Impact of Neglected Subgrid Processes on Aerosols & Their Direct Radiative Forcing for a Representative GCM Grid Spacing

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1. Motivation

Subgrid treatments for aerosols and their climate forcing are understudied, whereas subgrid treatments for meteorological processes in atmospheric models have been studied extensively.

- Need to quantify trace gas and aerosol subgrid variability and document the severity of neglecting this issue.
- What processes contribute most to subgrid aerosol variability, e.g. terrain, relative humidity differences, emissions, non-linearity of chemical reactions?
- What impact does neglected subgrid aerosol variability have on climate simulations?

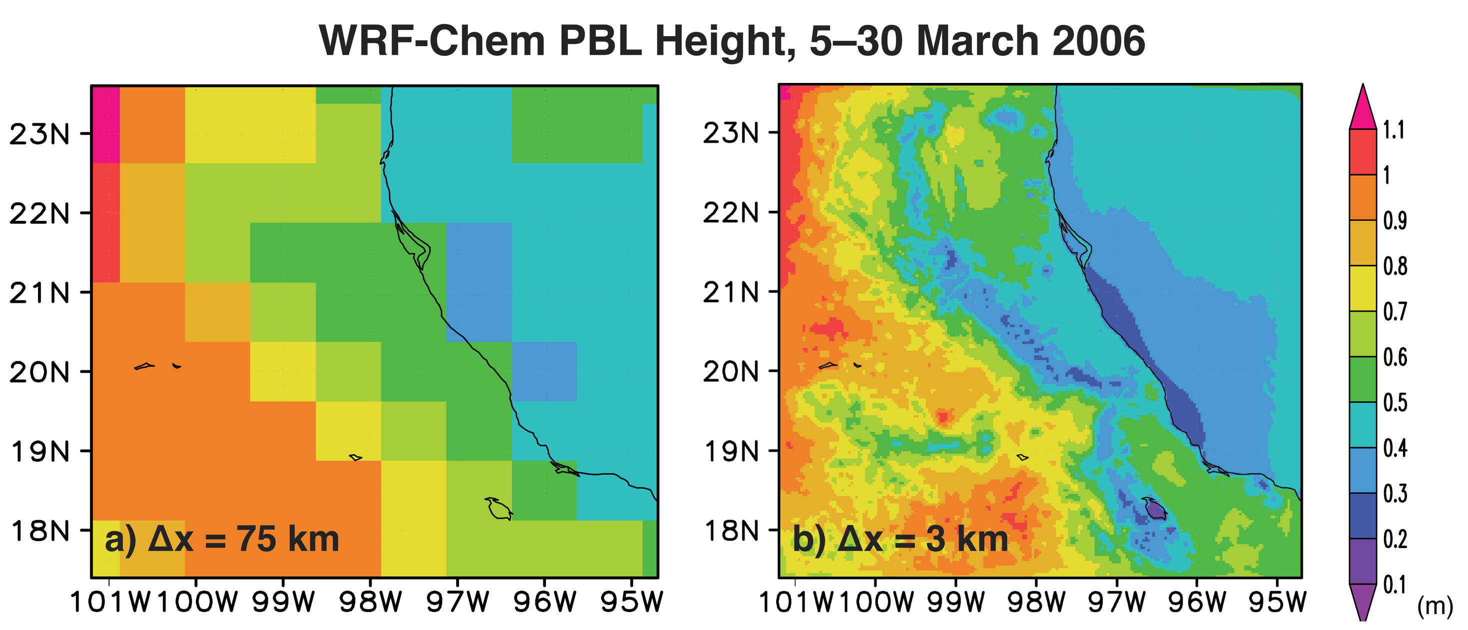

Figure 1. Simulated PBL height averaged over 5–30 March 2006 for the (a) 75-km and (b) 3-km domains used in this study. Added topographic complexity locally alters pollutant concentrations significantly. But, what is the net effect to the region as a whole?

