Modeling clear-sky vs. all-sky aerosol optical depth and radiative effects*

*Sprinkled with questionnaire results

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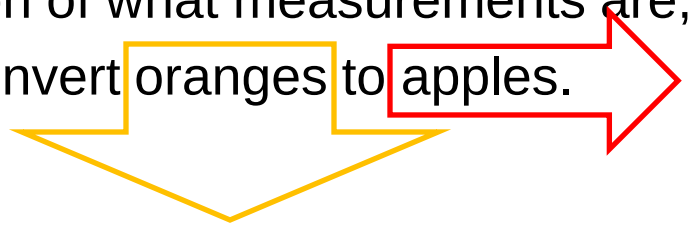
What to expect

- What this presentation is not:
  - A discussion about model-measurements comparisons related with co-location (championed by Nick)
  - A discussion about uncertainties in hygroscopic growth (championed by many, including AeroCom)

- What this presentation wants to be:
  - A discussion on the structural differences between models, including definitions
  - An exploration of what measurements are, and if they are what they say they are
  - A quest to convert oranges to apples.



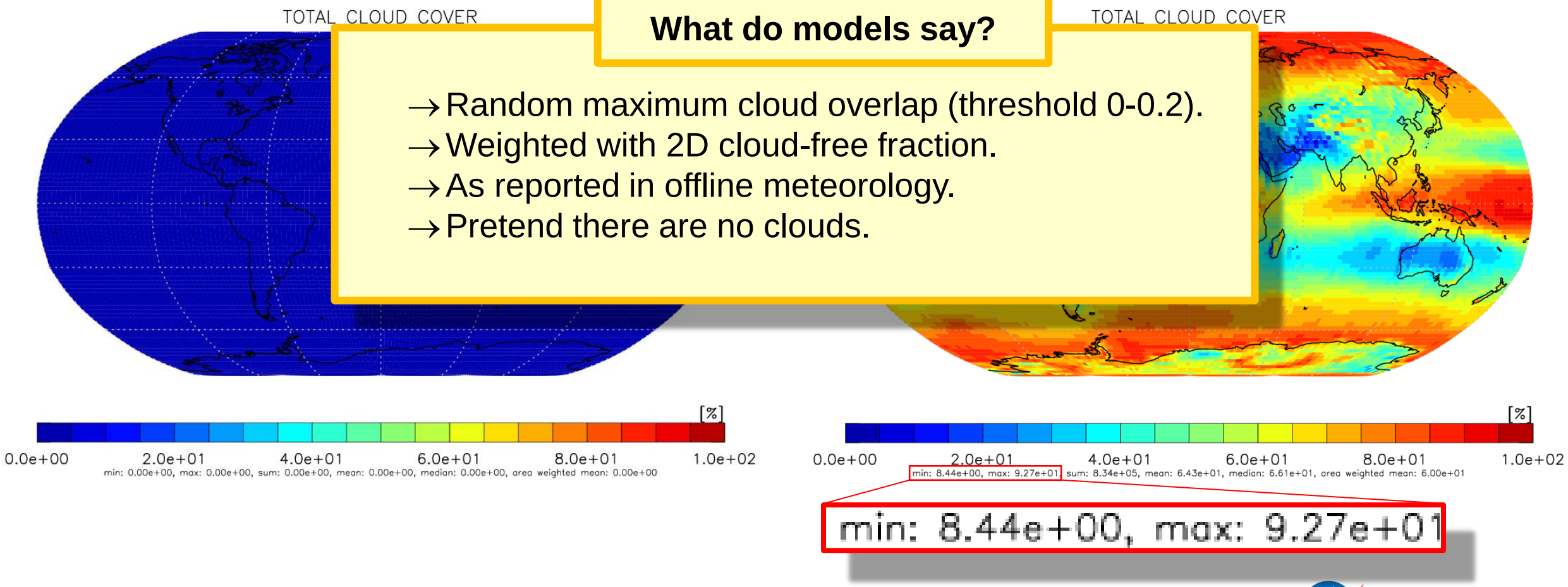
Definitions

Clear-sky → Model evaluation

All-sky → Impact on climate

What do models say?

→ Random maximum cloud overlap (threshold 0-0.2).
→ Weighted with 2D cloud-free fraction.
→ As reported in offline meteorology.
→ Pretend there are no clouds.



