Evaluating the resolution dependence of aerosol-cloud interactions in model simulations using A-Train observations

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Efforts to improve aerosol simulation

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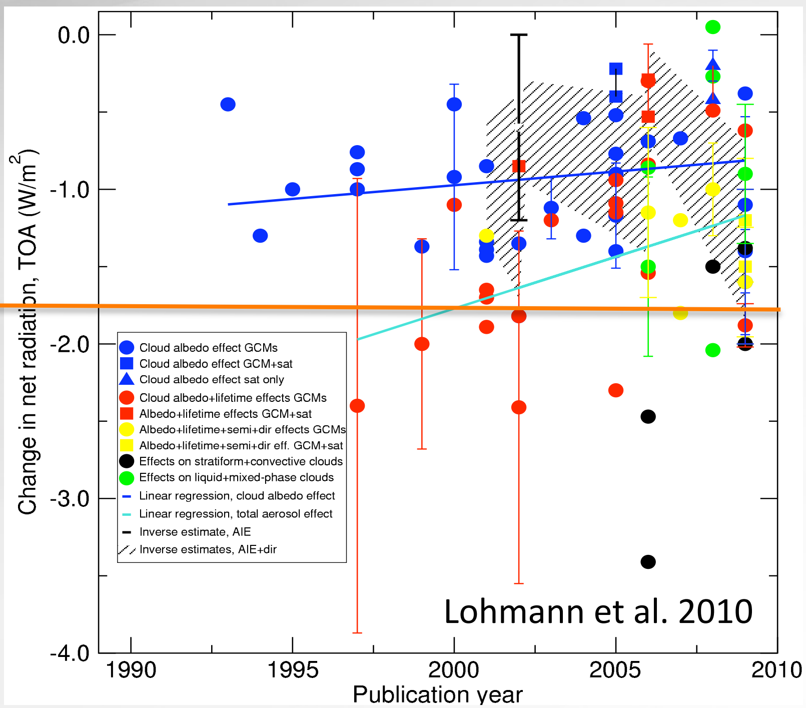
- Prescribed aerosol option (in cesm1.3)
- Diagnostic radiation for any MAM specie (in cesm1.3)
- AeroCom diagnostics (in cesm1.3 as history_aero_optics)
- MAM4: primary hydrophobic carbon mode added to MAM3 (PNNL, Wyoming)
- Less absorbing dust physprops file
- Unified treatment of convective transport and scavenging (PNNL)
- Resolution dependence of aerosol simulation (PNNL)
- Improved dust emission size distribution (Cornell, PNNL, Wyoming)
- Speciation of dust: optics (Cornell) & ice nucleation (Wyoming)
- More general aerosol thermodynamics (PNNL)
- Ammonium & nitrate (NCAR)
- Speciation of POM: hygroscopicity (PNNL)
- Ion-induced nucleation & subgrid homogeneous nuc (SUNY-Albany, PNNL)
- Marine organic sources (NC State, Harvard, LANL, Scripps, PNNL)
- Secondary organic aerosol intercomparison (MIT, NCAR, PNNL, LLNL, UM)
- Coupled fire smoke emissions (NCAR & PNNL)
- Coupled DMS emissions (LANL, ORNL, LLNL, PNNL)
- Coupling MAM to SNICAR (Flanner & PNNL)
- MAM volcanic aerosol (NCAR, PNNL)
- Geoengineering stratosphere, CCN (NCAR, PNNL)
- Frost flower sources (Scripps, LANL)

Background

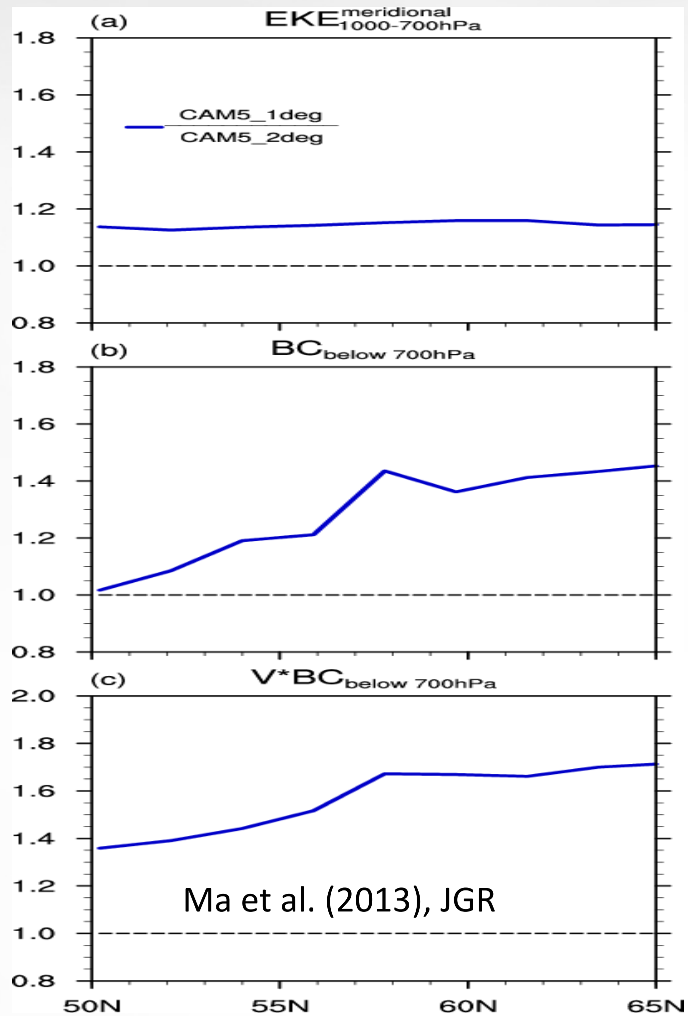
- Aerosol indirect forcing in CAM5 is higher than many other global models