2. Methodology

Use WRF-Chem to simulate differences in variability between two grid spacings, one with spacing on the order of a climate model, 75 km, and one on the order of a cloud-scale resolving model, 3 km.

- High-resolution domain serves as a proxy for added variability that would be present in the real world.
- Simulations encompass MILAGRO field campaign, March 2006.

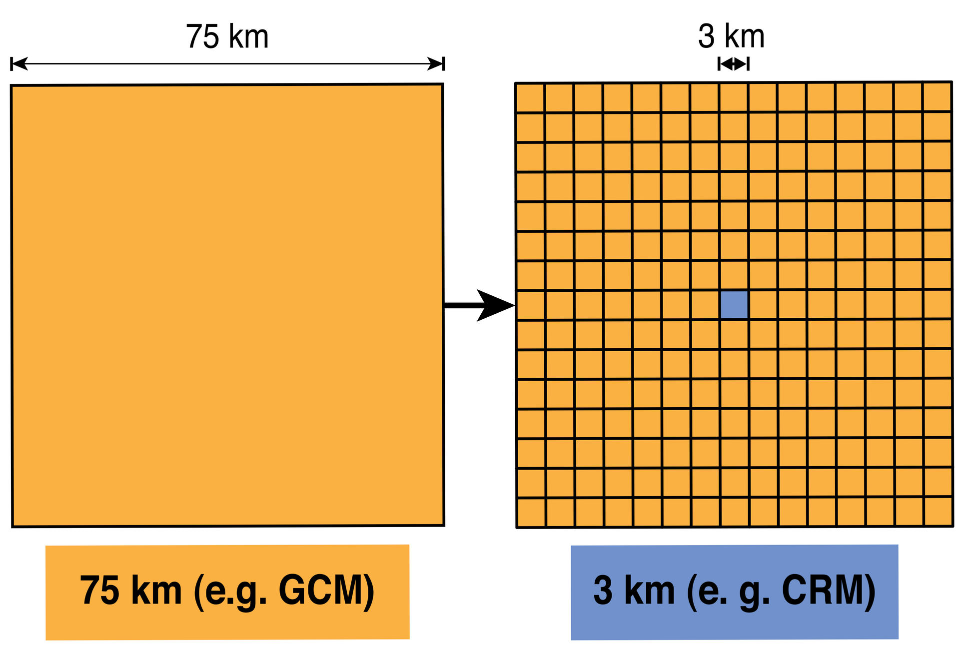

Figure 2. Within each 75-km grid cell lies 625 3-km grid cells. For clarity, not all 3-km cells are shown.

- Model grids aligned so cell edges match every 75 km. This allows easy comparison between grids and averaging of the high-resolution grid to compare with the coarse grid.
- Aerosol direct effect turned on, but indirect effect turned off for this preliminary work.

3. Impact of Scale on Aerosol Field

Impact of increased resolution on aerosol is to add small-scale variability, and often to reduce bias compared to coarser simulations.

