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Aerosol optical properties and its radiative effects to planetary boundary layer during air pollution episodes in North China: Intercomparison of a plain site and a mountainous site in Beijing

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The aerosol microphysical, optical and radiative properties of the whole column and upper planetary boundary layer (PBL) were investigated during 2013 to 2018 based on long-term sun-photometer observations at a surface site (~106 m a.s.l.) and a mountainous site (~1225 m a.s.l.) in Beijing. Raman-Mie lidar data combined with radiosonde data were used to explore the aerosol radiative effects to PBL during dust and haze episodes. The results showed size distribution exhibited mostly bimodal pattern for the whole column and the upper PBL throughout the year, except in July for the upper PBL, when a trimodal distribution occurred due to the coagulation and hygroscopic growth of fine particles. The seasonal mean values of aerosol optical depth at 440 nm for the upper PBL were 0.31 ± 0.34, 0.30 ± 0.37, 0.17 ± 0.30 and 0.14 ± 0.09 in spring, summer, autumn and winter, respectively. The single-scattering albedo at 440 nm of the upper PBL varied oppositely to that of the whole column, with the monthly mean value between 0.91 and 0.96, indicating weakly to slightly strong absorptive ability at visible spectrum. The monthly mean direct aerosol radiative forcing at the Earth's surface and the top of the atmosphere varied from −40 ± 7 to −105 ± 25 and from −18 ± 4 to −49 ± 17 W m^{-2}, respectively, and the maximum atmospheric heating was found in summer (~66 ± 12 W m^{-2}). From a radiative point of view, during dust episode, the presence of mineral dust heated the lower atmosphere, thus promoting vertical turbulence, causing more air pollutants being transported to the upper air by the increasing PBLH. In contrast, during haze episode, a large quantity of absorbing aerosols (such as black carbon) had a cooling effect on the surface and a heating effect on the upper atmosphere, which favored the stabilization of PBL and occurrence of inversion layer, contributing to the depression of the PBLH.

Keywords: aerosol optical properties, radiative effects, planetary boundary layer, dust, haze, Beijing