CAM5 (~1.8W/m^2)

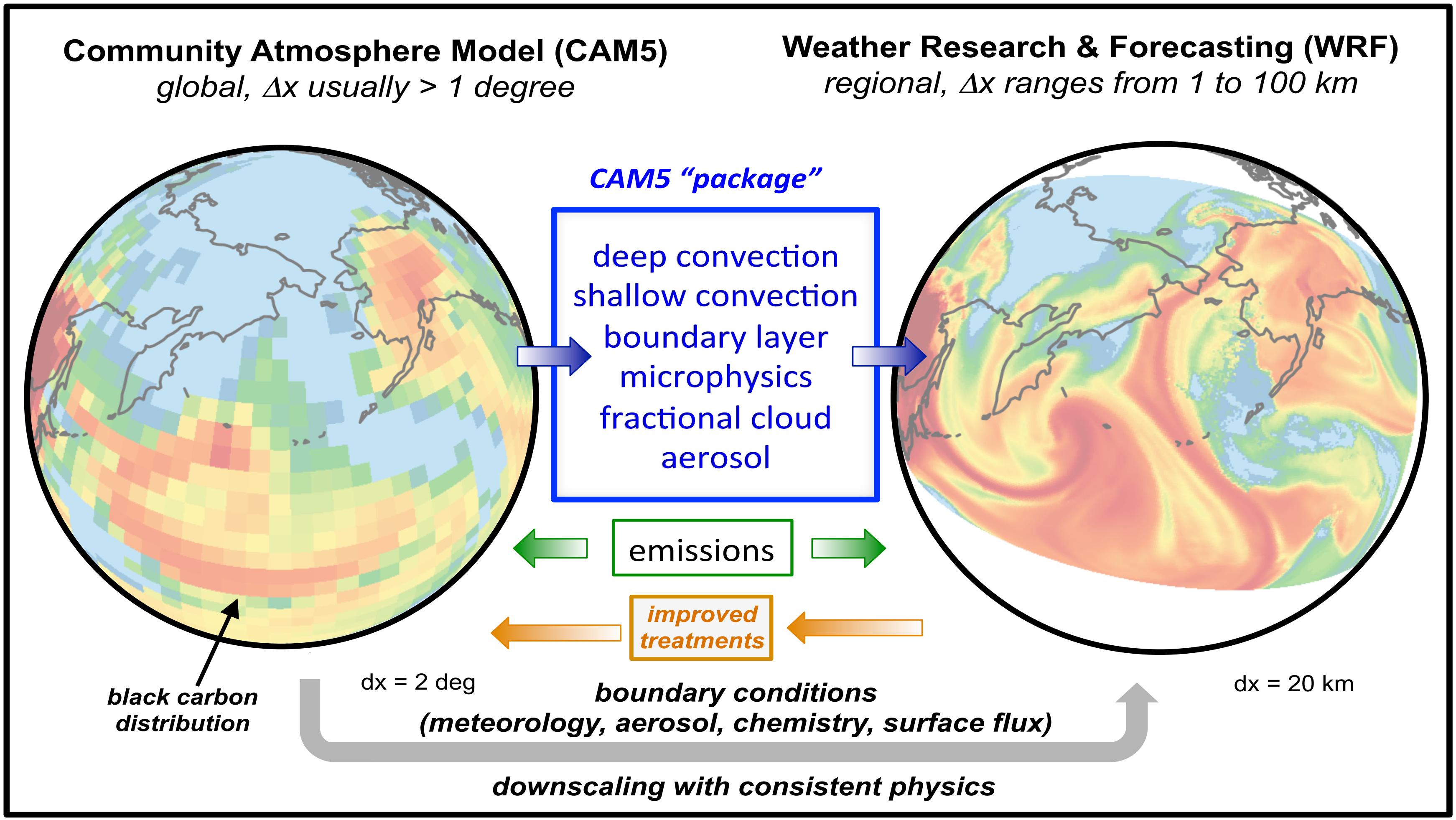


- Aerosol-cloud interactions can be amplified due to data aggregation (McComiskey and Feingold, 2012)

- Resolution dependence of aerosol transport may imply resolution dependence of aerosol distribution and aerosol-cloud interactions