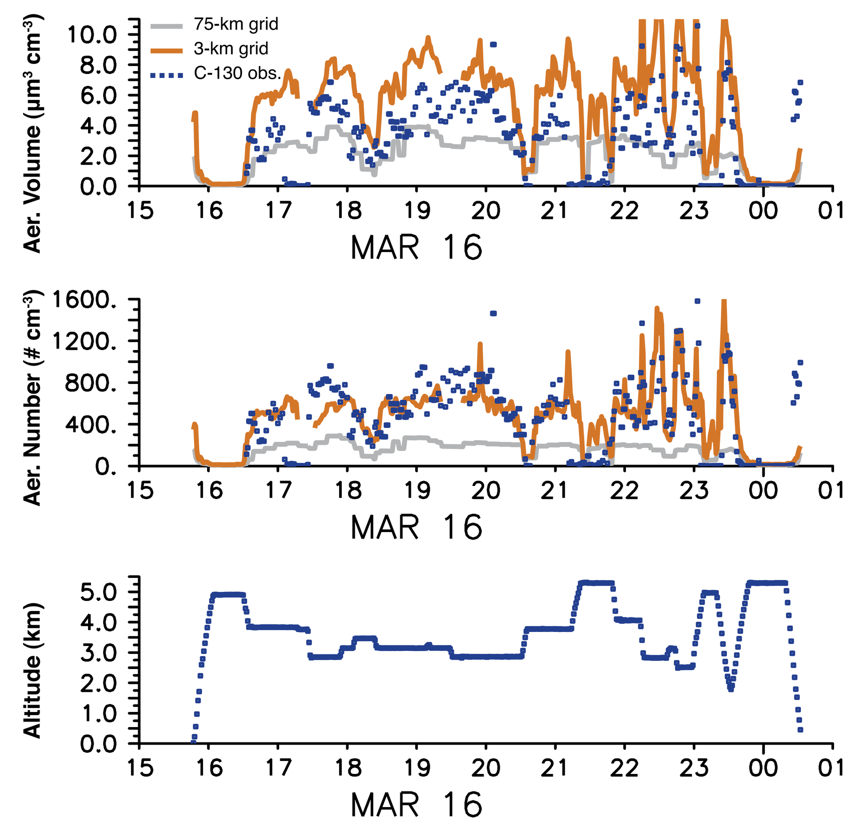

Figure 3. Comparison of submicron aerosol volume and number for the 16 March C-130 flight. Observations from the Optical Particle Counter (blue dots) are averaged to 1-min. intervals. Simulated results interpolated to the flight track for the 75-km grid (gray line) and 3-km grid (orange line) are sums of WRF-Chem size bins 3 and 4 (0.15625–0.625 µm).

