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WRF-Chem simulation of black carbon episodes over Europe: transportation, regional radiative forcing, and influence on snow melting in Alpine region

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Black Carbon (BC) plays an important role in the earth climate system in both regional and global scales. In addition to its strong light absorption effects and resulting direct and semi-direct radiative forcing when suspended in air, BC deposited on snow and ice surfaces can reduce the snow/ice albedo and accelerate the melting of snow cover and sea ice.

BC concentrations have been continuously monitored at 10 sites win Germany (German Ultrafine Aerosol Network, GUAN) and several other sites over Europe since 2008. Strong BC episodes in winter and spring time were observed with BC concentration peaking at 10 to 15 μg cm-3. Those episodes were featured by (1) highest BC concentrations mostly at the low altitude sites (Leipzig, Melpitz, Boesel, and Waldhof) over a large region of the northeast Germany, (2) concurrent increases of BC concentrations at high altitude sites (Augsburg, Schauinsland, Hohenpeissenberg, and Zugspitze), and (3) accumulating under a dominant high pressure system. However, it is worth to notice that the highest BC concentrations at the high altitude sites were found during spring and summer time.

To investigate both transportation and regional climate effects of BC over Europe, on-line fully coupled WRF-CHEM (v 3.2) simulations were conducted at nested multi-resolutions (36 km over Europe, 12 km over Germany, and 4km over specific interested regions, such as Leipzig-Saxony region and high altitude Zugspitze Alpine region for a pre-, during, and post- late spring episode period (March 20 to April 10, 2009). Sensitivity studies on anthropogenic emissions at different resolutions, 1.0 degree (ARCTAS), 0.5 degree (EMEP) and 1/8$\times$1/16 degree (EUCAARI) were made. At the same time, MEGAN biogenic emissions and MODIS fire emissions were employed.

Modeled meteorological fields are evaluated by surface observations and radiosounde vertical profiles, and the square correlation coefficients are in general between 0.8 to 0.95. Good agreement is found between observed and simulated PM2.5 and total particles numbers (40-800 nm). The simulated aerosol optical depth (AOD) is found to capture the spatial pattern of MODIS AOD at 550 nm. At 12 km resolution, the model is able to accurately predict the BC concentrations at most of the sites, and 4 km resolution further benefits the simulations at the high-altitude sites, mainly due to the enhanced meteorological field over the complicated topology.

Direct and indirect effects of aerosol particles and BC are analyzed by switching on/off the total anthropogenic and/or BC primary emissions, and calculating net changes of surface temperature, downward shortwave radiation, planetary boundary height, NO2 photolysis rate, aerosol and cloud albedo etc. Furthermore, the calculations of the changes of snow albedo is embedded into the WRF-Chem simulations by tracking the BC dry/wet depositions and their impacts on the surface albedo, and used to investigate the influence of deposited BC on the snow melting on Alpine areas during BC episodes.