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Evaluating the Resolution Dependence of Aerosol Simulation: Climatology and Extremes

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Specified dynamics CAM5 simulations

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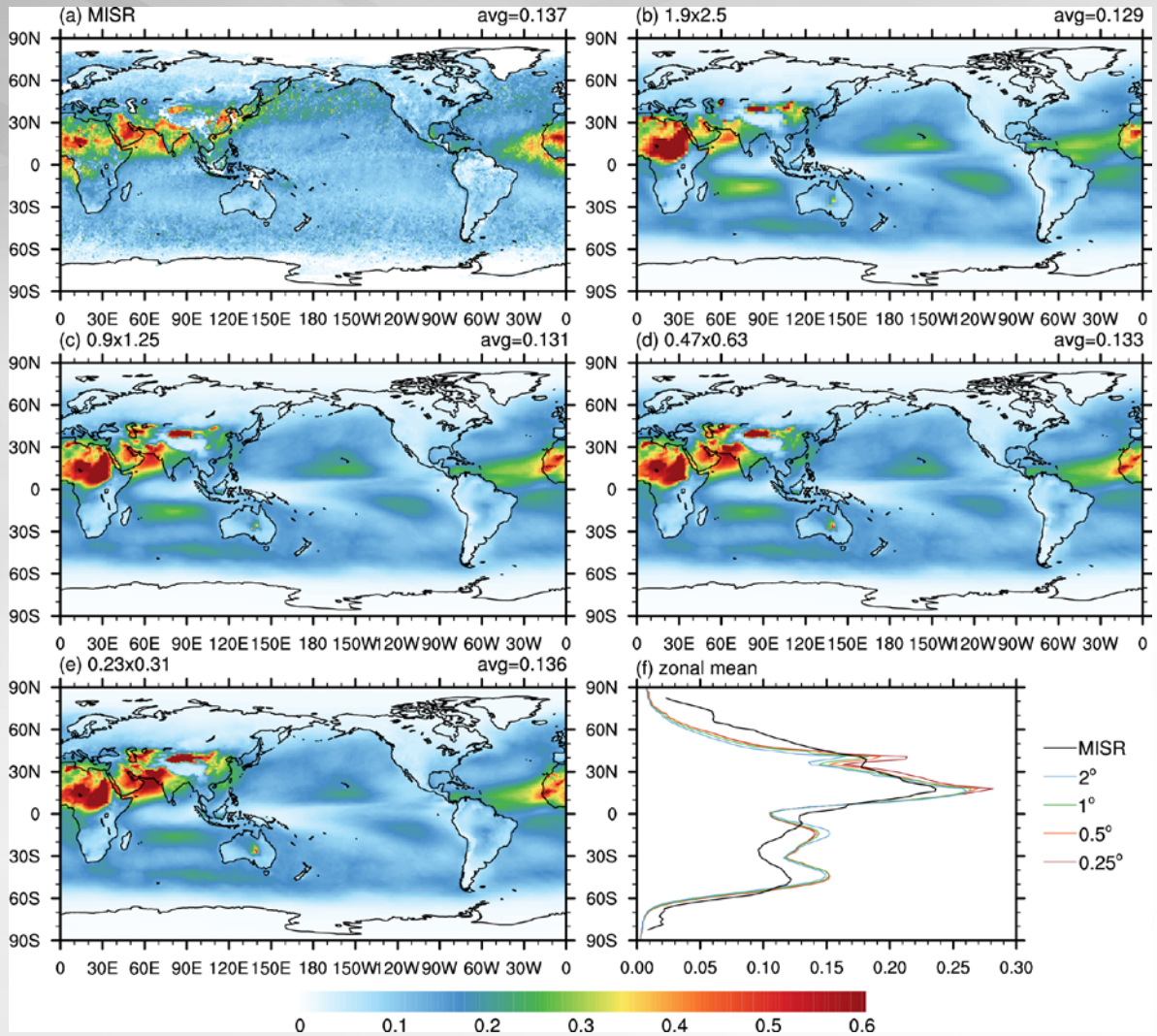
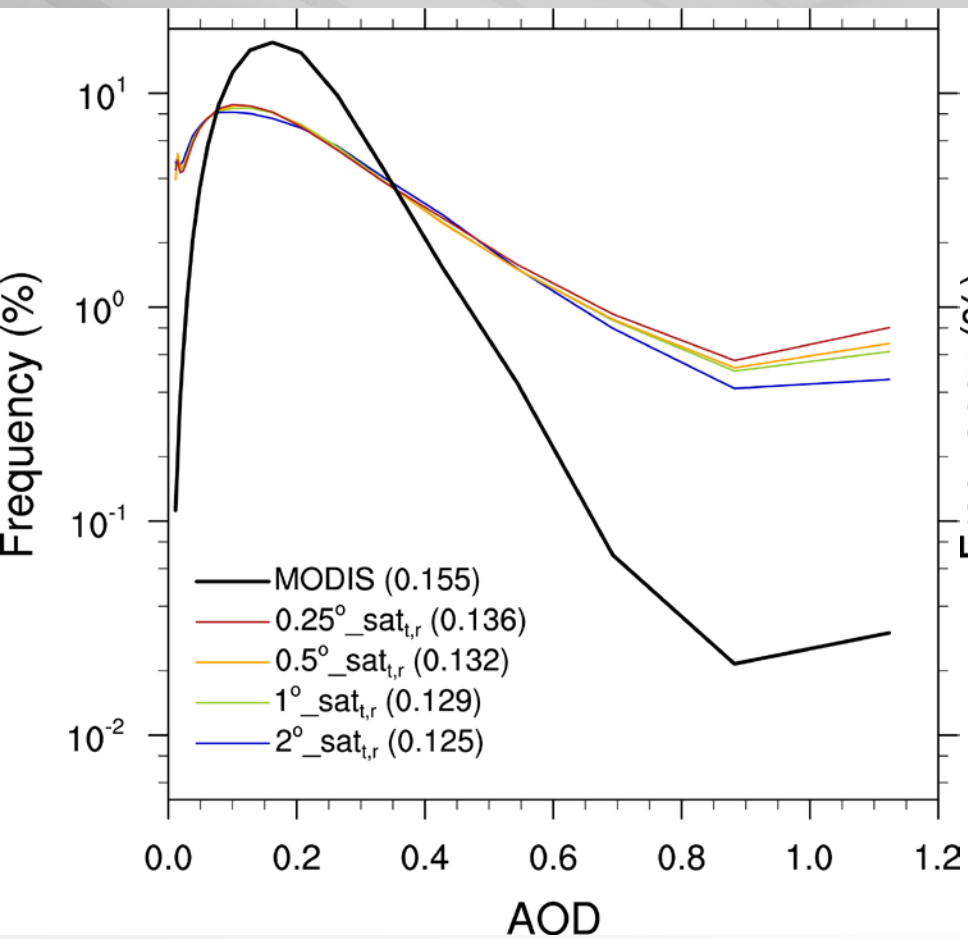
- Standard offline meteorology methodology (3-dimensional wind and temperature, 2-dimensional surface wind stress, surface heat and moisture flux, surface temperature are prescribed. Wind-mass fixer is applied to ensure the time evolution of surface pressure and wind are consistent.)
- Year Of Tropical Convection (YOTC) analysis (0.15°), regridded to 2°, 1°, 0.5°, and 0.25° CAM5 grids using mass conservation interpolation
- Surface moisture flux comes from 0.25° CAM5 simulation, scaled to ~2.99 mm/day 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° configuration, and is kept the same for other resolutions.
- AeroCom diagnostics
- Direct comparison with satellite observations. Output along satellite track.