GISS ModelE2.1, annual mean, year 2000

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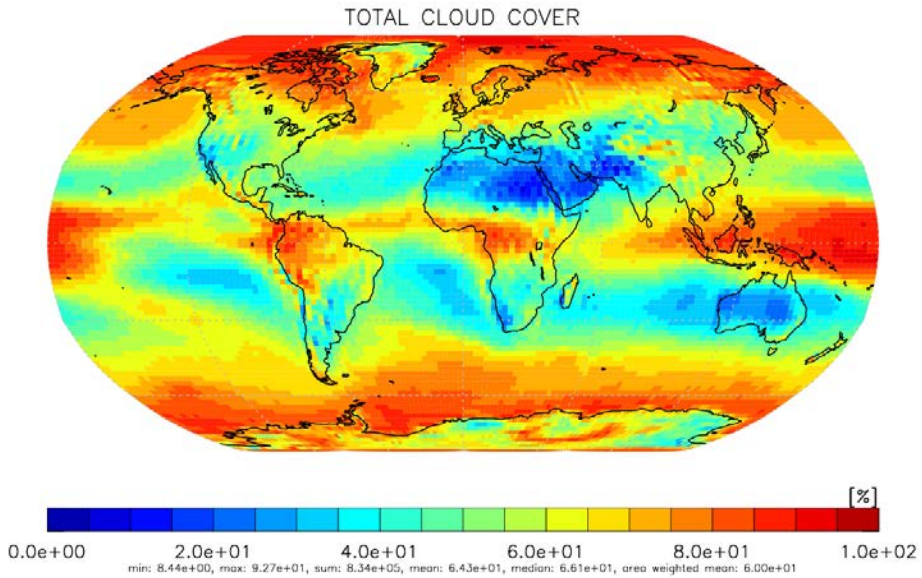
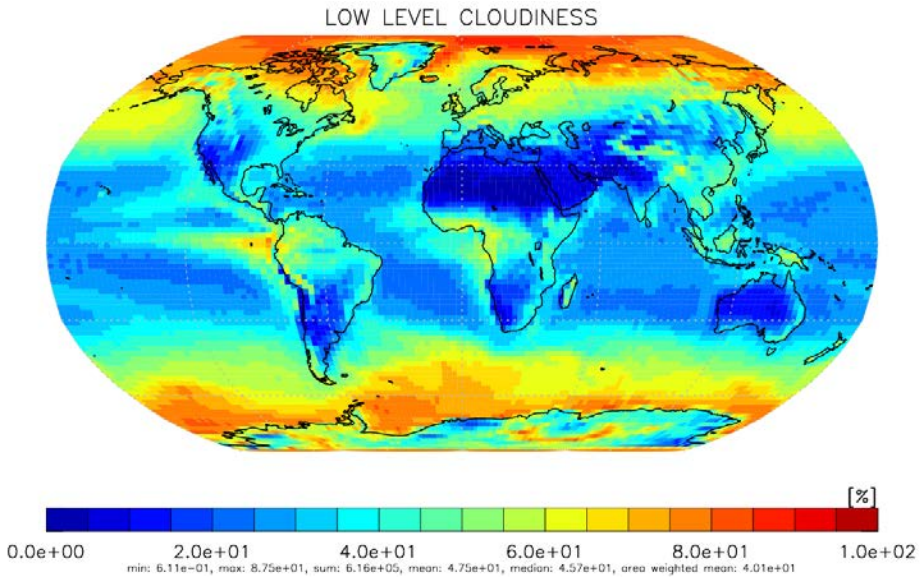
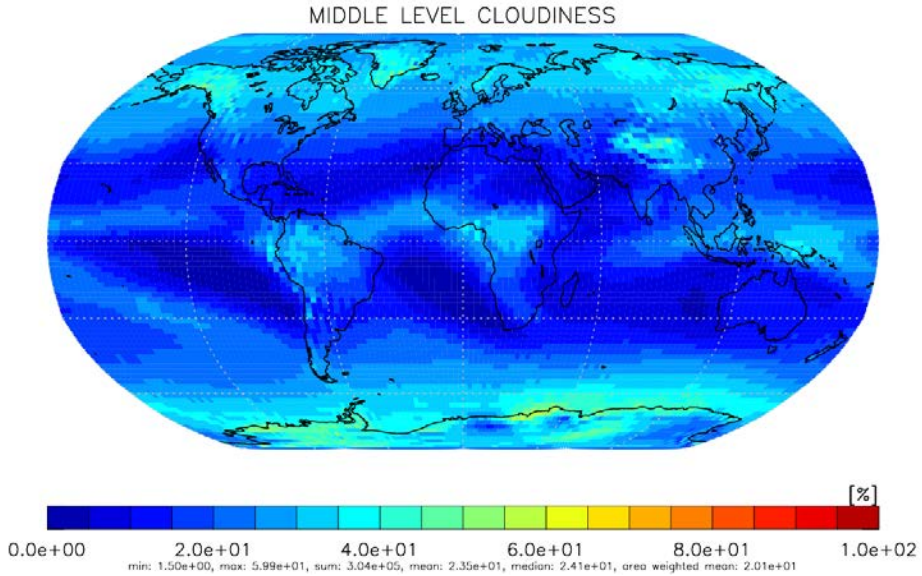
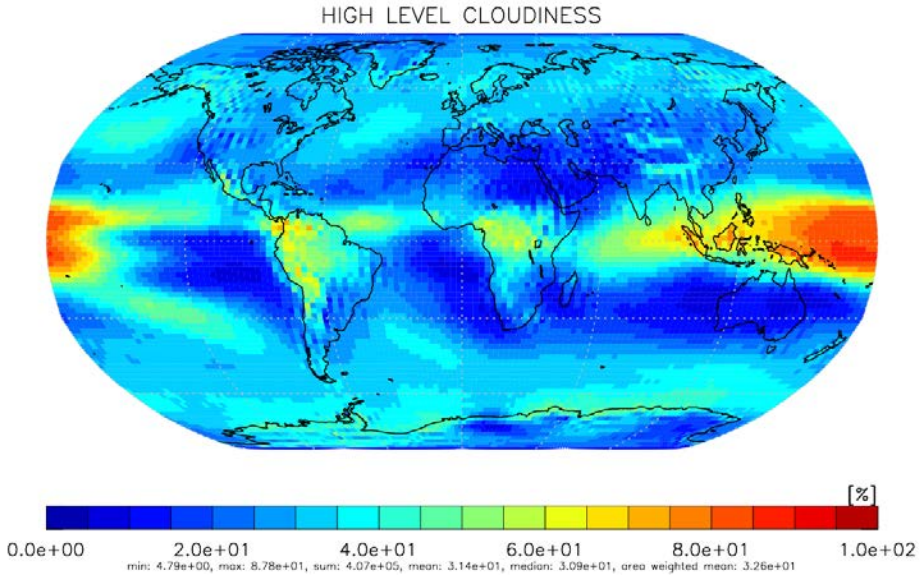
Decomposing all-sky









