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Influences of Meteorological Anomalies on An Extreme Winter Haze Event in Beijing - A Numerical Study Using WRF-Chem

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Beijing has made great efforts to reduce anthropogenic emissions for the last decade and its air quality, consequently, does show a slight improvement since 2007 as reflected by the decreasing Air Pollution Index (API) trend. However, during the January 2013, this megacity was frequently shrouded by heavy haze and the $PM_{2.5}$ observed in an urban site was higher than 75 μg $m^{-3}$for two thirds of that month. On 12^{th} January, an unprecedented haze event assaulted Beijing with the daily $PM_{2.5}$ soared to 568.5 μg m^{-3} and API hit the upper limit. Through the analysis of historical meteorological data, we found that Beijing experienced the lowest average wind speed and the highest relative humidity (RH) in this January since 2000 and the frequency of prevailing northerly winter winds was abnormally low. We suggested that the high $PM_{2.5}$ levels during this month including the extreme haze were mainly attributed to the climate anomalies in wind and RH. A series of simulations using a coupled meteorology-chemistry model (WRF-Chem) was used to study the role of the unique climate anomalies played in the episode as a case. The unusual week winds at surface and strong southerly winds at the 300-900 m layer created a strong temperature inversion and thus humidity and pollutants were trapped within the shallow boundary layer beneath the inversion, which was the main reason for the episode. Sensitivity simulations suggested that the local emission was the major contributor at the surface (40 m) whereas the regional contribution dominated at the upper layer (40-1500 m). Emergency and more stringent long-term emission controls should be applied in Beijing and surrounding provinces to prevent severe pollutions in case similar anomalous meteorological conditions occur again. During the episode, both surface weather pattern and transport pathway showed unique behaviors under the climate anomalies. The transport pathway even extended from the East China Plain, indicating that emission reductions over a wider area are also needed.