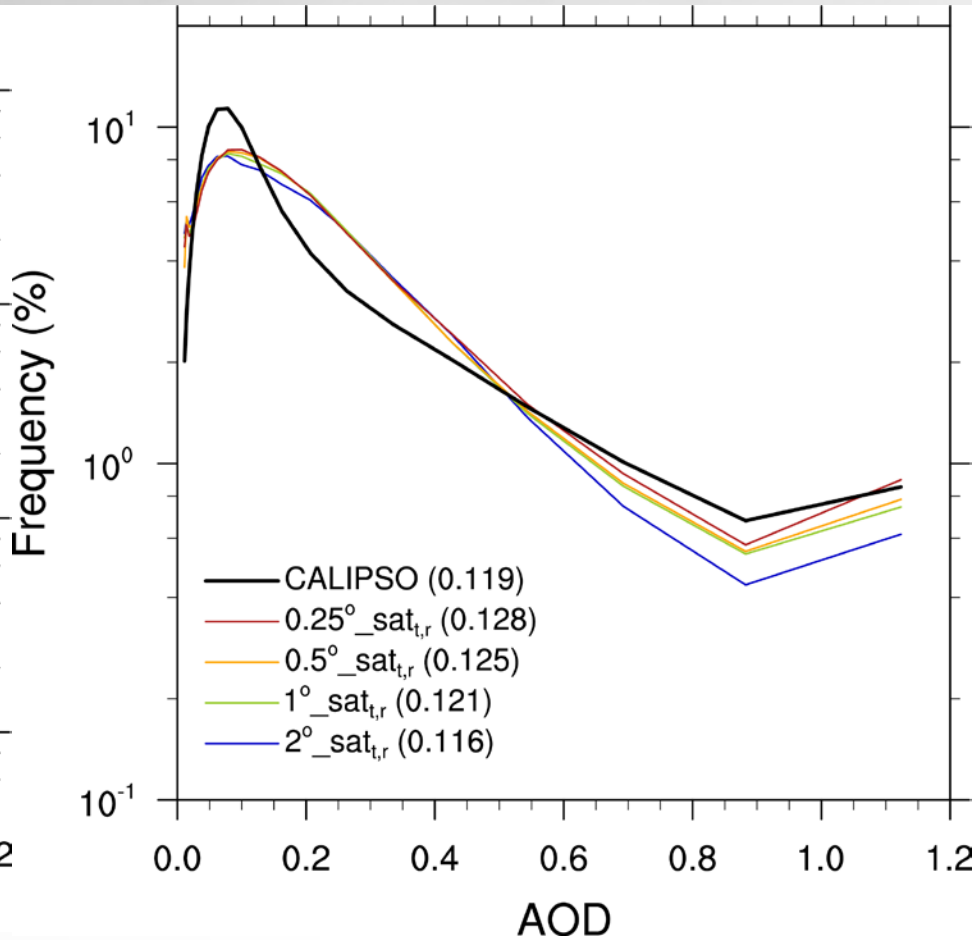
Aerosol Optical Depth



- AOD climatology (annual mean) is not sensitive to resolution.

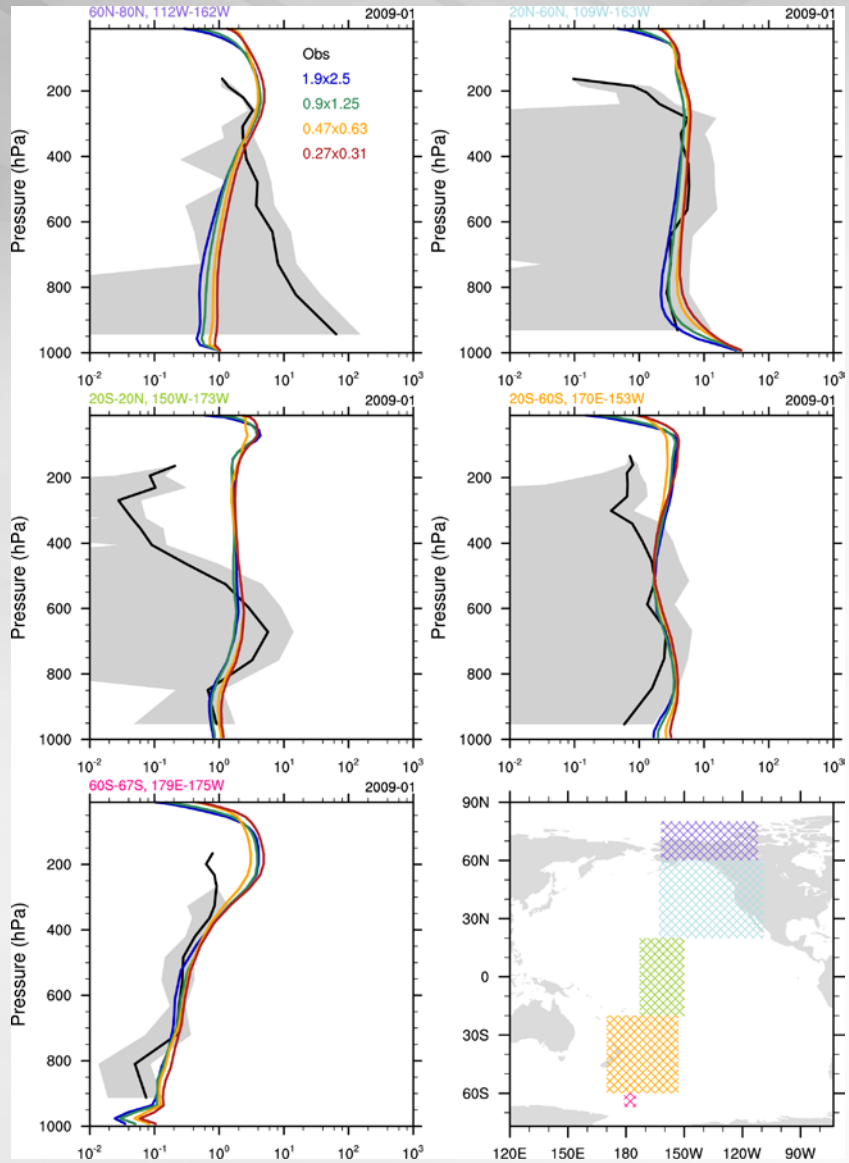
AOD evaluated against A-train observations