Annual mean, year 2000

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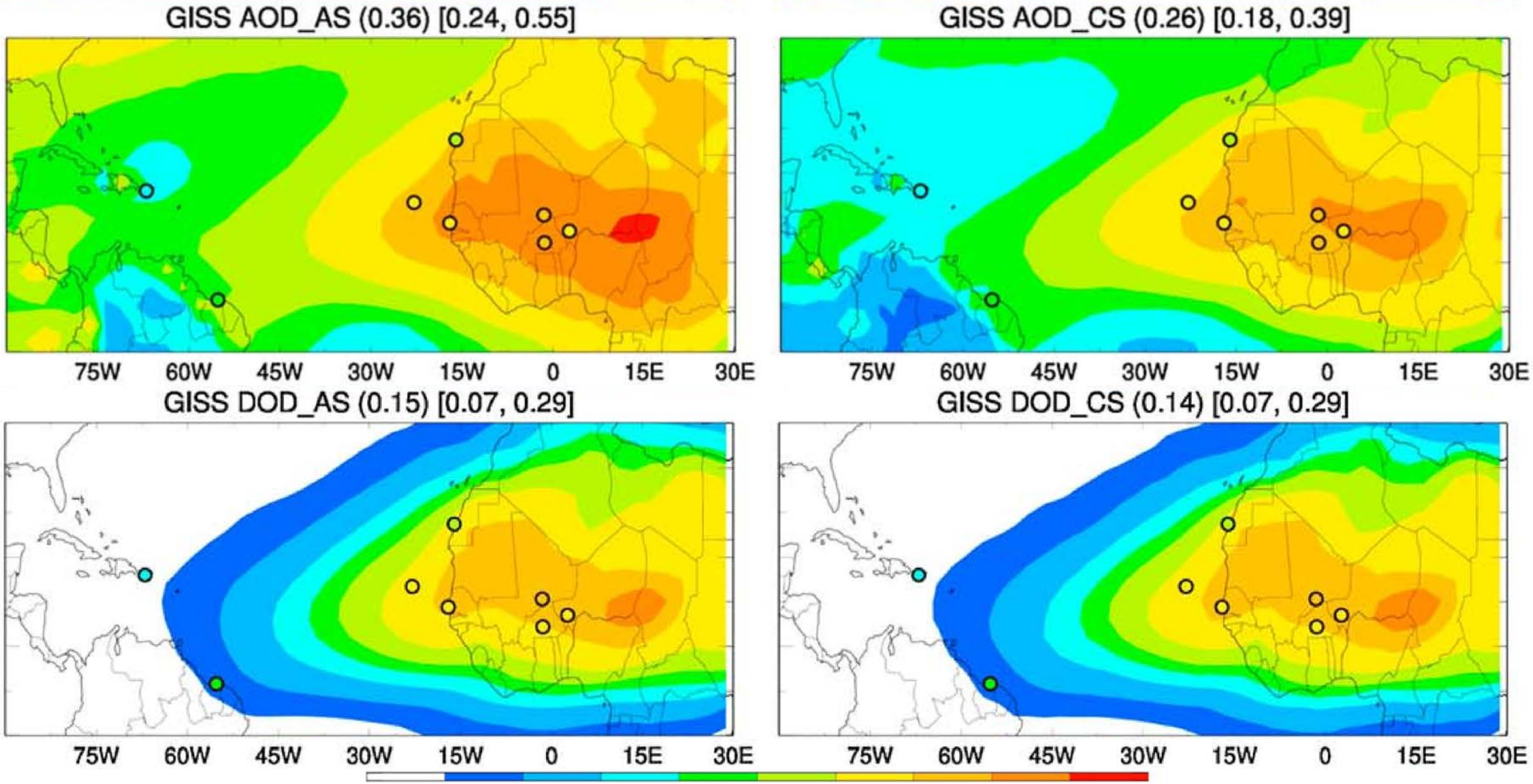
Things that affect as/cs AOD calculations in models

- Definition of cloud-free/cloudy conditions
  - How is partial cloudiness affecting AOD in a gridbox?
  - How is total cloudiness in the column calculated?

- Hygroscopic growth calculations
  - Which species swell?
  - Are there mixing state considerations?
  - Which formula is used?

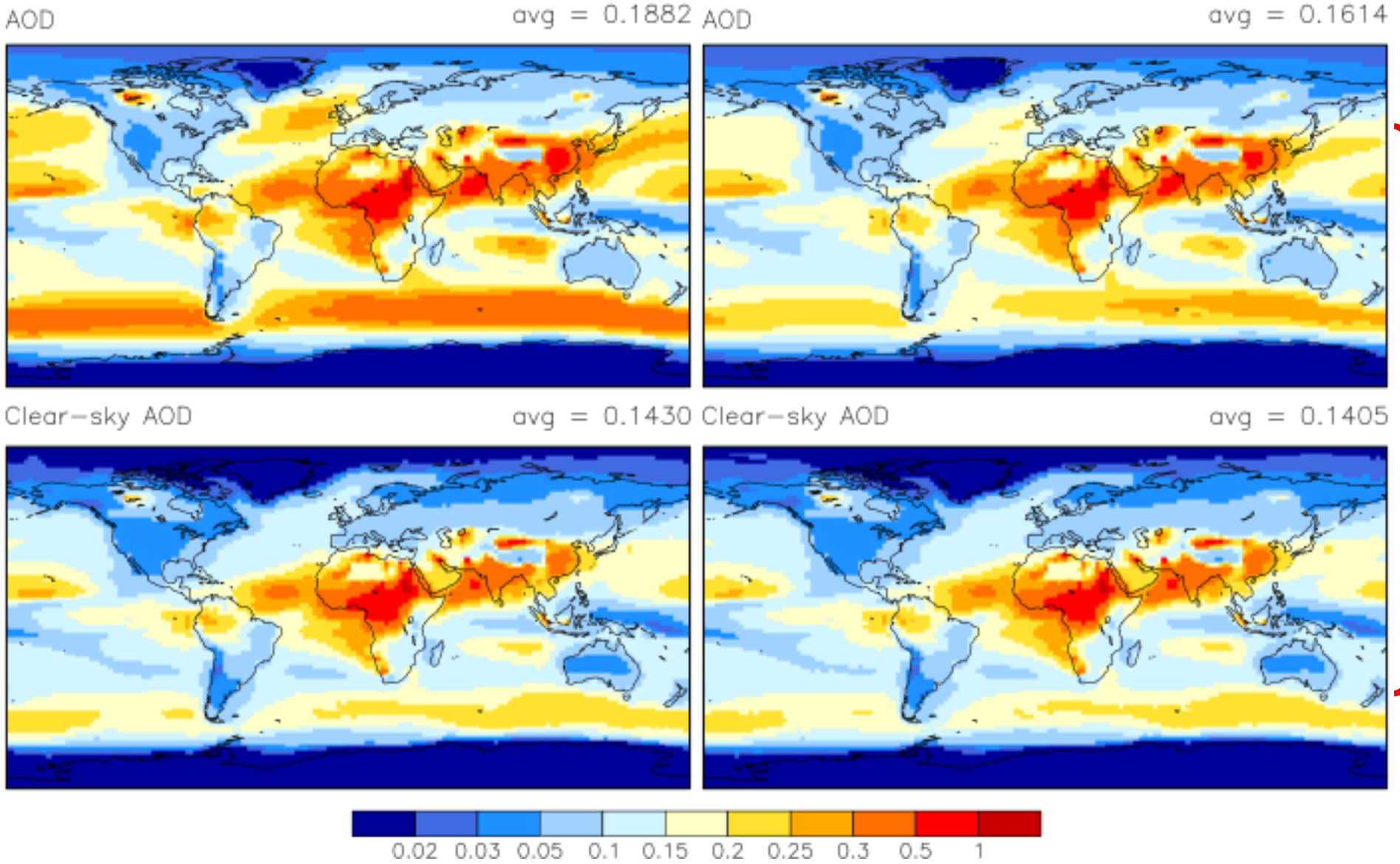
- Subgrid assumptions on relative humidity
  - Is there a different value used inside and outside of clouds?

