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Influences on aerosol optical properties and CCN activities due to variability of size distributions of black carbon

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The Model of Aerosol Dynamics, Reaction, Ionization, and Dissolution with resolution of a mixing state of black carbon (BC) (referred to as MADRID-BC hereafter) has been recently developed to accurately simulate the time evolution of the entire BC mixing state due to condensation. Mie and Kohler theories, which take into account the entire BC mixing state, are implemented in the MADRID-BC box model in order to accurately calculate aerosol optical properties and cloud condensation nuclei (CCN) activities resulting from changes in the entire BC mixing state. In this study, we apply MADRID-BC to evaluate the influences of variability of BC core size distributions on aerosol optical properties and CCN activities associated with changes in BC mixing states in air parcels horizontally transported out from an urban area in Japan within the planetary boundary layer over the ocean.

Various size distributions of BC cores have been observed in the atmosphere in previous studies. In an urban center in the Tokyo metropolitan area in Japan, where intensive BC emissions take place, a median diameter of mass size distribution of BC cores was observed to be 130 nm. During one of the flights of the Pacific Exploration of Asian Continental Emission phase C (PEACE-C) aircraft mission, a maximum mass median diameter of BC cores of 220 nm was observed in air, which was likely influenced by anthropogenic sources in Japan and experienced some aging processes.

In this study, we performed two sensitive simulations for typical air parcels influenced by Japanese anthropogenic sources in spring, using the BC core size distributions with a smaller mass median diameter of 130 nm, and the other a larger mass median diameter of 220 nm. These two median diameters are the minimum and maximum observed values in the atmosphere that have been reported in the literature. Other than the size distribution of BC cores (i.e., mass median diameters), these two sensitivity simulations use the same input and calculation procedures (e.g., using the same bulk amounts of aerosols and gaseous concentration as constraints). These simulations are referred to as the 'smaller BC size case' and 'larger BC size case,' hereafter. It is noted that the number concentration of BC particles is greater and smaller for the 'smaller BC size case' and 'larger BC size case,' respectively, because the same total BC mass concentration is used for these simulations.

The evaluation shows that the absorption coefficients at a wavelength of 550 nm in the 'smaller BC size case' are greater by 25% than those in the 'larger BC size case'. The differences in the absorption coefficients are largely due to the differences in the surface area of BC cores in each simulation. The evaluation also shows that the fractions of hydrophilic BC mass at 0.05% supersaturation in the 'larger BC size case' are greater by 80% than those in the 'smaller BC size case'. Note that according to Kohler theory, particles with larger diameters tend to have a hydrophilic nature. Because most BC mass is distributed over larger BC core diameters for the 'larger BC size case,' the hydrophilic particles contain most of the total BC mass in the 'larger BC size case'. These results indicate that the variability of BC core size distributions could have greater influence on the atmospheric lifetime of BC than that on the light absorption through changes in BC mixing states in this particular case, even when the bulk mass amounts of individual compounds in air parcels are the same.