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

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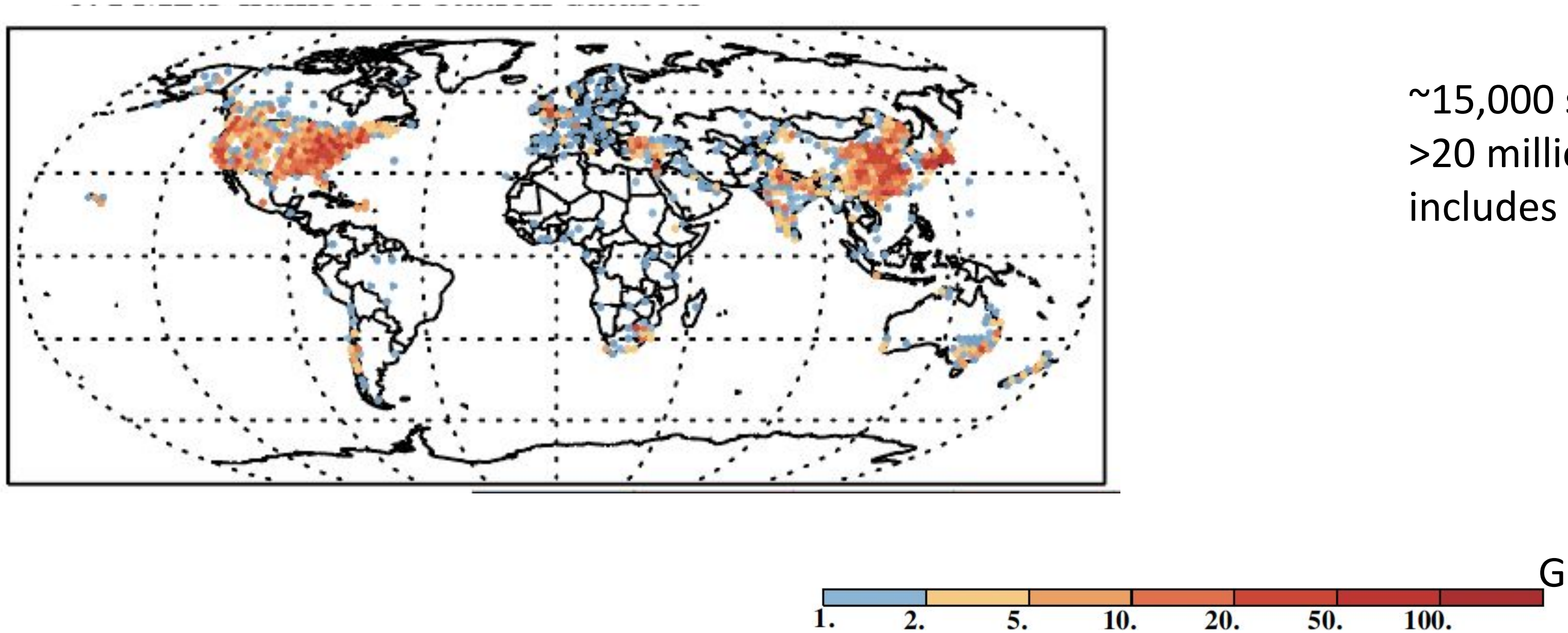
Under review:
ACPD:https://egusphere.copernicus.org/preprints/2024/egusphere-2024-1617/

~15,000 station datasets
>20 million obs
includes data outside of US and Europe

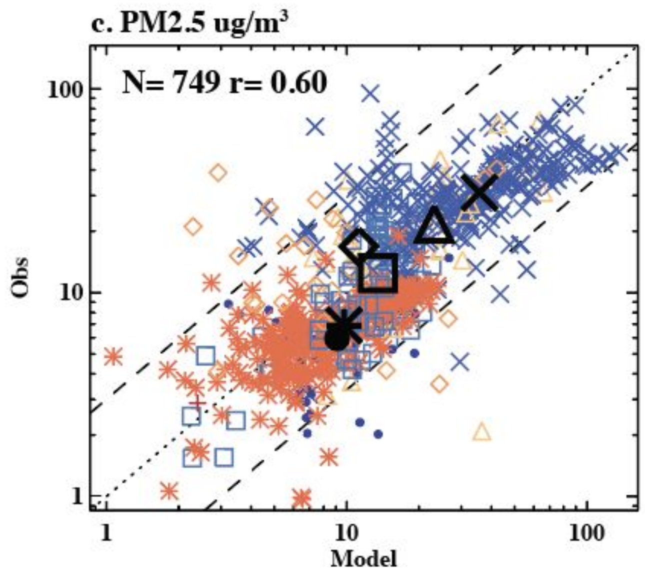


Grided to 2x2 so we can see

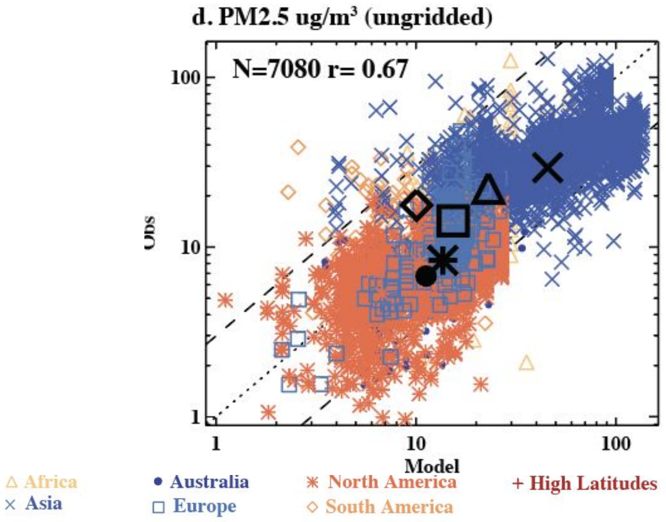
Goals:

1)identify and compile aerosol datasets
2) understand spatial distribution (temporal)
3) easy to use dataset for modelers

