ParisFog Campaign (ParisFog 2012/13)

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Introduction and motivation

Fog has tremendous hazards on traffic on the road, on the sea, in the air and on the rail. The latest tragic example for this occurred in January 2013 in London, where a helicopter hit a construction crane during fog causing two fatalities (Gwyn, 2013). There is a great demand, for example from airports, for more reliable fog forecasts to prevent such accidents. Improved fog forecasts require a better understanding of the numerous complex mechanisms during the fog life cycle. To gain these insights extensive measurement campaigns are inevitable. Because of the similarity of fog and cloud formation, whose crucial role in climate is uncontested, the state of knowledge of climate can be expanded on the same time.

Scientific objectives

Cloud and fog droplets form on cloud condensation nuclei (CCN) at atmospheric water vapor supersaturations. The presence of anthropogenic CCN can lead to a modification of cloud microphysical properties and lifetime, thereby inducing indirect climate effects. Uncertainties of climate predictions are mostly caused by the poor understanding of the climate effects of aerosols. CCN activation of atmospheric aerosol particles also plays and important role for their life-cycle as wet deposition is a major removal process.

The main goal of this study are in-situ measurements of aerosol activation at the SIRTA site in Paris during foggy conditions in wintertime, with the aim to achieve a better understanding of the relative importance of aerosol size, composition and mixing state. Both the impact of the aerosol population on the fog properties as well as the effects of fog processing on the aerosol properties will be investigated in detail.

Reason for choosing station

ParisFog is a series of field campaigns aiming on fog research. It has taken place at the Site Instrumental de Recherche par Télédétection Atmosphérique (SIRTA) several times since 2006. SIRTA is located on the immediate vicinity of Ecole Polytechnique Palaiseau, on the Saclay plateau, a semi-urban environment about 20 km south of Paris. SIRTA hosts active and passive remote sensing instruments to continuously quantify cloud and aerosol properties, as well as key atmospheric parameters (Haeffelin et al., 2005). Furthermore, during the ParisFog campaign in the winter season October to March, additional measurement instruments are provided and operated by several research institutes. During this time, the goal is to closely observe surface conditions, large- and small-scale dynamics, radiation, turbulence, precipitation, droplet- and aerosol-microphysics and -chemistry. ParisFog is exceptional and outstanding through its combination of in situ and remote sensing instruments on such a long-term basis to describe the mechanisms of fog formation and dissipation (Haeffelin et al., 2010).

Method and experimental set-up

Dry number size distributions of total and interstitial aerosols were measured by the applicant with a scanning mobility particle sizer (SMPS). The measured diameters range from 13 nm to 750 nm. The total and the interstitial aerosols were measured with two different inlets. The total number size distribution was measured behind a heated inlet. This way, all aerosols can be measured including the hydrometeors residuals as these evaporate in the heated inlet before entering the SMPS. On the interstitial inlet system an aerodynamic size discriminator is attached. The cut-off size was 1 µm from 17.10.2012 to 14.11.2012 and 2 µm from 14.11.2012 to 07.01.2013. This inlet samples only the non-activated aerosols, as the ambient particles larger than the applied cutoff size discriminator are expected to be predominately activated cloud droplets. The 1 µm cut-off was used partially because it was assumed that grown (haze) but not activated aerosols are measured by the interstitial inlet by mistake. The measurements were conducted with one SMPS, alternately switching behind the total and the interstitial inlet for six minutes each. Figure 1 shows an hourly averaged total (red) and interstitial (green) aerosol size distribution during the fog event on 10.10.2012 05:30. It can be seen that at larger diameters the total size distribution shows slightly higher particle number concentration. The difference in the integrated aerosol number concentration between the total and interstitial aerosol size distribution is interpreted as the number of fog droplets residuals (i.e. CCN). The number concentration of fog residuals in this example was 150 cm^{-3}.

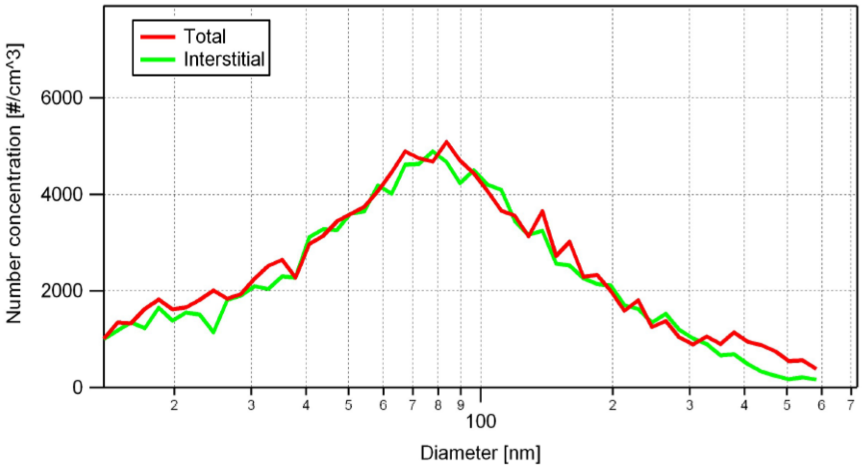

Figure 1: Hourly averaged total and interstitial particle size distributions during the fog event on 10.10.2012 05:30. The difference in the spectra for D >~300 nm is interpreted as CCN.

