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Aging and long-range transport processes of black carbon: global simulation with a chemistry-aerosol climate model

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Present global aerosol models generally have a severe tendency to underestimate atmospheric concentrations of black carbon (BC) especially in remote areas like the polar regions as shown by the recent model intercomparison project under the IPCC (ACCMIP/AeroCOM). Such underestimates of BC are basically coming from large uncertainties in aging process which makes hydrophobic BC to hydrophilic, and subsequent removal by precipitation. This problem in global BC modeling causes still a large uncertainty in the estimate of atmospheric heating and climate impacts of BC (Kerr, Science, 2013). This study attempted to improve global simulation of BC and re-evaluate radiative forcing of BC in the framework of a chemistry-aerosol coupled climate model MIROC-ESM-CHEM. Our previous study (Sudo and Endo, 2011) had successfully reproduced the concentration and seasonal cycle of BC observed at the Syowa station in the Antarctic, by applying a simplified aging scheme that considers coating of BC with SO_4^{2-} (Liu et al., 2011) to the MIROC-ESM-CHEM model. Our model, however, could not reproduce well the observed BC levels and seasonality in the northern high latitudes including in the Arctic. This study developed a new scheme to simulate more explicitly aging of BC associated with condensation of SO_4^{2-} and organic compounds from oxidation of VOCs. Additionally, several improvements were also added to the model for better simulating dry/wet deposition and emissions seasonality. Our improved model with the new aging scheme appears to relatively well reproduce the observed BC concentrations and seasonality in the Arctic region. Our simulation also showed that Arctic BC comes mainly from fossil fuel burning in winter to spring, but from the Siberian biomass burning in summer. The new model estimated radiative forcing of BC to be 0.83 W m^{-2} which is about two times larger than the estimate by our original model with no aging scheme (0.41 W m^{-2}), or the model ensemble mean in the IPCC report.

Keywords: black carbon, soot, aging, long-range transport, radiative forcing, global model