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Diagnostic analysis of winter PM2.5 pollution in the North China Plain: the impacts of regional transport and atmospheric boundary layer variation

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Air pollution has become a regional problem recently in the North China Plain (NCP), which is heavily populated with industrialized city clusters. Local air quality is frequently affected by air pollutant transport in this region, as well as other meteorological conditions. This work tries to reveal the roles of air pollutant transport and the atmospheric boundary layer (ABL) variation in the development of air pollution episodes. Two cities (Dezhou and Cangzhou in Shandong and Hebei provinces respectively) at the center area of the NCP were chosen, and PM2.5 in wintertime of two years (December 2016 and December 2017 to January 2018) was taken into concern (wintertime is the major period of air pollution in the NCP and PM2.5 is the major air pollutant). Data of meteorological observation and PM2.5 concentration monitoring over NCP were used to construct hourly wind and PM2.5 concentration fields. High quality ABL soundings provided detailed information of the ABL depth and its diurnal evolution. A simple box model was employed to simulate the PM2.5 variation in these two cities, by using the spatial gradients and temporal variation rates in the diagnostic fields of wind and PM2.5 concentration. The simulation results were encouraging for given source strengths in these two cities, and with the observed ABL depths. After further tuning of the model parameters, two factors were isolated. One was the entrainment of upper-layer air pollutants into the ABL in the morning. The other one was the temporary accumulation of PM2.5 concentration during the day-to-evening period. By including these effects, the model simulated the PM2.5 concentration in these two cities excellently (The correlation coefficients between the simulation and observation were 0.85 and 0.79 (p=0.01) for Cangzhou and Dezhou respectively, and the normalized mean bias were -0.003 and -0.048). Based on these simulations, the contribution rates of different terms affecting the PM2.5 episodes were assessed. It is shown that, the rates for terms of source, deposition, wind advection and ABL depth variation were 40∼52%, -37%∼-22%, 43∼103%, -4∼37%, respectively. Local source emission and regional air pollutant transport were the main causes for these episodes. In particular, severe haze episodes usually associated with significant ABL-entrainment effect in the morning and temporary accumulation of PM2.5 concentration during the day-to-evening period. The contribution rates of these two factors were estimated as high as 2∼16% and 24%-26%.