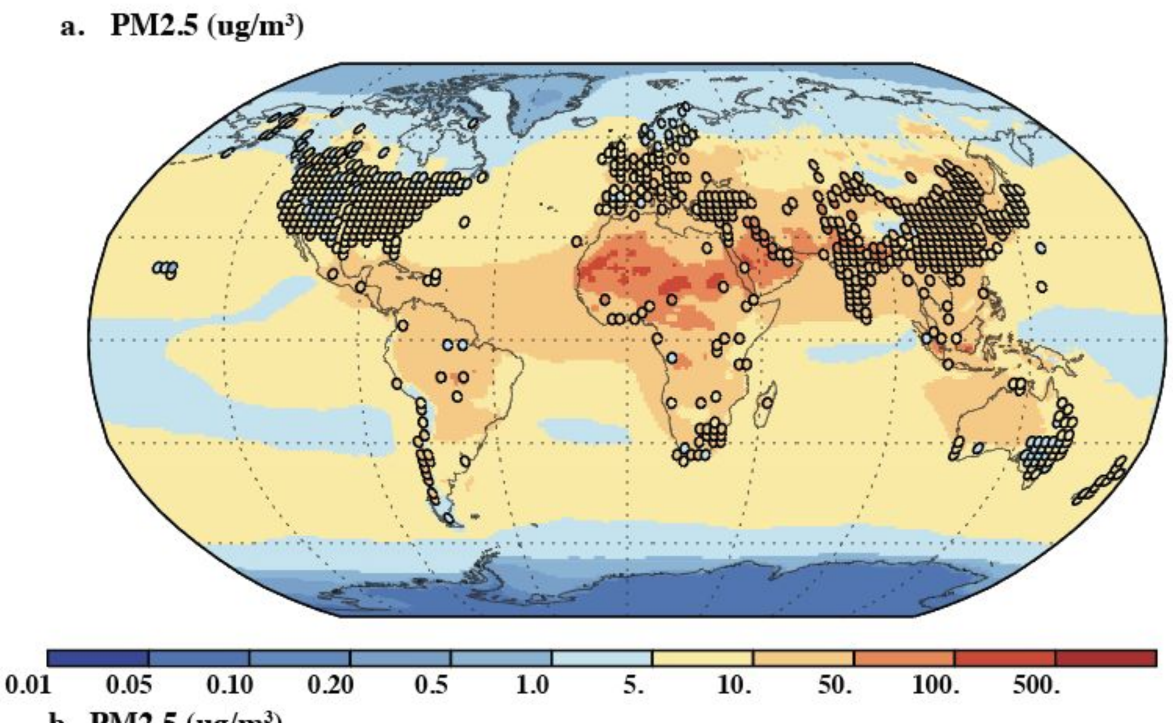
Gridded comparison



ungridded comparison



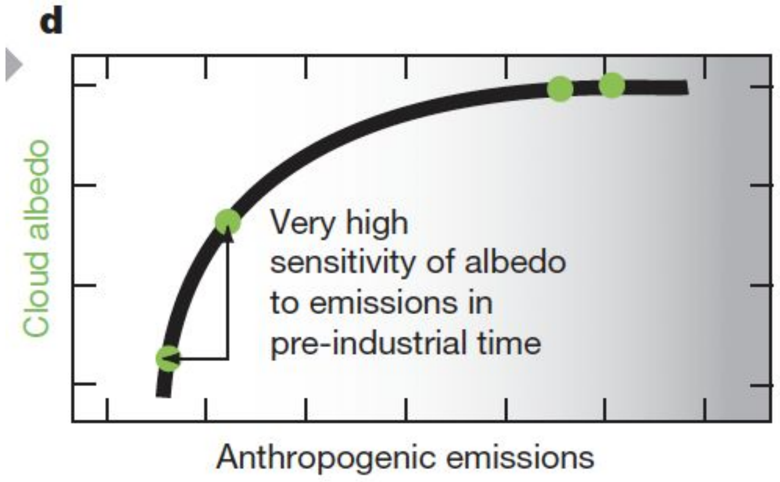
bold black symbols are regional averages



Modeled range in values: 3-4 orders of magnitude

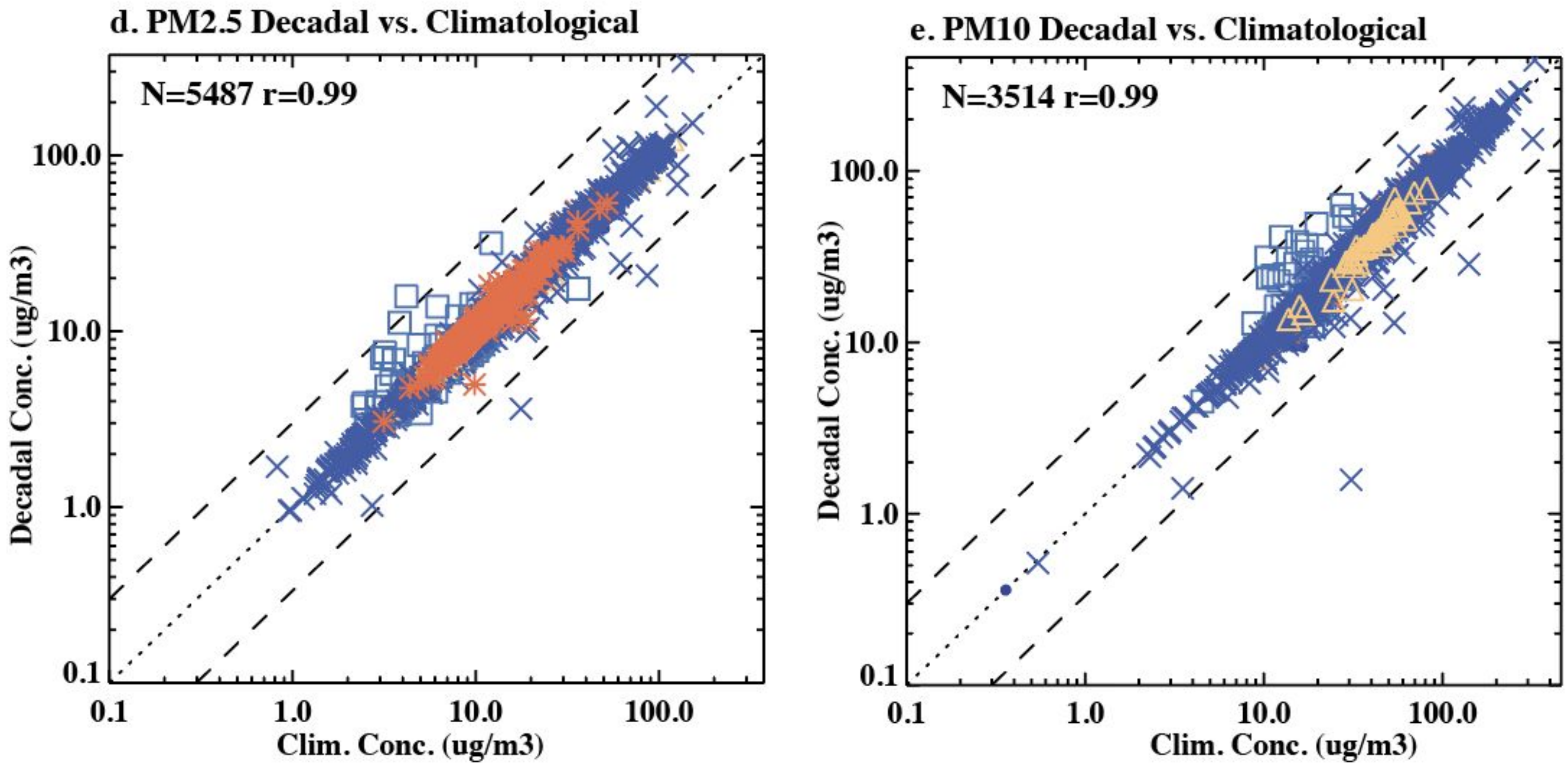
Complimentary dataset to satellite and ground based remote sensing

