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Exploring the severe winter haze in Beijing: the impact of synoptic weather, regional transport and heterogeneous reactions

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Extreme haze episodes repeatedly shrouded Beijing during the winter of 2012–2013, causing major environmental and health problems. To better understand these extreme events, we performed a model-assisted analysis of the hourly observation data of PM2.5 and its major chemical compositions. The synthetic analysis shows that, (1) the severe winter haze was driven by stable synoptic meteorological conditions over northeastern China, and not by an abrupt increase in anthropogenic emissions. (2) Secondary species, including organics, sulfate, nitrate, and ammonium, were the major constituents of PM2.5 during this period. (3) Due to the dimming effect of high loading of aerosol particles, gaseous oxidant concentrations decreased significantly, suggesting a reduced production of secondary aerosols through gas phase reactions. Surprisingly, the observational data reveals an enhanced production rate of secondary aerosols, suggesting an important contribution from other formation pathways, most likely heterogeneous reactions. These reactions appeared to be more efficient in producing secondary inorganics aerosols than organic aerosols resulting in a strongly elevated fraction of inorganics during heavily polluted periods. (4) Moreover, we found that high aerosol concentration was a regional phenomenon. The accumulation process of aerosol particles occurred successively from southeast cities to Beijing. The apparent sharp increase in PM2.5 concentration of up to several hundred μg m-3 per hour recorded in Beijing represented rapid recovery from an interruption to the continuous pollution accumulation over the region, rather than purely local chemical production. This suggests that regional transport of pollutants played an important role during these severe pollution events.