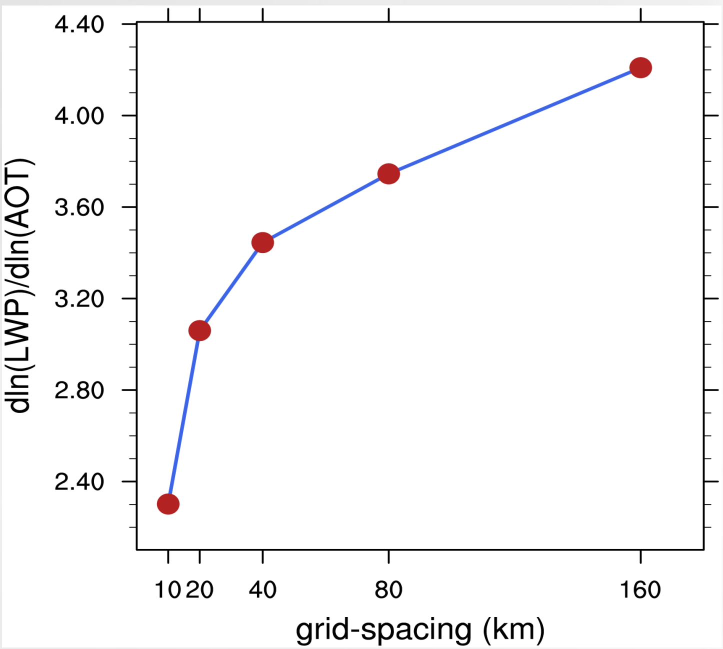
Downscaling from CAM5 to WRF-Chem



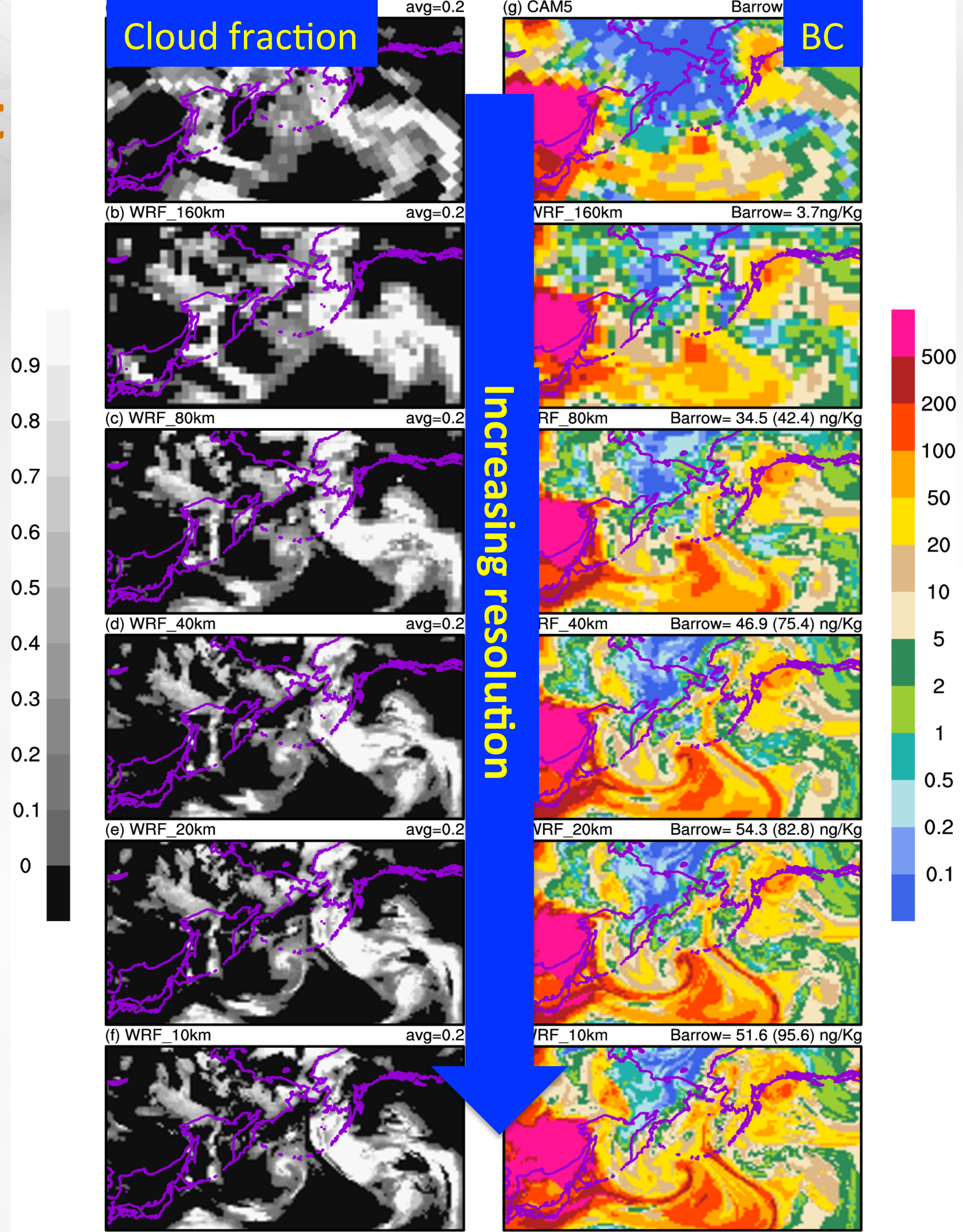
Ma et al. (2013), GMDD

Long-range transport of aerosols

- Filamentary structure in high-resolution runs
- Lower cloud susceptibility in high-resolution runs