- Surface concentration measurements available during cloudy time periods (remotely sensed products have large uncertainties in the presence of clouds: Marshak et al., 2021)
- Surface concentrations provide composition (only available for very large AODs in AERONET)
  - Important for sign of radiative forcing (BC vs. OC)
  - Important for knowing composition which gives trends (industrial SO4 versus agricultural NOx)
- Need surface concentrations for air quality studies.
- Surface concentrations can detect low versus very low concentrations (important for aerosol-cloud interactions in remote regions.)



Carslaw etal., 2013

Is a climatology (1986-2023) different than decadal average (2010-2019)? No

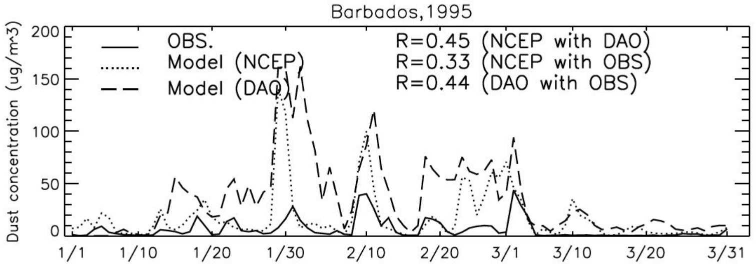


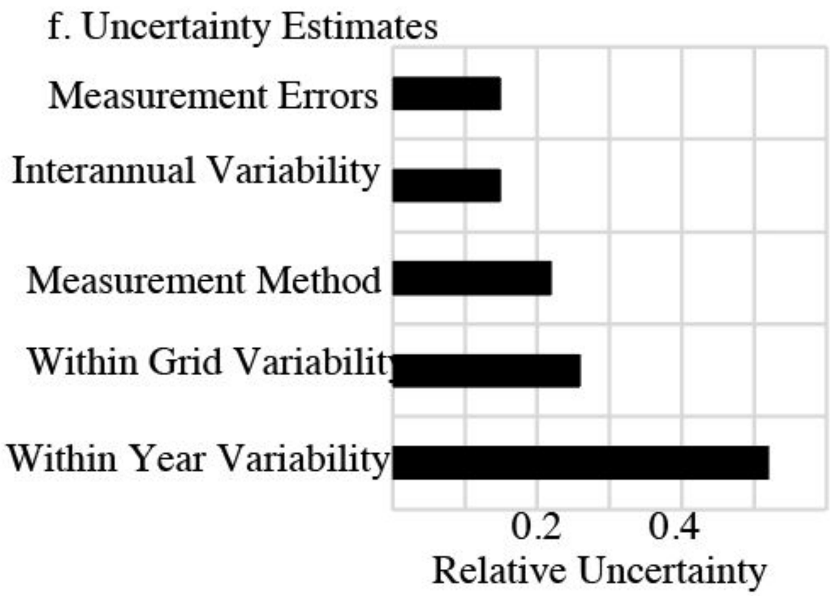
Very important climatic trends (a few pecent per year) are not important for spatial variability comparisons across multiple orders of magnitude

Sources of uncertainties based on PM2.5 in data

- Normalized Std Dev
  = Std Dev/mean
- To evaluate interannual variability (IAV), stations > 10 years of data
  - Calculate with same data, IAV and within year variability
  - Also measurement errors (not all have them)
- For within grid variability, use 2x2 grid box, and calculate mean and std.
- Between network measurement differences: use CSN versus IMPROVE (Hand et al., 2017): 0.30
- Total: 0.6 normalized standard deviation: Factor of ~3

