Pacific Northwest
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Spatial Heterogeneity of Aerosols

August 15, 2023

Jerome Fast

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

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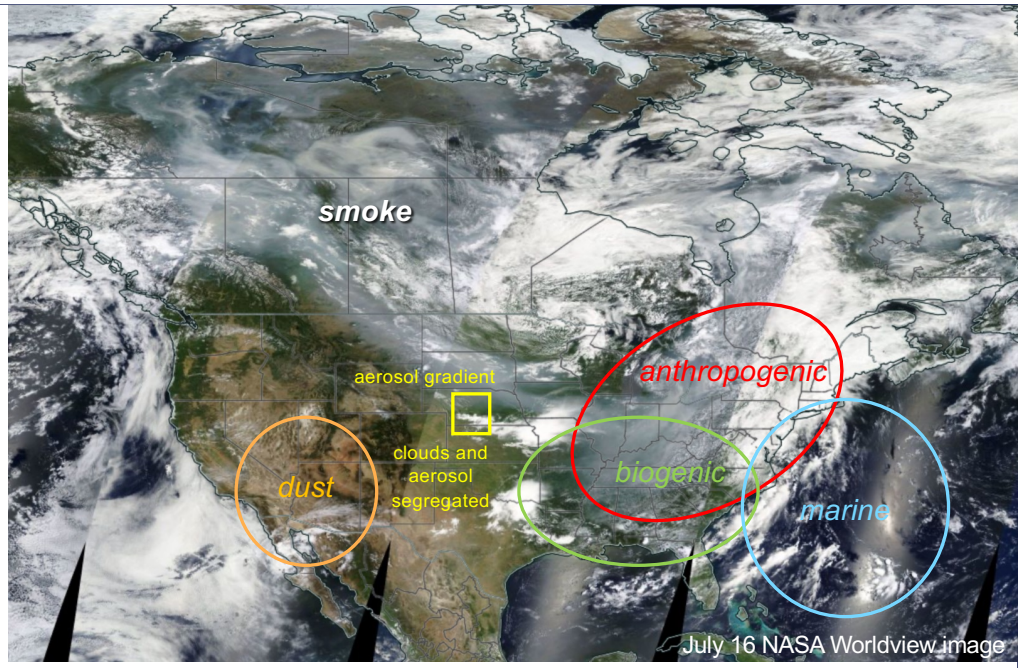
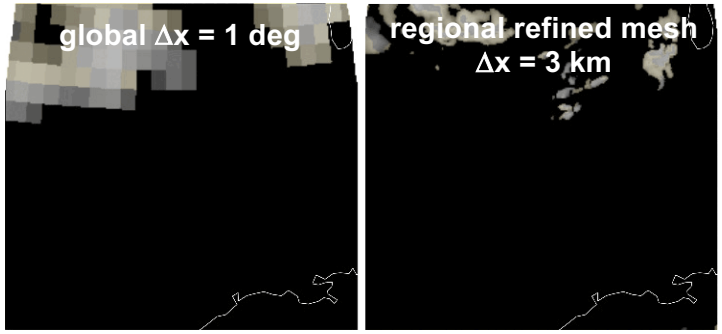
Motivation



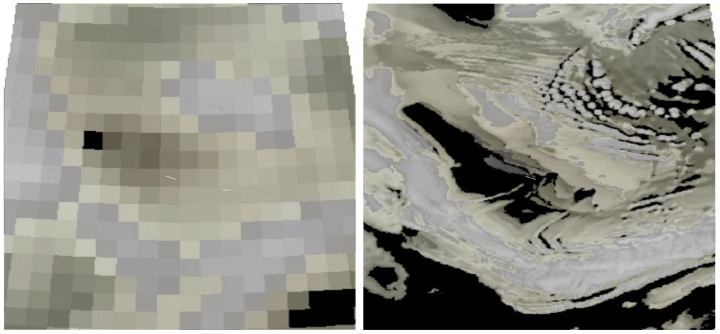
- Emissions, new particle formation, coagulation, condensational growth, chemical transformation, phase changes, turbulent mixing and transport, removal processes and ambient meteorology all contribute to **complex aerosol distributions**, but …
- Models assume aerosol properties **are constant** in a grid cell and ignore effects of subgrid-scale variability
- In contrast, many models account for subgrid-scale variability in clouds to a certain extent (e.g., cloud fraction)
- Therefore, what are the implications of employing coarse grid sizes and ignoring subgrid-scale variability on the overall **aerosol burden, lifetime, and radiative forcing**?