All-sky vs. clear-sky AOD in the GISS ModelE2.0



Kim et al., 2014

All-sky vs. clear-sky AOD in the NoRESM1.2/2



Gridbox mean RH

Clear-sky mean RH

Kirkevåg et al., AeroCom 2019 poster

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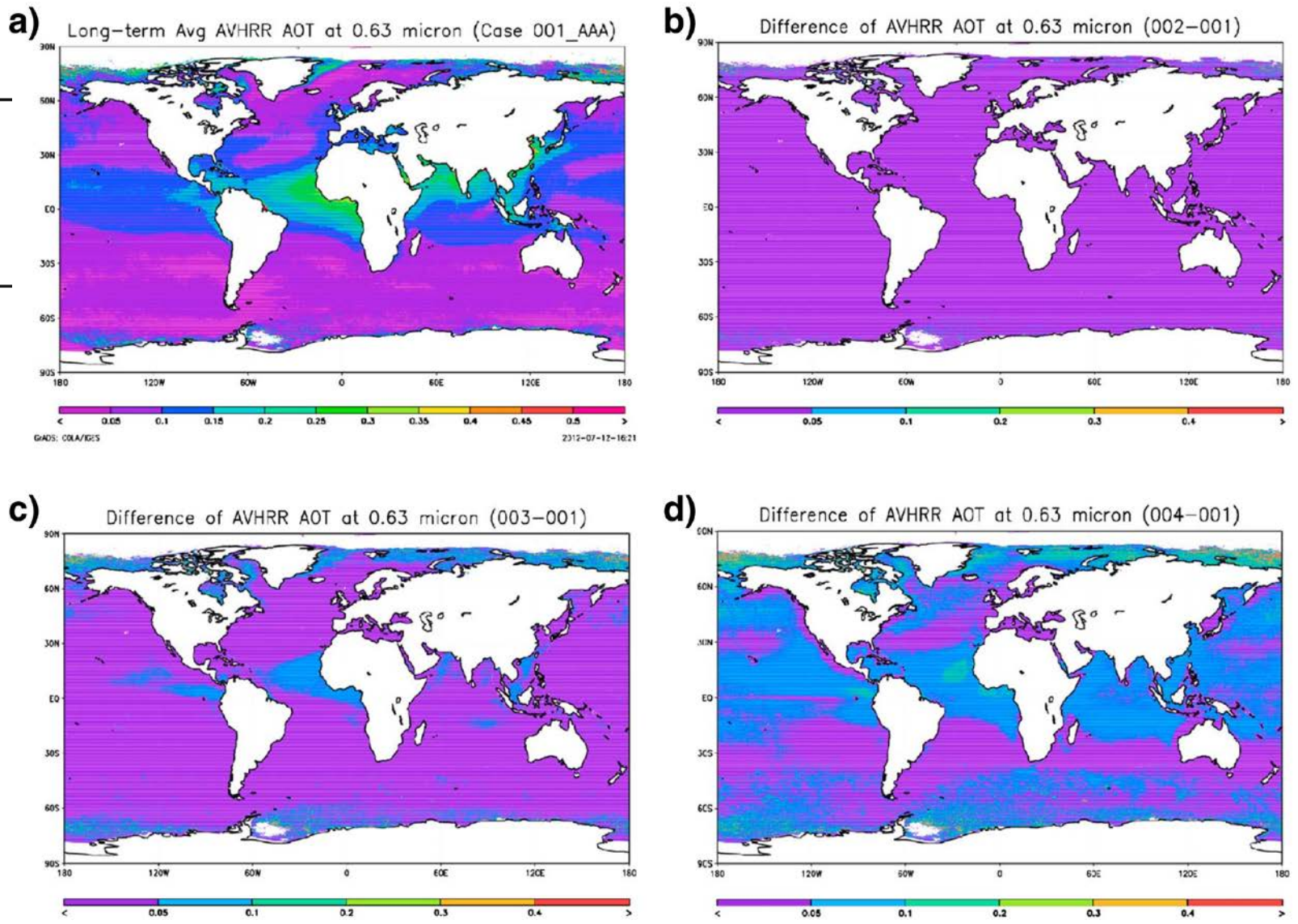
Remote sensing clear-sky considerations

- How perfect co-location do we need?
- How close to a cloud can we go?
  - How close does a retrieval succeed?
    - AERONET: a successful retrieval should be clear of clouds at altitudes of 6km within a diameter of 14.3 km. At the maximum AERONET SZA of 77 degrees, this circle extends to a diameter of 52 km. Of course, lower clouds could be closer – a 1 km cloud could be as close as ~2.4km when SZA = 50deg.
  - How do the error characteristics change near to clouds?
- How thin does a (e.g. sirrus) cloud need to be for a retrieval to miss it?
- How does AERONET deal with internal mixtures?

AVHRR cloud probability (cpb) parameter

Data Sets (Case #)	Clear-Sky Definition
1 (001)	cpb ≤ 0.5%
2 (002)	cpb ≤ 1%
3 (003)	cpb ≤ 5%
4 (004)	cpb ≤ 15%

[..] cloud contamination imposes not only a positive bias on AOT values but also a positive bias on its long-term trend such that negative trends become less negative and positive trends become more positive. A cloud probability value of ≤1% has been identified as an optimal criterion for clear-sky definition to minimize the cloud contamination in the AVHRR aerosol retrieval while still retaining strong aerosol signals.