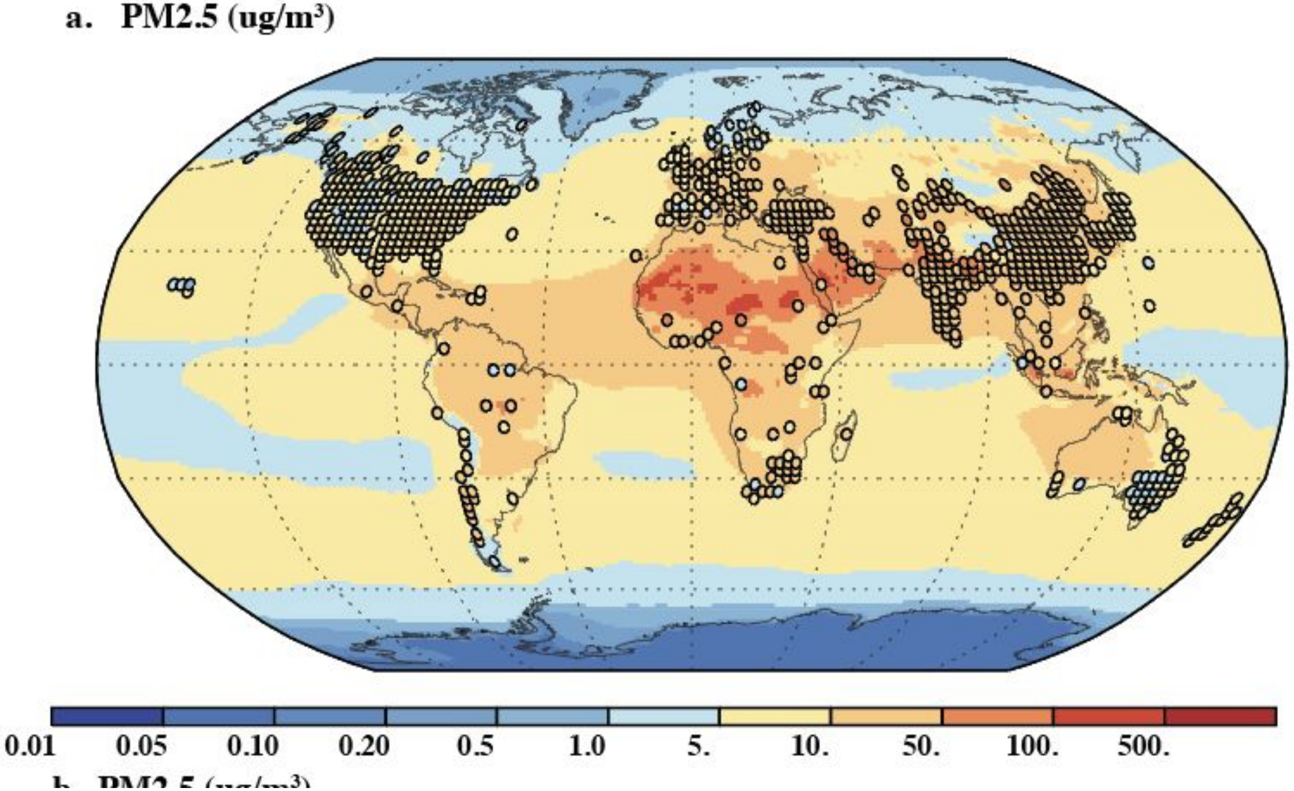
Aerosols come in pollution events





Dominated by within year (month) variability and within grid variability

PM2.5 compare to CAM6.1



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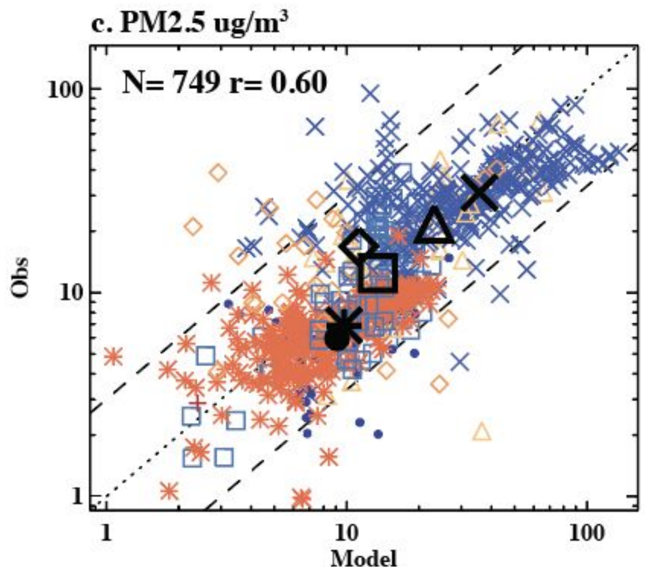
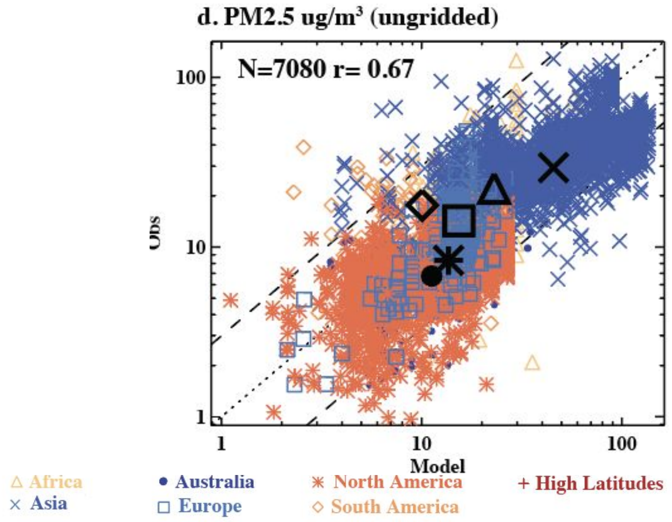
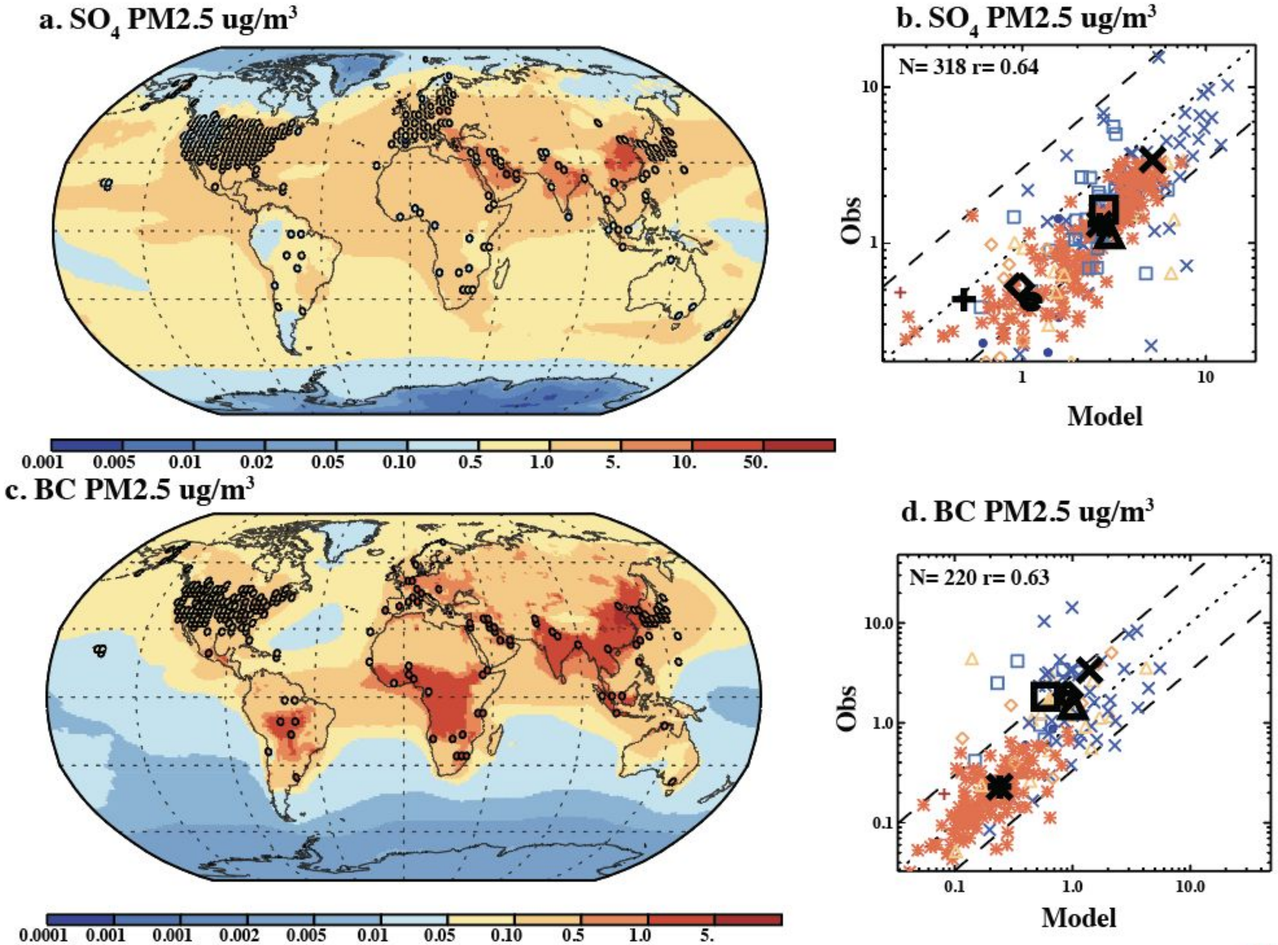