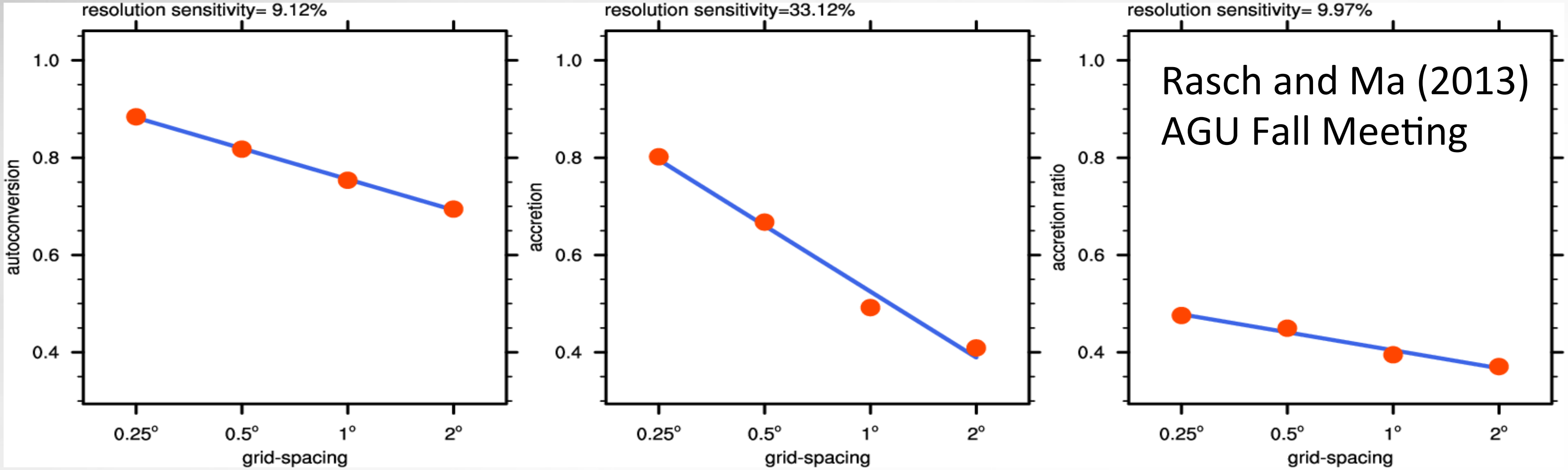


Ma et al. (2013), GMDD



Higher resolution leads to

- precipitation intensity increases
- accretion rate increases (function of Qr, not a function of Nc)
- drier atmosphere (less clouds), less scavenging of aerosols
- larger aerosol burden
- “convective” cloud fraction decreases + “stratiform” cloud fraction increases



Science questions

- Is this behavior region- and season- dependent?
- What is the net effect on aerosol indirect forcing with increasing resolution?
- Do results converge with increasing resolution? Is it resolution-dependent?
- At what resolution the model produces the most realistic aerosol indirect forcing?

Specified dynamics CAM5 simulations

- Standard offline meteorology methodology (3-dimensional wind and temperature, 2-dimensional surface wind stress, surface heat and moisture flux, surface temperature are prescribed. Wind-mass fixer is applied to ensure the time evolution of surface pressure and wind are consistent.)

- Year Of Tropical Convection (YOTC) analysis (0.15°), regridded to 2-deg, 1-deg, 0.5-deg, and 0.25-deg CAM5 grids using mass conservation interpolation

- Surface moisture flux comes from 0.25-deg offline CAM5 simulation, scaled to ~2.99 global annual mean.

- Model time step and dynamical sub-stepping are kept the same for all resolutions

- Model calibration for aerosol, cloud, and convection parameterizations in the 2-deg configuration, and is kept the same for other resolutions.

- AeroCom diagnostics that compares properties at cloud-top.

- Direct comparison with satellite observations. Output along satellite track.

Challenges

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- ***Huge* amount of data**
  - Pre-processing (YOTC analysis data processing)
  - I/O during runtime (writing instantaneous output is not fun)
  - Analysis (get a coffee, do emails, work on something else, go home!?)

- **Compensating errors through tuning in the free-running model due to unrealistic meteorology**
  - convectively unstable
  - cold bias in UTLS
  - weak surface wind

- **Physics not designed for very high resolution (model unstable and/or producing unrealistic results)**

- **A-Train data processing/interpretation (about 9.5 million 20-km footprints in 2009)**

