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Development of a method to measure the hygroscopicity of black carbon-containing particles

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Black carbon (BC) aerosols are generated by the combustion of fossil fuels and biomass. During transport in the atmosphere, BC particles acquire ”coating materials” through the condensation of semi-volatile gaseous components, and coagulation with the other aerosols. Freshly emitted BC particles are generally hydrophobic, so the hygroscopicity of BC-containing particles is largely controlled by the composition and amount of coating materials. Although measurement of the hygroscopicity of ambient BC-containing particles is important to understand their cloud condensation nuclei activity and optical properties, measurement data are still quite limited (McMeeking et al, 2011; Liu et al. 2013). In this study, we present a modified single particle soot photometer (SP2) as a humidified-SP2 (hSP2), which quantifies the BC mass and the amount of coating material within individual aerosol particles, under controlled relative humidity (RH), by detecting both the laser-induced incandescence emitted and laser light scattered from each BC-containing particle. High time-resolved measurements of growth factor (GF: the ratio of wet particle diameter to dry diameter) and hygroscopicity parameter κ for BC-containing particles can be achieved by combining an aerosol particle mass analyzer (APM) or a standard SP2 with the newly developed hSP2.

We have tested the hSP2 in the laboratory using both homogeneous ammonium sulfate, and internally mixed particles of BC (fullerene soot) and ammonium sulfate. These particles were dried and classified by an APM and subsequently measured by the hSP2 between 60% and 90% RH. We assumed a core-shell geometry for the BC-containing particles, and took account of the reduction in refractive index of the coating materials due to their hygroscopic growth. Measured GFs of the laboratory-generated BC-containing particles agreed with GFs predicted by κ-Köhler theory to within measurement uncertainty, demonstrating the applicability of the hSP2 for ambient measurements.

Keywords: black carbon, hygroscopicity