ungridded comparison



bold black symbols are regional averages

Compare by constituent as well: SO4 and BC

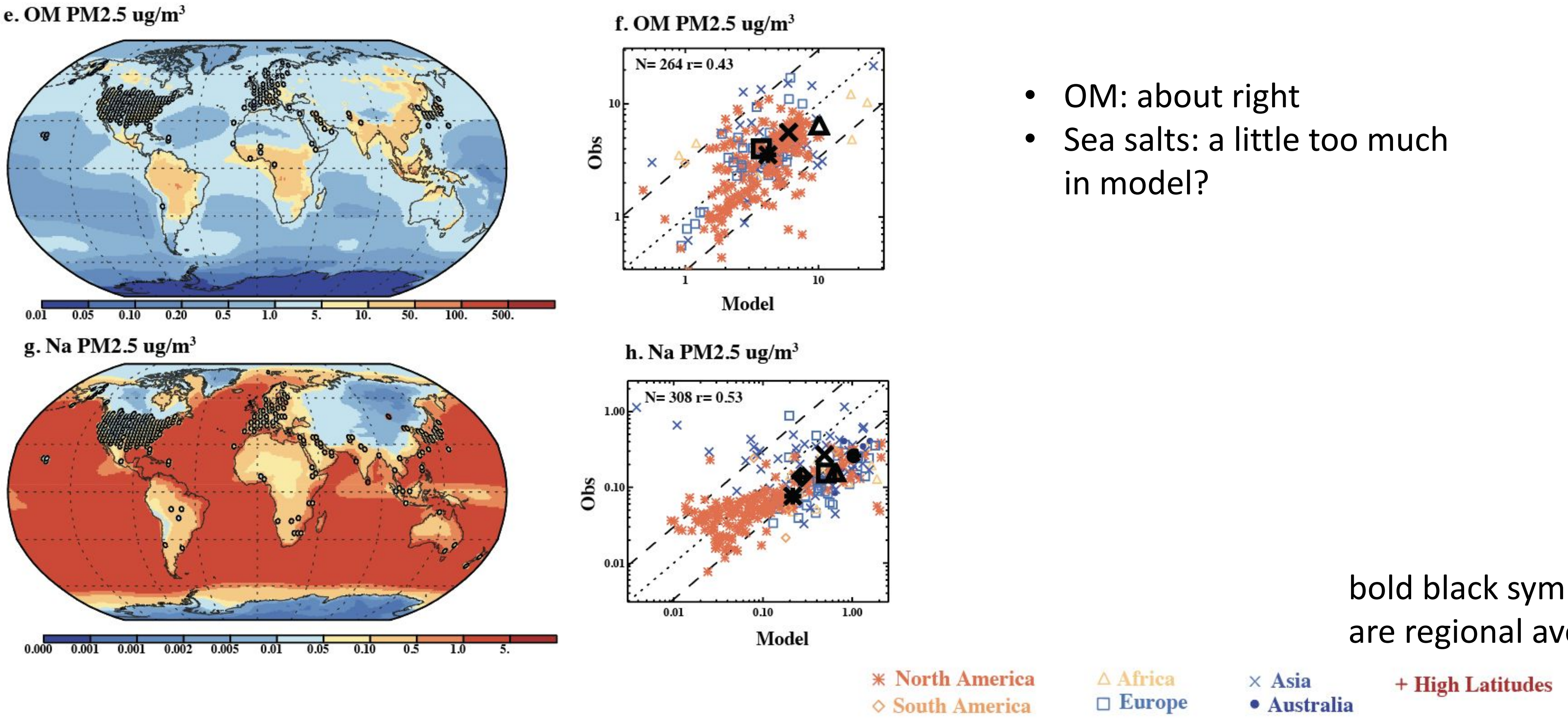


- Much less data for constituents than total mass in PM2.5
- Model SO4 too high in some regions
- BC/EC maybe a little low

