Pacific Northwest
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How Models Use (or Don't Use) Measurement Uncertainties

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Integrated Cloud, Land-Surface,& Aerosol System Study
ICLASS

ASR
Atmospheric System Research

Caveat: opinions expressed in this presentation are mine alone

Accounting for Measurement Uncertainty

- Modelers (mostly climate modelers) often treat aerosol measurements as "truth" with little to no discussion about measurement uncertainty and how it might impact the conclusions of their studies.
  - *Some aerosol instruments/measurement have relatively more uncertainty*
  - *The same instrument operated by different people / organizations and procedures could produce different levels of uncertainty*
- What is most useful is a single number describing measurement uncertainty, i.e., ± X μg m^{-3} , ± X %, etc., (assuming random errors)
  - *Uncertainty that various in time or space would be harder to account for*
- If a modeling paper accounts for measurement uncertainty, it is usually done by adding error bars. But often omitted if plots get too "cluttered / busy".
- Reviewers could/should ask for this information, but often do not
  - *An issue for the modeling community as a whole*

Example: MAM4 Development

Geosci. Model Dev., 9, 505–522, 2016
www.geosci-model-dev.net/9/505/2016/
doi:10.5194/gmd-9-505-2016
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Description and evaluation of a new four-mode version of the Modal Aerosol Module (MAM4) within version 5.3 of the Community Atmosphere Model

X. Liu[1,a], P.-L. Ma[1], H. Wang[1], S. Tilmes[2], B. Singh[1], R. C. Easter[1], S. J. Ghan[1], and P. J. Rasch[1]

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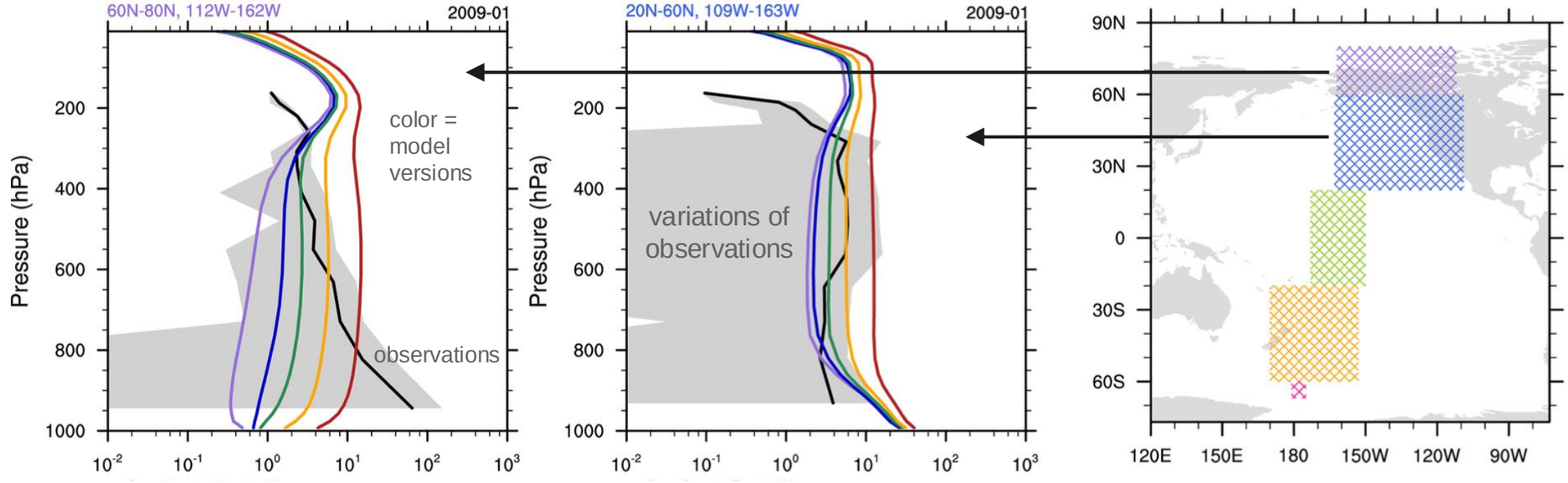
Documentation of the current version of the Model Aerosol Model (MAM) now used in E3SM

Focuses on BC predictions since model parameterizes chemical aging to include hydrophobic and hydrophilic BC