- Much better agreement with CALIPSO
- Resolution sensitivity for high-AOD (>0.6) occurrence

BC vertical profile evaluated against aircraft measurements (January climatology)



- BC vertical profile (January climatology) shows some resolution sensitivity (higher BC concentration is observed with increasing resolution), though large bias remains.

Climatology of aerosol lifecycle

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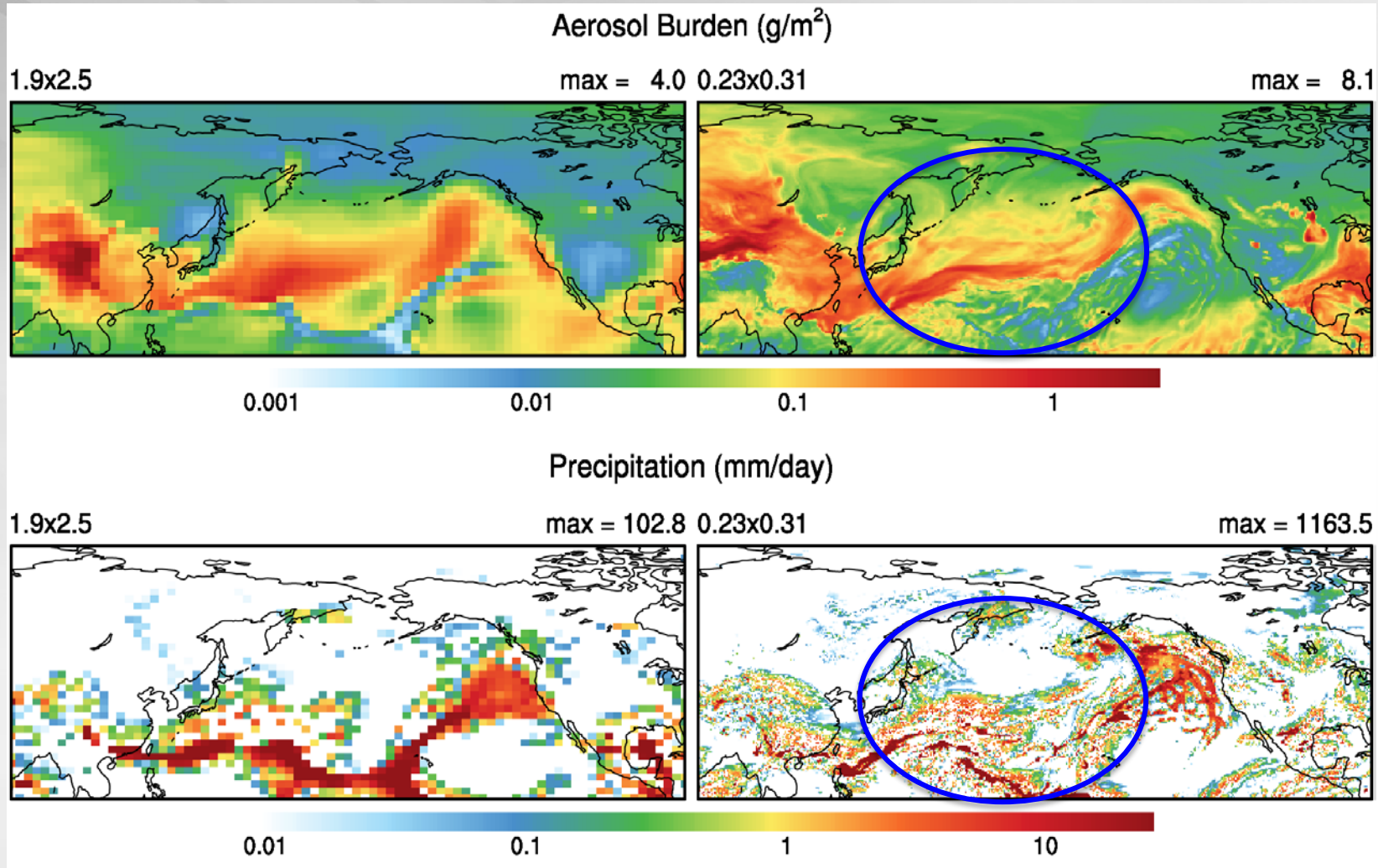
