AERO-MAP: A data compilation and modelling approach to understand the fine and coarse mode aerosol composition

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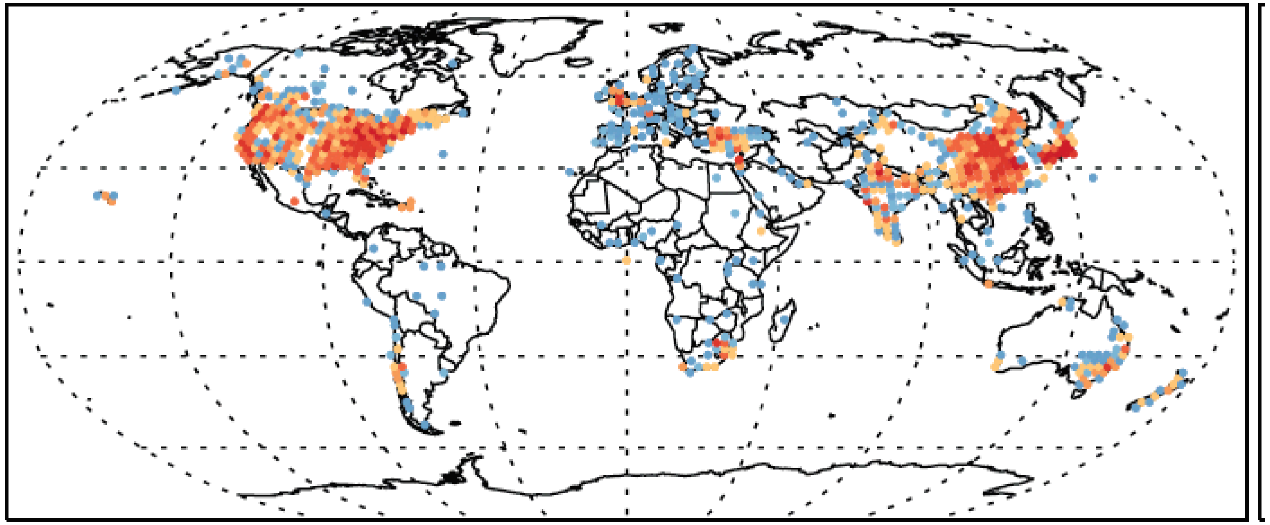
c. PM2.5 number of stations

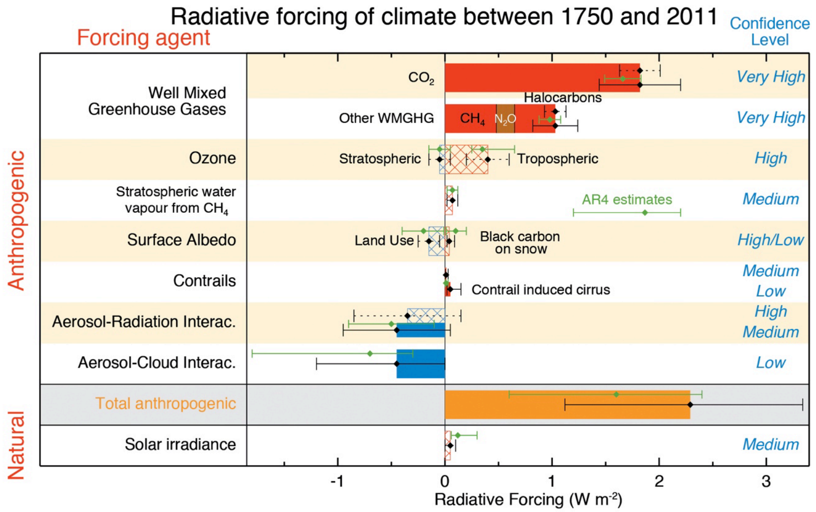


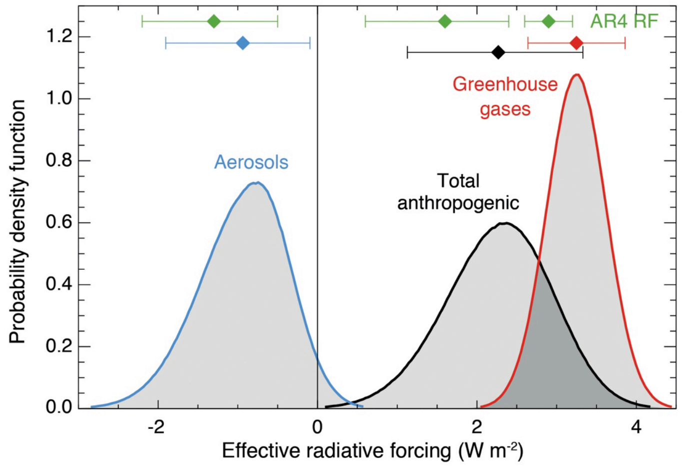
~14,000 stations
>20 million obs
includes data outside of US and Europe

Grided to 2x2 so we can see

https://essd.copernicus.org/preprints/essd-2024-1/

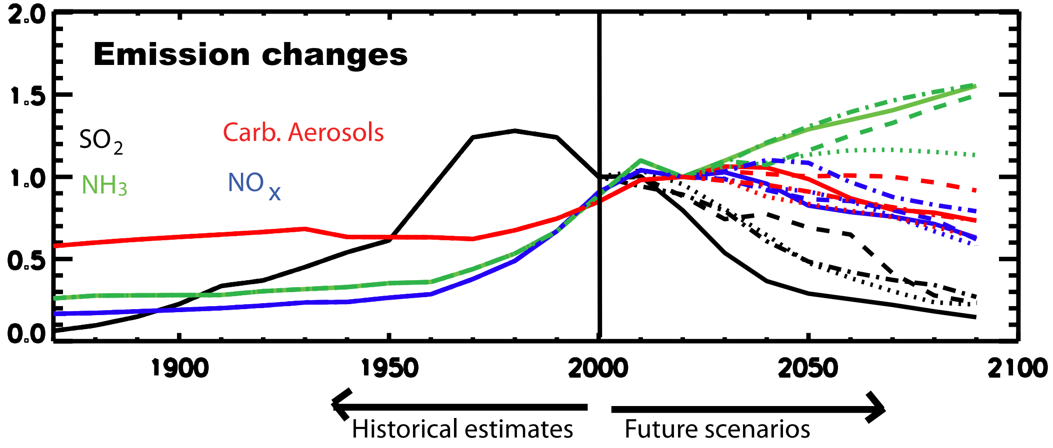
Aerosols important for understanding climate





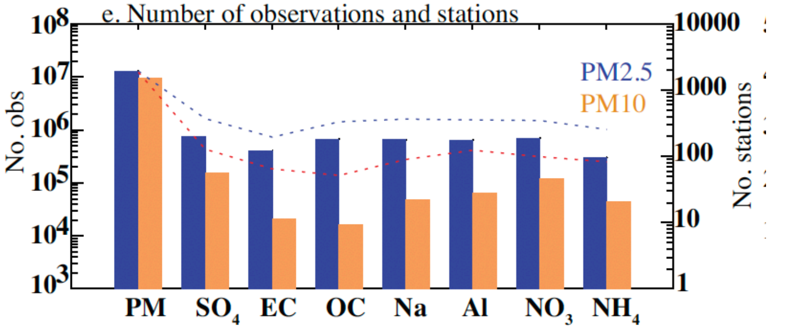
IPCC, 2014

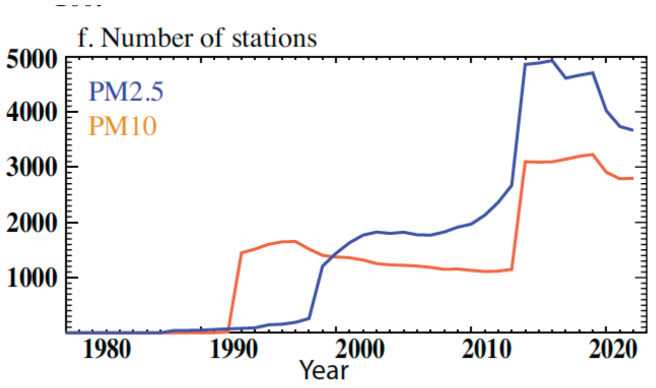
- Aerosols large source of uncertainty in current radiative forcing and PI/PD changes
- Different aerosol sources have different trends going into the future
- Different aerosols have different impacts (warming versus cooling, cloud interations, biogeochemistry)