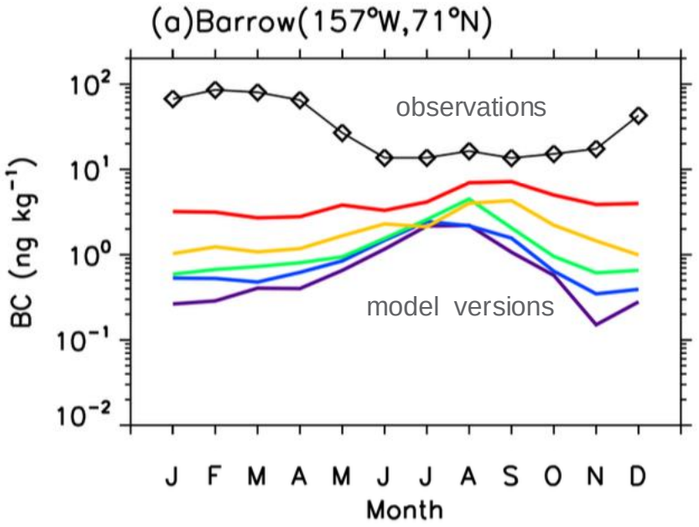
- Aircraft (7 campaigns) and surface observations (4 sites) used to evaluate aerosol predictions
- No mention of measurement uncertainty of BC measurements
- BC instruments likely different between aircraft campaigns and various measurement sites, so measurement uncertainty likely different as well

Example: MAM4 Evaluation



portion of HIPPO flights

model means over a box, but aircraft over flight track



- Would be useful to include error bars quantifying measurement uncertainty, but in this case model errors are likely much larger than measurement uncertainties
- Not sure that cut-off sizes were for the BC instruments, and how that was accounted for when comparing with predictions

Example: E3SM Diagnostics

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Earth System Model Aerosol–Cloud Diagnostics (ESMAC Diags) package, version 1: assessing E3SM aerosol predictions using aircraft, ship, and surface measurements

Shuaiqi Tang[1], Jerome D. Fast[1], Kai Zhang[1], Joseph C. Hardin[2], Adam C. Varble[1], John E. Shilling[1], Fan Mei[1], Maria A. Zawadowicz[3], and Po-Lun Ma[1]