SD CAM5 simulations

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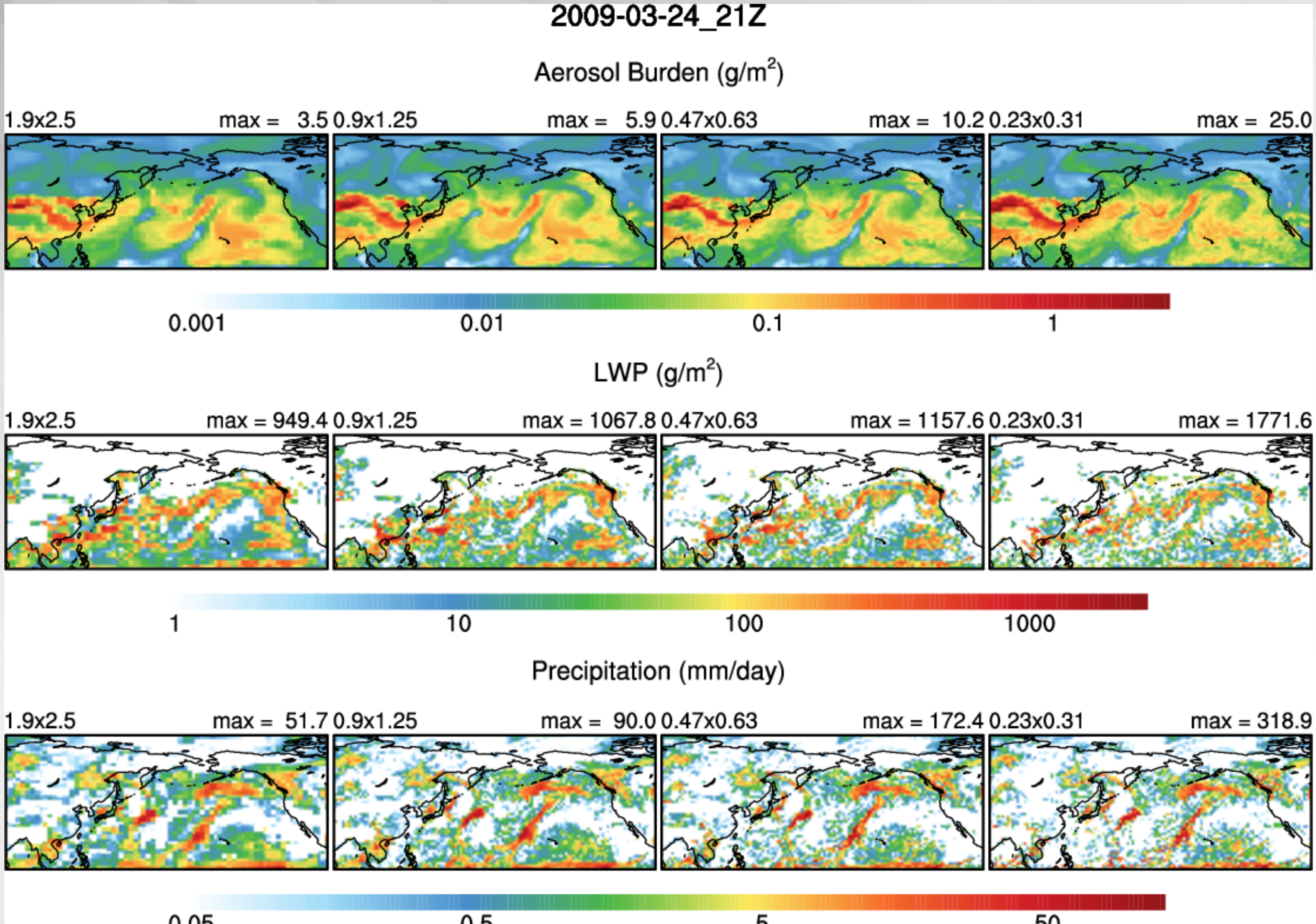
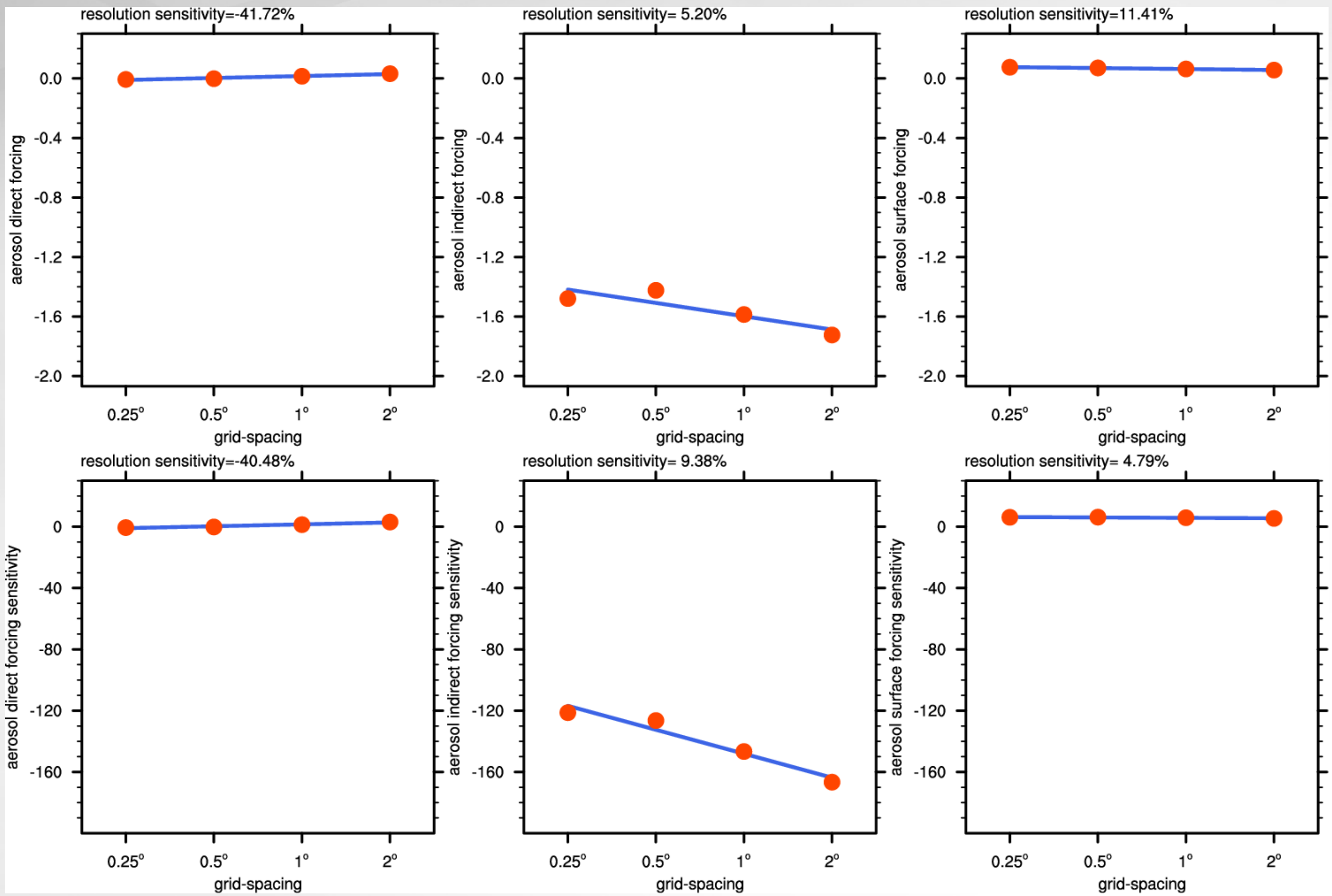
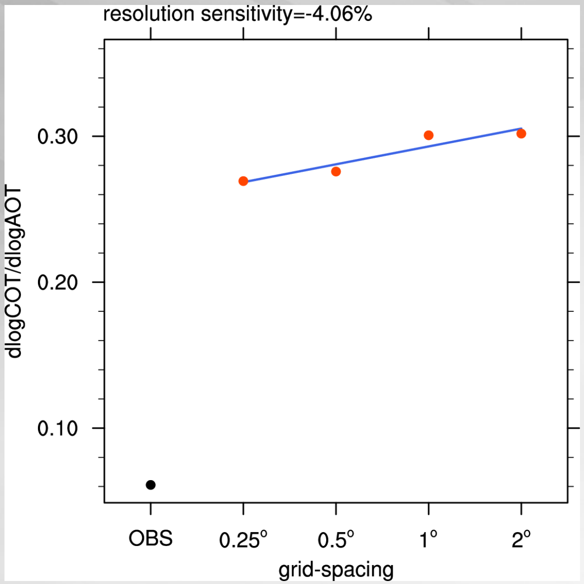