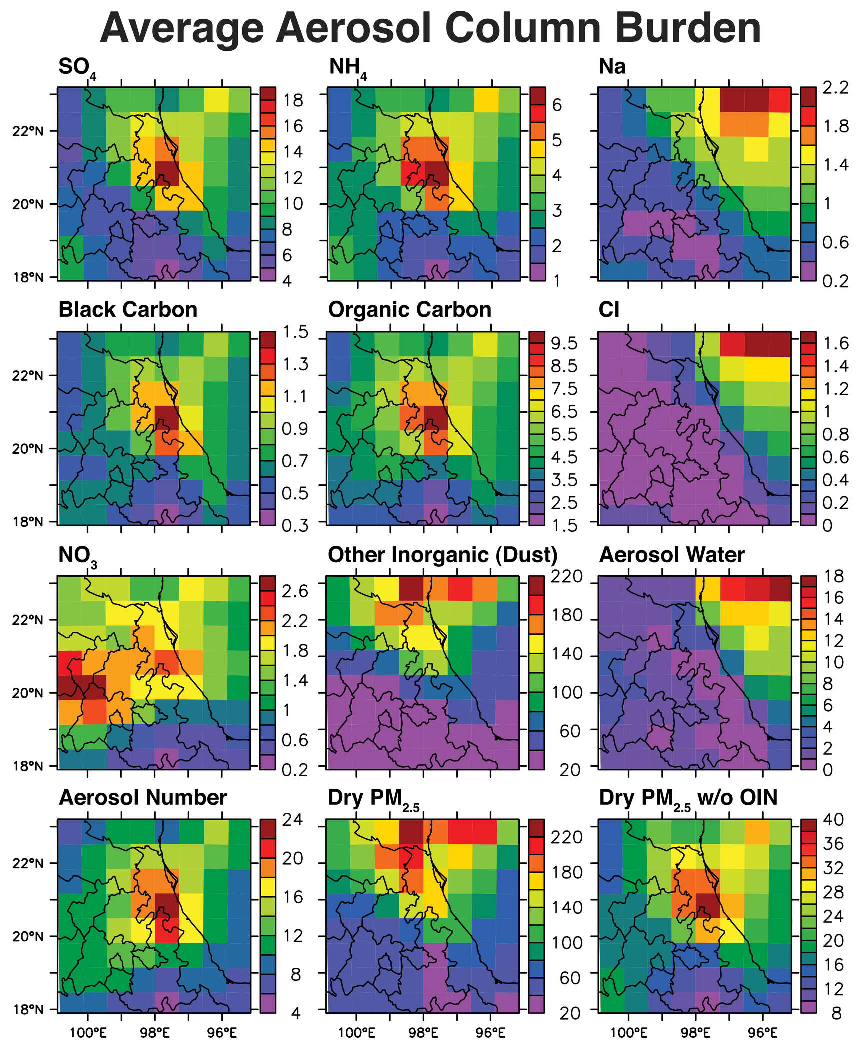

Figure 4. Time-averaged aerosol burden by species for the 75-km simulation, as simulated by WRF for MOSAIC size bins 1–6 (up to 2.5 µm diameter), the period 4–21 March 2006, and only including cloud free columns. Units for particulate matter are mg m^{-2} and units for aerosol number are 10^9 m^{-2}. Particulate matter is shown both with and without the other inorganic species, i.e., dust.

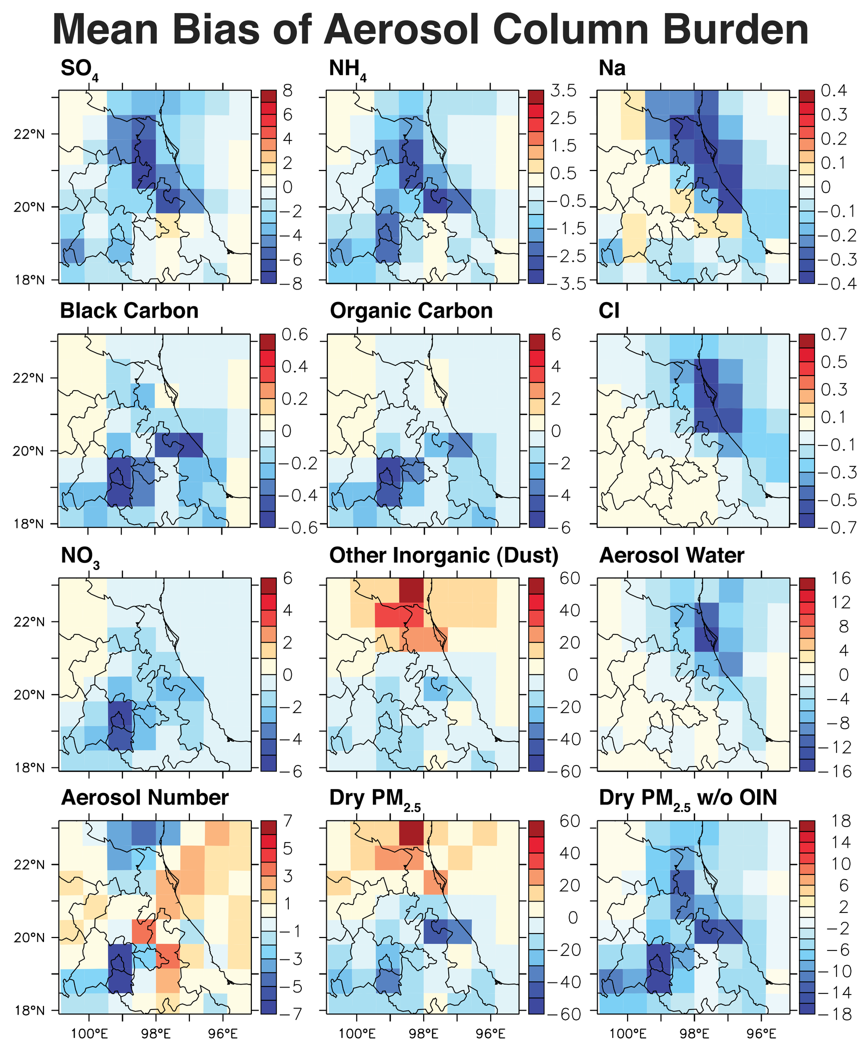

Figure 5. Mean bias between 75- and 3-km simulations on the 75-km grid corresponding to the aerosol column burdens shown in Figure 4.