Furthermore, a dew point mirror (DPM) was installed behind the total inlet. As the total inlet is heated, the DPM is not measuring the actual dew point during fog. However, by means of the ambient temperature, the measured dew point value and the Clausius-Clapeyron equation the condensed water content (CWC) of the air can be calculated. In addition, a particle volume monitor (PVM-100) was provided by the CNRM group from MeteoFrance in Toulouse. This instrument measures the liquid water content (LWC) and the effective radius of the fog droplets. The LWC measured by the PVM-100 was found to compare well with the CWC retrieved from the DPM measurements.

Finally, a cloud condensation nuclei counter (mini-CCN) was installed by CNRM (Greg Roberts) behind the total inlet. It was operated with scanning supersaturations in the range from 0.05% to 0.6% in order to determine the actual supersaturation in the ambient air.

All instruments were running from 17.10.2012 until 7.1.2013 with little interruptions due to electrical power outages or little instrument errors.

For all fog events the activated fraction has been calculated. This parameter is defined as (Verheggen et al., 2007):

$$F_N(D_p) = \frac{(N_{tot}(D_p) - N_{\text{int}}(D_p))}{N_{tot}(D_p)} \quad (1)$$

where $N_{tot}(D_p)$ is the dry number size distribution of the total aerosol and $N_{int}(D_p)$ is the respective size distribution of the interstitial aerosol. The activated fraction is size-dependent. It was calculated for every size bin measured by the SMPS. As the total and interstitial SMPS scans are shifted in time, the activated fraction can be calculated with 4 subsequent total scans (~1 h average) and the average of 4 corresponding interstitial scans. The activated fraction as function of the diameter was fitted with a Hill-equation. This way the following characteristic values can be retrieved (Figure 2): The plateau value is the value which the fitted activation curve is reaching at its maximum. Plateau values < 1 are an indication for entrainment of drier air and/or patchiness of the fog. D_{50} is the value where 50% of the aerosols are activated to droplets.

D_{half} is the value at which the fitted activation curve is reaching half of the plateau value. Since the plateau value was rarely reaching 1, it is more appropriate to consider the D_{half} values for the interpretation of the activation process.

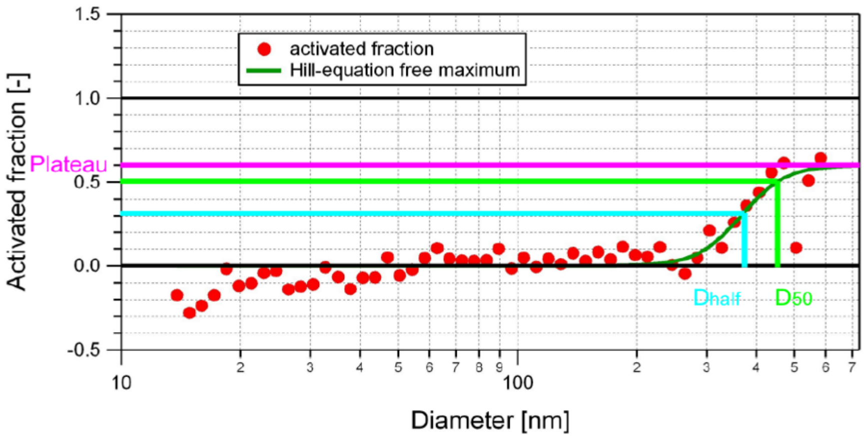

Figure 2: Activated fraction on 10.10.2012 05:30 obtained from an hourly average. D_{50}, D_{half} and plateau value are indicated.

Preliminary results and conclusions

Ten fog events have been selected and analyzed so far. It was found that the activation of aerosols during these fog events can be characterized by comparing SMPS measurements of the total and interstitial aerosols. The plateau value rarely reaches during fog events and it fluctuates strongly within the several fog events (see Figure 3). For a more detailed analysis of the variability of these plateau values it could be useful to take into account data of wind directions to take into consideration or rule out entrainment of fog-free air. Furthermore, it requires to make use of the best temporal resolution the SMPS data can provide. Even though it was found, that to gather basic information about the activation diameters and plateau values, an averaging of several SMPS scans seems to be more accurate. It is inherent in this method and therefore inevitable to compare SMPS scans taken at slightly different times. It is necessary that the number size distributions between these times are adequately similar. If this is not the case, for example because of an influenced size distribution by local pollution, it has to be considered to skip such data from the analysis.