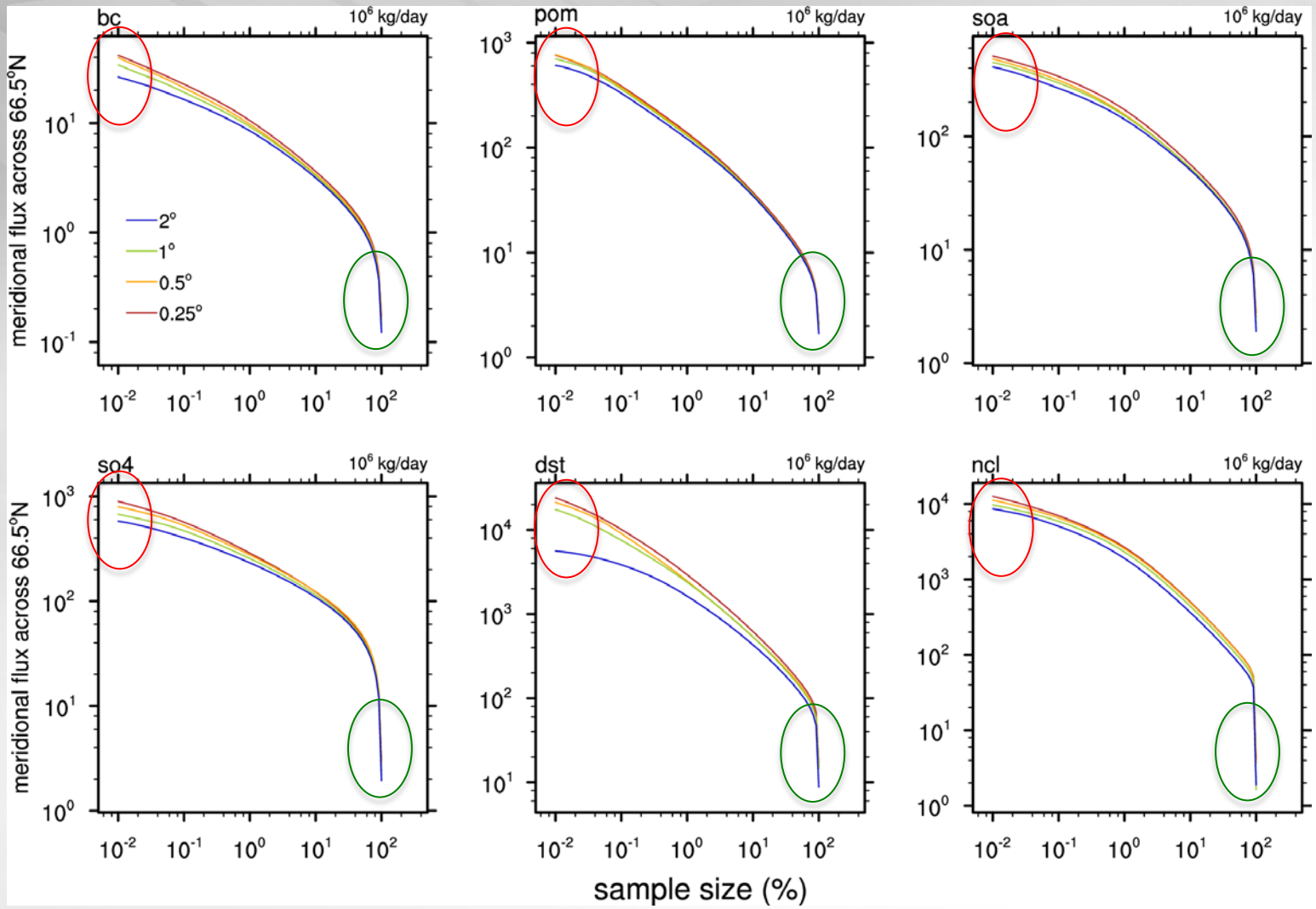
	1.9x2.5	0.9x1.25	0.47x0.63	0.23x0.31
Source (Tg/yr)	7.767	7.766	7.766	7.764
emission	7.767	7.766	7.766	7.764
Sink (Tg/yr)	7.750	7.750	7.751	7.749
dry deposition	1.727	1.644	1.549	1.446
wet deposition	6.022	6.106	6.202	6.303
Lifetime (day)	3.078	3.208	3.345	3.678
Burden (Tg)	0.065	0.068	0.071	0.078
accumulation	0.065	0.068	0.071	0.078

- BC lifetime and burden increases with increasing resolution.
- Other aerosol species show similar overall resolution sensitivity.

