ACTRIS TNA Activity Report

Influence of water uptake on the particle light scattering coefficient at a boreal site in Northern Europe (WetNephAtHyytiälä)

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Introduction and motivation

Aerosol particles can take up water and thus can change their size and chemical composition depending on the ambient relative humidity (RH). This is especially important for the particle light scattering, which strongly depends on RH. Therefore, long-term in-situ measurements of aerosol optical and microphysical properties are usually performed at standardized dry conditions to avoid the RH-effect when quantifying and characterizing the main aerosol properties (WMO/GAW, 2003). This is especially important for the aerosol light scattering coefficient $\sigma_{sp}(\lambda)$ which strongly depends on RH (λ denotes the wavelength). These dry measured values significantly differ from the ambient and thus climate relevant ones. The knowledge of this RH effect is therefore of crucial importance for climate forcing calculations. In addition, it is also needed for the comparison or validation of remote sensing with in-situ measurements.

The key parameter to describe the influence of RH on the aerosol light scattering is the scattering enhancement factor $f(\mathrm{RH},\lambda)$:

$$f(RH,\lambda) = \frac{\sigma_{sp}(RH,\lambda\,)}{\sigma_{sp}(RH_{dry},\lambda\,)}$$

where $\sigma_{sp}(RH,\lambda)$ is the scattering coefficient at a certain RH and wavelength λ and $\sigma_{sp}(RH_{dry},\lambda\,)$ is the corresponding dry scattering coefficient. The magnitude of the scattering enhancement depends on the chemical composition and on the size of the particle, which determine the scattering properties and the hygroscopicity of the particle. The scattering enhancement can be measured by using a humidified nephelometer as has been done in Hyytiälä (see below).

f(RH) has been investigated at different European sites (see e.g. Zieger et al., 2013) and clear differences was found between different aerosol types. An example is given in Figure 1, where the probability density function of measured *f*(RH)-values (at 85% RH) for different European sites is shown. In addition, it has been shown that the validation of remote sensing data (LIDAR, MAX-DOAS, satellite, see e.g. Zieger et al., 2011, 2012) is not a trivial task due to the spatial inhomogeneity of the particles.

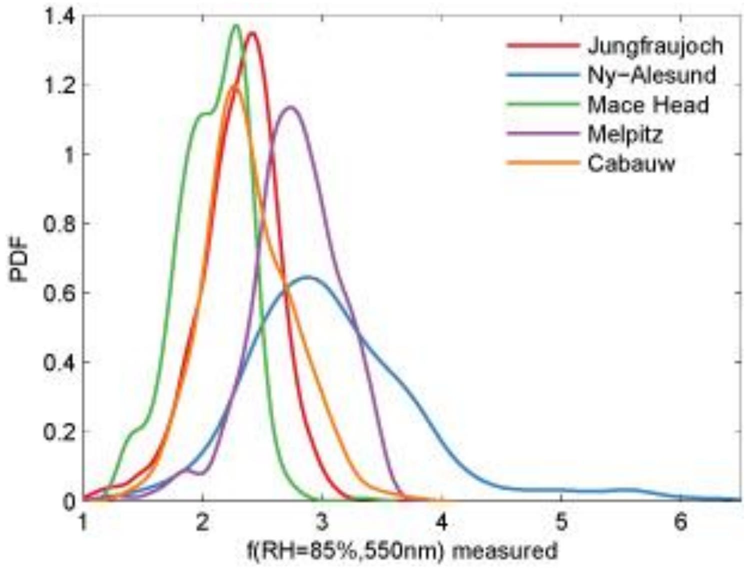

Figure 1 : Probability density function (PDF) of measured scattering enhancement f (RH=85 %, 550 nm) at different European sites (see legend). Figure taken from Zieger et al. 2013.

Scientific objectives

Two main scientific questions were asked for this field experiment:

1) What is the magnitude of the scattering enhancement *f*(RH) in the boreal forest region of northern Europe?
2) Can an optical closure between airborne (Zeppelin), ground-based in-situ and remote sensing aerosol measurements be achieved?

Many aerosol types have been characterized with respect to *f*(RH) using a similar instruments as the one deployed here (see Zieger et al., 2013), but the aerosol mainly originating from boreal areas has not been measured so far, which will be done in this work. Additionally, we will look at the long-range transported aerosol. The *f*(RH)-measurements will be compared to further micro-physical and chemical measurements that are routinely performed at the station. This is a needed task to develop a site specific model for the prediction of *f*(RH) without RH-dependent measurements.

The PEGASOS campaign also offered the unique opportunity to link our ground-based measurements to the profile measurements recorded on the Zeppelin. Here, especially the newly developed White-light Humidified Optical Particle Spectrometer (WHOPS, operated by the Paul Scherrer Institute) will be added to the data analysis. It was part of the Zeppelin instrument package and retrieved profiles of hygroscopic growth factors. All ground-based and airborne measurements can then be integrated and compared to columnar aerosol measurements and retrievals (e.g. size distribution and single scattering albedo) of AERONET.

Reason for choosing station

The SMEAR II station in Hyytiälä provides an excellent infrastructure with all the relevant auxiliary aerosol measurements. This includes the particle number size distribution (DMPS, APS and OPC), the dry particle scattering coefficient (TSI nephelometer), the chemical composition (ACSM), hygroscopic growth (HTDMA) and meteorological site. In addition, routinely remote sensing measurement are performed at Hyytiälä including aerosol optical depth measurements of the Sun photometer (AERONET). Also with its location, it is very suitable to answer our scientific research questions (1.). In addition, the PEGASOS campaign took place at the same time, with aircraft and Zeppelin measurements of aerosol properties close by (2.).