E3SM Simulated Spatial Variability

Central United States (CUS)



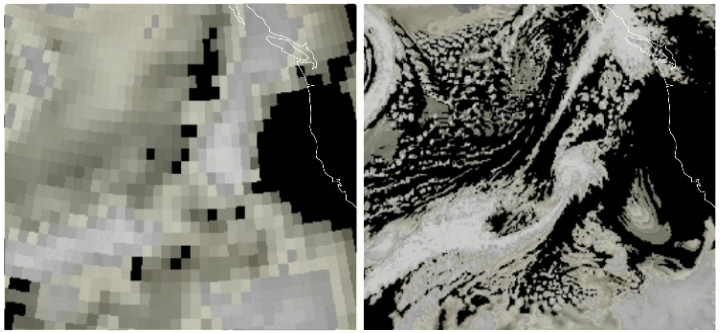
Eastern North Atlantic (ENA)



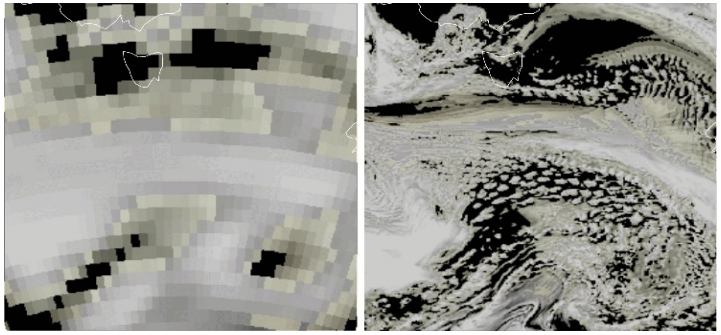
gray: cloud

tan: aerosol

Northeastern Pacific (NEP)



Southern Ocean (SO

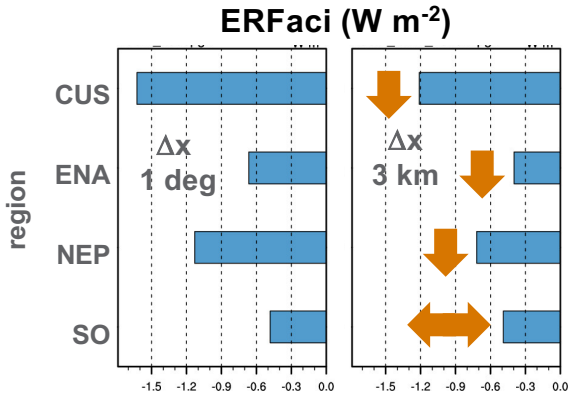


- Aerosols and cloud become segregated, especially for broken cells, which reduces ACI