Methodology

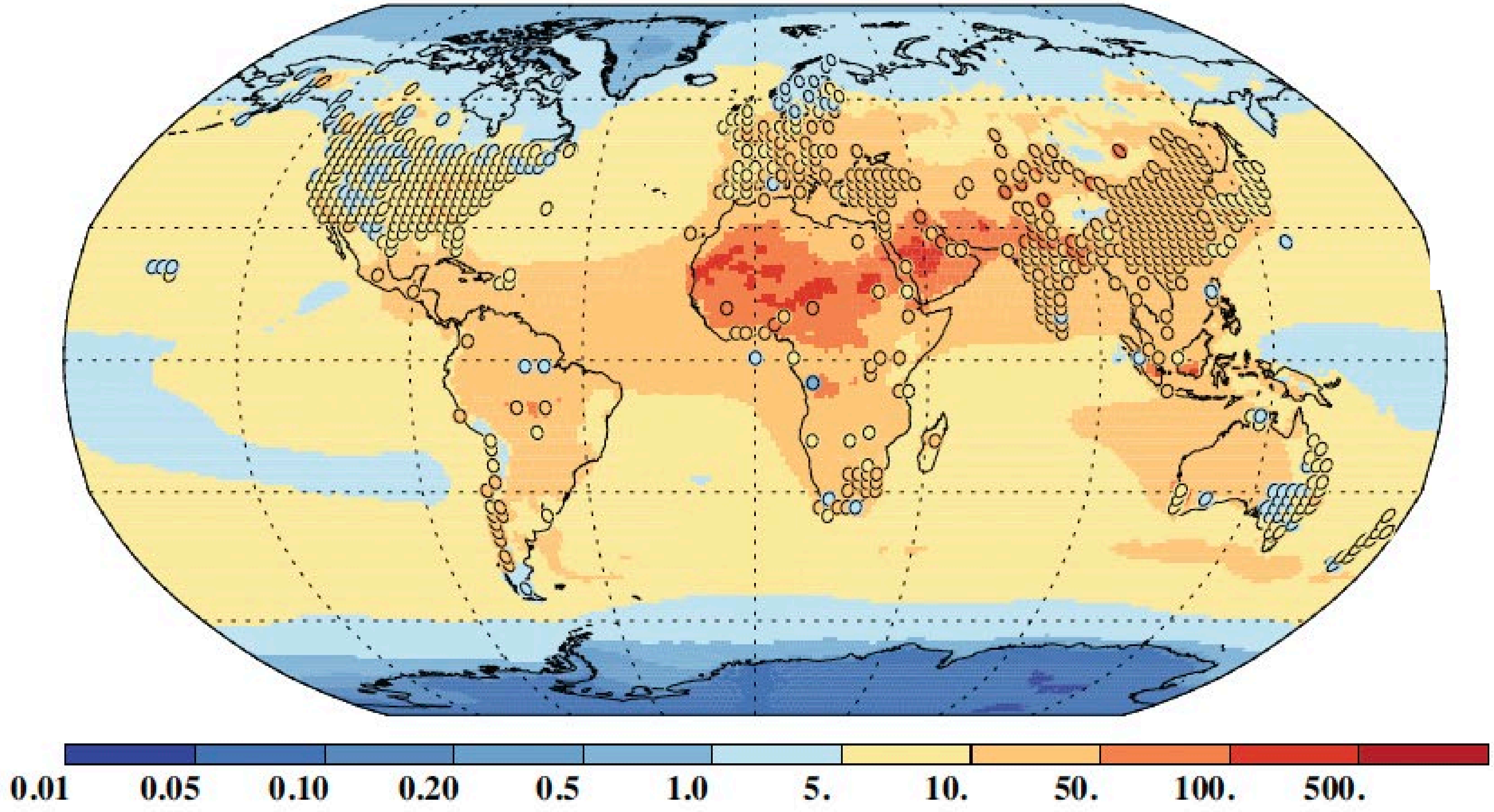
- Compile total PM, SO4, EC/BC, OM/OC, Na, Al, NO3 and NH4 for PM2.5 and PM10 at the daily to weekly level globally (much more data available then in previous datasets (Szopa et al., 2021
- This is the first paper presenting annual means across 1986-202 time period. More papers will follow with temporal resolution
- Compare to CESM model (default)+ added NO3/NH4 from Vira et al., 2021
- Add in other sources:
  - Agricultural dust (tuned to Ginoux et al., 2012 satellite estimate)
  - Road dust, industrial emissions, coarse OC and BC (from Klimont et al. 2017)
  - Add in primary biogenic emissions (Mahowald et al., 2005; Burrows et al., 2009; Heald and Spracken 2009)
- Average to 2x2 grid for display (where there is data there is often too much to display)
- Convert modeled composition to observed composition when needed (e.g. dust to Al or sea salts to Na).





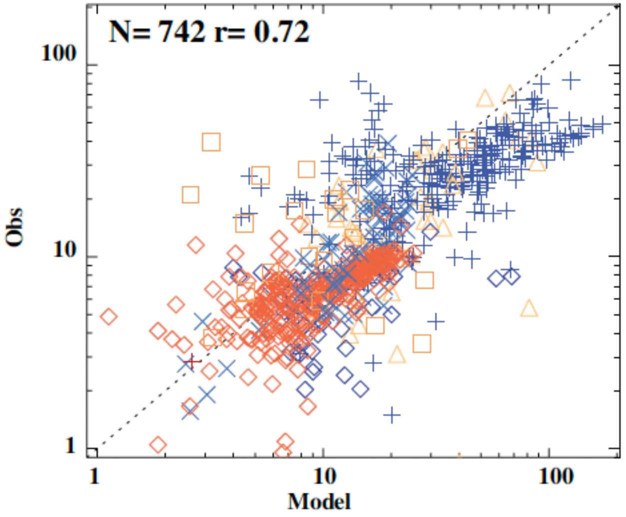
PM2.5

a. PM2.5 (ug/m³)



Gridded comparison

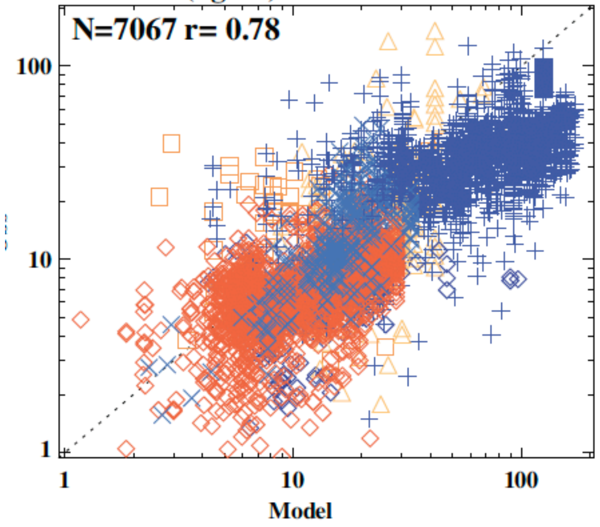
c. PM2.5 (ug/m³)



