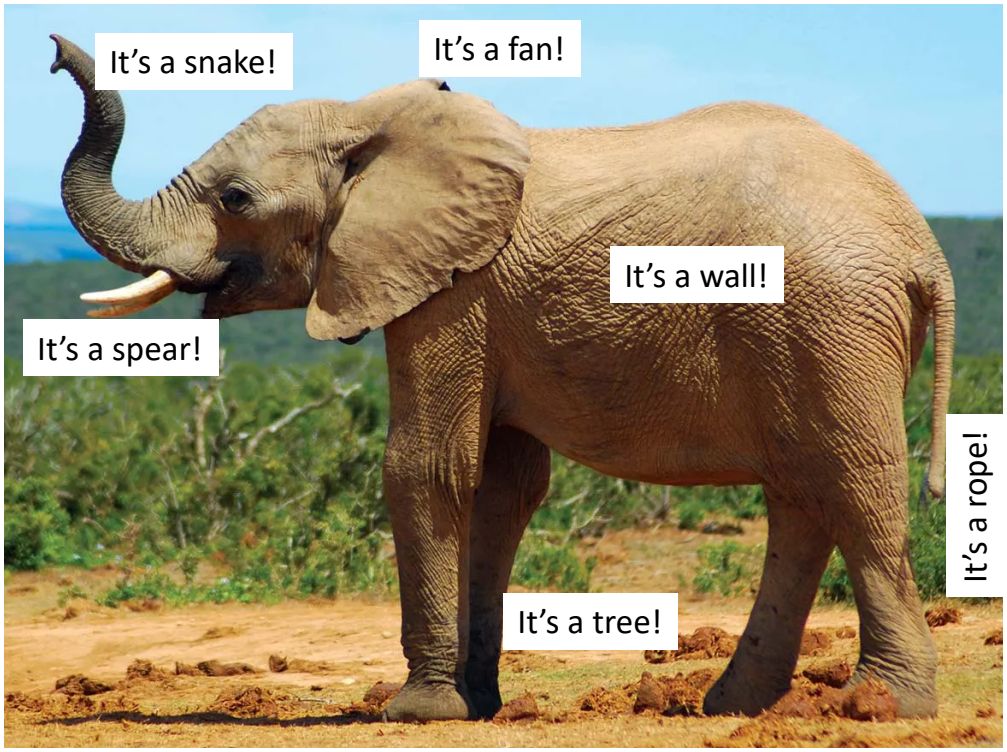
Type of quantity	Example
Column-integrated diagnostic quantities	AOD
Spatially-resolved diagnostic quantities	CCN concentrations, scattering/absorption coefficients
In-situ measurements of prognostic bulk quantities	Total number concentration, total mass concentrations
Size-resolved prognostic quantities	Number distribution, mass distribution
Mixing-state-resolving prognostic quantities	Per-particle composition

Diagnostic quantities:

- Not directly predicted by models but can be calculated (diagnosed) based on model output.
- Additional assumptions needed for calculations.
- Examples: AOD, CCN concentration, extinction coefficient

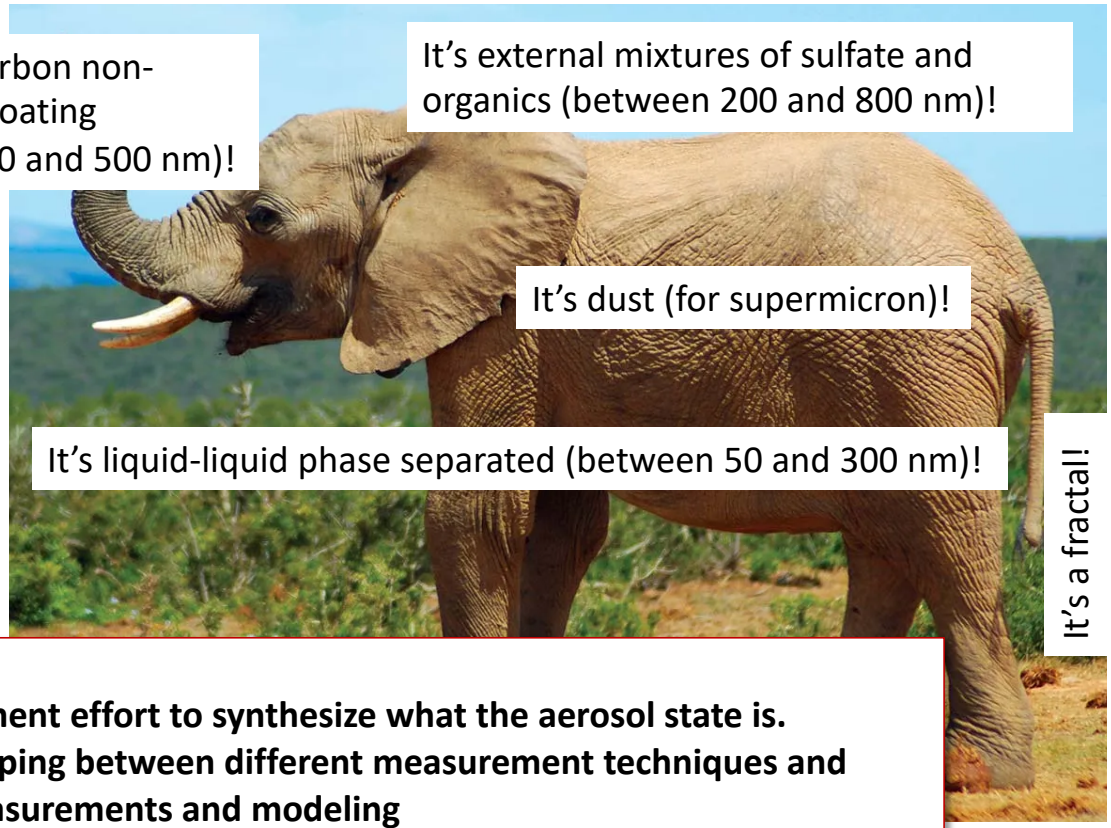
Prognostic quantities:

- Directly predicted by models.
- Which variables these are depends on the structure of the model.
- Examples: total number concentration per mode/bin, species mass concentrations per mode/bin.



Encyclopædia Britannica, African savanna elephant

Wanted: Best estimate of the aerosol state



Challenges:

- **Different instruments see different aspects of mixing state.**
- **Models and measurements track different quantities**
- **Not enough data coverage**

Path forward:

- **Multi-instrument effort to synthesize what the aerosol state is.**
- **Develop mapping between different measurement techniques and between measurements and modeling**
- **Develop measurement techniques that scale.**

How is this going to improve global models

Creating a synthesized view of what the aerosol actually is …

- … will provide us with strong constraints on model predictions.
- … will enable us to fix structural uncertainty in aerosol models.
  - This could be as simple as choosing a different mode structure, but may require other infrastructure, e.g., a more flexible framework for modal models and constructing appropriate test suites
- … will move us closer to getting the right results for the right reasons.