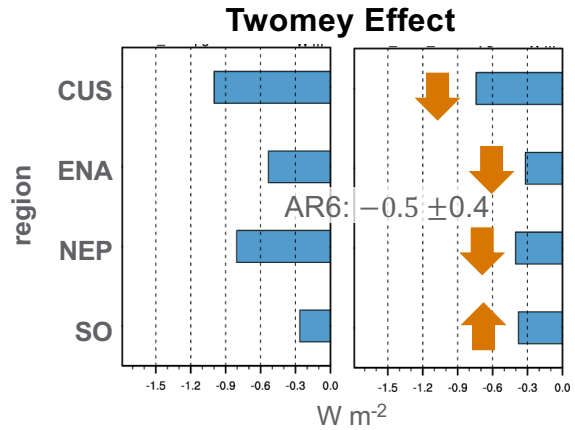
from EAGLES project, Po-Lun Ma

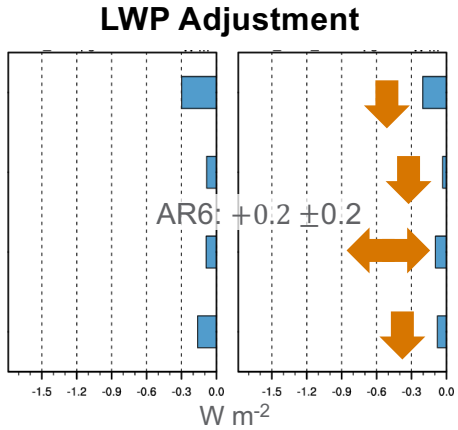
E3SM Aerosol Radiative Forcing

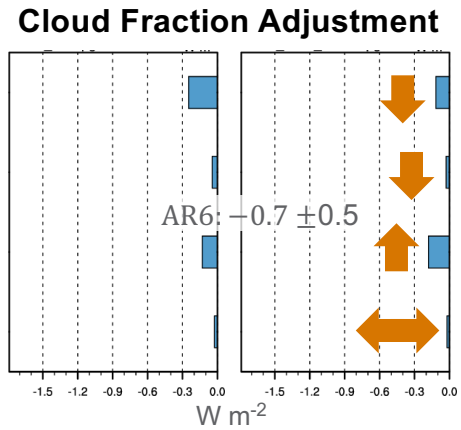
from EAGLES project, Po-Lun Ma, Johannes Muelmenstaedt



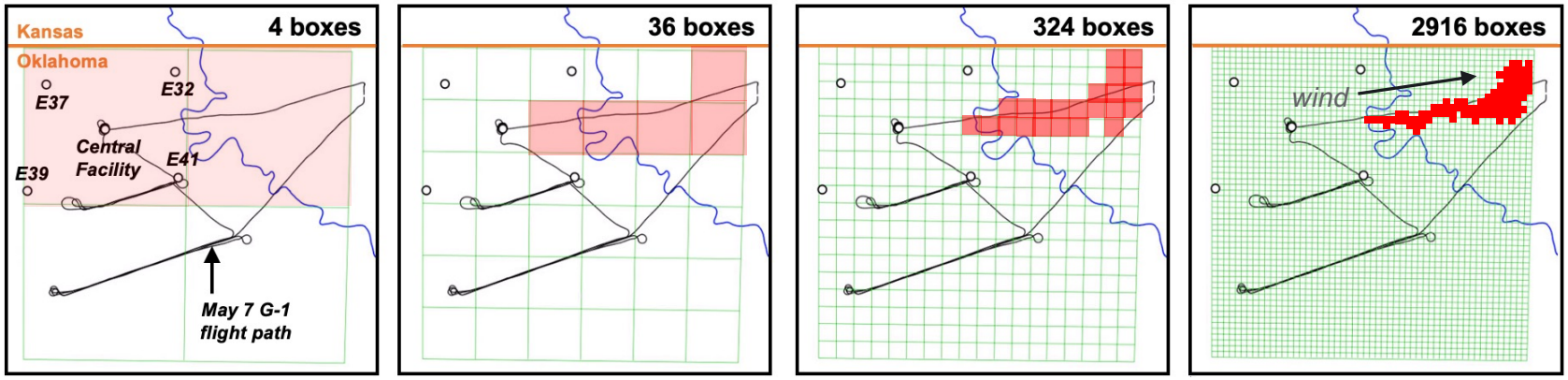
- E3SM v2 higher than most climate models: AR6 models = -1.0±0.7 W m^{-2}, but E3SM = -1.35 W m^{-2}
- Higher resolution reduces ERFaci from -1.35 to -1.0 W m^{-2}
- Decomposition of ERFaci suggest that the total might not be right for the right reasons, i.e., LWP adjustment is still the wrong sign.
- Increasing resolution helps ERFaci, but better physics is still needed
- What happens if Δx < 3 km?







Grid Resolution Affects Aerosol Processes



Δx = 81 km boxes
~ current climate models

Δx = 27 km boxes
~ near-future climate models

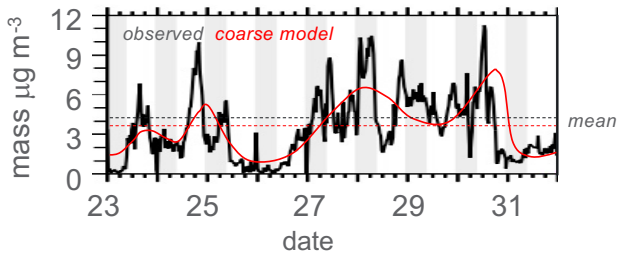
Δx = 9 km boxes
~ current global forecast models

Δx = 3 km boxes
"cloud-system resolving" model

- Emissions from point sources and/or small area sources will be artificially spread over a large area at coarse grid spacings, resulting in wider and more dilute plume with different chemistry than at higher resolutions
- For many reasons, aerosol chemistry will likely be different at low and high resolution
- Superimposing multiple point and area sources at various stages of aging will further complicate issues of scale