◇ Australia × Europe
+ Asia △ Africa

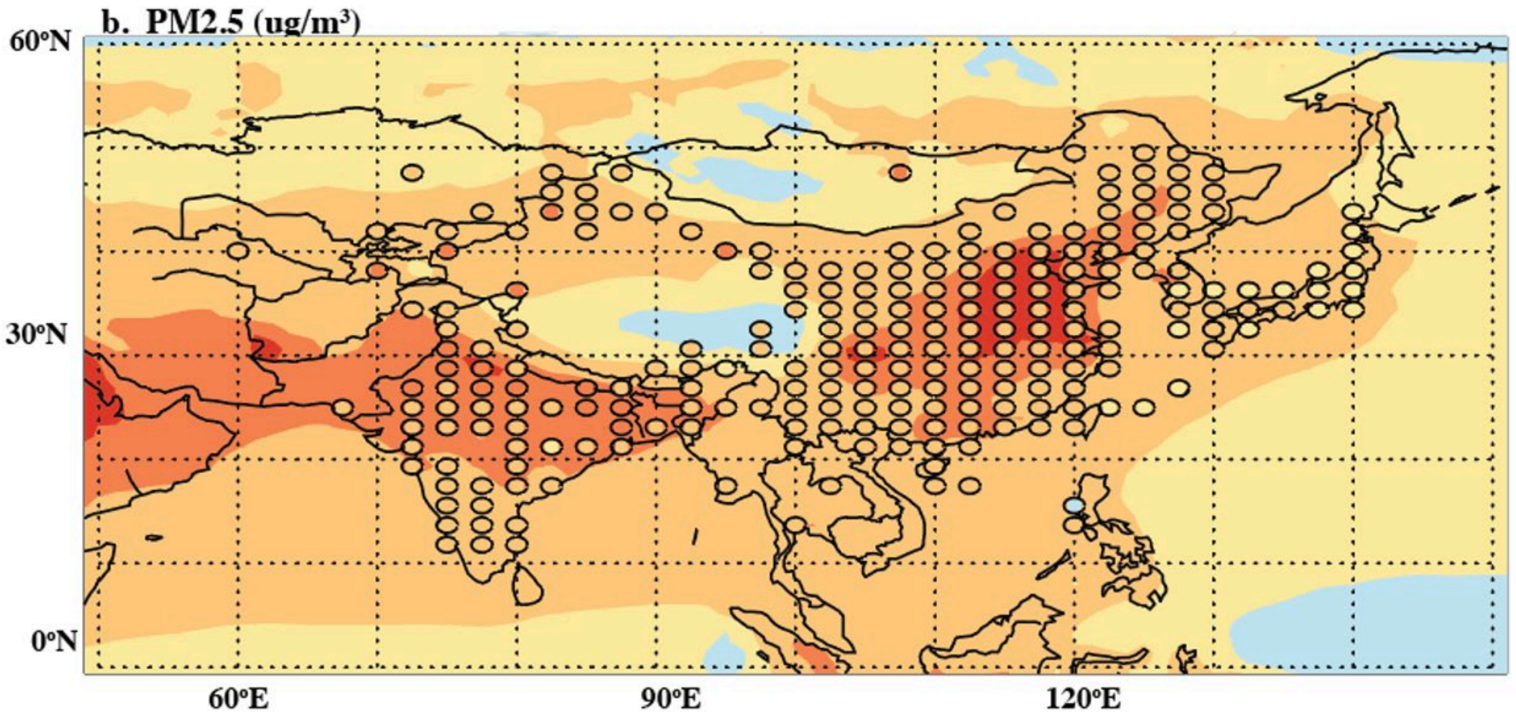
ungridded comparison

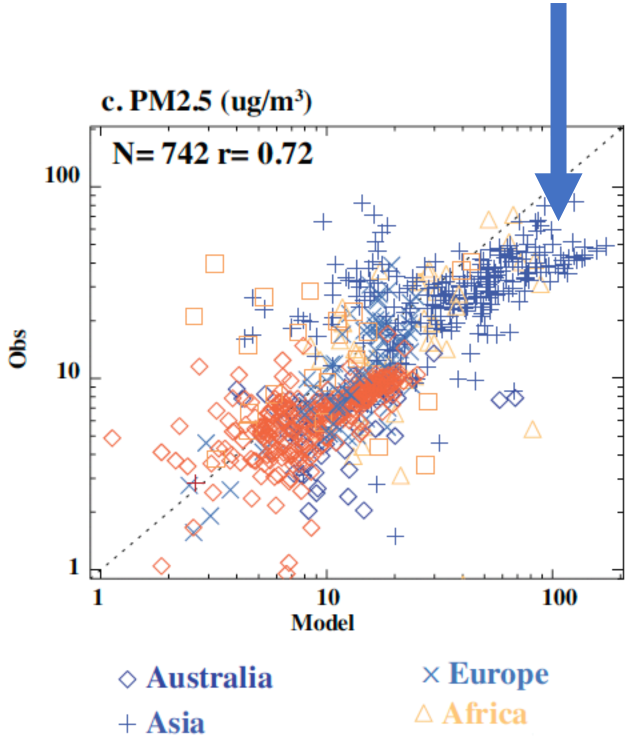
d. PM2.5 (ug/m³)

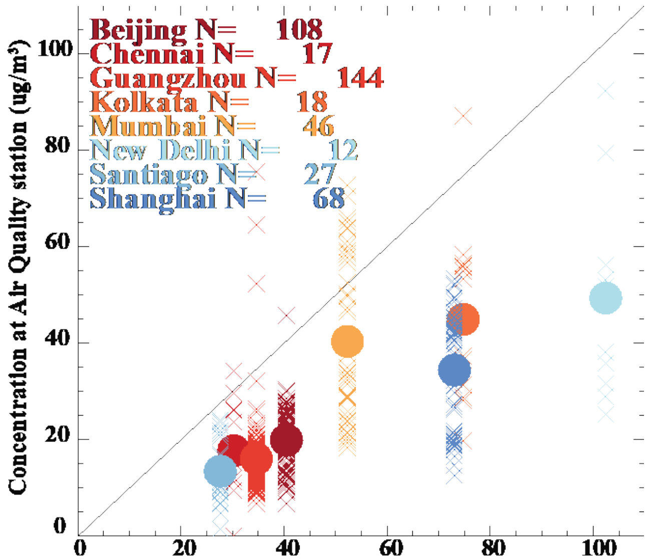


□ South America + High Latitudes
◇ North America

Model too high over Asia?

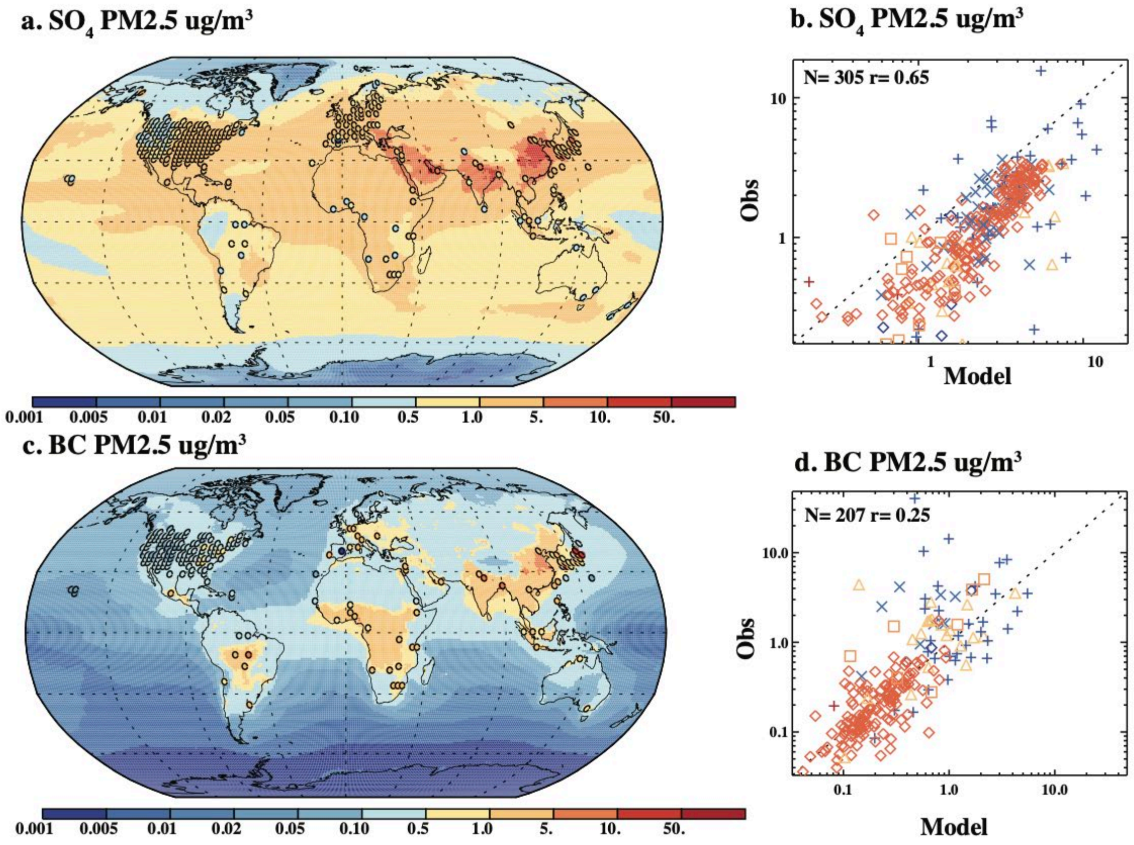






Included a lot of new data from China and India: there seems to be a systematic bias between Chinese and and Indian air quality data versus US embassy data: unclear why.

Compare by constituent as well.