Zhao et al., 2013

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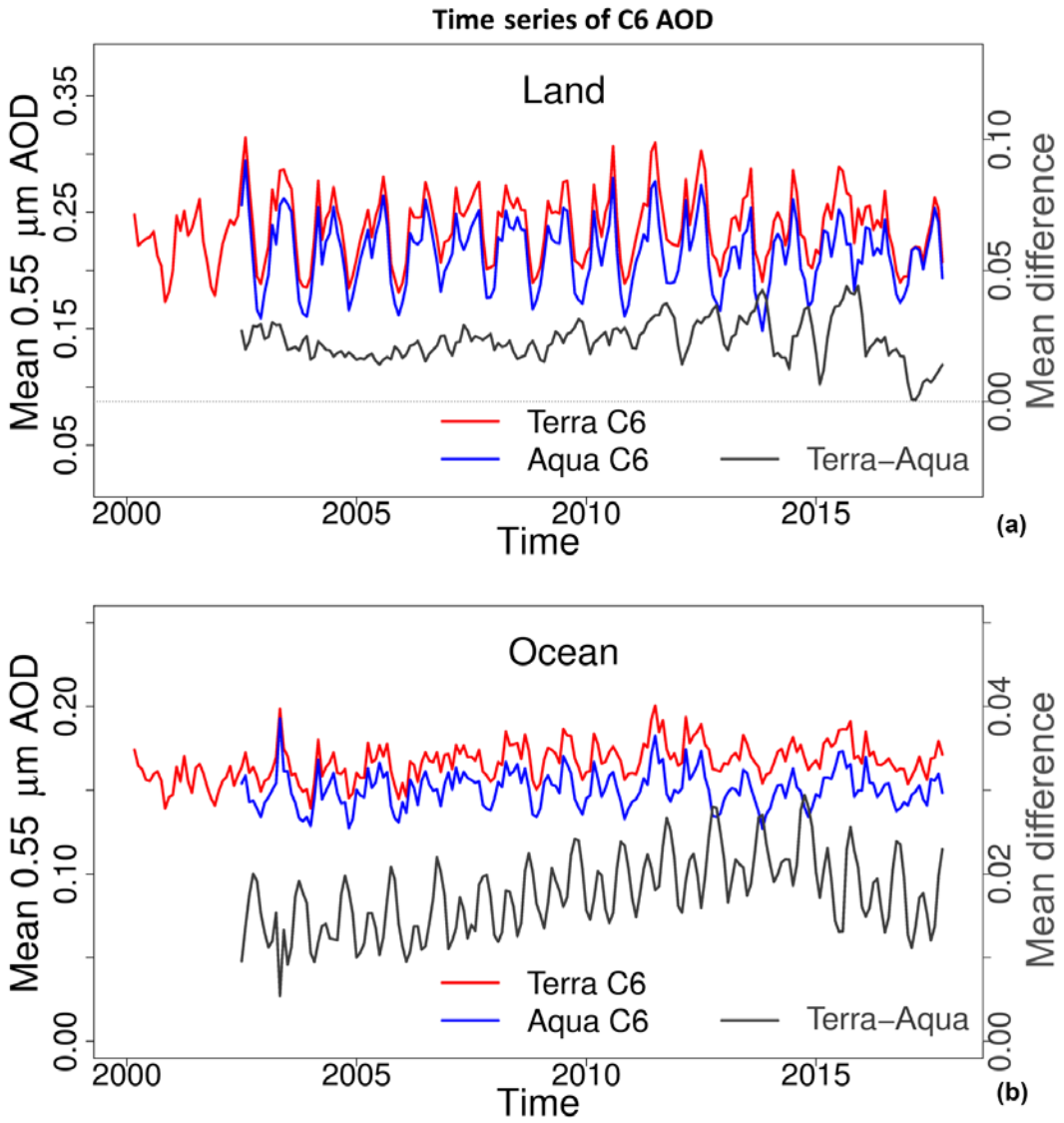
MODIS Terra vs. Aqua



Probably the differences are not related with the different cloudiness due to different overpass times.

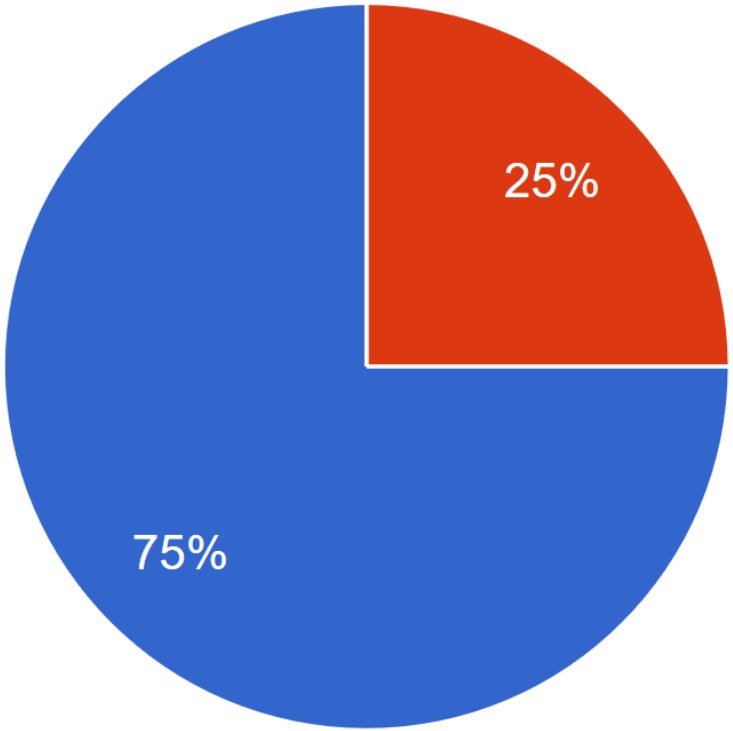
Levy et al., 2018

More google poll results (12 models)

What are models doing right now?