Filamentary structure

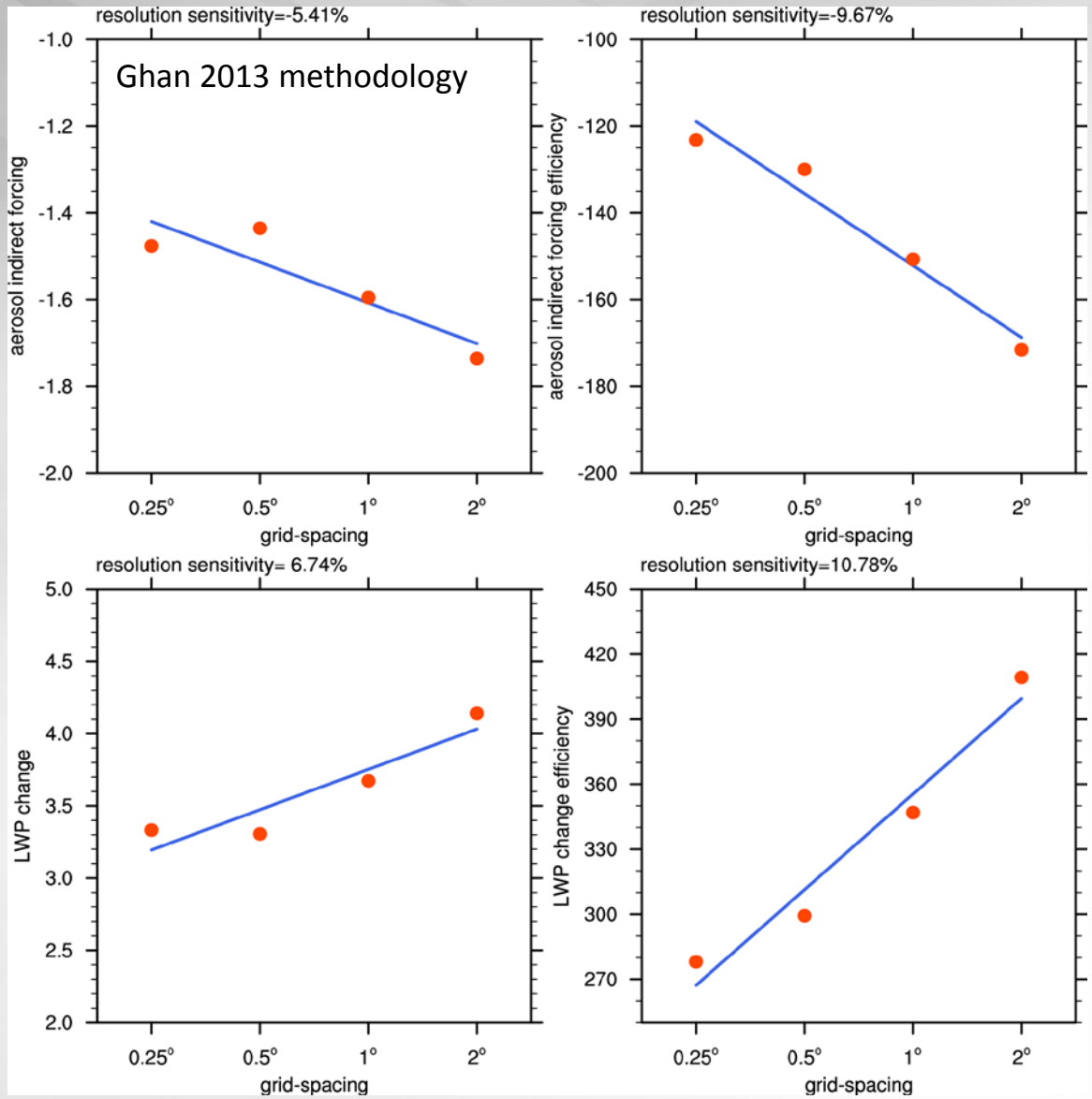


Aerosol transport into the Arctic



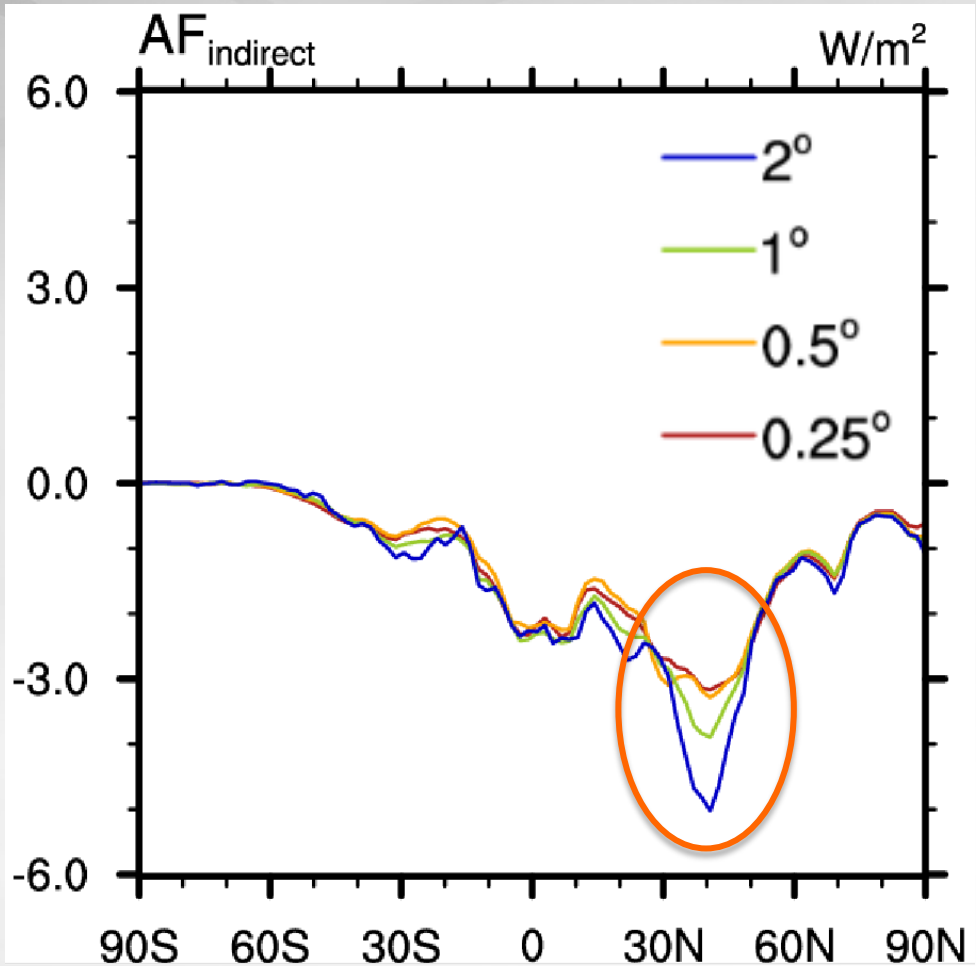
- Extreme events of aerosol transport into the Arctic can be enhanced by a factor of 2-10, but climatology remains similar (differ only by about 50%)

Aerosol indirect forcing



- Difference between pair simulations: PD and PI aerosol forcing
- Annual mean global aerosol indirect forcing (and aerosol-induced increase of LWP) reduces with increasing resolution
- More so for aerosol indirect forcing efficiency (and LWP change efficiency), defined as ΔAIF/ΔAOD and ΔLWP/ΔAOD.

Regional aerosol indirect forcing



- In N.H. mid-latitudes where aerosol indirect forcing is strongest, the resolution sensitivity is also the largest, producing ~ 2 W/m^2 difference in annual mean aerosol indirect forcing between the lowest and highest resolution simulations.