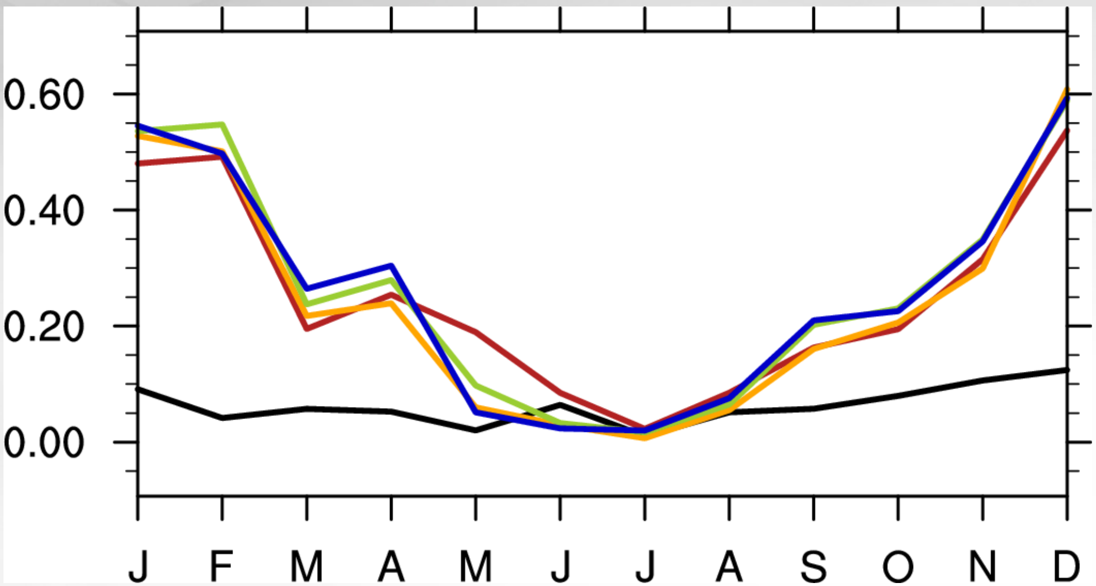
Aerosol forcing decomposition

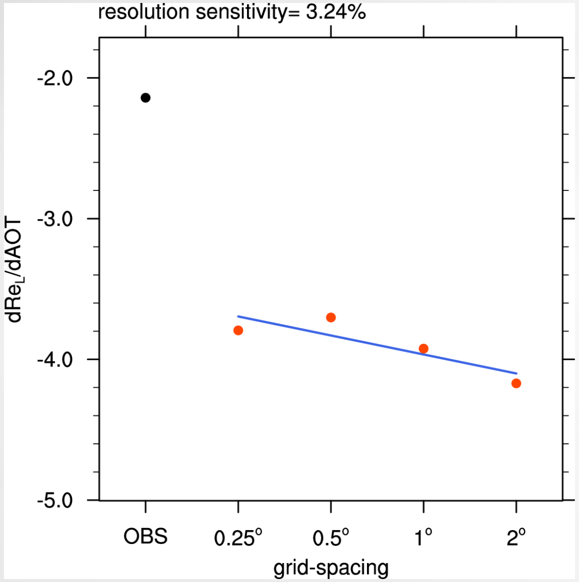
- Ghan (2013) methodology

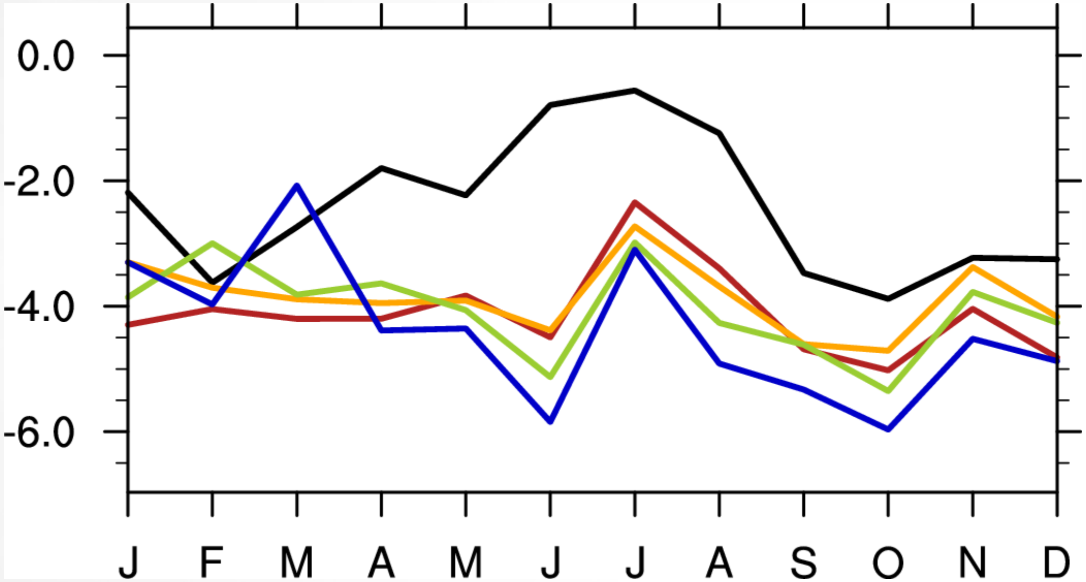


