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Effects of relative humidity on aerosol light scattering in the Arctic

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Aerosol particles experience hygroscopic growth in the ambient atmosphere. Their optical properties - especially the aerosol light scattering - are therefore strongly dependent on the ambient relative humidity (RH). In-situ light scattering measurements of long-term observations are usually performed under dry conditions ($\mathrm{RH} < 30-40\,\%$). The knowledge of this RH effect is of eminent importance for climate forcing calculations or for the comparison of remote sensing with in-situ measurements.

This study combines measurements and model calculations to describe the RH effect on aerosol light scattering for the first time of aerosol particles present in summer and fall at the high Arctic. For this purpose, a field campaign was carried out from July to October 2008 at the Zeppelin station in Ny-Ålesund, Svalbard.

The aerosol light scattering coefficient $\sigma_{sp}(\lambda)$ was measured at three distinct wavelengths ($\lambda = 450$, 550, and 700 nm) at dry and at various, predefined RH conditions between 20 % and 95 % with a recently developed humidified nephelometer (WetNeph) and with a second nephelometer measuring at dry conditions (DryNeph). In addition, the aerosol size distribution and the aerosol absorption coefficient were measured. The scattering enhancement factor $f(\mathrm{RH},\lambda)$ is the key parameter to describe the RH effect on $\sigma_{sp}(\lambda)$ and is defined as the RH dependent $\sigma_{sp}(\mathrm{RH},\lambda)$ divided by the corresponding dry $\sigma_{sp}(\mathrm{RH}_{\mathrm{dry}},\lambda)$. During our campaign the average $f(\mathrm{RH}=85\,\%,\lambda=550\,nm)$ was 3.24 ± 0.63 (mean $\pm$ standard deviation), and no clear wavelength dependence of $f(\mathrm{RH},\lambda)$ was observed. This means that the ambient scattering coefficients at $\mathrm{RH}=85\,\%$ were on average about three times higher than the dry measured in-situ scattering coefficients. The RH dependency of the recorded $f(\mathrm{RH},\lambda)$ can be well described by an empirical one-parameter equation. We used a simplified method to retrieve an apparent hygroscopic growth factor g, defined as the aerosol particle diameter at a certain RH divided by the dry diameter, using the WetNeph, the DryNeph, the aerosol size distribution measurements and Mie theory. With this approach we found on average for g values of 1.61 ± 0.12 (mean $\pm$ standard deviation). No clear seasonal shift of $f(\mathrm{RH},\lambda)$ was observed during the 3-month period, while aerosol properties (size and chemical composition) clearly changed with time. While the beginning of the campaign was mainly characterized by smaller and less hygroscopic particles, the end was dominated by larger and more hygroscopic particles. This suggests that compensating effects of hygroscopicity and size determined the temporal stability of $f(\mathrm{RH},\lambda)$. During sea salt influenced periods, distinct deliquescence transitions were observed.

At the end we give a method on how to transfer the dry in-situ measured aerosol scattering coefficients to ambient values for the aerosol measured during summer and fall at this location.