Model Evaluation

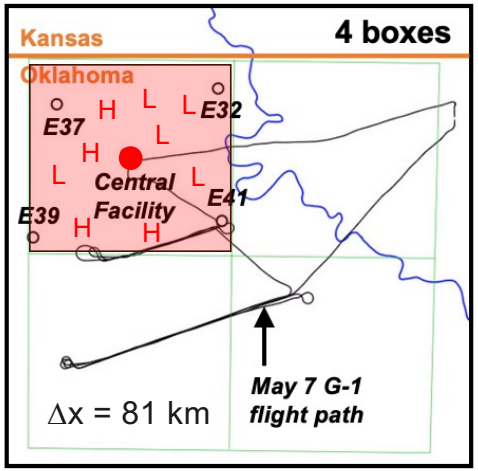
- What is the representativeness of point measurements?
  - Can we compare a grid cell average to a point measurement? This is done routinely, without much thought whether it is appropriate or not.
  - What grid cell size is appropriate to compare to a grid cell?
- How do we best evaluate aerosol models with variable resolution with various type of in situ measurements (i.e., ground, aircraft, ship)?

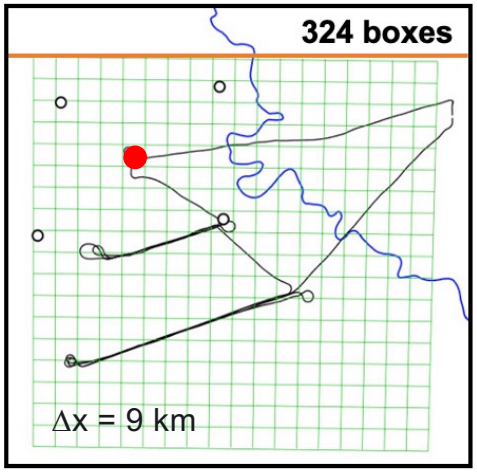


To reduce representativeness issues, climate models often compute long-term averages, but this ignores temporal variations that might be important.

High resolution model theoretically should be able to better represent spatiotemporal variability.

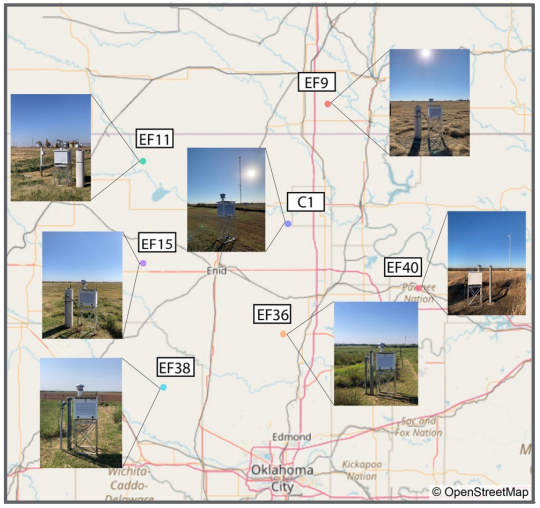
- Grid spacing and resolution is not the same!
  - Need multiple Δx to resolve aerosol variations





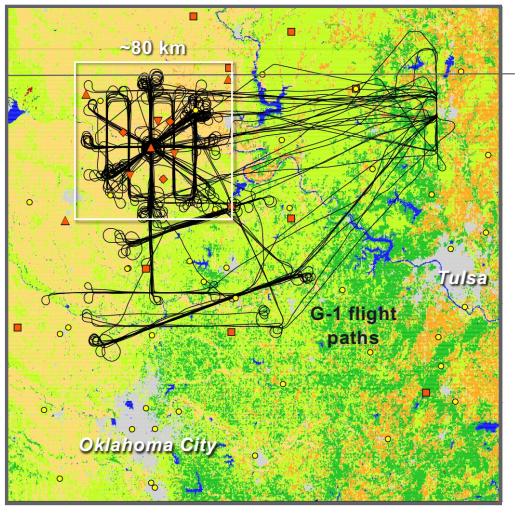
Using ARM Data to Characterize Spatial Variability

