

Impacts of black carbon aging on its spatial distribution and radiative effect in the global scale

OSHIMA, Naga^{1*}; TANAKA, Taichu²; KOSHIRO, Tsuyoshi¹; KAWAI, Hideaki¹; DEUSHI, Makoto¹; KOIKE, Makoto³; NOBUHIRO, Moteki³; KONDO, Yutaka³

¹Meteorological Research Institute, ²Global Environment and Marine Department, Japan Meteorological Agency, ³Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo

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. Freshly emitted hydrophobic BC particles become internally mixed with other water-soluble compounds through aging processes and they are converted to hydrophilic BC. Internal mixing with sufficient water-soluble compounds enhances the BC absorption efficiency of solar radiation, and the hydrophilic BC particles are able to serve as cloud condensation nuclei (CCN), which can be removed from the atmosphere by precipitation. Consequently, aging processes of BC influence its atmospheric lifetime and play an important role for the spatial distributions of BC and its radiative effects. However, a simple approach using constant values of the conversion rate from hydrophobic BC to hydrophilic BC (such as 24 hours) has been widely used in most global models and there were large uncertainties in estimating the spatial distribution of BC and its radiative forcing in previous studies. Recent studies pointed out the necessity of an advanced parameterization of BC aging processes to improve the quantitative estimation of the climate impacts of BC.

Recently, Oshima and Koike [2013] developed a new parameterization of BC aging based on the physical and chemical processes. In this parameterization, the conversion rate from hydrophobic BC to hydrophilic BC is expressed as a production rate of condensed materials normalized by the hydrophobic BC mass concentration. In this study, we applied this parameterization to the global-scale aerosol model MASINGAR-mk2 included in the MRI's earth system model [Yukimoto et al., 2012], which enables the representation of spatial and temporal variations of the conversion rate of BC aging depending on atmospheric conditions (the original approach assumed the constant conversion rate of 1.2 days).

We performed the model calculation with the BC aging parameterization for 2008-2009. We find that the conversion time scales from hydrophobic BC to hydrophilic BC exhibit distinct spatial variations and they were approximately one day and one week over the source regions in East Asia and the remote regions in the Arctic, respectively. We also performed the model calculation with the constant conversion rate (1.2 days) for the comparison. Over the source regions in East Asia, both calculations give small differences in BC mass concentrations and they reproduced the seasonal variations of BC mass concentrations observed by the surface measurements reasonably well. On the other hand, the both calculations give large differences in BC mass concentrations over the Arctic regions and the calculation with the parameterization improved the prediction of the BC mass concentration, which was underestimated in the constant-rate calculation.

The direct radiative forcing by BC (annually and globally averaged at the top of atmosphere) was approximately 0.3 W m^{-2} for the calculation with the parameterization (approximately 0.2 W m^{-2} for the constant-rate calculation). This result indicates that the aging process of BC in the micro-scale can significantly impact on the spatial distribution and radiative forcing in the global-scale through the parameterization. However, the calculations shown in this study do not take into account the enhancement of BC light absorption due to coatings and they may underestimate the direct radiative forcing. We will introduce model results including the enhancement effect in this presentation.

References

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