- Neglecting subgrid variability results in less aerosol mass for most species, with the exception of dust.
- Scale dependence of online dust emission results in more dust emitted at the coarse scale.

4. Impact of Scale on Direct Aerosol Radiative Forcing

Subgrid errors in aerosol fields lead to errors in direct aerosol radiative forcing, which lead to uncertainty in climate predictions.

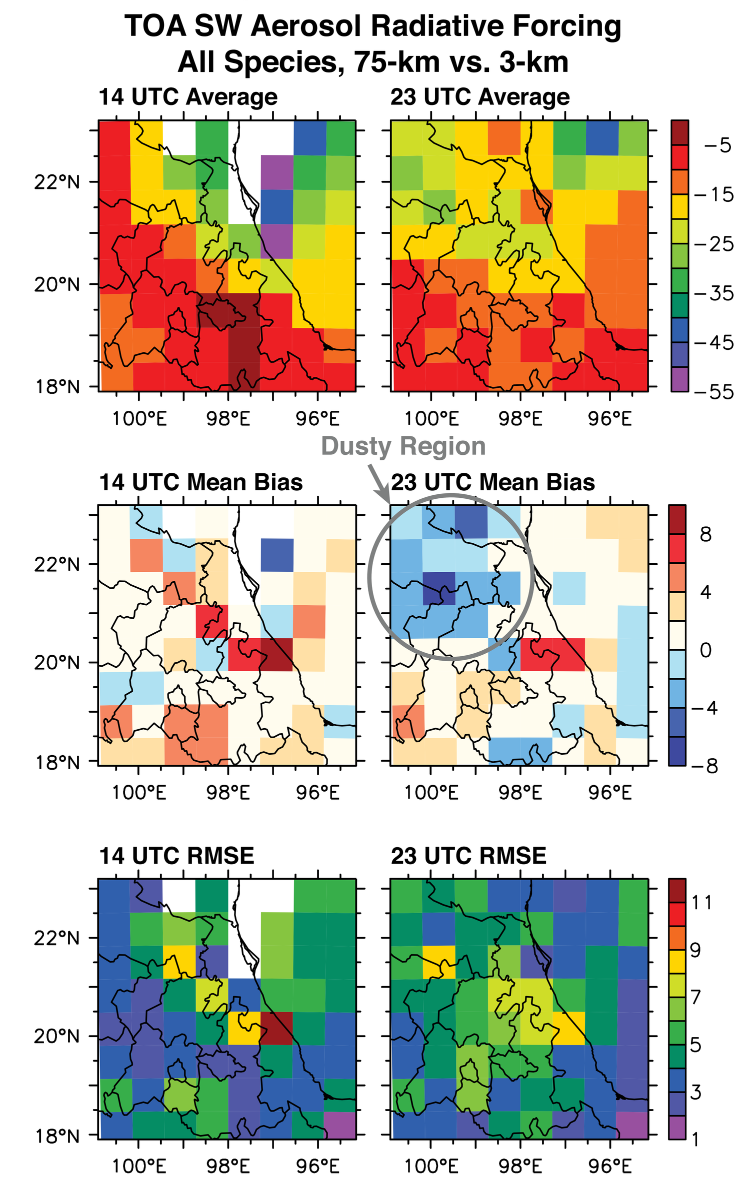

Figure 6. Comparison showing spatial variation of shortwave direct aerosol radiative forcing (ARF) for the 75-km simulation vs. the 3-km simulation when including all aerosol species. Results averaged for the period 4–21 March 2006 for the respective hour. Units are W m^{-2}.