Cloud susceptibility









Cloud susceptibility

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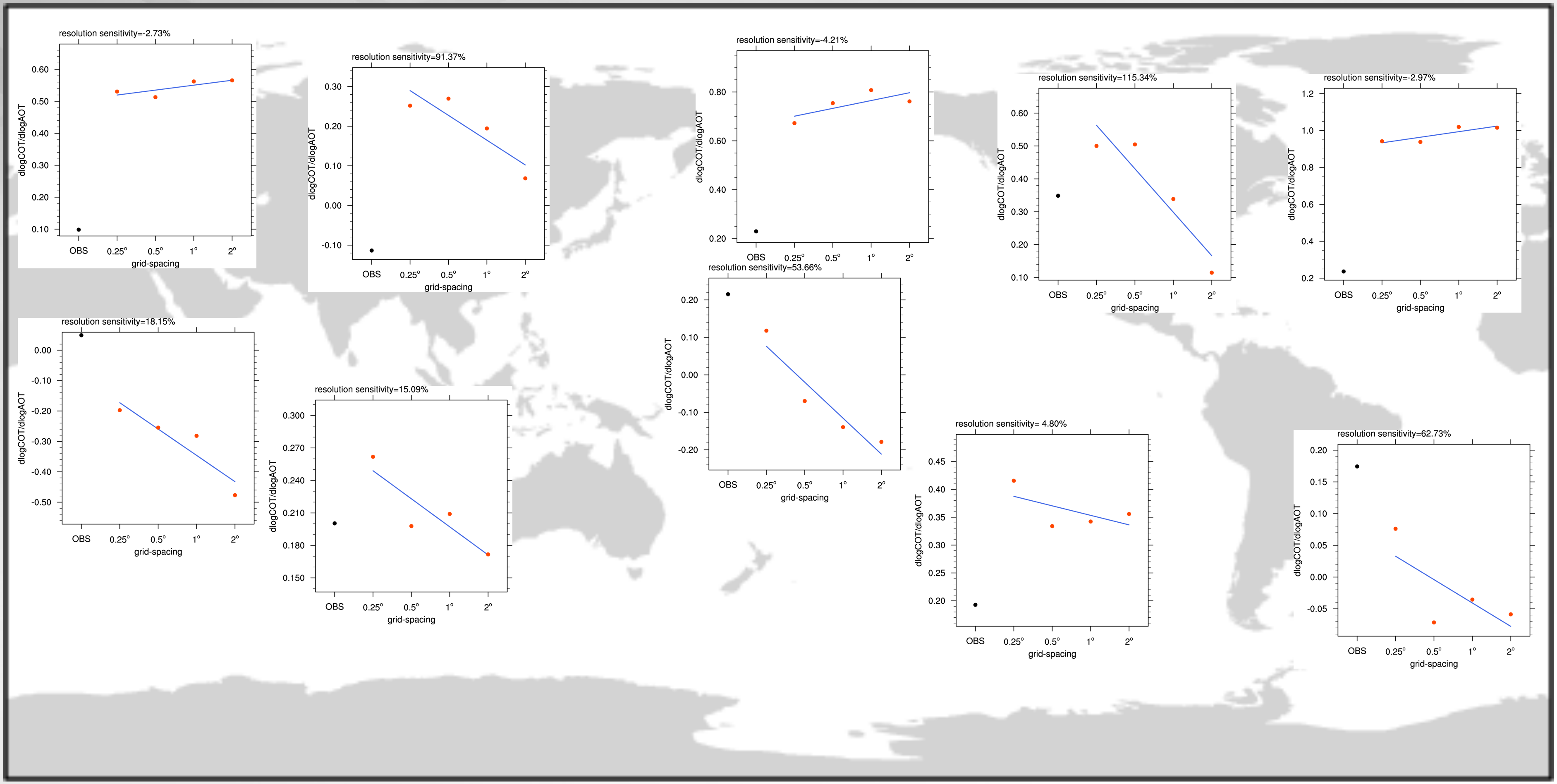