POPs Network



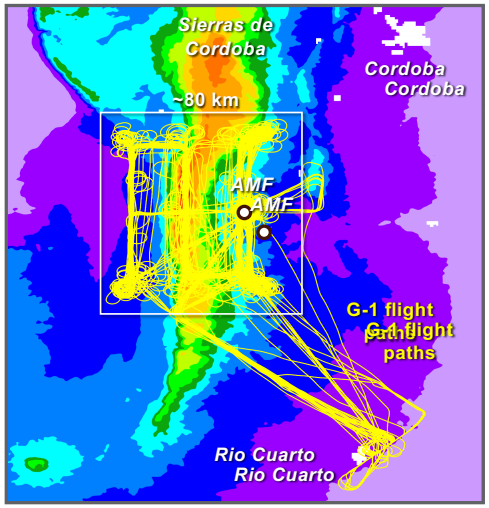
- POPs instruments at 7 sites
- *Asher et al. JGR, 2022*

HI-SCALE



- Ground and aircraft
- Large # of constant altitude flight legs
- *Fast et al. BAMS, 2019*

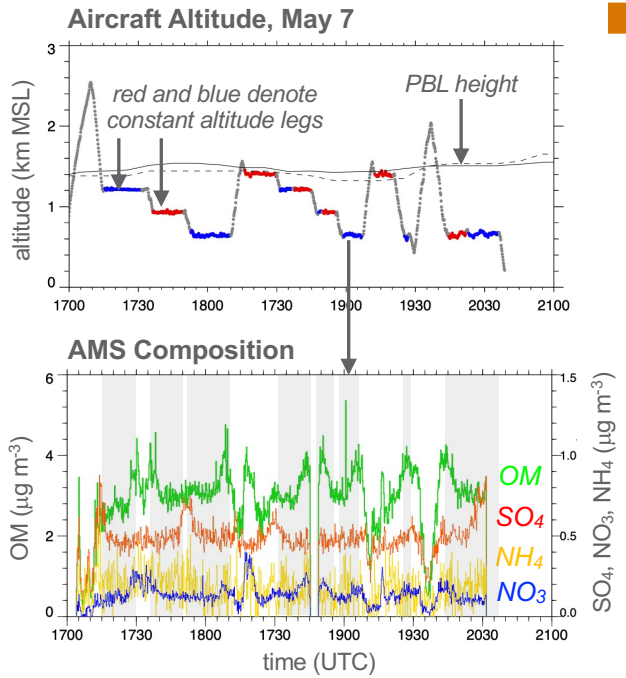
CACTI



- Ground and aircraft
- Large # of constant altitude flight legs
- *Varble et al. BAMS, 2021*

- Other past G-1 aircraft deployments assuming suitable flight paths
- Upcoming UAS and Bombardier deployments?

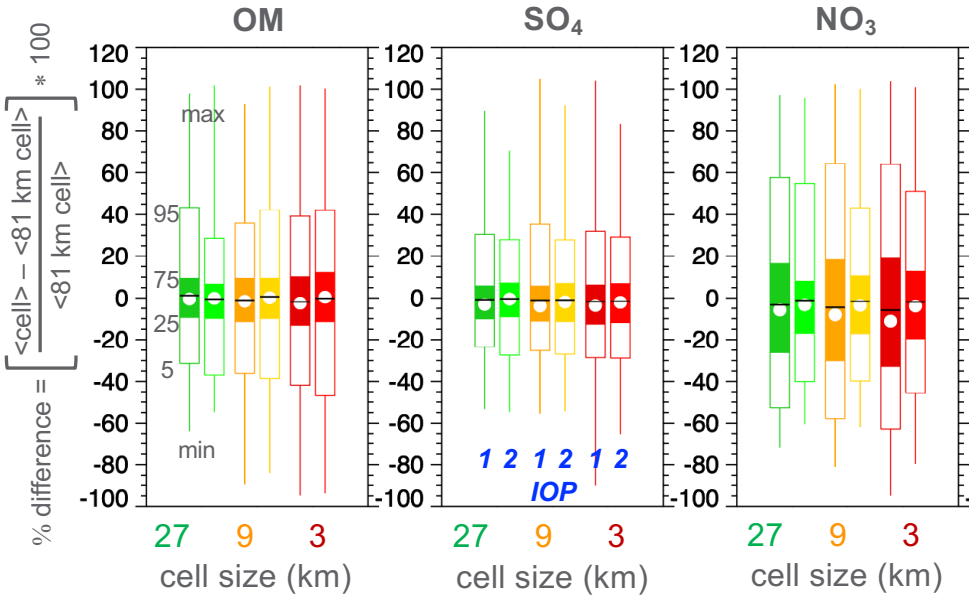
Spatial Composition Variability during HI-SCALE