- Much less data than PM

bold black symbols are regional averages

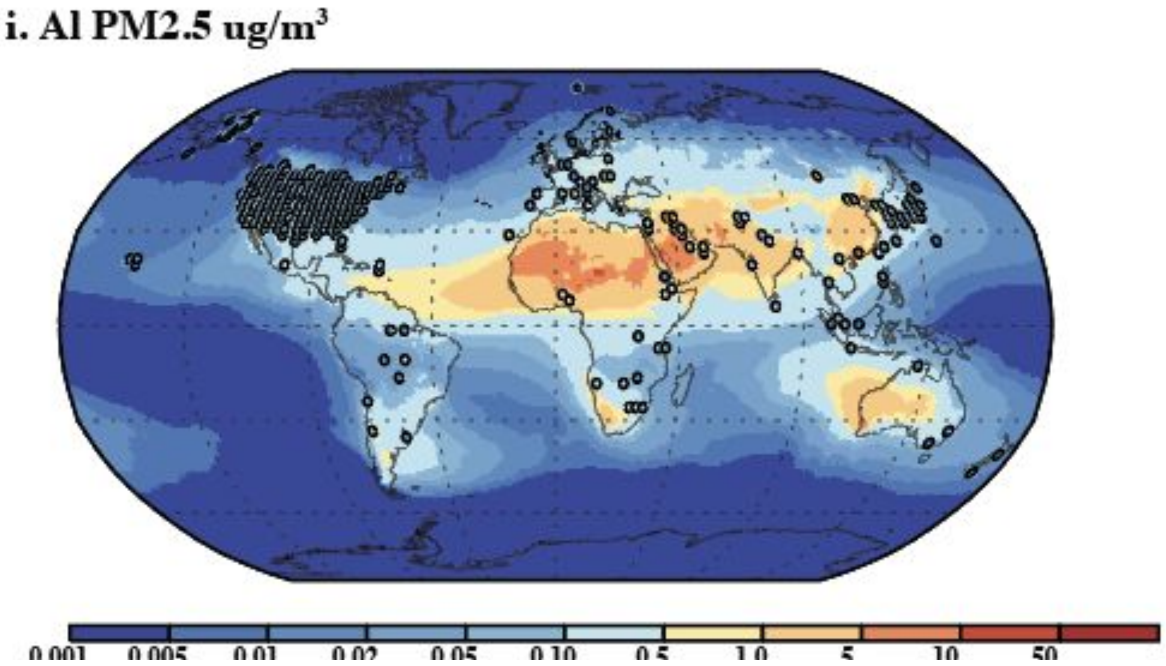
OM and sea salts (Na)

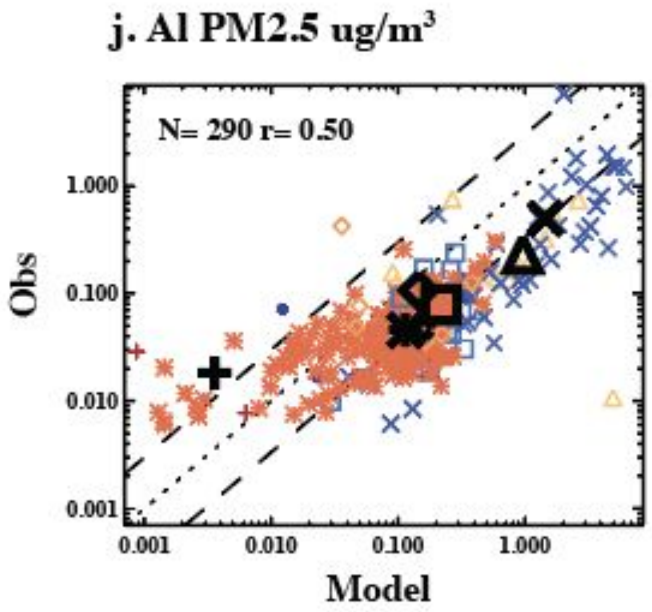


- OM: about right
- Sea salts: a little too much in model?

bold black symbols are regional averages

PM2.5 constituents: dust (Al)

