Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U04-04 Room:211 Time:April 29 09:45-10:00

Aerosol measurements by aircraft and modeling studies

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Most aerosol components scatter solar radiation; however, black carbon (BC) aerosols efficiently absorb it and lead to heating of the atmosphere. Because of these effects, the role of BC particles in the climate system has been recognized to be particularly important. However, there remain large uncertainties in the calculations of the spatial distributions of BC and its light absorption in current global models. One of the main causes is considered to be large uncertainties in the vertical transport and wet removal processes of BC adopted in aerosol models. Understandings of the vertical transport and wet removal processes of BC are critically important because they directly controls spatial distribution of BC and its radiative effects. To improve our understanding of these processes, aircraft measurements covering the entire altitude range of the troposphere are needed; however, there have been no aircraft observations of BC measurements covering the entire altitude range of the troposphere over East Asia since the ACE Asia and TRACE-P campaigns in spring 2001.

The Aerosol Radiative Forcing in East Asia (A-FORCE) aircraft campaign was conducted over the Yellow Sea, the East China Sea, and the western Pacific Ocean in March-April 2009 (Oshima et al., 2012; Moteki et al., 2012; Koike et al., 2012; Takegawa et al., 2013). During the campaign, 120 vertical profiles of BC particles, carbon monoxide (CO) concentrations, aerosol number concentrations, and cloud microphysical properties were measured at 0-9 km in altitude. The A-FORCE measurements showed that concentrations of BC were greatly enhanced in the free troposphere (FT) over the Yellow Sea. In this study (Oshima et al., 2012), the transport efficiency of BC (namely the fraction of BC particles not removed during transport) for sampled air parcels was estimated from changes in observed BC-to-CO ratios, because CO can be used as an inert combustion tracer within a timescale of a few weeks. The transport efficiency of BC decreased primarily with the increase in the precipitation amount that air parcels experienced during transport, and its value was about 70-90% and 30-50% at 2-4 km and 4-9 km levels, respectively.

Vertical transport and removal processes of BC over East Asia in spring were examined through numerical simulations for the A-FORCE campaign using a modified version of the regional-scale three-dimensional chemical transport model WRF-CMAQ (Oshima et al., 2013). The simulations reproduced the vertical distributions of the transport efficiency of BC observed by the A-FORCE campaign reasonably well, indicating the validity of the treatment of the wet removal processes of aerosols in the model. We identified three major transport pathways for BC export from East Asia to the western Pacific in spring. One pathway was the planetary boundary layer (PBL) outflow through which BC was advected by the low-level westerlies without uplifting out of the PBL (weak BC removal). The second pathway was through uplifting from the PBL to the FT by migratory cyclones over northeastern China and the subsequent eastward transport in the lower FT (moderate BC removal). The third pathway was orographic uplifting and/or convective upward transport from the PBL to the FT over inland-southern China followed by westerly transport in the mid-FT (strong BC removal).

We will introduce our studies with a particular focus on the importance of the aerosol measurements by aircraft and its importance for modeling studies in this presentation.

References

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Keywords: Aircraft measurements, Aerosols, Black carbon, Aerosol model, Transport, Removal