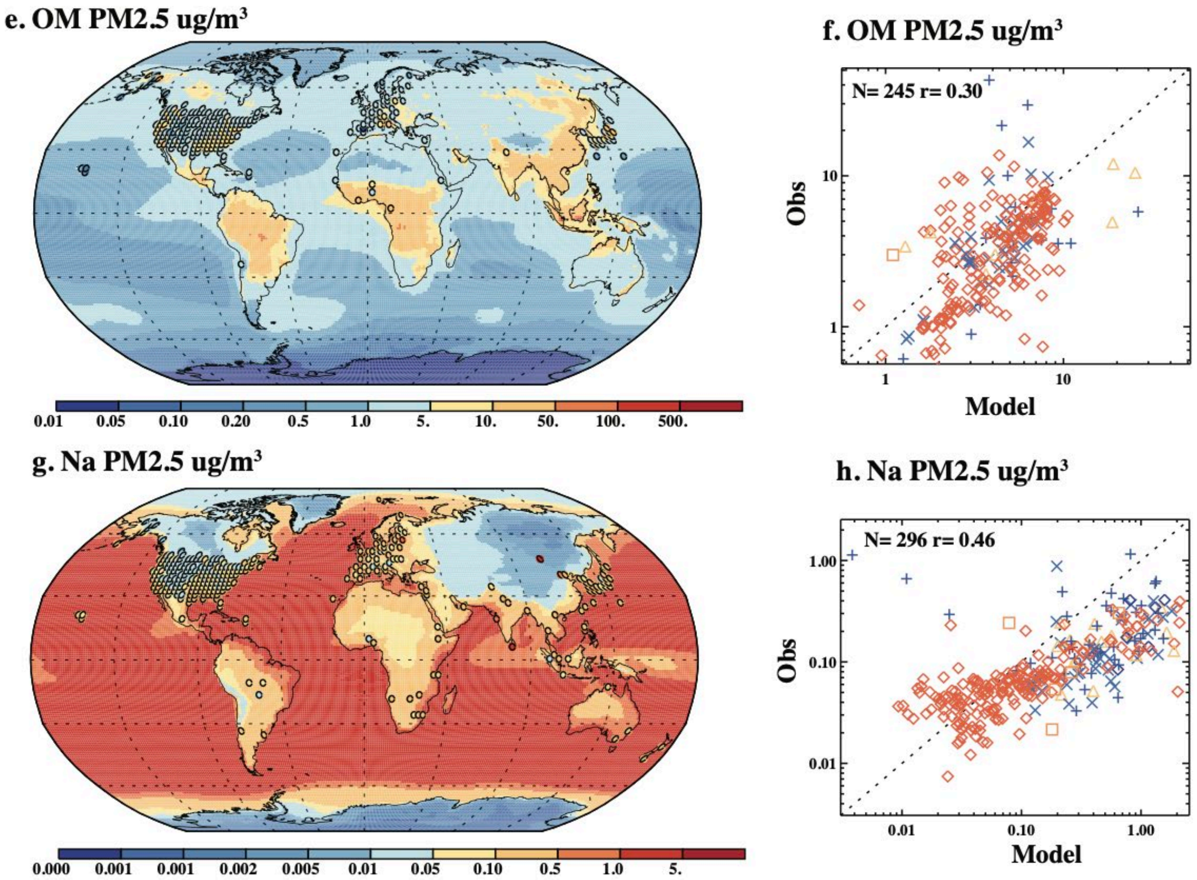


Model SO4 too high
BC/EC about right

Much less data than PM

Liu et al., 2011, 2016

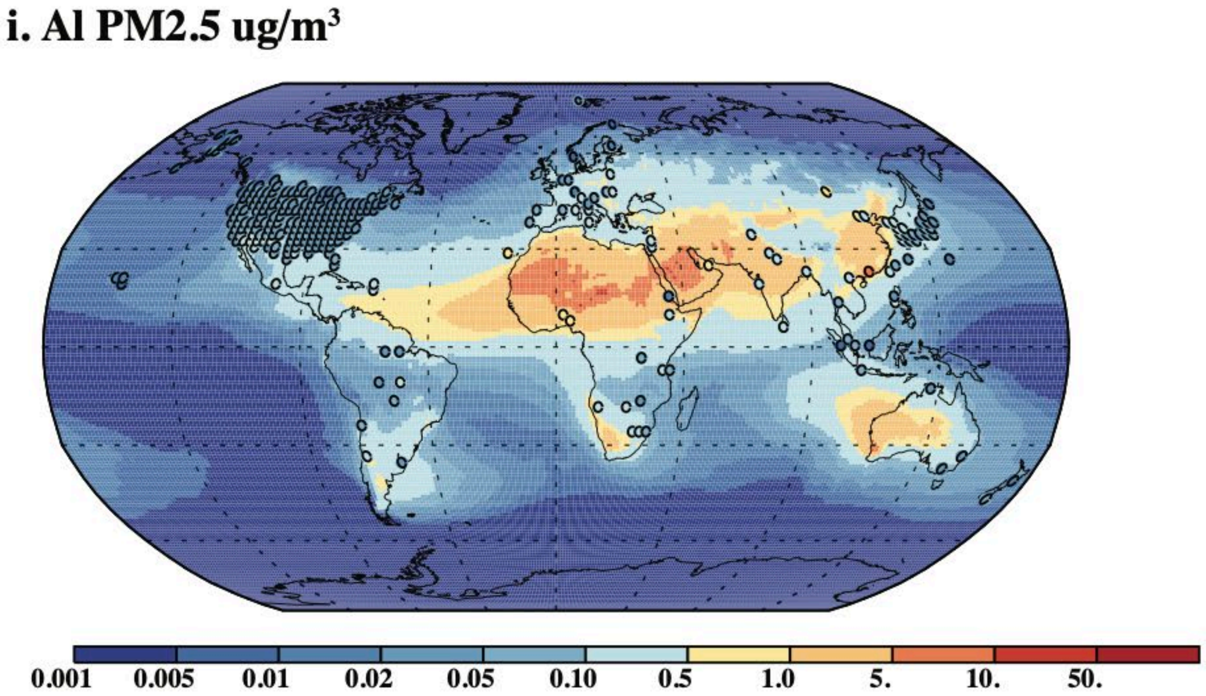
PM2.5 constituents

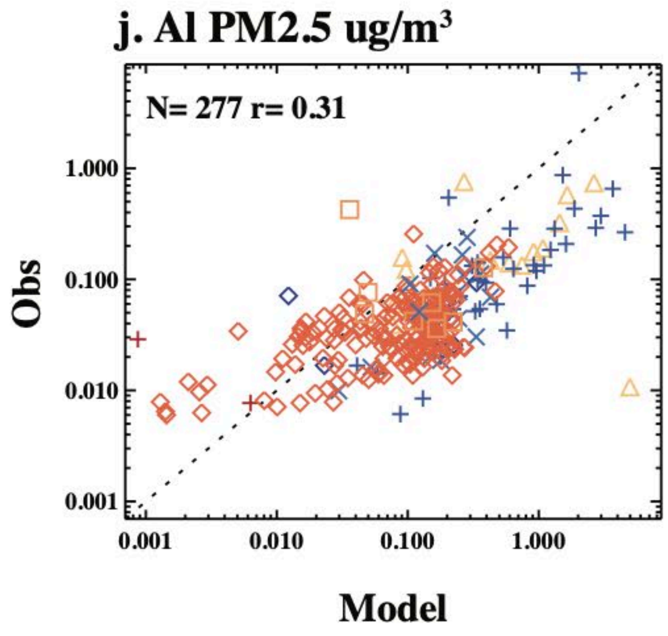


- OM/OC: a little high: much less data

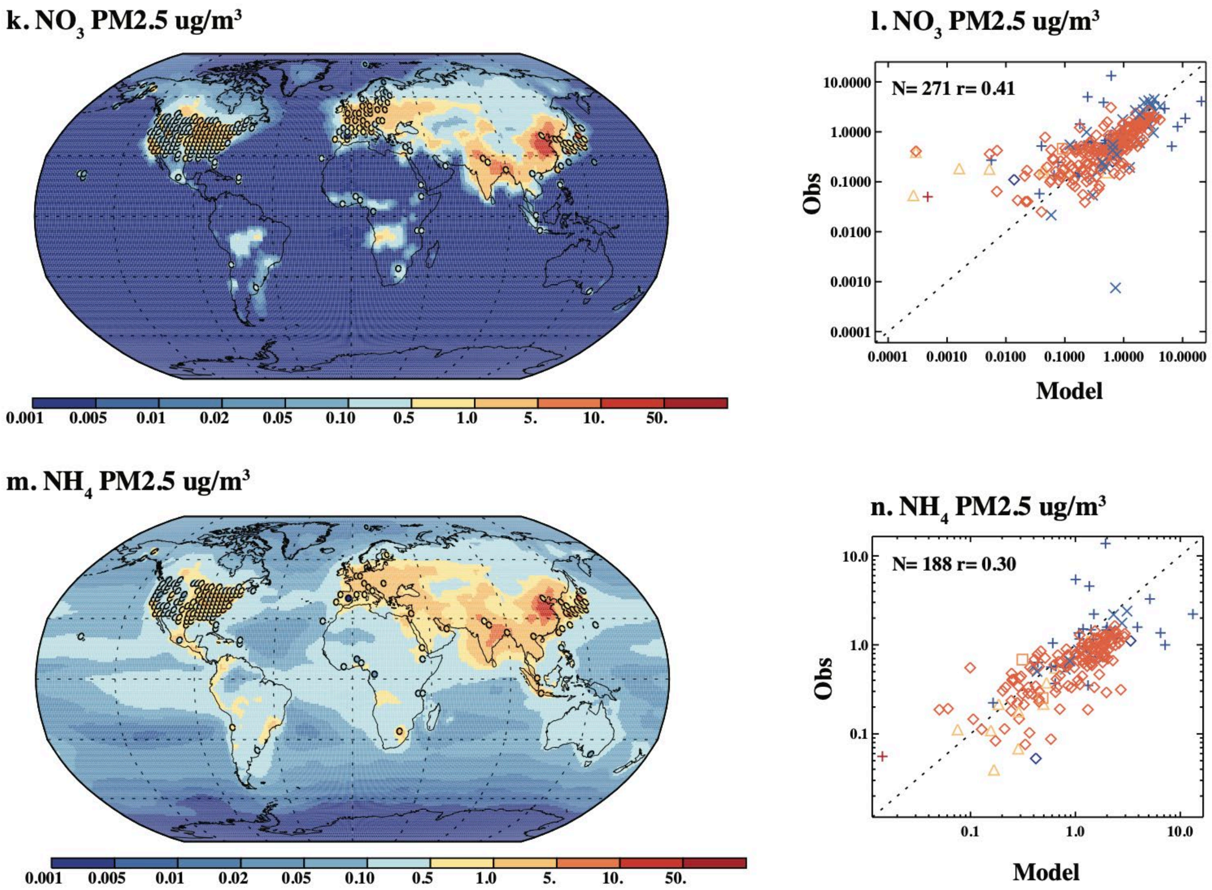
- Na: model too flat compared to obs. (need industrial source of Na?