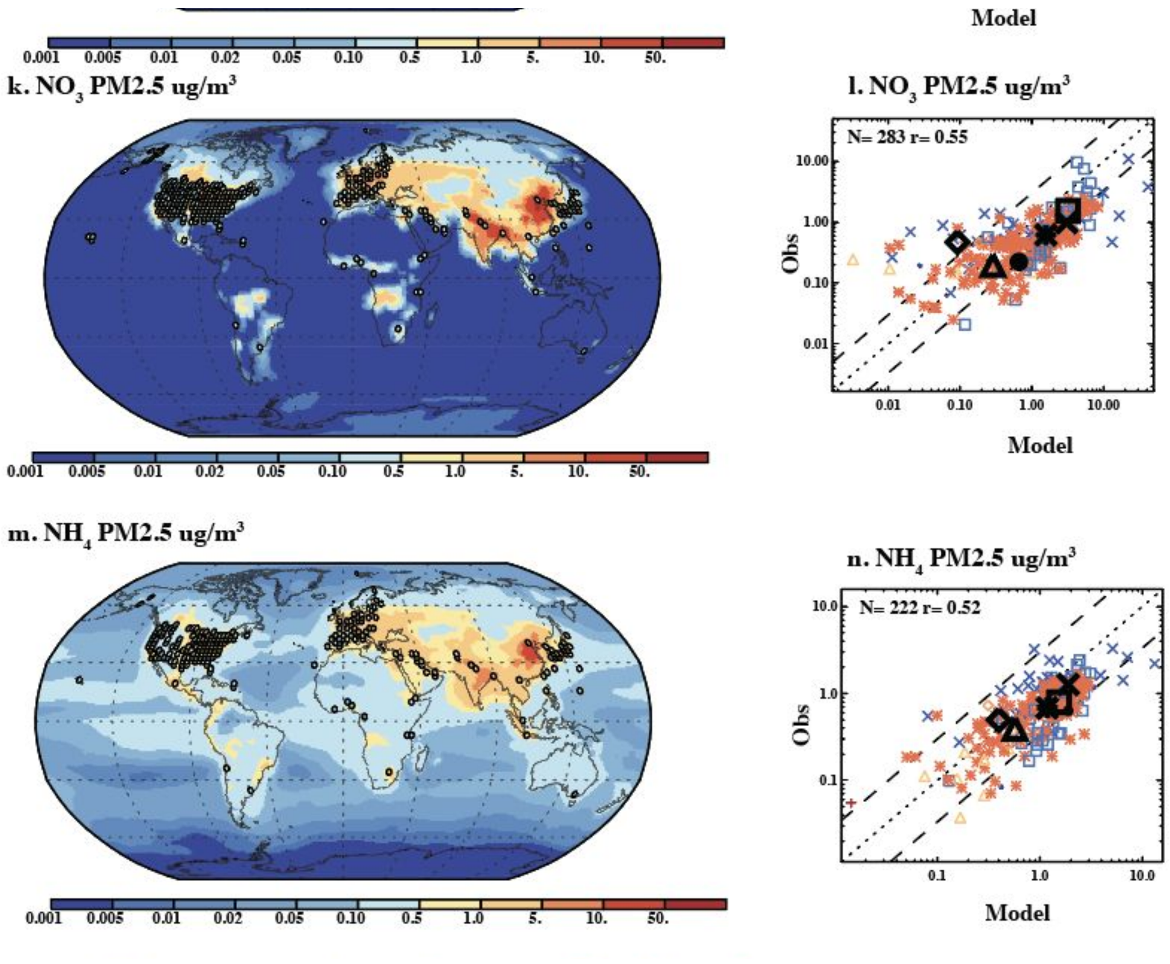




- Dust a little high here
- (like CESM many dust models can't match surface concentrations, AOD and deposition at the same time: Huneus et al., 2009.

bold black symbols are regional averages

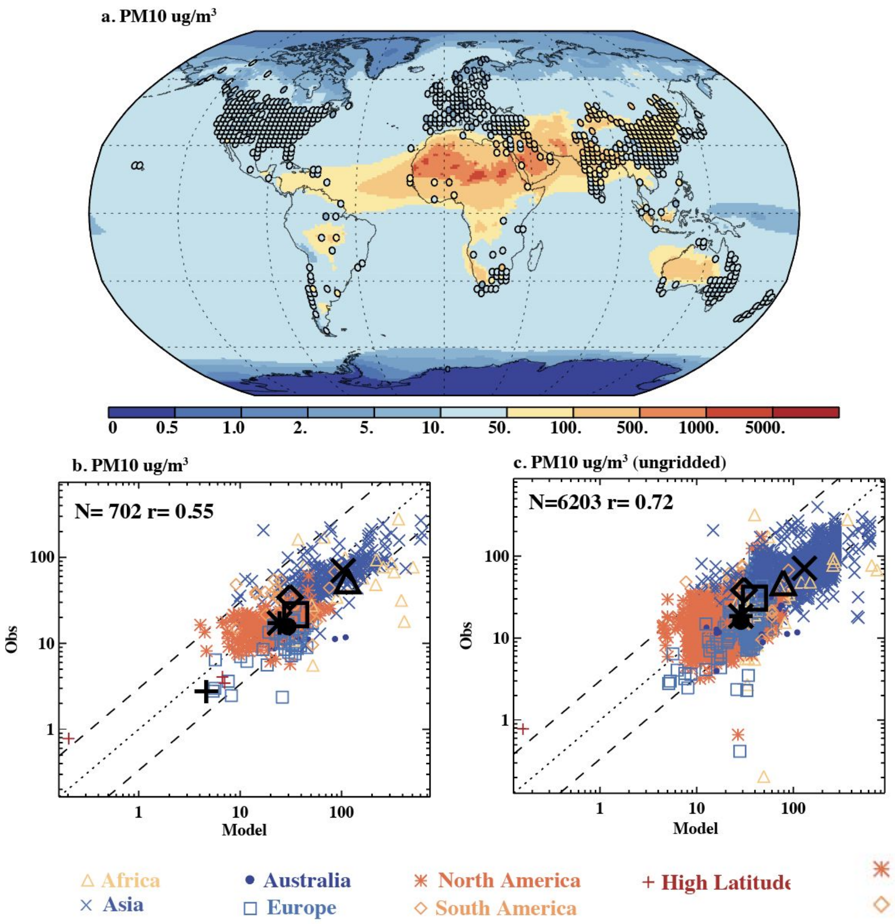
PM2.5 Nitrogenous aerosols



- Not included in CAM6.1: needed to add from chemistry model runs(Vira et al., 2021)
- Overpredicts NO_3 (likely because no thermodynamic model)

bold black symbols are regional averages

Similar information for PM10 (although there tends to be less composition data)



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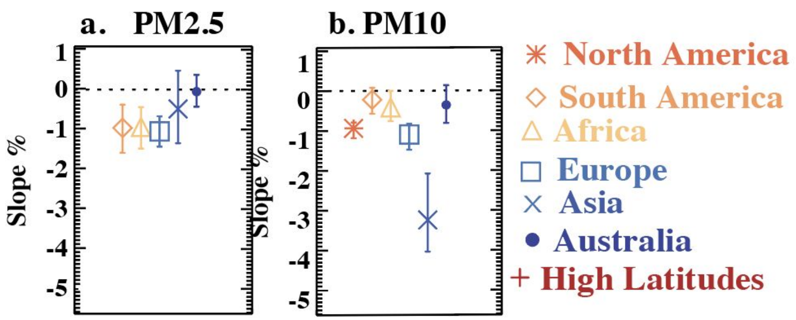
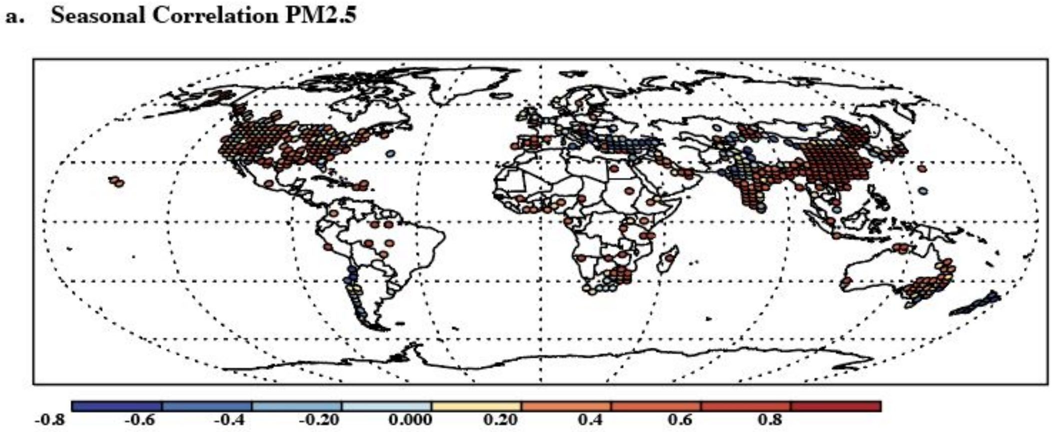
Datasets include temporal variability

