

Could secondary organic aerosols act as brown carbon?: Laboratory studies of aerosol absorption

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Recently, brown carbon, light absorbing organic matter other than soot has been discovered in the atmospheric aerosols of various origins such as soil humics, humic-like substances (HULIS), tarry materials from combustion, and bioaerosol. The absorption cross sections of brown carbon increase very sharply with decreasing wavelength. However, it is still unknown if secondary organic aerosols (SOA) could act as a brown carbon or not, because no detailed experimental studies about absorption of SOA have been performed. In the present study, we performed laboratory experiments to measure the optical properties of SOA produced in the photochemical smog chamber at National Institute for Environmental Studies (NIES), Japan.

The NIES chamber, which is a 6 m³ stainless steel cylinder coated with Teflon, was filled with 760 Torr of dry purified air and then the reactants were introduced. Three different reactions to produce SOAs including A) toluene/OH/NO_x photochemical reaction, B) c-hexadiene/O₃ reaction, and C) alpha-pinene/O₃ reaction, were adopted. The SOAs produced in the chamber were continuously introduced into instruments to measure the optical properties, an originally developed cavity ring-down spectrometer (CRDS) (extinction at 355 and 532 nm), a nephelometer (TSI, scattering at 450, 550, and 700 nm), and a PSAP (Radiance Research, absorption at 462, 526, and 650 nm). The size distributions of aerosol were also measured by a scanning mobility particle sizer (SMPS) (TSI). The concentrations of gaseous reactants were monitored with an FT-IR spectrometer.

Extinction, scattering, and absorption efficiencies of SOAs are calculated by dividing the extinction, scattering, and absorption coefficients (which were measured with CRDS, nephelometer, and PSAP, respectively) by total mobility cross section measured with SMPS. Refractive index of SOA is determined by comparing the size parameter dependence of extinction, scattering, and absorption efficiencies with Mie theory. As a result, it was found that 1) the SOA produced in the toluene/OH/NO_x photochemical reaction has significant absorption at 355 nm and a small but non-negligible absorption at 532 nm, 2) the SOA produced in the c-hexadiene/O₃ reaction has non-negligible absorption at 355 nm. In contrast, no significant absorption was found for the SOA produced in the alpha-pinene/O₃ reaction for both of 355 and 532 nm. Sato et al. [2007] reported that the SOA produced in the toluene/OH/NO_x photochemical reaction includes nitro-aromatic compounds such as 3-nitrotoluene and 4-nitro-o-cresol. Since nitro-phenol solutions are known to have a strong absorption at around 350 nm, the nitro-aromatic compounds in the SOAs may contribute to the absorption observed in the present study.

Using the obtained refractive index, the mass absorption cross sections of SOA produced in the Toluene/OH/NO_x photochemical reaction are estimated. The mass absorption cross sections for the SOA are found to be 1/15-1/20 of that for typical black carbons. Our results suggest that SOAs have a potential to have significant effects on radiation balance for the case that concentrations of light absorbing SOA are higher enough than those of black carbon particles.