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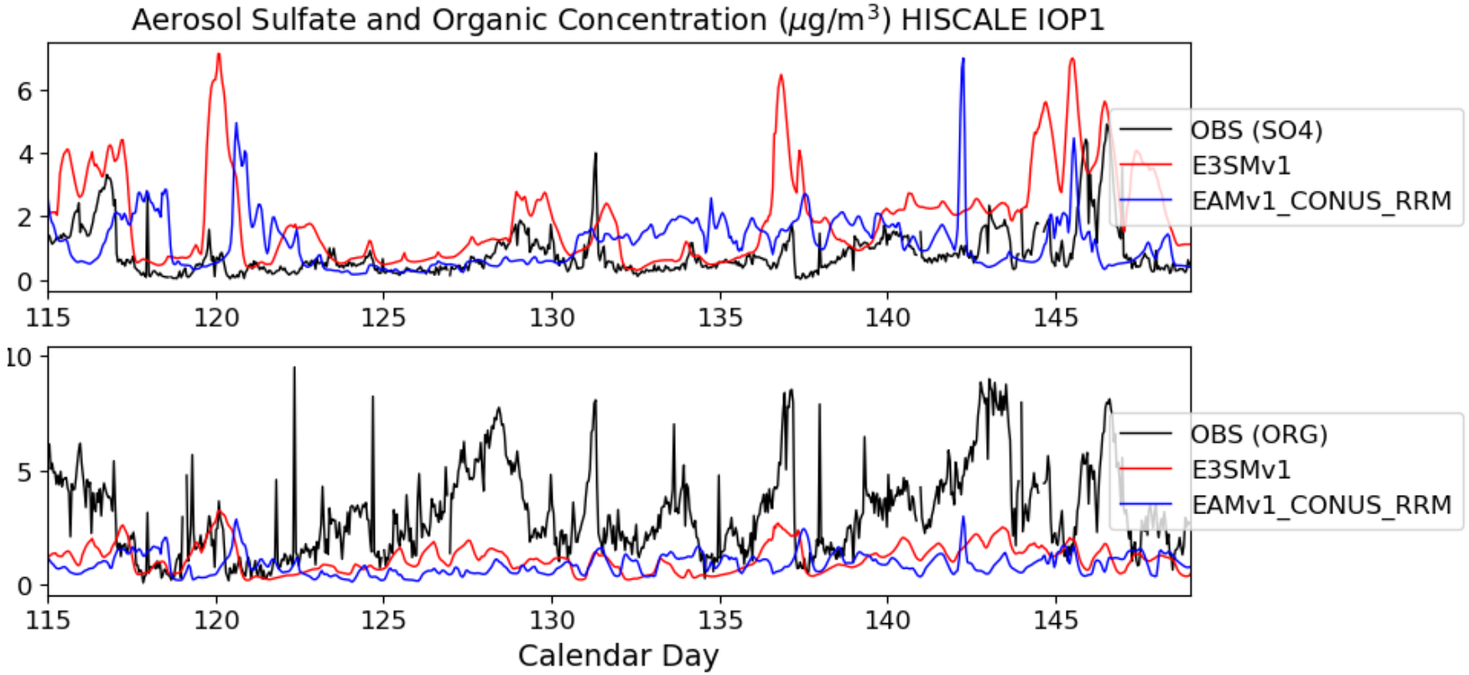
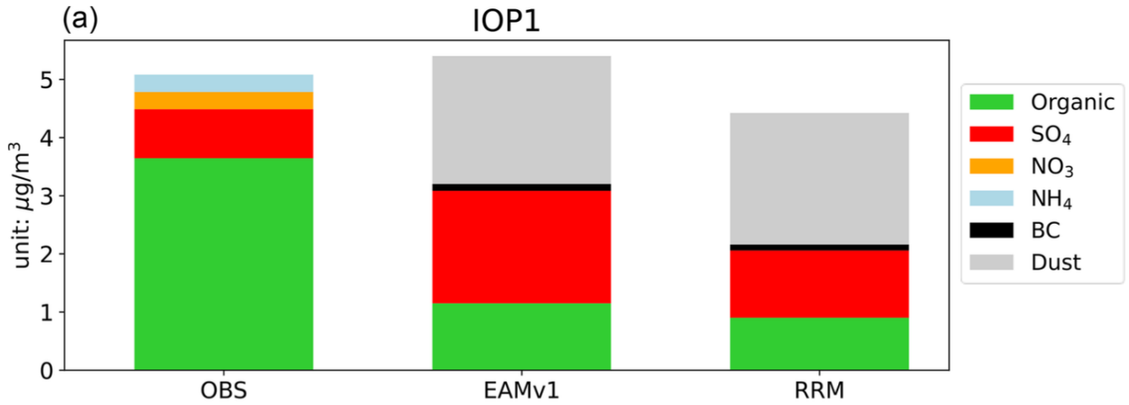
Documentation of new E3SM diagnostics package using ARM data

Version 2 now available that includes ACI metrics

- Series of aircraft, ship, and surface "simulators" and automated statistics and plots
- Creates apples-to-apples comparisons, e.g., having same cut off sizes for ACSM measurements and predictions that use modal size distributions
- Does not account for measurement uncertainty. Assumes statistical measures of variation are larger than measurement uncertainty