- Annual averages for each year for each variable are in the dataset



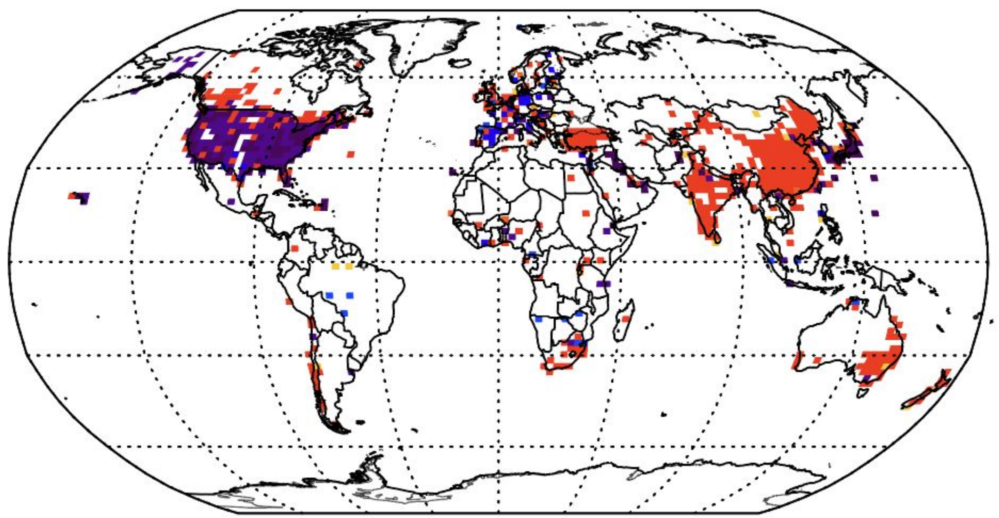
- Trends per year (1-sigma) using Thiel-Sin method
- 2001-2023

- Climatological monthly means also provided



Here used to correlate between model and observations to see if seasonal cycle simulated: mostly true but some regions with bias

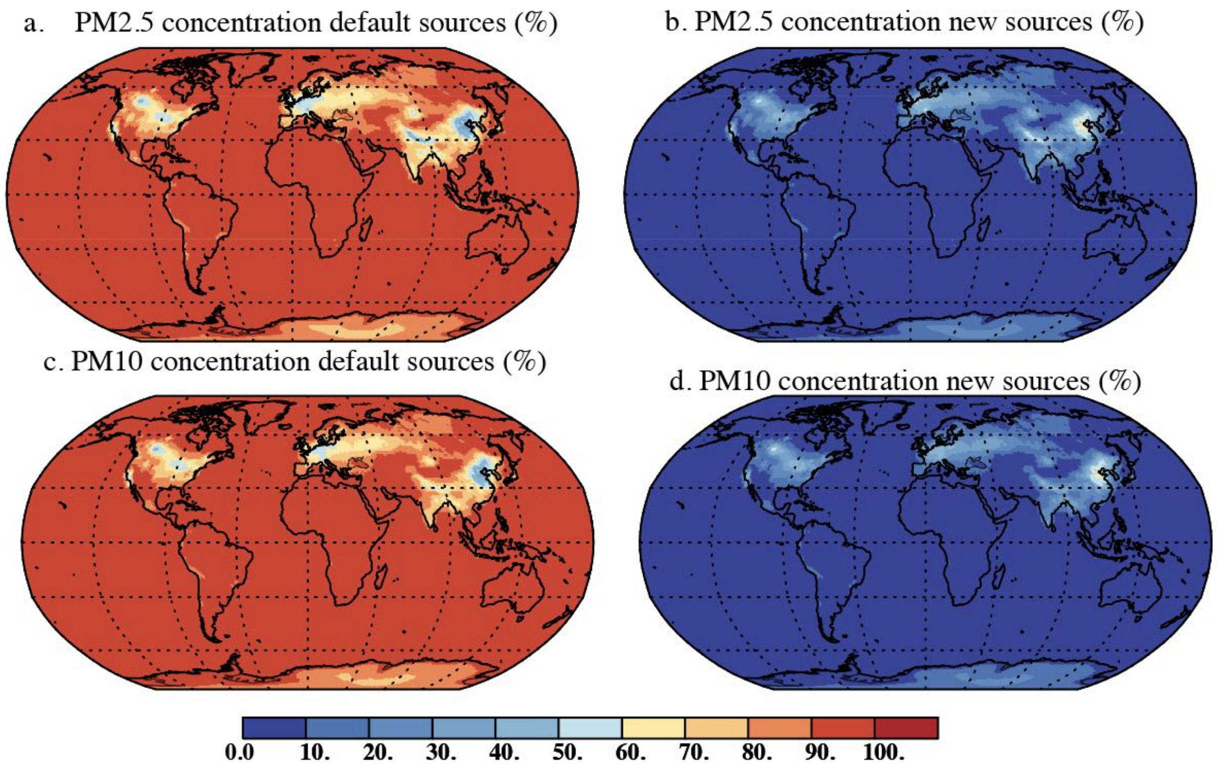
Most areas of the globe or even of land have no data



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 (unless AOD>0.3)
- 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 in same places we need more satellite data (e.g. Millet eta l., 2024)

CESM does not include NOx: could cause bias in trends?



- Most important: N aerosols: need for climate simulations
    - 10% of global amount aerosols
    - Regional can be 50% for large areas
    - Have different trends (upward due to land use) than sulfate (downward due to less fosssli fuels)

Summary conclusions

- New compilation for use in comparing model aerosols to data
  - Identifies data sources
  - Much more data in non-US and non-European areas in this compilation
- Includes composition data as available
- **Need more in situ data to constrain current distribution of aerosols**
- Models need to include N aerosols or they are missing important aerosol trends.