Effect of meteorological variability on fine particulate matter simulations over the contiguous United States

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ABSTRACT

Meteorological processes play a vital role in air quality simulations by affecting atmospheric chemical kinetics, emissions, advection, diffusion, and deposition. We quantify the impact of meteorological variability on the Community Multiscale Air Quality (CMAQ) model simulated particulate matter of aerodynamic diameter 2.5 μm or smaller ($PM_{2.5}$) over the contiguous United States (CONUS). The meteorological variability is represented using the Short- Range Ensemble Forecast (SREF) produced operationally by the National Oceanic and Atmospheric Administration (NOAA). A hierarchical cluster analysis technique is applied to down-select a subset of the SREF members that objectively accounts for the overall meteorological forecast variability of SREF. Three SREF members are selected to drive offline CMAQ simulations during January, April, July, and October 2016. Model results show that the meteorological variability affects all the processes that control $PM_{2.5}$, but has a stronger influence on emissions, vertical diffusion, aerosol processes, cloud processes, and dry deposition compared to horizontal advection, vertical advection, and horizontal diffusion. Averaged over CONUS, CMAQ simulations driven by all three meteorological configurations capture the observed daytime low and nighttime high $PM_{2.5}$ mass concentrations but underestimated the observed concentrations. $PM_{2.5}$ levels across the three simulations agreed well during daytime but showed larger variability during nighttime. The integrated process analysis shows that vertical diffusion is the main driver for larger nighttime variability except during October, when both the emissions and vertical diffusion play important roles. The meteorology-induced variability in $PM_{2.5}$ is estimated to be 0.08–24 $\mu g/m^3$ over the CONUS with larger variability over the eastern U.S.