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Measurement of the Hygroscopicity and Wet Removal of Black-Carbon-Containing Particles in the Urban Atmosphere of Tokyo

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Megacities are very large, concentrated anthropogenic sources of black carbon (BC) aerosols. Freshly emitted BC particles inside megacities affect local air quality and regional and global climate. The microphysical properties (e.g., number size distribution, coating thickness, and hygroscopicity) of atmospheric BC-containing particles are important because their efficiency of wet removal from the atmosphere can be highly dependent on these properties. In this study, we developed a method for independent measurement of the hygroscopicity of BC-free and BC-containing particles, and then applied it to the ambient observation in the urban atmosphere of Tokyo.

A single particle soot photometer (SP2) was modified as a humidified-SP2, which quantifies the BC-core mass (BC content within a BC-containing particle) and optical diameter of individual aerosol particles, under controlled relative humidity (RH), by detecting both the laser-induced incandescence emitted and laser light scattered from each particle (Schwarz et al., 2014, Journal of Aerosol Science). Measurements of growth factor (GF) and hygroscopicity parameter κ for BC-free and BC-containing particles can be achieved by combining an aerosol particle mass analyzer with the newly developed humidified-SP2.

This method was tested in the laboratory and then employed in ambient observations in summer 2014. The ambient measurements were made while also measuring number size distribution of BC cores in rainwater with a nebulizer–SP2 system. Throughout the observation period, for BC-containing particles with a dry diameter of about 200 nm, the particles with smaller BC fractions tended to represent greater water uptake, and the number fraction of the less hygroscopic (GF $<$ 1.2 at 85% RH) BC-containing particles was more than 70% of the total BC-containing particles. The measured average number size distribution of BC cores in rainwater was larger than that in the surface air before precipitation began, and the dependence of the wet removal of BC-containing particles on their BC-core sizes was successfully explained by the measured microphysical properties of BC-containing particles in the air and an assumed maximum supersaturation that the particles would have experienced during rain events. These measurement data indicated that BC-containing particles in Tokyo, especially particles with small BC cores (or with high critical supersaturation), were efficiently transported upward without being removed by precipitation.