Example: E3SM Evaluation



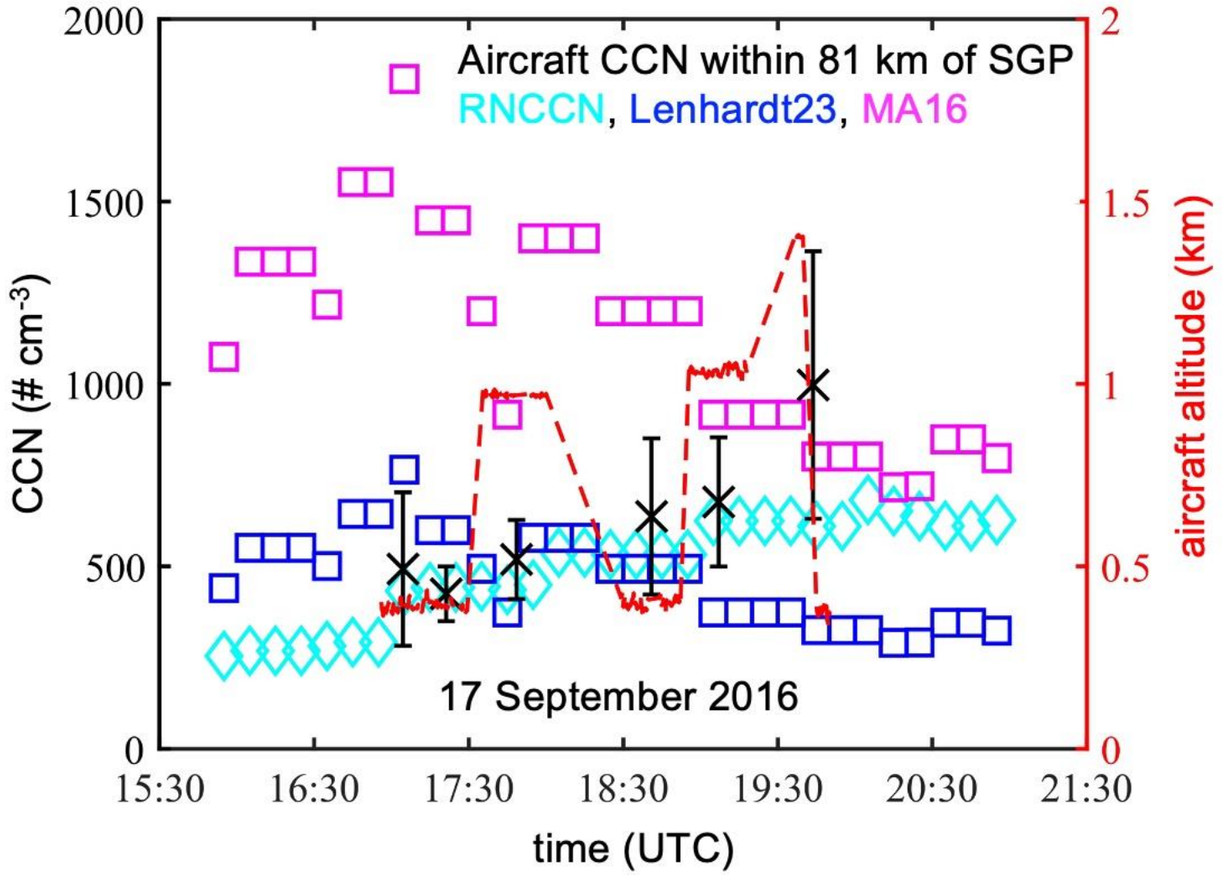


Plot generated by ESMAC Diags

- Comparison between ACSM and model predictions for HI-SCALE campaign
- Would be useful to include error bars quantifying measurement uncertainty (uncertainty due to spatial representativeness is another story)
- How does one best communicate measurement uncertainty in these types of plots that summarize all data?

Example: Derived Measurements

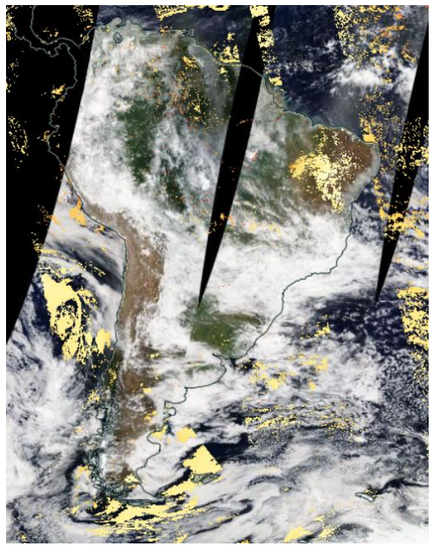
RNCCN Vertical CCN profile VAP evaluated against in situ CCN measurements