Al/dust


i. Al PM2.5 ug/m³
0.001
0.005
0.01
0.02
0.05
0.10
0.5
1.0
5.
10.
50.

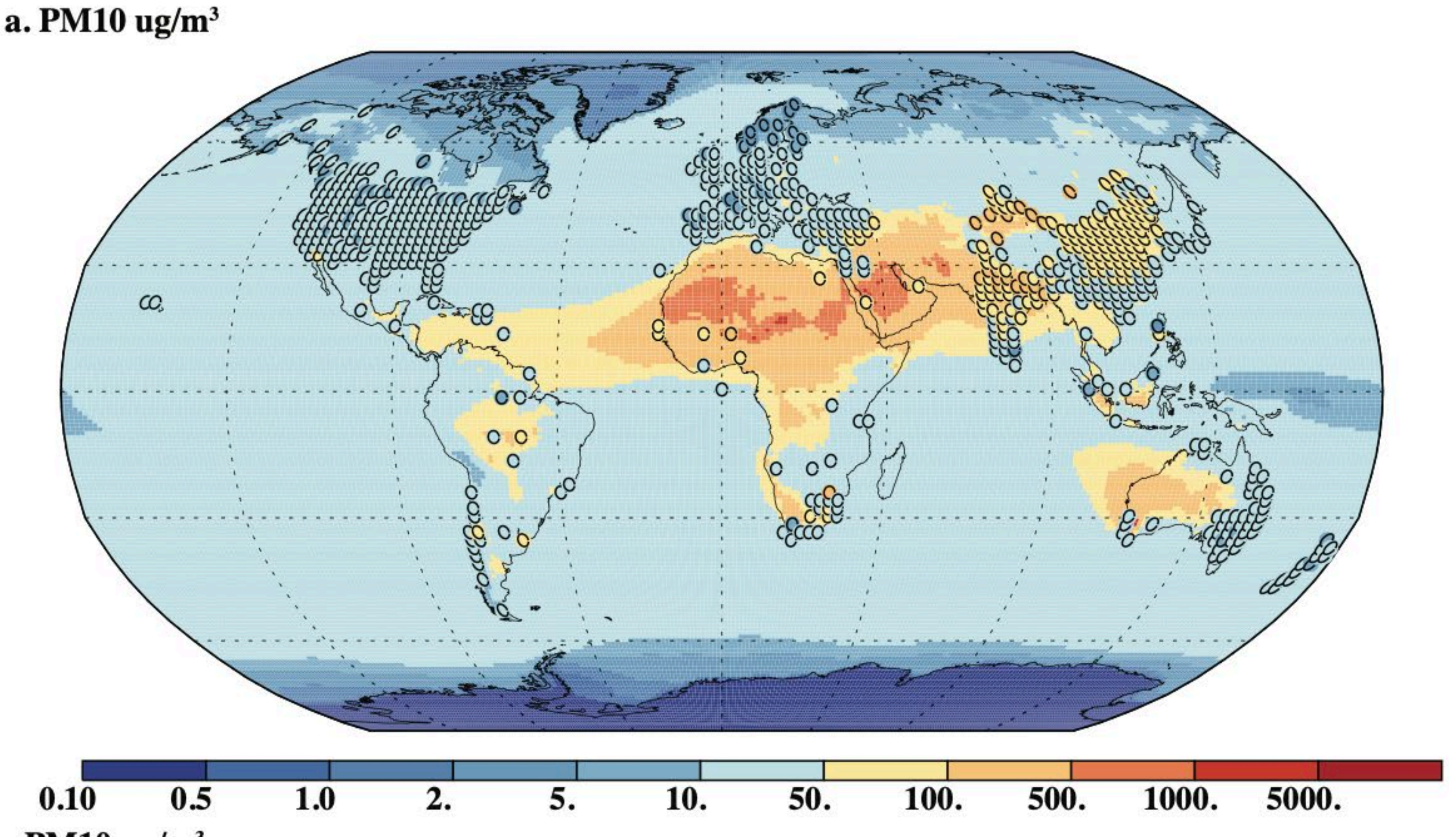

j. Al PM2.5 ug/m³
N= 277 r= 0.31
Obs
1.000
0.100
0.010
0.001
0.001
0.010
0.100
1.000
Model

PM2.5 Nitrogen aerosols

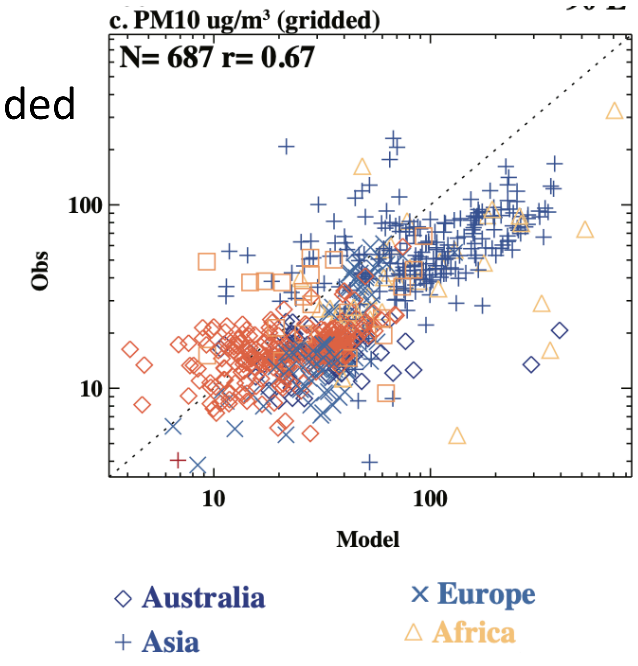


Needed to half NO3 (Vira et al., 2021)
(likely because no thermodynamic model)