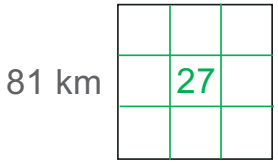


gray shading = constant legs within PBL

- Similar methodology applied to other aerosol properties (*Fast et al. ACP, 2022*)

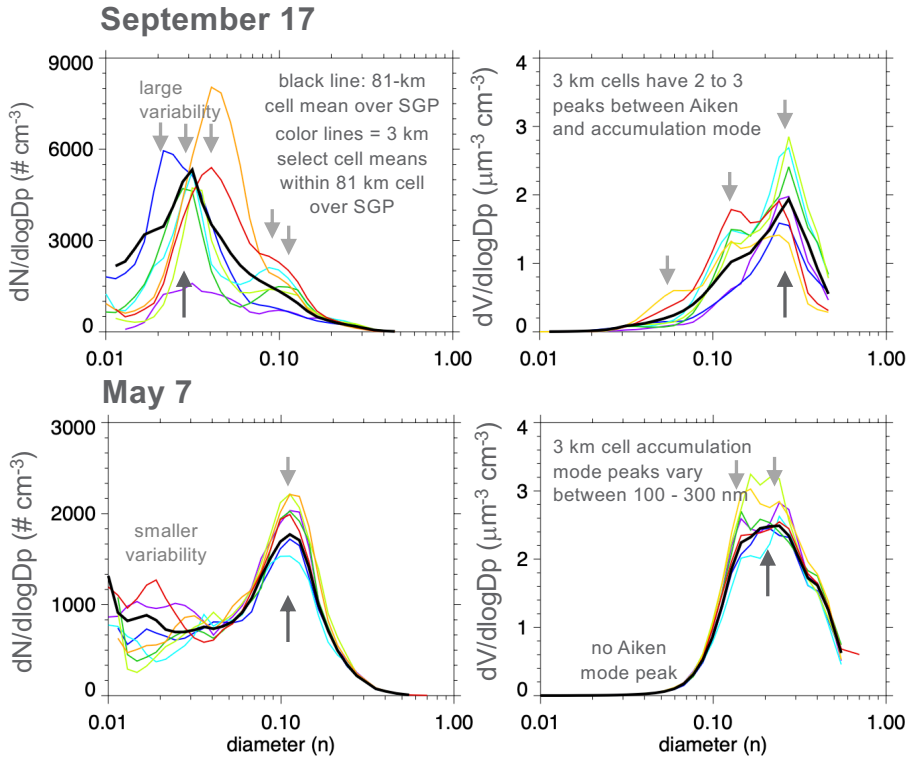
Transform Time Series into PDFs for All Flights