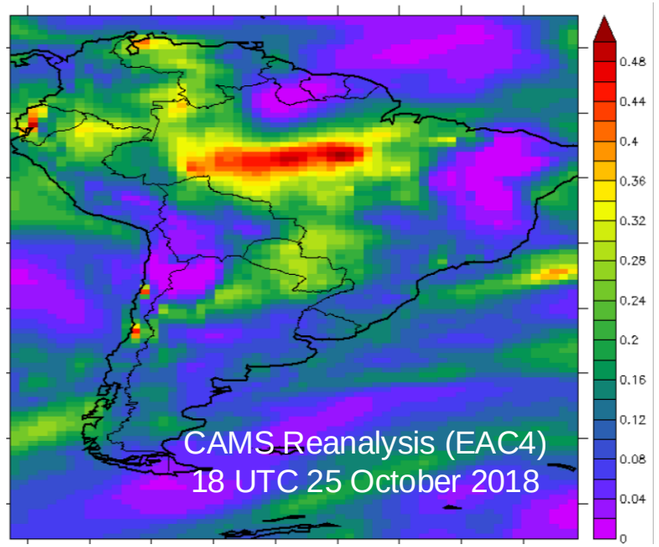


- Some VAPs are based on multiple datastreams, each with their own measurement uncertainty
- How is VAP uncertainty defined and is that more complicated for modelers to understand?

