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Vertical transport mechanisms of black carbon over East Asia in spring during the A-FORCE aircraft campaign

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Black carbon (BC) aerosols efficiently absorb solar radiation in the atmosphere. The absorption leads to heating of the atmosphere and melting of some additional snow or sea ice, therefore exerting a substantial impact on radiation budget in the climate system. The vertical transport processes of BC from the planetary boundary layer (PBL) to the free troposphere (FT) are critically important, because they directly control the global- and regional-scale spatial distributions of BC; however an understanding of this process is still limited. In order to understand these points, the Aerosol Radiative Forcing in East Asia (A-FORCE) aircraft campaign was conducted over East China Sea and Yellow Sea in March-April 2009 and 120 vertical profiles of BC were obtained at 0-9 km in altitude. The major objective of this study is to understand the vertical transport mechanisms of BC particles and their transport pathways over East Asia in spring using results from the 3-D chemical transport model (WRF-CMAQ) calculations and the A-FORCE observation data.

The original CMAQ model does not take into account differences in rainout and washout processes. In this study, we modified the CMAQ model to treat rainout and washout processes separately. We conducted the WRF-CMAQ model calculations with horizontal resolution of 81 km $*$ 81 km and with 21 layers in vertical, and used the model results in March-April 2009. We also estimate transport efficiency of BC on the basis of the calculation with wet deposition and that without wet deposition using the modified CMAQ model.

Comparisons of the model results with the A-FORCE observations show that the model reproduces relatively well the vertical distributions of mass concentration and transport efficiency of BC, including dependences on precipitation that air parcels had been experienced during transport, although the model overestimated the mass concentrations of BC in the FT.

Using the validated model results during the A-FORCE period (20 March to 30 April 2009), we find that the pronounced convergences of mean horizontal mass fluxes of BC integrated within the PBL (700-1000-hPa column) over northern-eastern and inland-southern (around the high-altitude mountains) China. Corresponding to the convergence areas, we find two types of the pronounced upward mass fluxes of BC from the PBL to the FT (at the 700-hPa level) over northern-eastern and inland-southern China. The major uplifting mechanism of BC over northern-eastern China is cyclones with modest amounts of precipitation. In addition to cumulus convections, orographic lifting along the high-altitude mountains plays important role for the upward transport of BC to the FT over inland-southern China, in spite of the largest wet deposition amounts of BC in East Asia due to large amounts of precipitation. The latitudinal difference of precipitation induced by the moisture supply by the low-level southerlies is responsible for the spatial distributions of BC and its transport efficiency in the atmosphere.

The mean eastward mass fluxes of BC were pronounced in the lower troposphere over the midlatitude region (35?50N) and in the middle troposphere over the subtropical region (20?35N) at the 140E vertical cross section during the A-FORCE period. We find that the upward transports over northern-eastern and inland-southern China, followed by the westerly transports in the lower and the middle FT, respectively, make major contributions to the exports of BC from East Asia to the Pacific in spring.

Keywords: Aerosol, Black carbon, Transport, Wet deposition, East Asia, Regional-scale aerosol model