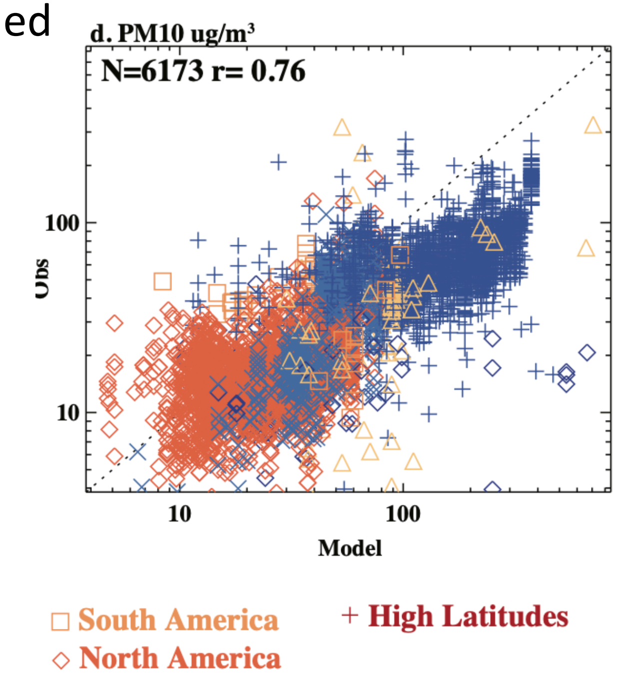
PM10



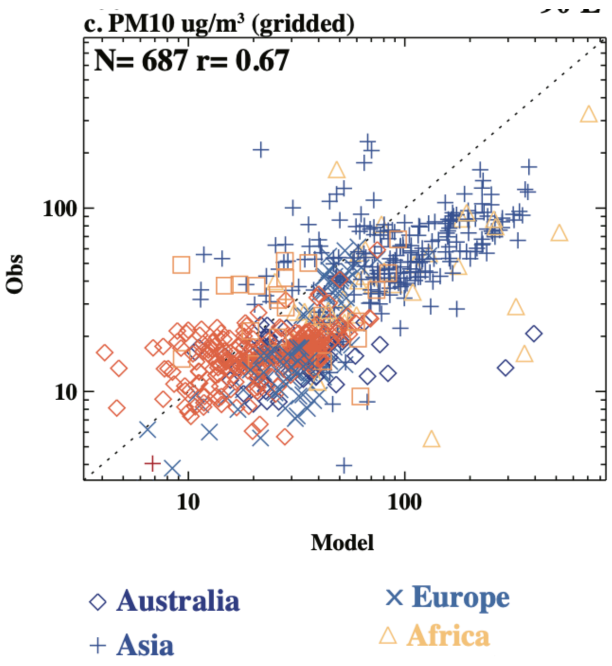
gridded

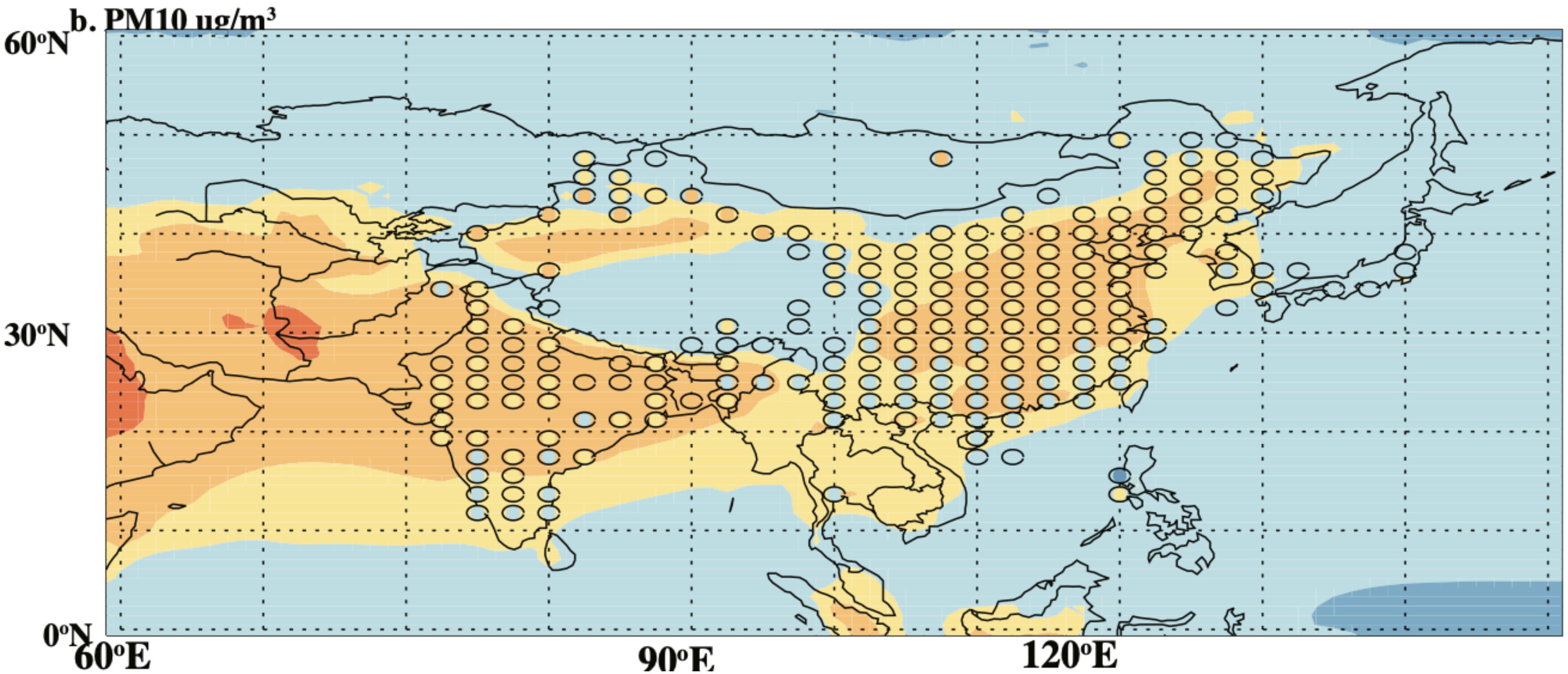


ungridded



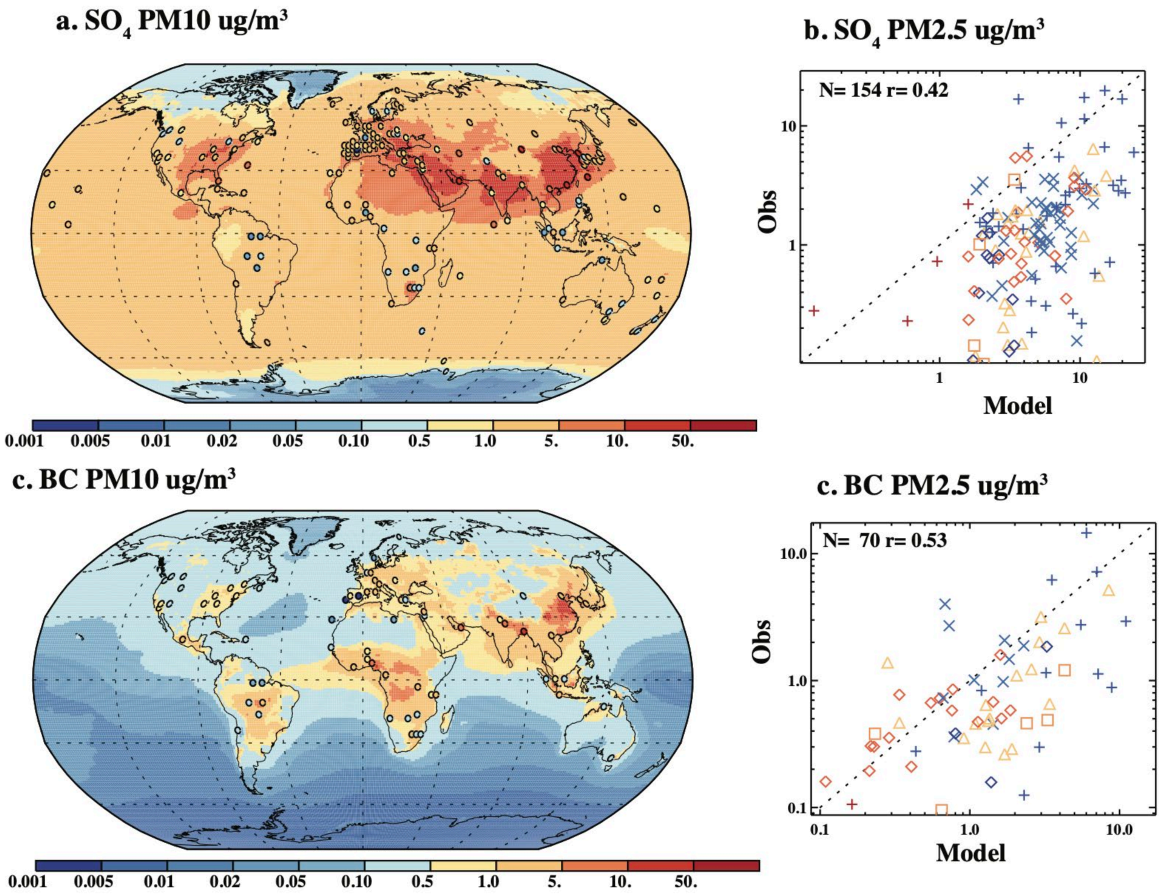
Similar bias over asia?





Or new data not representative?

