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Simulating aerosol-radiation-cloud feedbacks on meteorology and air quality over eastern China under severe haze conditions in winter

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The aerosol-radiation-cloud feedbacks on meteorology and air quality over eastern China under severe winter haze conditions during January 2013 are simulated using the fully coupled on-line Weather Research and Forecasting/Chemistry (WRF-Chem) model. Three simulation scenarios including different aerosol configurations are undertaken to distinguish the impact of aerosol radiative (direct and semi-direct) and indirect effects on meteorological variables and air quality. Simulated spatial and temporal variations of PM2.5 are generally consistent with surface observations, with a mean bias of $^{-1}8.9$ μg/m3 ($^{-1}5.0\%$) averaged over 71 big cities in China. Comparisons between different scenarios reveal that aerosol radiative effects (direct effect and semi-direct effects) result in reductions of downward shortwave flux at the surface, 2 m temperature, 10 m wind speed and planetary boundary layer (PBL) height by up to 84.0 W/m2, 3.2 oC, 0.8 m/s, and 268 m, respectively. The simulated impact of the aerosol indirect effects is comparatively smaller. Through reducing the PBL height and wind speeds, the aerosol effects lead to increases in surface concentrations of primary pollutants (CO and SO_2) and PM2.5. The aerosol feedbacks on secondary pollutants such as surface ozone and PM2.5 mass concentrations show some spatial variations. Surface O_3 mixing ratio is reduced by up to 6.9 ppb due to reduced incoming solar radiation and lower temperature. Comparisons of model results with observations show that inclusion of aerosol feedbacks in the model significantly improves model performance in simulating meteorological variables and improves simulations of PM2.5 temporal distributions over the North China Plain, the Yangtze River Delta, the Pearl River Delta, and Central China. Although the aerosol-radiation-cloud feedbacks on aerosol mass concentrations are subject to uncertainties, this work demonstrates the significance of aerosol-radiation-cloud feedbacks for real-time air quality forecasting under haze conditions.