HIgh mass RESolution Measurements of Aerosol Composition at Cabauw, HIRESMACC

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Introduction and motivation / Scientific objectives

Atmospheric aerosols have direct and indirect effects on the global climate. Particles alter the properties of clouds by acting as cloud nucleation nuclei (CCN) and as surface for heterogeneous reactions. Also particles are known to have adverse health effects (Pope and Dockery, 2006).
Amongst others these effects depend on the chemical composition of the particles.

Aerosol chemical composition can be measured with high time resolution by the Aerodyne High Resolution Time-of Flight-Aerosol-Mass-Spectrometer (HR-ToF-AMS). In this campaign the applicants operated a HR-ToF-AMS at the CESAR-tower in Cabauw, the Netherlands in November 2011. The purpose was to characterize the non refractory aerosol-composition and to compare the results to data from the newly developed high resolution Thermo-Desorption-Proton-Transfer-Mass-Spectrometer (TD-PTR-ToF-MS) that was operated at Cabauw during this period. Previous comparisons of HR-TOF-AMS measurements with the quadrupole mass spectrometer TD-PTR-MS were performed by the group in summer 2008 and spring 2009 (Mensah et al., 2012). To investigate the seasonal cycle of aerosol chemical composition at Cabauw and to deepen the comparison of the two instruments, further measurements in autumn season were needed to widen the range of meteorological and atmospheric chemical conditions covered in our observations. Note that the use of high mass resolution for both instruments allowed for a much more detailed analysis of the composition of the organic fraction of the aerosol than previously performed, thus contributing to an improved understanding of organic aerosol formation and aging processes.

Data analysis involves instrument comparison with the co-located TD-PTR-TOF-MS. Using high resolution mass spectrometric data from both instruments the relative contributions of N- and O-containing organics to the aerosol composition are determined. This deepens the understanding of processes involved in organic aerosol mass formation and aging.

Additionally, this campaign acted as a trial for the upcoming PEGASOS-campaign in May 2012, partly in parallel with aerosol measurements onboard a Zeppelin over Cabauw.

Reason for choosing station

Besides the fact that the previous campaigns mentioned above were also performed at Cabauw Experimental Site for Aerosol Research (CESAR), it is located at a rural site and is a representative for North-West Europe. Depending on the wind directions, the conditions can be either of maritime or continental character.
Furthermore, the plain geography of the Netherlands and especially in the area of Cabauw reduces ambiguities in terms of air parcel convection and turbulences.

Method and experimental set-up

The Aerodyne HR-ToF-AMS was deployed in the tower basement and connected to the aerosol sampling manifold installed at the 60 m platform. From there, it measured the size distribution and chemical composition of particles and was operated 24 hours/ 7 days a week for 5 weeks with a time resolution of 4 minutes. Its transmission efficiency for particles in a range of 70 nm to 500 nm is almost 100 % (Jayne et al., 2000).
The sampling line was shared by other aerosol instrumentation like an SMPS. Close to the AMS inlet, a Condensation Particle Counter (CPC, TSI 3025a) was deployed, resulting in an overall flow of 380 mL min^{-1} between the manifold and the AMS inlet through 3 m stainless steel tubing with an inner diameter of 4 mm.
Once a week the instrument was maintained and calibrated for the ionization efficiency and particle size using a calibration rack containing an aerosol-generator and a Differential-Mobility-Analyzer (DMA), and a CPC (TSI 3025a). To determine the gas phase background signal, measurements with an in line particle filter was performed every 2-3 days.

The TD-PTR-ToF-MS sampled from a height of 5m above the ground through a 10 m long copper tube with an inner diameter of 4mm. It is equipped with both a gas and an aerosol inlet and collects ambient particles in the size of 70 µm to 2 µm at an air sample flow rate of 1L/min (Holzinger et al., 2010a; Holzinger et al., 2010b)

Preliminary results and conclusions

The following graphs show preliminary data from AMS measurements:

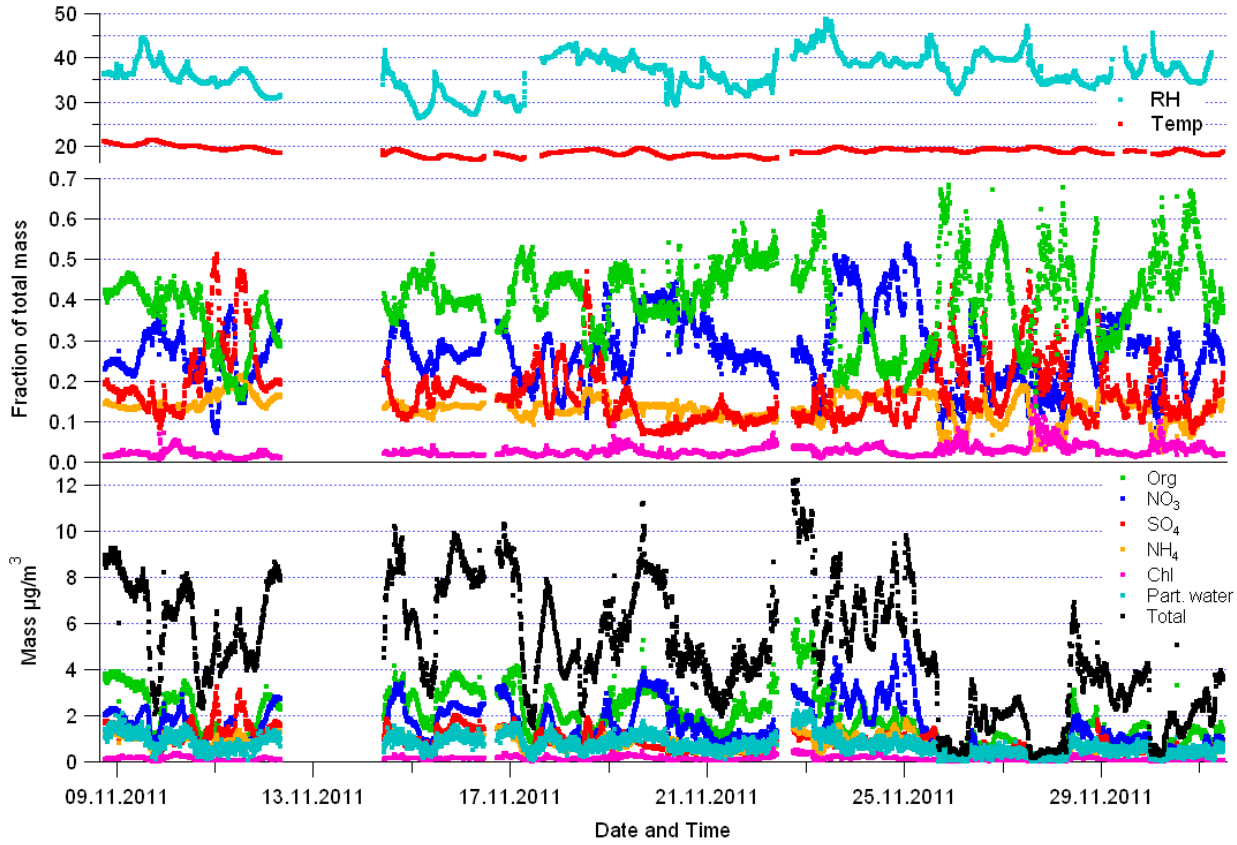

Fig. 1: Mass concentrations and fractional abundances of aerosol species; relative humidity (RH) and temperature (Temp)

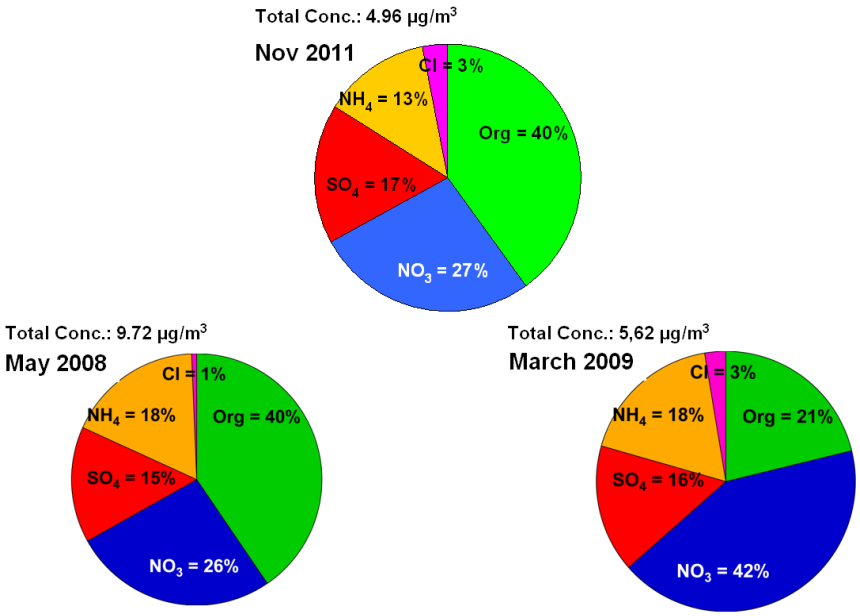

Fig. 2: Aerosol components average

Figure 1 shows the temporal evolution of the total aerosol mass as well as of the most important aerosol species. Clearly seen are a number of periods with different mass loadings and different fractional abundances of these species, partly dominated by organics, sulfate or nitrate. These observations have to be referred to meteorological data like wind directions.
A first evaluation of the diurnal cycles shows night time maxima of the total mass and of the concentrations of Organics and nitrate. The last can be explained by the heterogeneous conversion of nitrate in the night and the volatilization of nitrate, especially ammonium nitrate, during the day.

The average particulate mass loading measured by the HR-ToF-AMS during November 2011 (Fig. 2) was 4.96 µg m^{-3} (collection efficiency = 0.5) and lower than observed in previous campaigns in May 2008 (9.72 µg m^{-3}) and March 2009 (5.62 µg m^{-3}), both with a dynamic, nitrate-mass-dependent collection efficiency. The organic fraction was the dominant species (40 %) in November 2011, followed by nitrate (27 %) and sulphate (19 %). The observed aerosol composition was thus overall similar to the results from summer 2008, whereas in spring 2009 a dominant nitrate fraction (42 %) was observed (Mensah et al., 2012).

Outcome and future studies

A first evaluation of the particle concentrations, which were measured by CPC's at the AMS- and the PTR-MS inlet, respectively, shows good agreement. Hence, the TD-PTR-ToF-MS- and the AMS data are comparable and will be used in detailed analysis of the composition of the organic fraction of the aerosols. Amongst others, further AMS data analysis will evaluate aerosol composition as function of size. For more detailed analysis of the organic fraction elemental analysis and Positive Matrix Factorization (PMF) will be performed.

In addition, this campaign proved to be a successful test campaign for the follow-up field measurements at the CESAR tower in May 2012, which partly took place in parallel with observations on aerosols onboard a Zeppelin flying over Cabauw and was coordinated with a European intensive measurement period defined by EMEP.

References

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