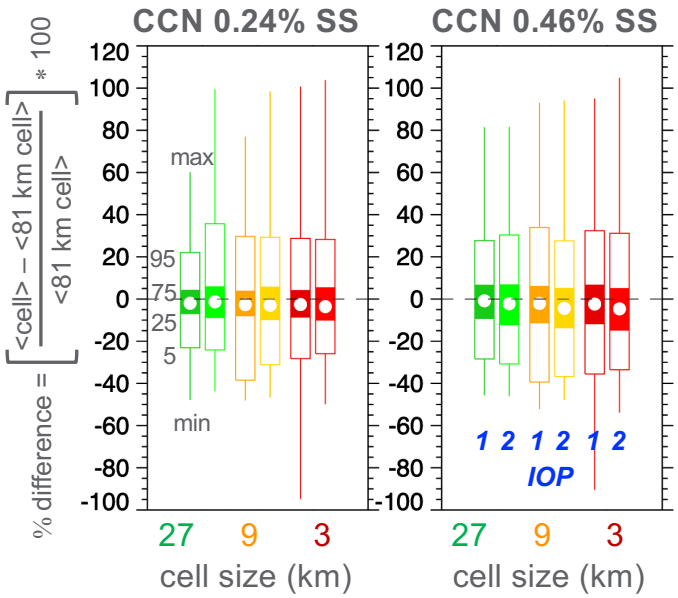


- Smaller variability than OM
- Larger variability than OM

Spatial CCN Variability during HI-SCALE

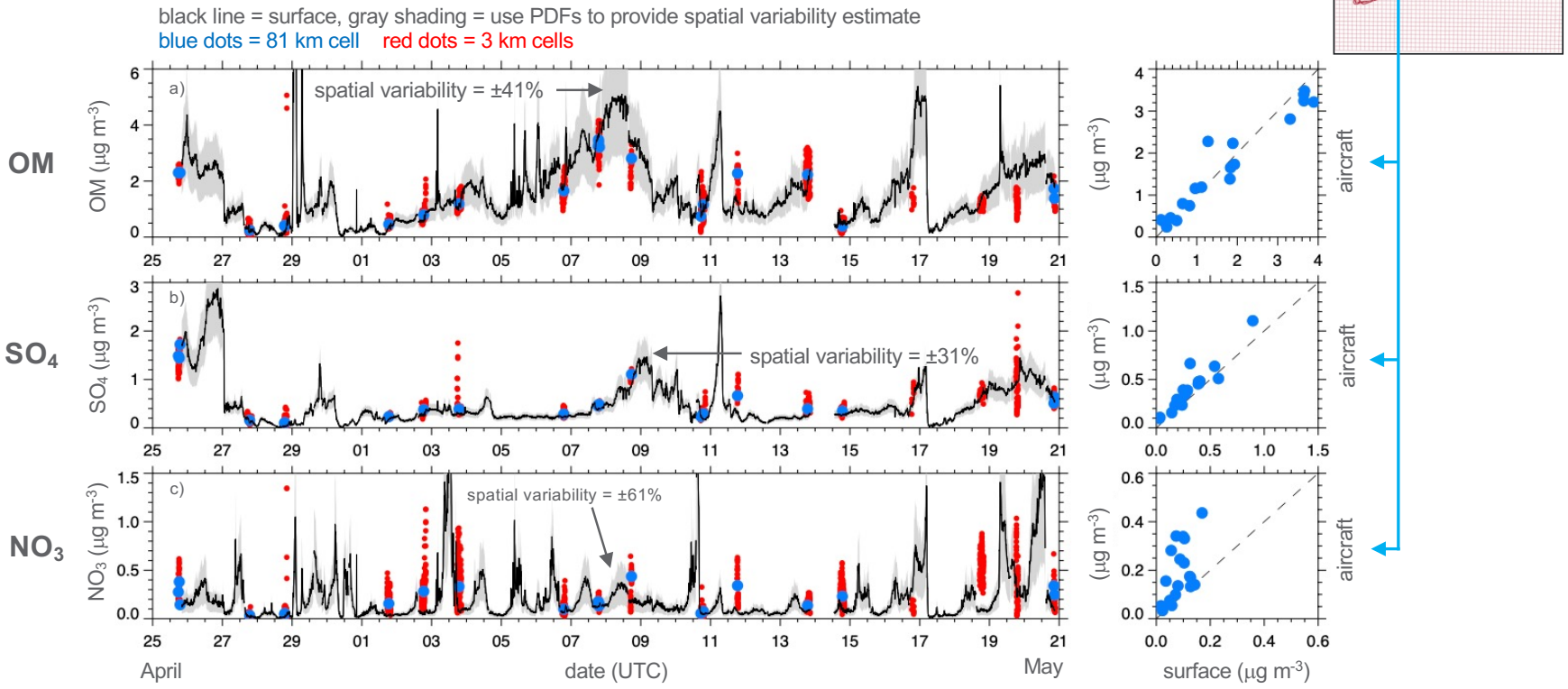


Variability in #, Hygroscopicity, and Size for All Flights



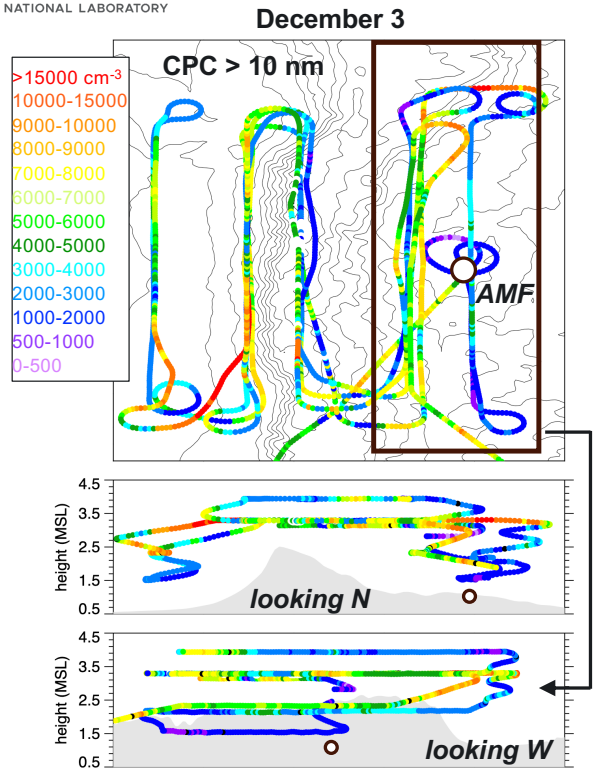
- Traditional climate models cannot resolve variability in size (i.e., different growth rates) that impacts CCN and aerosol-cloud interactions

HI-SCALE: Representativeness