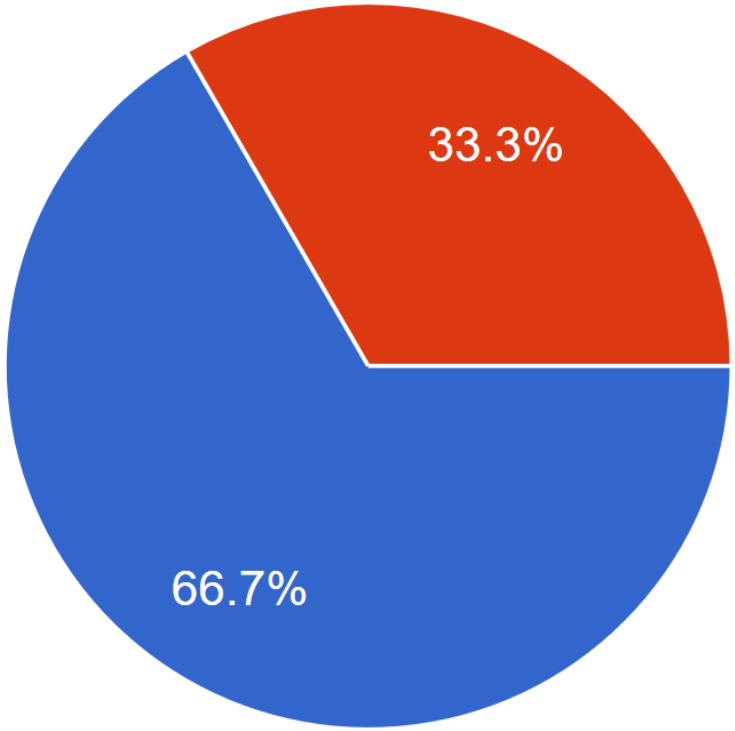
The model includes […] calculations

csAOD



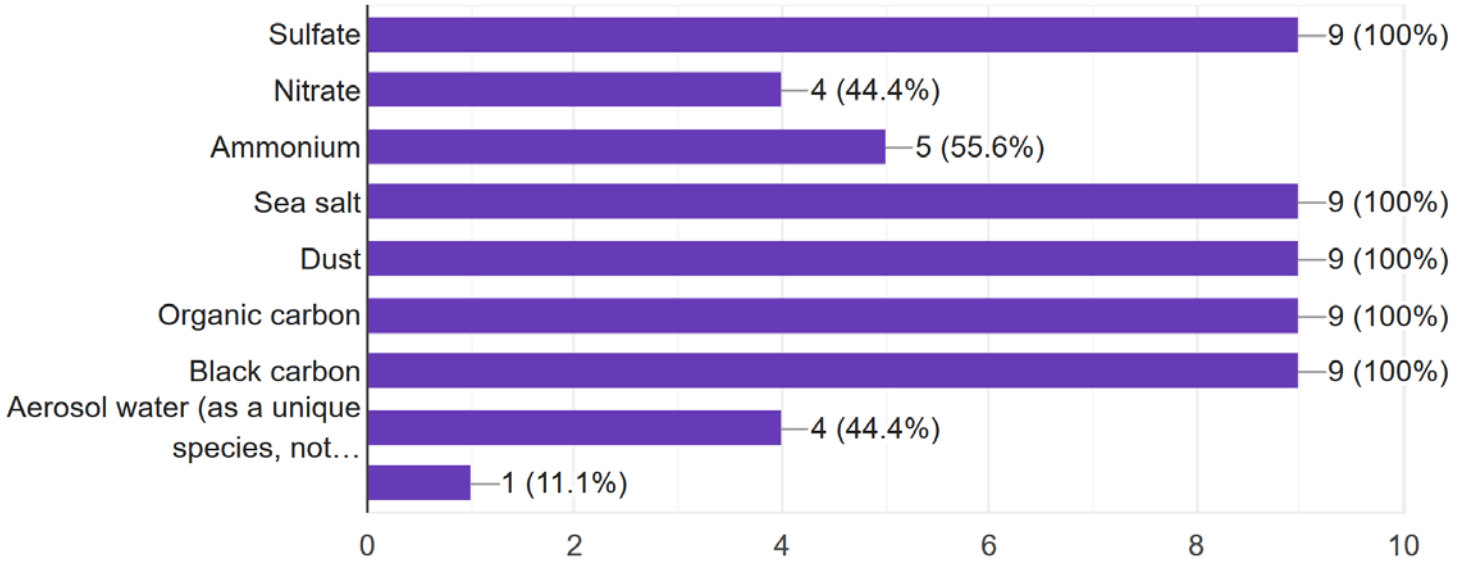
Yes
No

asAOD



Species contributing to […]