Understanding the resolution dependence of aerosol-cloud interaction

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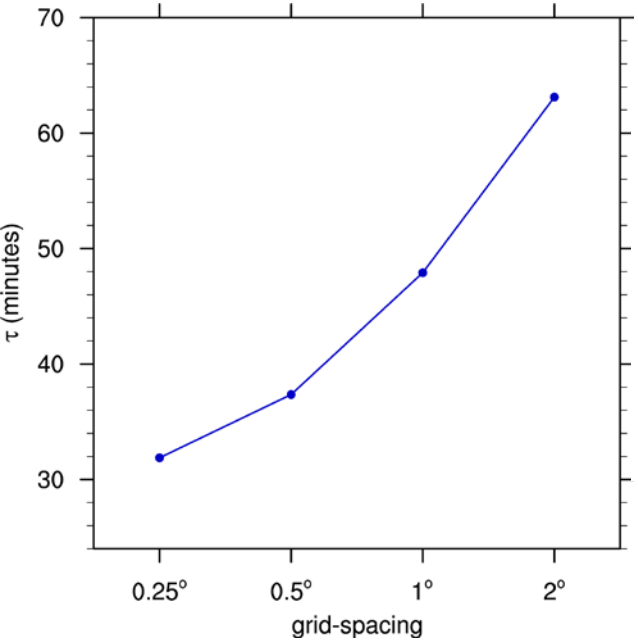
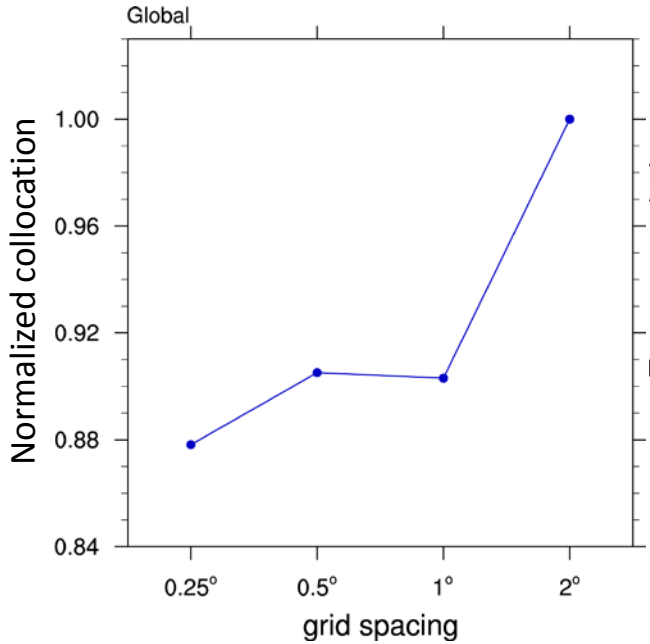
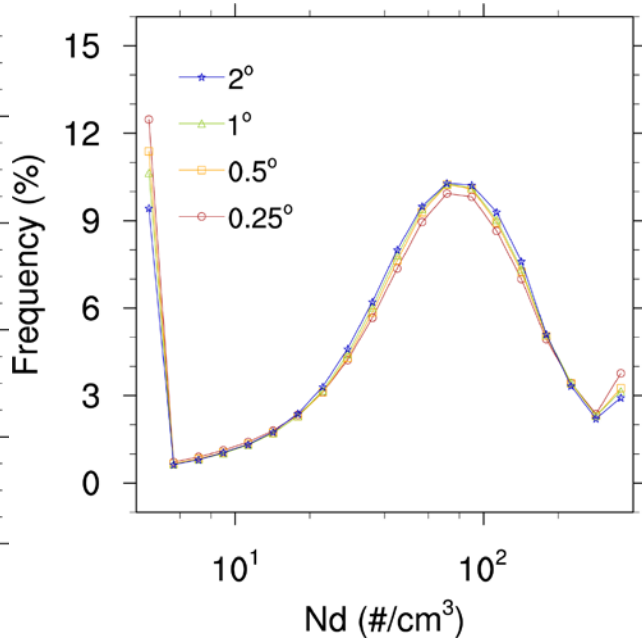
Qc removal time scale



Collocation



Droplet number at cloud base



- Resolution sensitivity for aerosol-cloud collocation (consistent with Ma et al., 2014, GMD)
- Higher frequency for high and low droplet number occurrence with increasing resolution.
- Shorter residence time for liquid condensate with increasing resolution.
- Rasch, Ma, et al. (in prep) discusses the mechanisms in detail.

Take-home messages

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- Increasing resolution partially reduces the model bias in aerosol climatology (e.g., low estimates of aerosol concentration in remote regions and high estimates of aerosol indirect forcing), but large biases still remain even in the highest model resolution simulation. Adequately addressing model uncertainties associated with model physics and boundary forcings (e.g., emission inventory) is required to further improve the simulation.
- Extreme pollution events (that can have impacts on public health and aerosol-cloud-precipitation interactions) are better resolved by the high-resolution simulation.
- Current parameterization suite produces stable and reasonable simulation at 0.25° resolution.