Understanding Aerosol Vertical Transport During Heavy Aerosol Pollution Episodes in the North China

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Due to excessive anthropogenic emissions, heavy aerosol pollution episodes (HPEs) often occur during winter in the Beijing-Tianjin-Hebei (BTH) area of the North China Plain. Extensive observational studies have been carried out to understand the causes of HPEs; however, few measurements of vertical aerosol fluxes exist, despite them being the key to understanding vertical aerosol mixing, specifically during weak turbulence stages in HPEs. In the winter of 2016 and the spring of 2017 aerosol vertical mass fluxes were measured by combining large aperture scintillometer (LAS) observations, surface PM$_{2.5}$ and PM$_{10}$ mass concentrations, and meteorological observations, including temperature, relative humidity (RH), and visibility, at a rural site in Gucheng (GC), Hebei Province, and an urban site at the Chinese Academy of Meteorological Sciences (CAMS) in Beijing located 100 km to the northeast. These are based on the light propagation theory and surface-layer similarity theory. The near-ground aerosol mass flux was generally lower in winter than in spring and weaker in rural GC than in urban Beijing. This finding provides direct observational evidence for a weakened turbulence intensity and low vertical aerosol fluxes in winter and polluted areas such as GC. The HPEs included a transport stage (TS), an accumulative stage (AS), and a removal stage (RS). During the HPEs from 25 January 2017 to January 31, 2017, in Beijing, the mean mass flux decreased by 51% from 0.0049 mg m$^{-2}$s$^{-1}$ in RSs to 0.0024 mg m$^{-2}$s$^{-1}$ in the TSs. During the ASs, the mean mass flux decreased further to 0.00087 mg m$^{-2}$s$^{-1}$, accounting for approximately 1/3 of the flux in the TSs. A similar reduction from the TSs to ASs was observed in the HPE from 16 December 2016 to 22 December 2016 in GC. It can be seen that from the TS to the AS, the aerosol vertical turbulent flux decreased, but the aerosol particle concentration within surface layer increased, and it is inferred that in addition to the contribution of regional transport from upwind areas during the TS, suppression of vertical turbulence mixing confining aerosols to a shallow boundary layer increased accumulation.