csAOD



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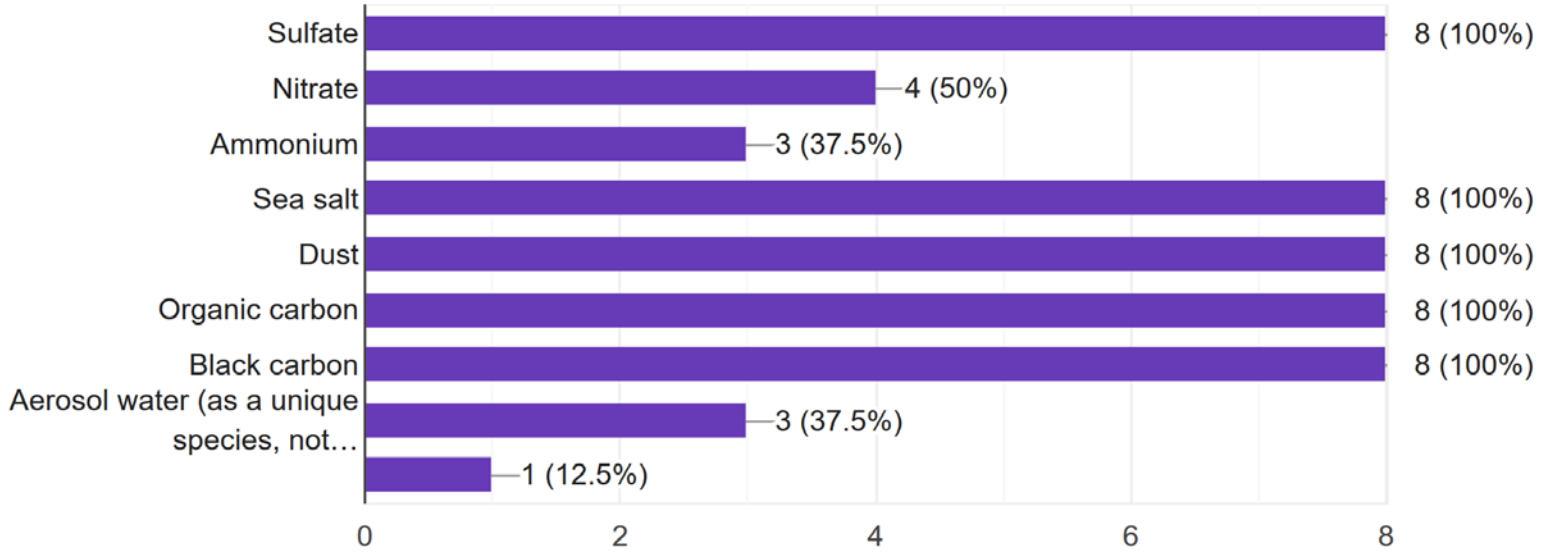
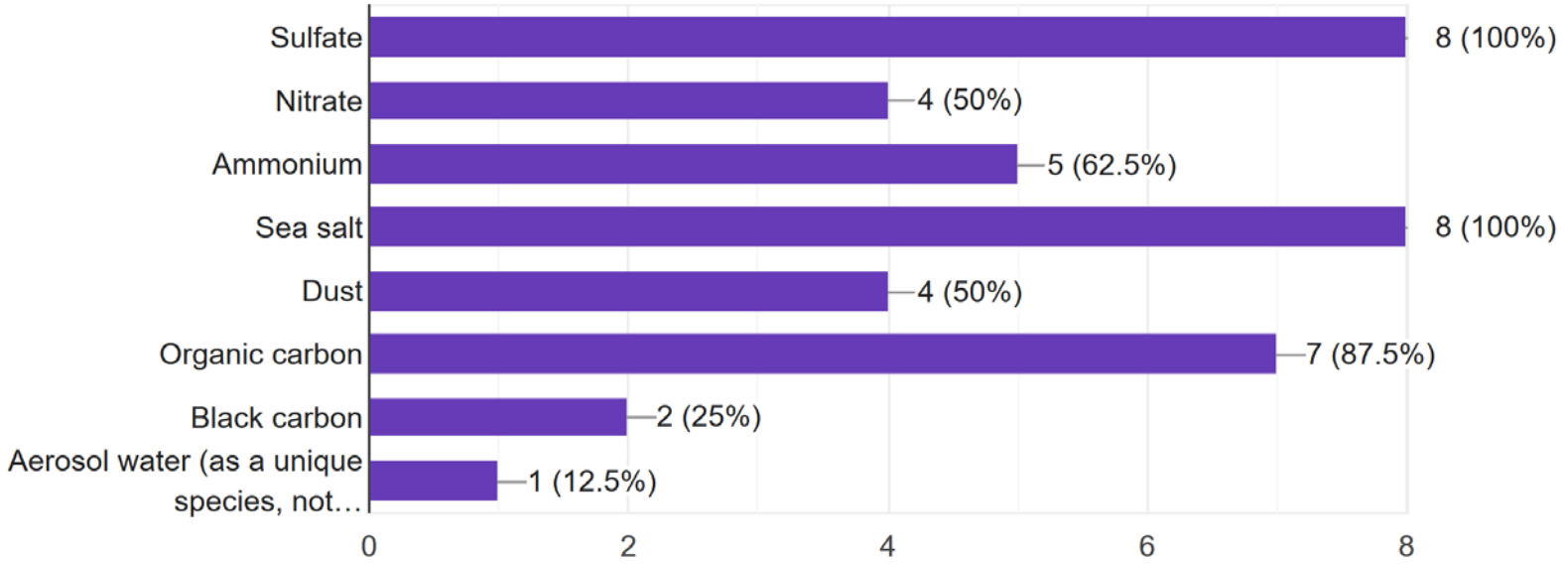


Which species grow hygroscopically in […] calculations?

csAOD



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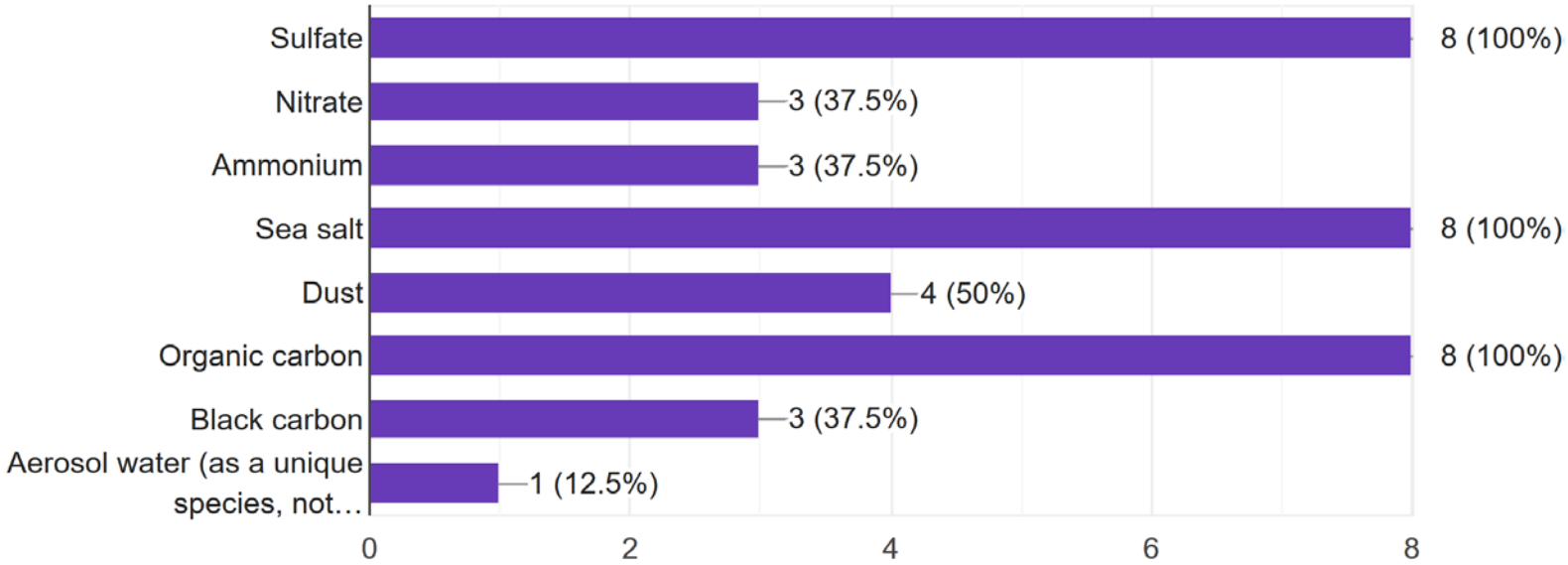
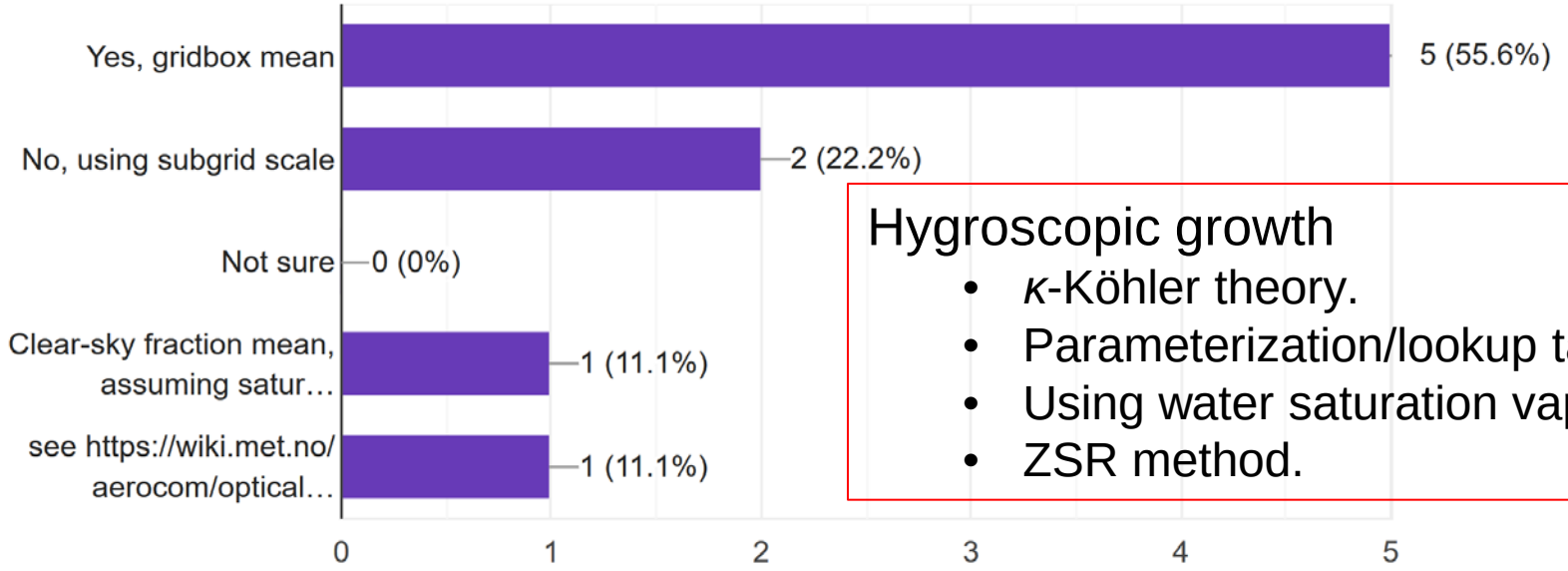