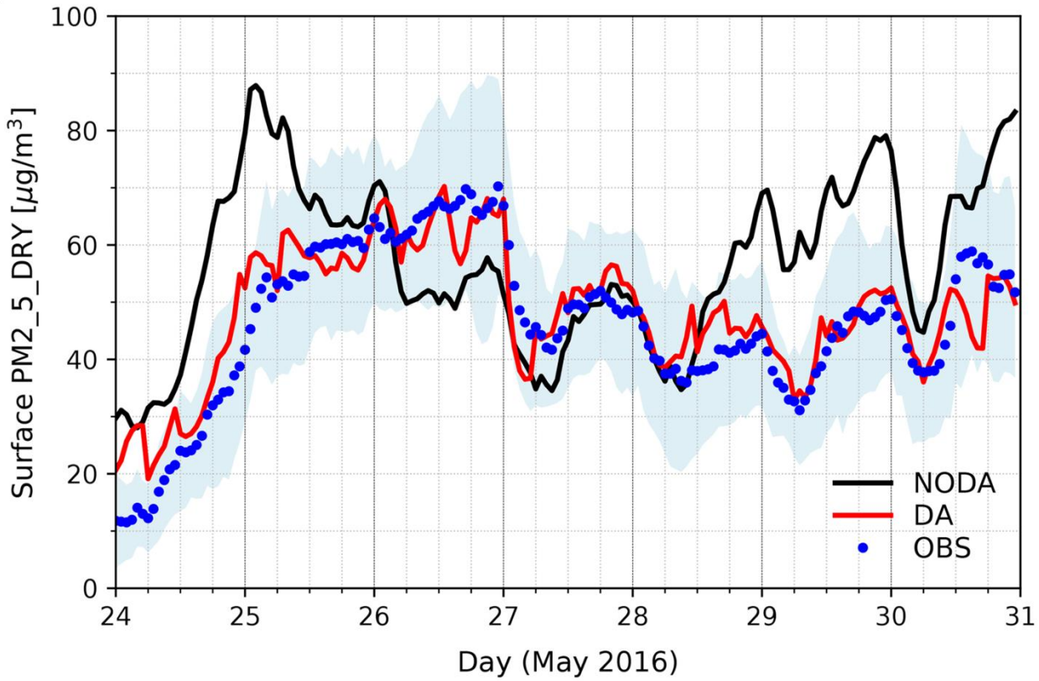
Data Assimilation

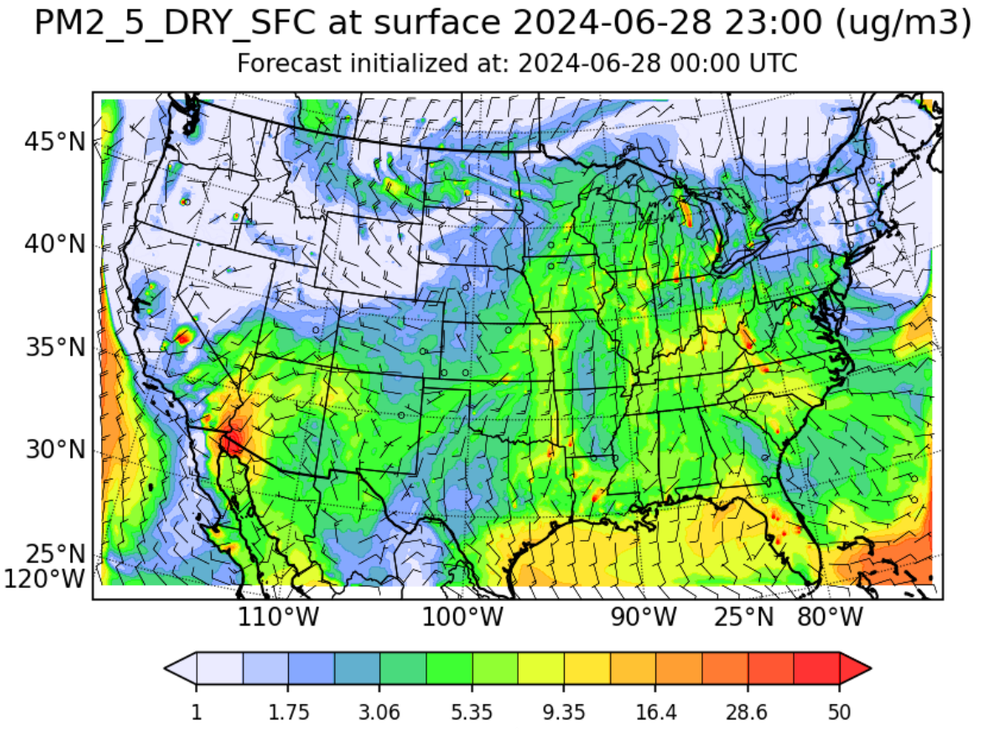
- Data assimilation (DA) approaches “nudge” model predictions towards observations
- Measurement (also spatial representativeness) uncertainty becomes very important when using DA … goes directly into complicated mathematical equations
- Weather models have sophisticated DA schemes that account for known measures of uncertainty for a wide range of meteorological instrumentation (in situ vs satellite)
- DA for aerosols is still in its infancy, in part because the spatiotemporal availability of aerosol measurements is far less than for meteorological quantities
- Some global aerosol models use DA using satellite AOD that subsequently makes assumptions to apportion AOD increments to aerosol specie mass
- Some groups exploring DA using surface PM2.5 networks

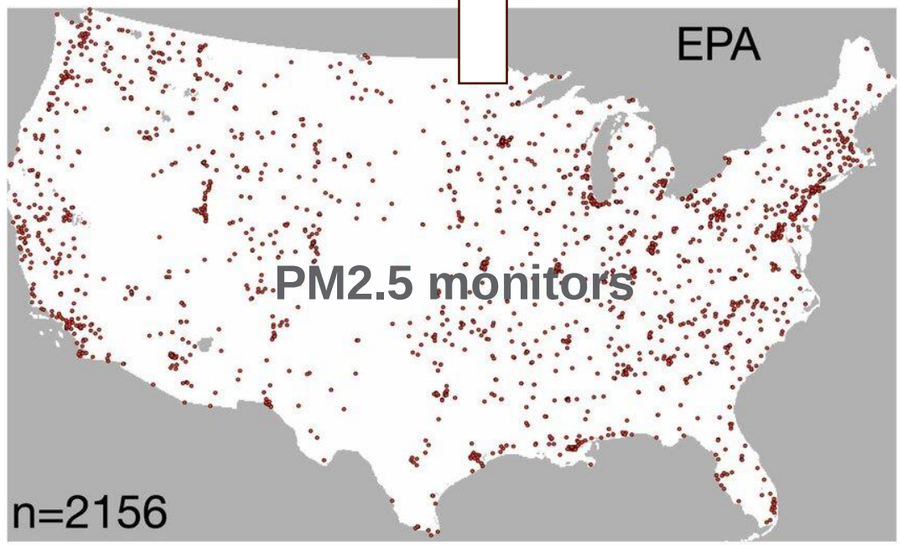




Example: WRF-Chem







- Assume DA improves PM2.5 prediction between observation stations
- Use DA to improve initial conditions or create aerosol analyses
- What happens above the surface?

What's the Future?

- Even though modelers do not use measurement uncertainty in their analysis as much as they should, having that information is still important
- Need to make measurement uncertainty easy to find
- Future DA efforts with aerosols will need this information

Note: Measurement Uncertainty ≠ Observational Uncertainty (which is often used by global modelers)

In journal articles, "observational uncertainty" often refers to variations of observations within a region … so it is more like a statement of spatial variability. This is used for meteorological quantities, but less so for aerosol properties.