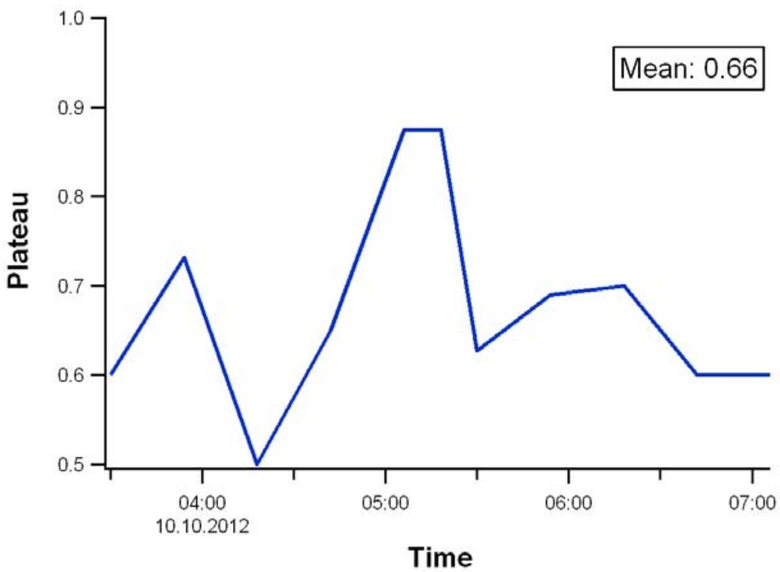

Figure 3: Plateau values of activation during the fog event on 10.10.2012, obtained from half hour averages.

The median of the D_{half} range between 252 nm and 400 nm. The median over all 10 fog events is 287 nm (Figure 4). The literature values of D_{50} are between 70nm and 280nm for cloud droplets, depending on LWC and aerosol number concentration (Hallberg et al., 1994; Henning et al., 2002; Schwarzenboeck et al., 2000). The D_{50} values for the high altitude research station Jungfraujoch are around 100 nm (Hammer et al., 2013; Henning et al., 2002). Even though D_{half} and D_{50} are not fully intercomparable, this result suggests that aerosol activation diameters in fog are considerably higher than in clouds.

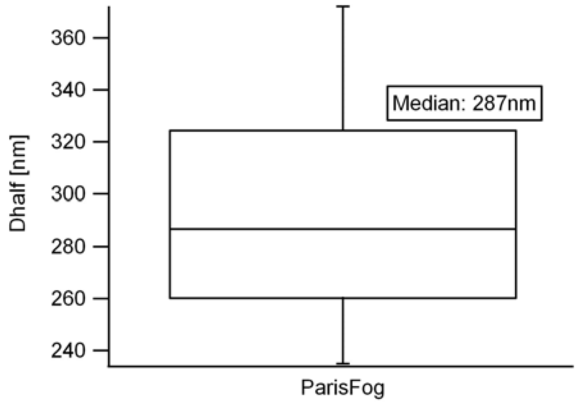

Figure 4: Observed activation diameters (D_{half}) (10th, 25th, median, 75th, 90th percentile) for all 10 fog events.

Outcome and future studies

Ten different fog events have been analyzed so far regarding the size-dependent activation behavior of aerosols to fog droplets. To select the dataset of the campaign for the fog events PVM-100 and visibilimeter data have been used. However, a precise and well defined fog event criterion has to be determined for further analysis taking into account the data of the liquid water content, the visibility and the activation together in a quantitative way. Additionally, the liquid water content measured by the PVM-100 will be further compared with the retrieved CWC. This will show to which extent the CWC based on the dewpoint measurement is a reliable method. This will especially be helpful for conducting measurements at sites where harsh weather conditions are present so that PVM-100 measurements can not easily be performed.

Furthermore, the mini-CCN data will be analyzed. By comparing these data with the size-dependent activation measurements from the SMPS, the ambient effective peak supersaturation can be retrieved but also the prevailing hygroscopicity of the particles summarized as one hygroscopicity parameter. This parameter will then further be compared to findings of a previous study made at the same station during MEGAPOLI 2010 campaign (Jurányi et al., 2013) where the hygroscopicity parameters was measured in winter 2010. A good established relationship between the hygroscopicity measurements conducted with two different CCNC instruments during two different campaigns would show if the mean hygroscopicity of the aerosols is changing between the different winter periods.

During ParisFog2012/13 an additional CCNC was installed from the CNRM group from MeteoFrance in Toulouse. This CCNC was performed behind a inlet with a size discriminator of 2.5 µm. Since this size discrimination is close to the size of interstitial aerosols a comparison study between the mini-CCN connected to the total inlet and the CCNC connected behind the PM2.5 inlet will be made. This analysis will shade more light on the question why the interstitial aerosols in the same size range of the activated aerosols were not able to grow to a fog droplets.

Finally, the dataset will be compared to predicted parameters like activation diameter or effective peak supersaturations with a single-column model (Bergot et al., 2007) or the Meso-NH, a 3D non-hydrostatic, pseudo-compressible research model (Lafore et al., 1998).

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