Are you using gridbox mean relative humidity, or some subgrid scale information?

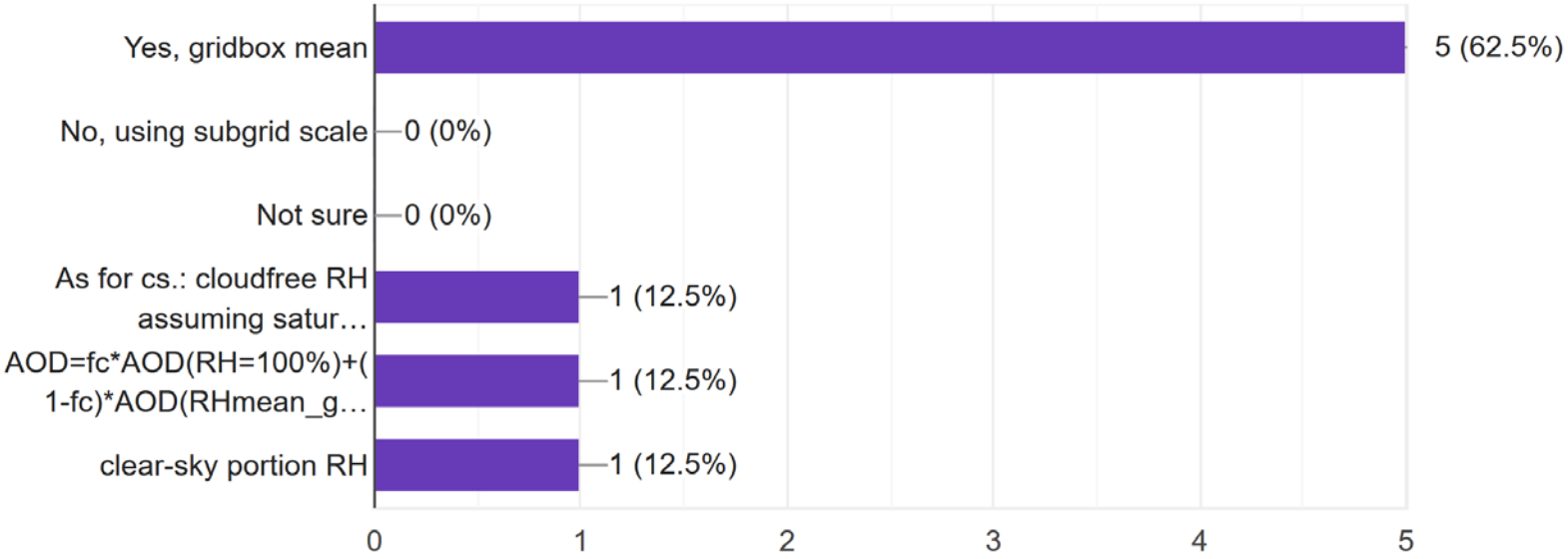
csAOD



Hygroscopic growth

- κ-Köhler theory.
- Parameterization/lookup table.
- Using water saturation vapor pressure.
- ZSR method.

asAOD



Other thoughts

- AOD is lognormally distributed (Sayer and Knobelspiesse, 2019)
  - [..] in continental outflow regions and near source regions over land, and on monthly or seasonal time scales, the difference is frequently larger than the Global Climate Observation System (GCOS) goal uncertainty on a climate data record (the larger of 0.03 or 10 %).
  - [..] ideally AOD aggregates such as satellite level 3 products (but also ground-based data and model simulations) should report geometric mean or median rather than (or in addition to) arithmetic mean AOD.

Thank you!

Express interest: kostas.tsigaridis@columbia.edu