Observations of cloud effects on aerosol light absorption and scattering

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The direct effect of aerosols to radiative forcing arises from light extinction by aerosol particles, i.e. light scattering from and absorption to the aerosols, and it still has a great uncertainty. Evaluation of its magnitude is complicated, because the optical properties depend on the wavelength of the incident light and the angular distribution of the scattered light, which, in turn, depends, e.g., on the size, concentration, and chemical composition of the aerosol particles.

The Puijo measurement station on the top of an observation tower (306 m a.s.l. and 224 m above the surrounding lake level) near the town of Kuopio in Finland has provided continuous data on aerosol-cloud interactions since 2006. Since then the station has been covered by clouds 15 % of the time and is occasionally influenced by e.g. sulphurous compounds and black carbon emitted from local sources. The former are good scatterers of light and the latter absorbs light efficiently.

With a special inlet setup (total and interstitial inlets) and a switching valve system we are able to separate the activated particles from the interstitial (non-activated) particles. This enables us to define the activation properties for aerosol size distribution between 3–800 nm, measured with two differential mobility particle sizers, light scattering at the wavelengths of 450, 550, and 700 nm, measured with a nephelometer (TSI Model 3563) and light absorption at the wavelength of 670 nm, measured with a Multi-Angle Absorption Photometer (Thermo Model 5012).

The level of cloud scavenging depends not only on the aerosol size but also its chemical composition and atmospheric age. We have found that during a cloud event the scattering and absorption values for non-activated particles compared to those for the activated particles are sometimes smaller and sometimes not (Leskinen *et al.* 2012). The decrease is, on an average, -22 % for absorption and -76 % for scattering.

The stronger decrease in scattering may be due to the fact that the absorptive material, e.g. fresh soot, is generally hydrophobic and therefore inhibits activation.. This results in a decrease in the single scattering albedo (SSA), which is the ratio of scattering to extinction (scattering + absorption). The SSA determines whether an aerosol layer causes net heating or cooling. For example, during two cloud events the SSA dropped from its initial value of 0.80–0.85 to as low as 0.4–0.5, on an average (Figure 1). A similar, but not as intensive, decrease in the SSA was observed by Berkowitz *et al.* (2011) in a foggy situation.

The scavenging is less efficient when the wind blows from the direction of local pollutant sources (the first cloud event in Figure 1) than when it blows from a cleaner sector with no local sources (the second cloud event in Figure 1). A similar observation was done by Sellegri *et al.* (2003) who concluded that the scavenging efficiency in clouds is enhanced by aging of organic species and subsequent mixing.

After the second cloud event the incoming air was clean and the scattering and absorption coefficients decreased to the same levels as during the second cloud. The low SSA values can be explained by the uncertainties in the low scattering and absorption coefficients and by the sensitivity of the SSA to the scattering coefficient value, especially in dry conditions.

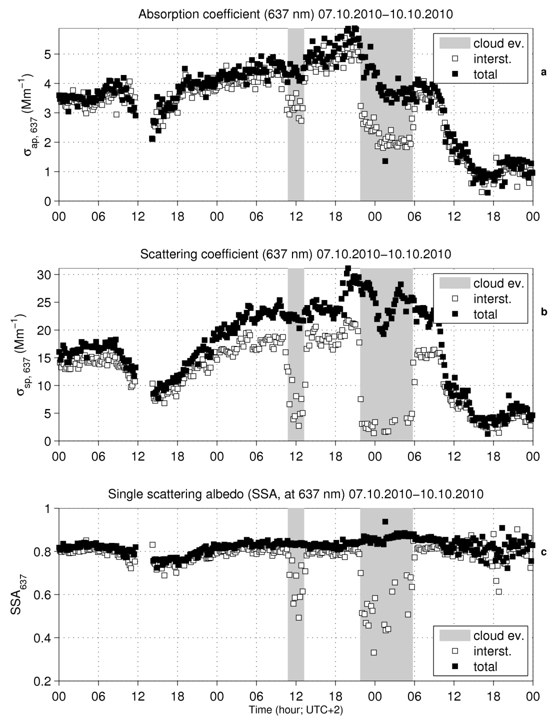

Figure 1. The evolution of (a) aerosol light absorption, (b) light scattering, and (c) single scattering albedo (SSA) around cloud events at Puijo in October 2010.

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