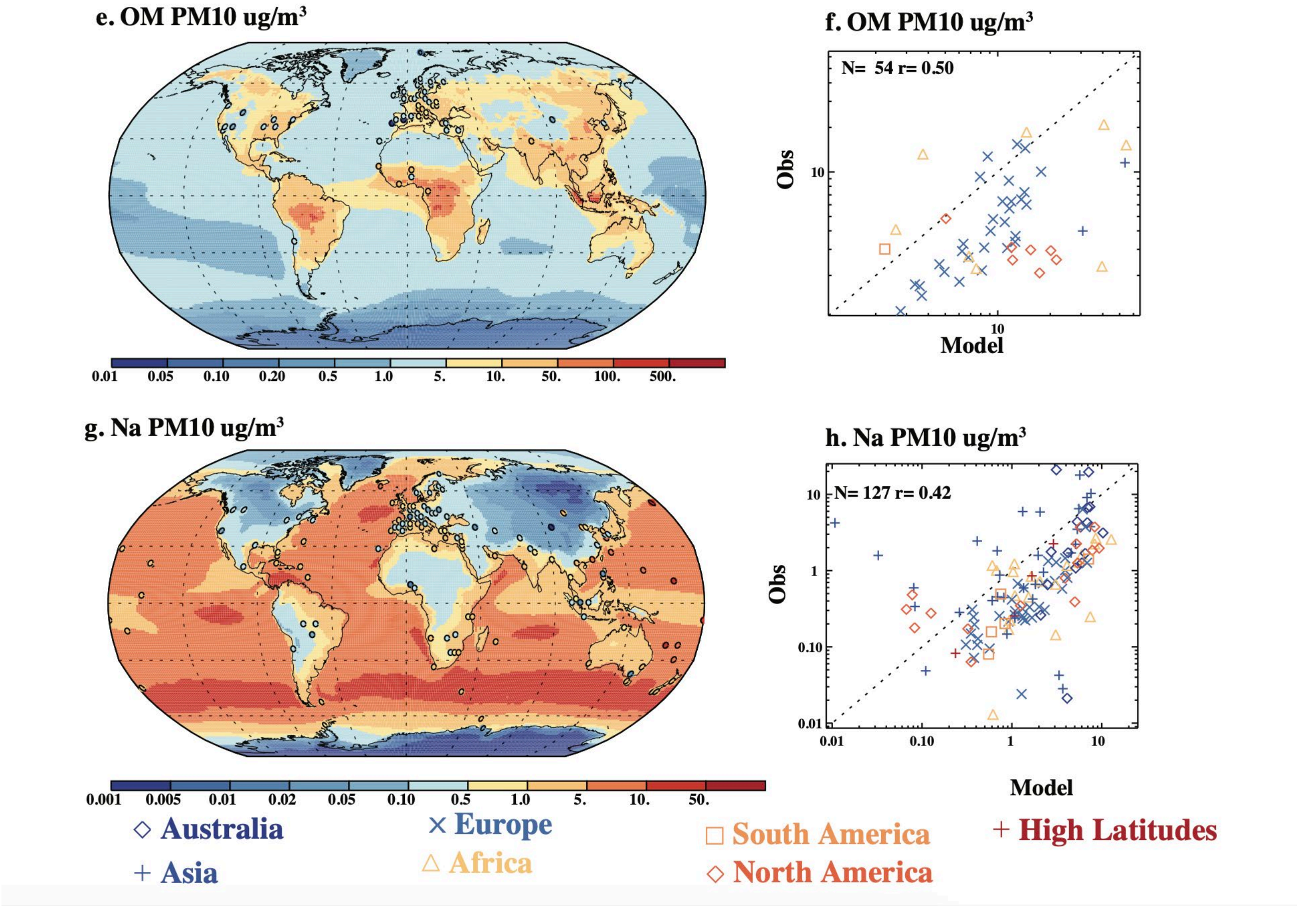
PM10 sulfate and BC/EC



Model over estimates sulfate in coarse mode

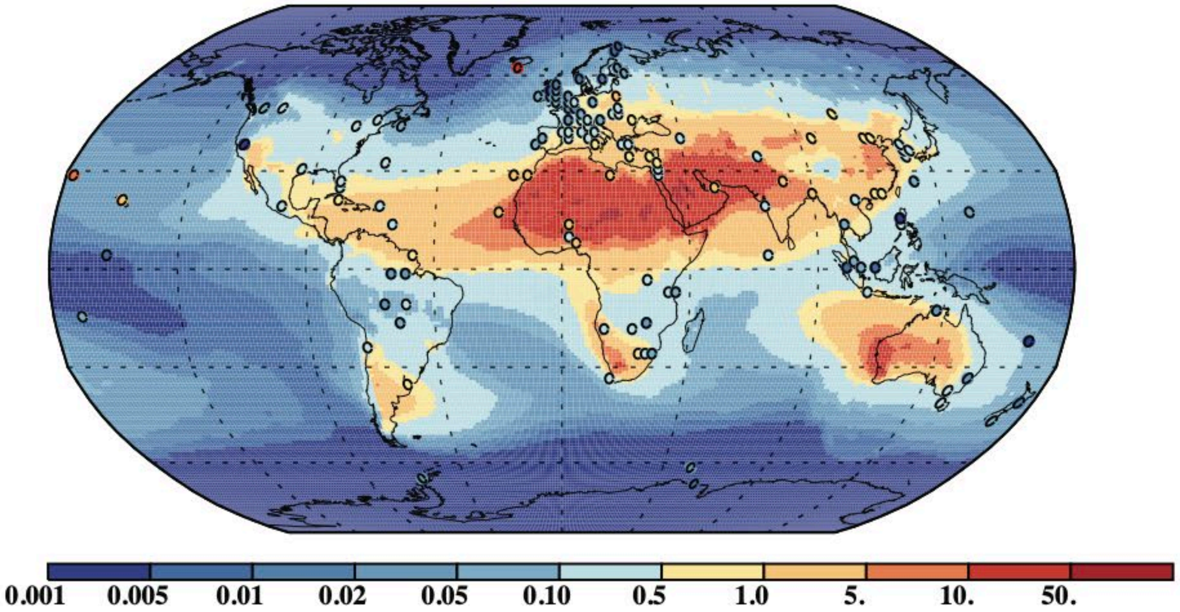
Added BC into coarse mode: maybe too much?