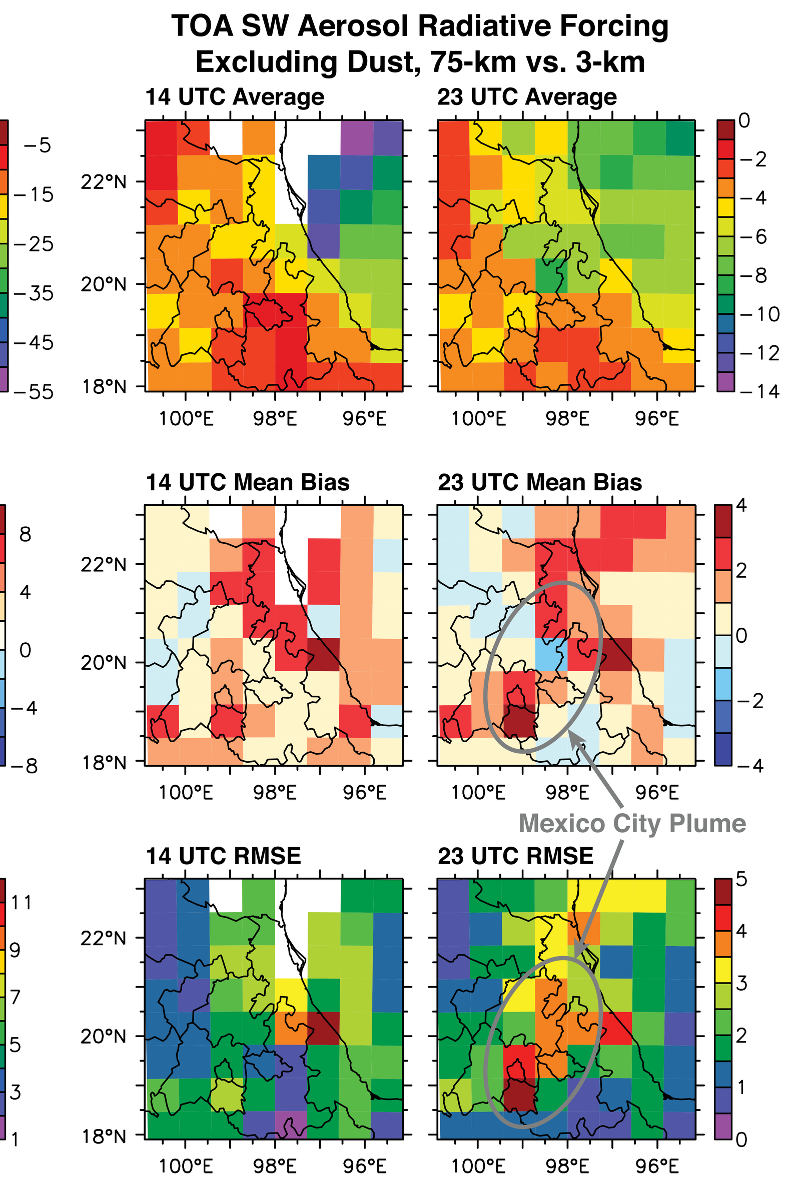

Figure 7. Same as in Figure 6 except that the comparison between the 75-km and 3-km simulations excludes dust from the aerosol composition when calculating the direct ARF.

- Dust emission dominates signal in “all aerosol species” analysis.
- Plume structure downwind of Mexico City becomes evident in scale induced error when excluding dust.
- Neglecting subgrid variability results in >30% error over much of central Mexico in TOA direct aerosol radiative forcing, whole domain average over 2 weeks is ~10% error.
- Need to expand study to other megacities to assess sensitivity to topography, season, dominant pollution type, etc.

5. References

Gustafson, W. I., Jr., Y. Qian, and J. D. Fast (2011), Downscaling aerosols and the impact of neglected subgrid processes on direct aerosol radiative forcing for a representative global climate model grid spacing, *J. Geophys. Res.*, *116*, D13303, doi:10.1029/2010JD015480.

Qian, Y., W. I. Gustafson, Jr., and J. D. Fast (2010), An investigation of the sub-grid variability of trace gases and aerosols for global climate modeling, *Atmos. Chem. Phys.*, *10*, 6917–6946, doi:10.5194/acp-10-6917-2010.

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