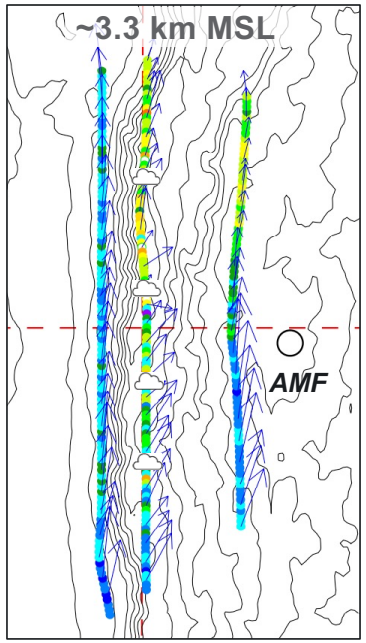


- Mean aircraft OM and SO_4 within 81 km box in the PBL is similar to ground measurements, but NO_3 is not

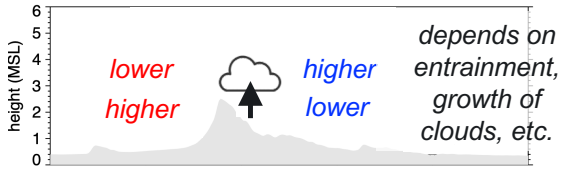
CACTI Example

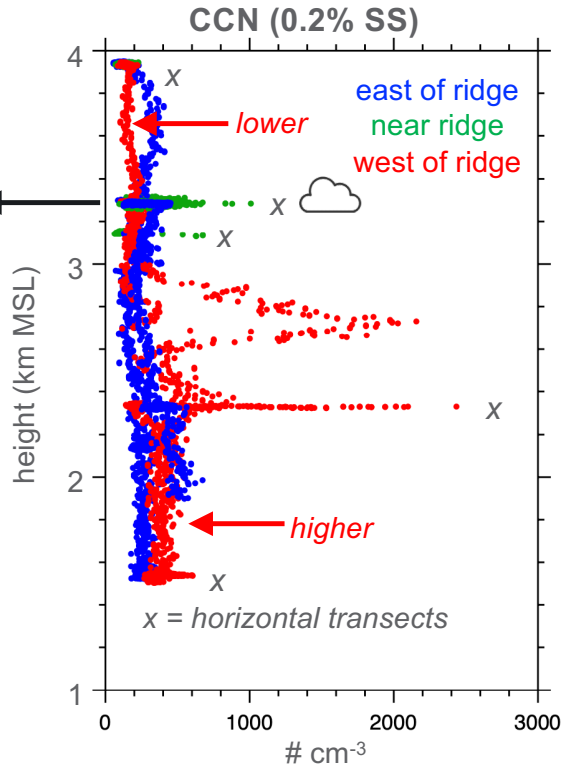


- Large variability in aerosol properties on many days

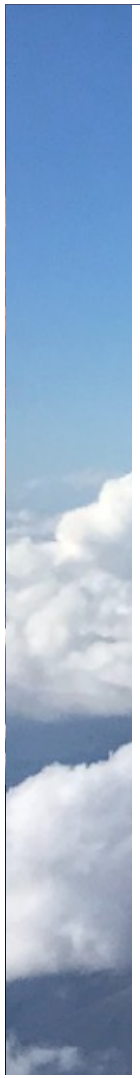


Do CCN gradients impact clouds?





- See Poster 2.24 for more details



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Questions?