Cloud susceptibility

first-indirect effect

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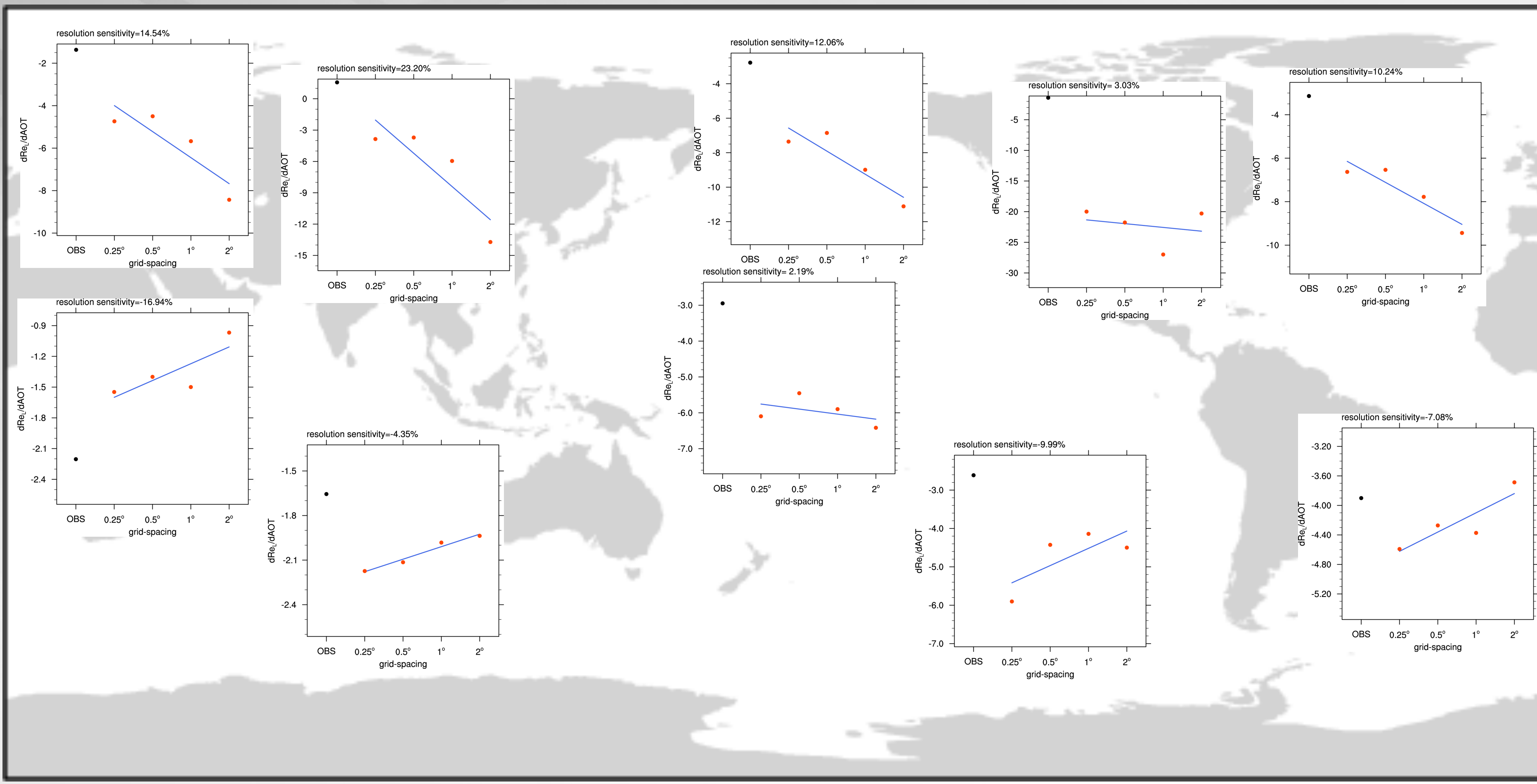

Next steps

- More careful analysis on region-dependence of cloud susceptibility
- S_{pop} calculation to evaluate aerosol second indirect effect
- Ice cloud susceptibility evaluated against CloudSat and CALIPSO
- Gaussian process emulation to provide insights into physical mechanisms
- Understand the uncertainty range of the satellite observations
- Do I want to evaluate vertical profiles? Pros and cons to be considered.
- Weakly nudged runs to explore the behavior of the free-running model.
- Quantify bias due to sampling difference
- Use COSP to remove bias due to algorithm difference
- Aerosol transport into the Arctic