Method and experimental set-up

A humidified nephelometer (WetNeph) was installed in the campaign container at the SMEAR station. It is a modified instrument, similar to the WetNeph described in detail by Fierz-Schmidhauser et al. (2010). Briefly, the aerosol scattering coefficient $\sigma_{sp}(RH, \lambda)$ and the back scattering coefficient $\sigma_{bsp}(RH, \lambda)$ are measured at three wavelengths (λ = 450, 525, and 635 nm) at defined RH between 20% and 95%. A new nephelometer (Ecotech Aurora 3000) was used instead of the previous used TSI instrument. The operation of the WetNeph needed a second nephelometer that measure $\sigma_{sp}(\lambda)$ and $\sigma_{bsp}(\lambda)$ at dry conditions in parallel. Here, two different nephelometer will be used: The nephelometer routinely measuring at SMEAR (TSI model, located in the aerosol cottage) and the dry nephelometer which was part of the ACS system (Aerosol Conditioning System by Ecotech), which was as well installed during the campaign by Marie Laborde. The commercial ACS system will additionally be compared to the WetNeph as well.

The measurements started on May 6, 2013 until August 16, 2013, when the instruments had to be dismantled because of an upcoming tower construction near to the field campaign containers. Unfortunately, power and computer failure caused a few days of data loss during the campaign.

Preliminary results and conclusions

The time series of the particle light scattering measured by the WetNeph at RH=85% and measured by the SMEAR II TSI nephelometer (at 450nm) at dry condition is shown in Figure 2a. Certain periods with elevated particle light scattering (increased concentration) can be identified. Figure 2b shows the probability density function of the resulting scattering enhancement for the entire field campaign (preliminary data, not all calibrations applied yet). It can be seen, that the *f*(RH) is significantly lower than the values measured at other European sites (see Figure 1), probably due to the large fraction of less-hygroscopic organic compounds.

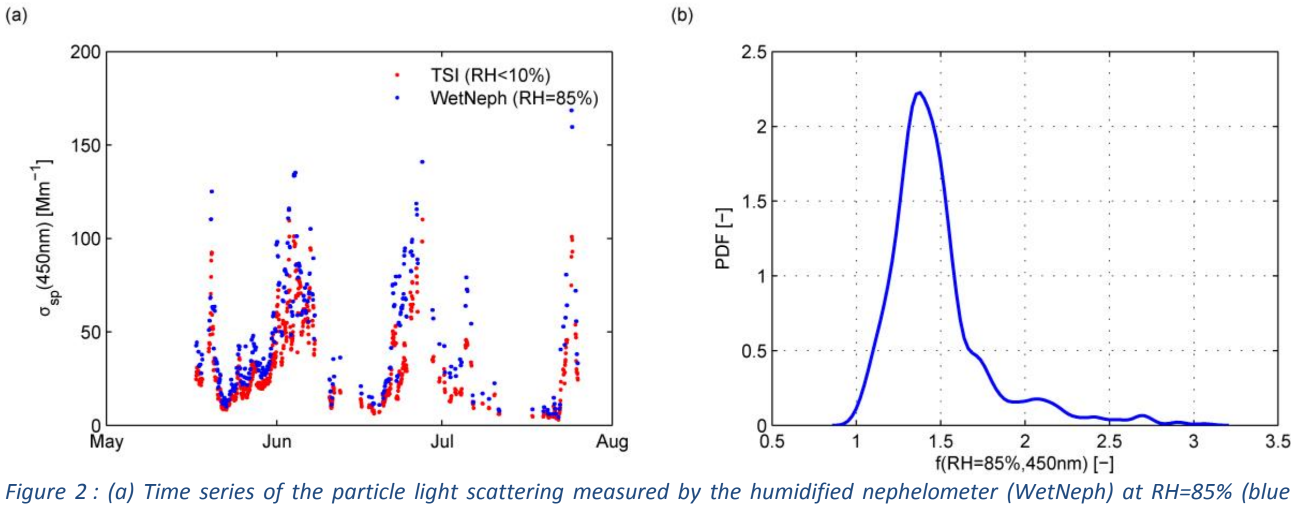

Figure 2 : (a) Time series of the particle light scattering measured by the humidified nephelometer (WetNeph) at RH=85% (blue point) and by the SMEAR TSI nephelometer at dry conditions (red points). (b) Probability density functions (PDF) of the scattering enhancement factor f(RH) at 85% and 450nm. All results are preliminary and not all corrections have been applied.

Outcome and future studies

The data analysis will be continued and the measured *f*(RH)-values will be linked to backtrajectories to identify the influence of the source regions to the magnitude of *f*(RH). In a next step, further aerosol in situ measured parameters will be added to the analysis. This includes data of the particle size distribution (DMPS, OPC, APS; in contact with Pasi Aalto), the absorption properties (Aethalometer and MAAP; in contact with John Backman) and chemical composition (ACSM; in contact with Mikko Äijälä). The columnar closure will include further data, e.g. from the ceilometer for the planetary boundary layer height (in contact with Ewan O'Connor), AERONET and the Zeppelin flights (in cooperation with Bernadette Rosati, PSI). It is envisaged to publish two separate publications on this dataset.

References

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