PM10 OC/OM and seasalts/Na

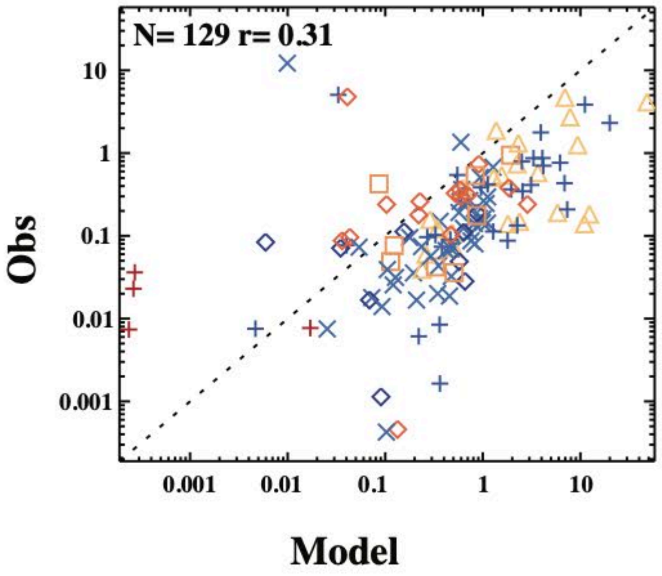


Dust/Al

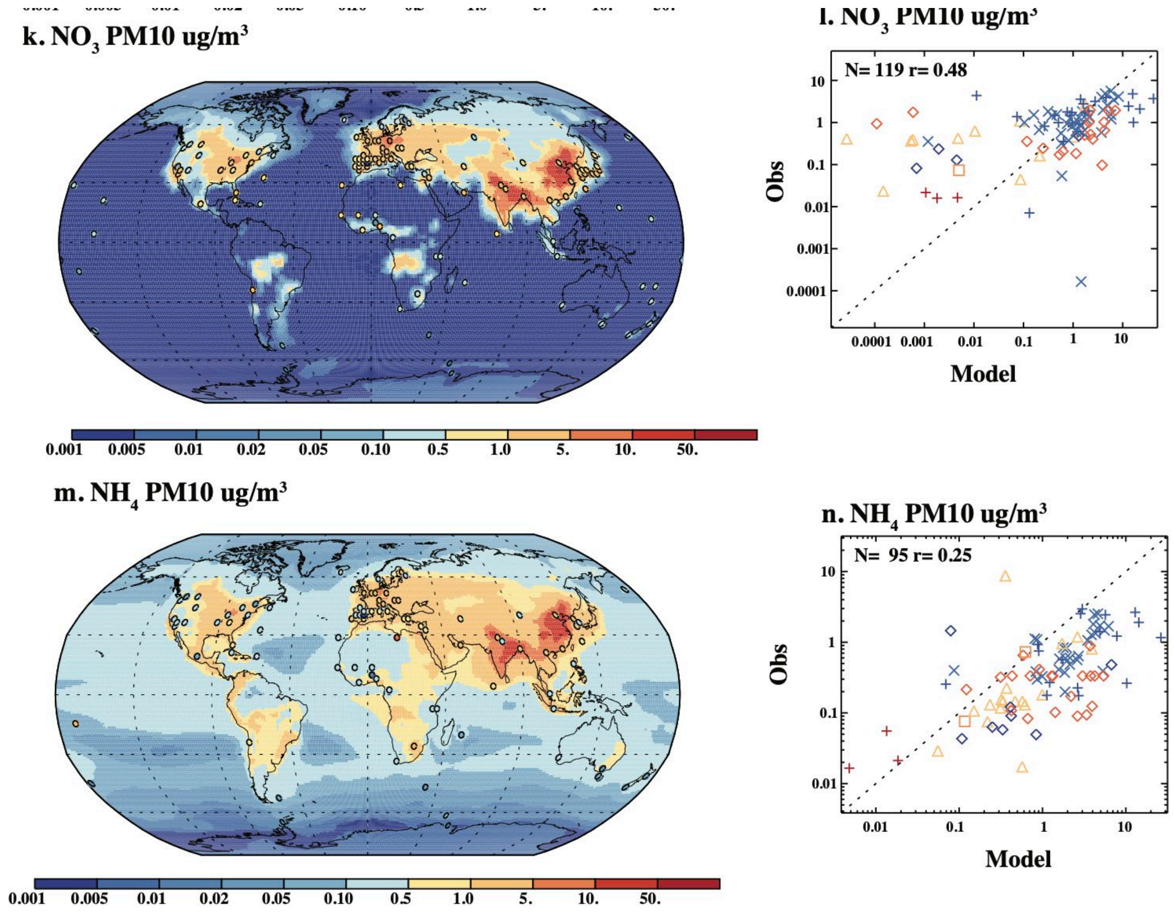
i. Al PM10 ug/m³



j. Al PM10 ug/m³



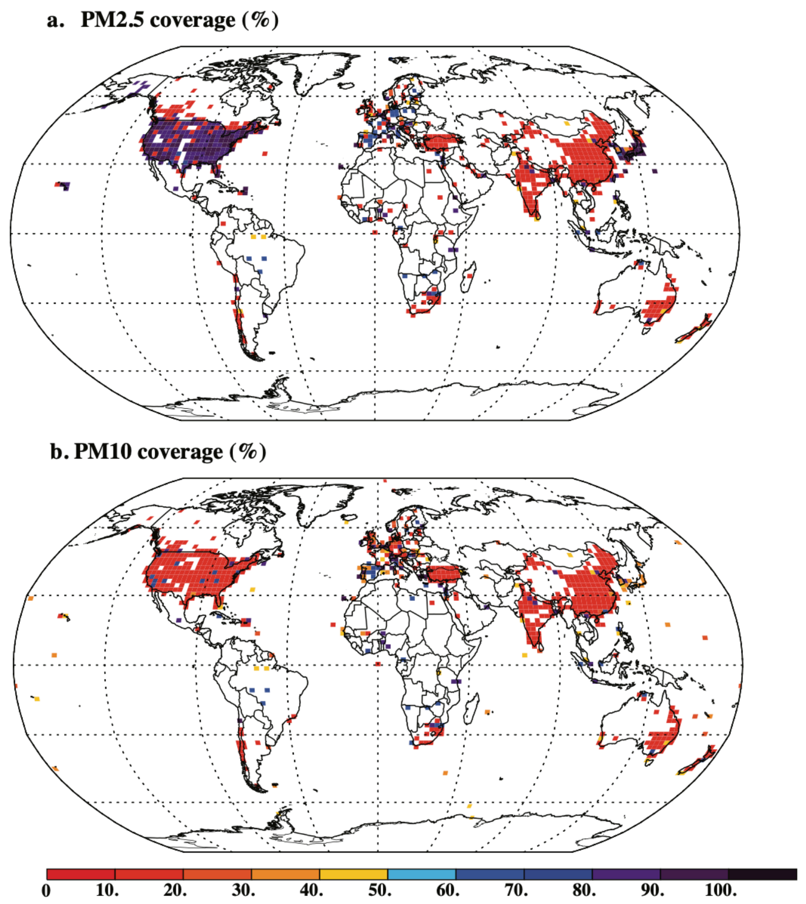
PM10 NO3 and NH4



Model doesn’t differentiate coarse versus fine, so this is all nitrogen

It’s very hard to get N aerosols right without thermodynamic model which was not in Vira et al., 2021.

Most areas of the globe or even of land have no data



Red: only PM, blue/purple also composition

3% of land is covered by observations of aerosol.

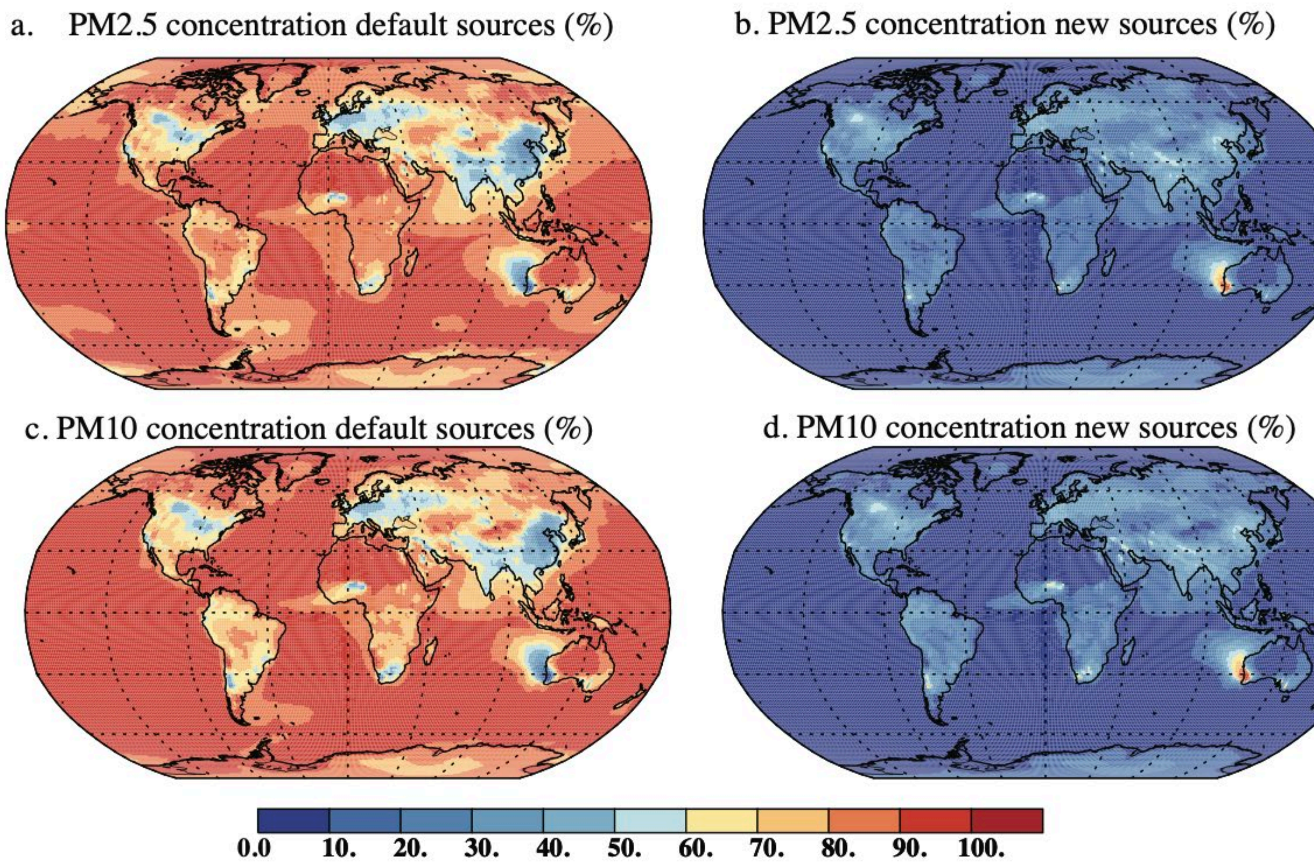
Surface aerosol amount and important composition is not well measured.

Cannot get composition from remote sensing.

N aerosols are going up, sulfate down: don't know where they are (Adams et al., 2001; Bauer et al., 2007)

Need more in situ data.

CESM does not include many important aerosols



- Most important: N aerosols: need for climate simulations
    - 30% of aerosols
    - Have different trends (upward due to land use) than sulfate (downward due to less fosssli fuels)
- Also: agricultural dust important to include
- (other additions didn't matter as much: road dust, coarse mode EC/BC, PBPs…)

Summary conclusions

- New annual compilation for use in comparing model aerosols to data
  - Much more data in non-US and non-European areas in this compilation
- Temporal variability will be next! (other ideas: glad to collaborate)
- Includes composition data as available
- **Need more in situ data to constrain current distribution of aerosols**
- **Models need to include N aerosols and agricultural dust or they are missing important aerosol trends.**
- (Aerosols even more unconstrained if we look farther back then 1980: see Mahowald et al., 2024, ACP).