Name of research institute or organization:

Max Planck Institute for Chemistry, Mainz
Cloud Physics and Chemistry Department

Title of project:

CLACE-3 (Cloud and Aerosol Characterization Experiment in the Free Troposphere)

Project leader and team

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Project description:

Aerosol particles are solid or liquid particles suspended in the air. Typical number concentrations are in the order of a few hundreds to several thousands of particles per cubic centimeter of air. Only few particles act as cloud condensation nuclei (CCN) and allow water to condense on them to form cloud droplets. As about 80% of the rainfall comes from clouds containing ice particles, special interest is paid to ice nuclei (IN). Those trigger the formation of ice particles. Until today it is not well understood which chemical components (e.g. sulphuric acid, ammonium, nitrate, various organic substances, mineral dust, sea salt, soot, or other materials) contained inside or on the surface of aerosol particles enable a particle to act as CCN or IN. Water soluble compounds are expected to favour the formation of liquid cloud droplets, while insoluble materials like mineral components may favour the formation of ice nuclei. In order to gain further insight, mass spectrometric measurements of cloud residuals and ice nuclei were performed at the Sphinx building of the high alpine research station Jungfraujoch during CLACE-3. This third in the series of CLACE (Cloud and Aerosol Characterization Experiment in the Free Troposphere) campaigns took place from February 15th until March 30th 2004.

The experiment was designed to investigate the chemical composition of aerosol particles. The Aerodyne Quadrupole Aerosol Mass Spectrometer (AMS) measures chemically resolved mass concentrations and size distributions of various non-refractory aerosol components, like sulphate, nitrate, ammonium and organics, in the size range of 20 - 1500 nm.

A special counterflow inlet (ICE-CVI, Institute for Tropospheric Research, Leipzig) was coupled to the AMS. It was designed for sampling small ice particles which have grown only by water vapor diffusion. The ice fraction is subsequently evaporated to make the residual particles, which are expected to be the original ice nuclei, available for analysis with the AMS. When operated without pre-impactor, the CVI allows to analyze the residuals of supercooled cloud droplets. Alternatively, interstitial/-background aerosol was sampled using an interstitial aerosol inlet.

During the whole observation period, several cloud events were sampled; mixed phase clouds as well as pure supercooled clouds. Switching the AMS between the sample lines of CVI and interstitial inlet was done manually.

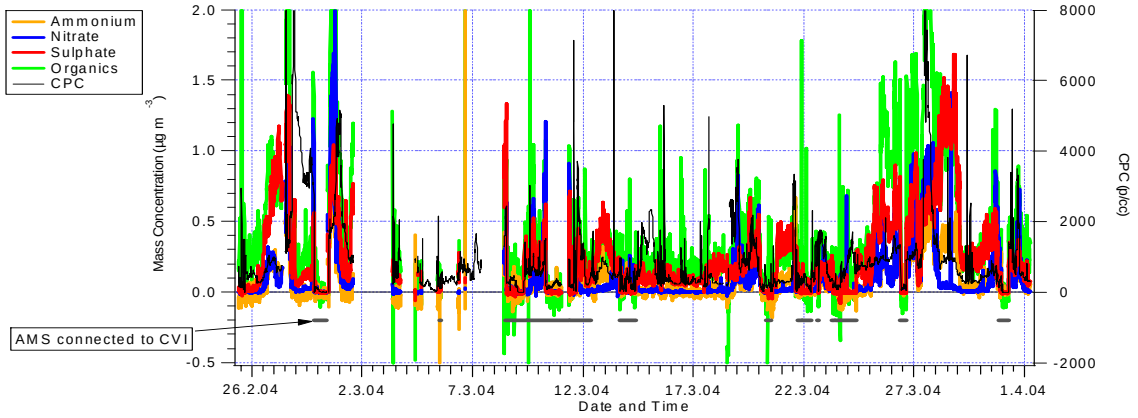
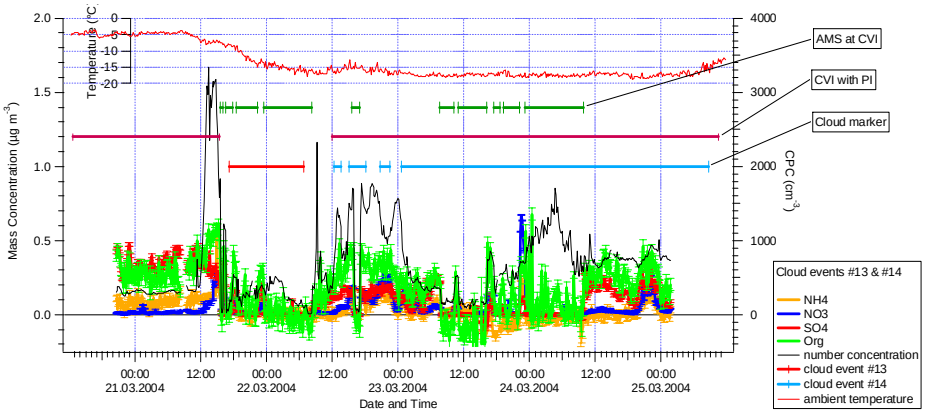


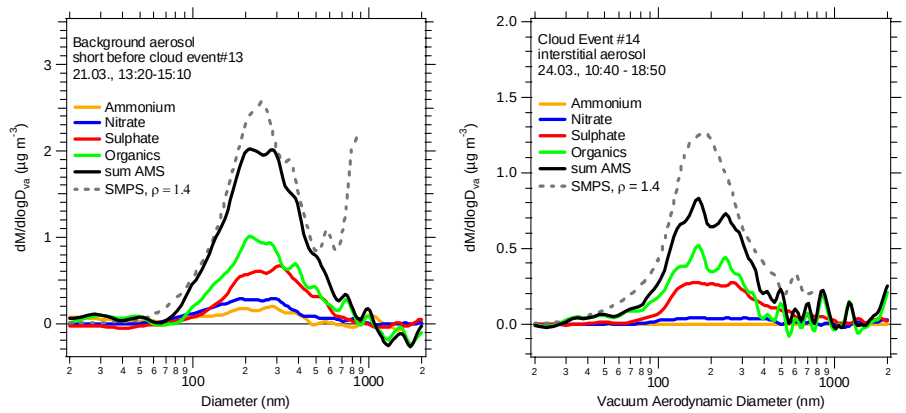
Figure 1: Time series of AMS mass concentrations

Figure 1 gives the time series of the AMS mass concentrations of ammonium, nitrate, sulphate and organics, together with the total particle number concentration measured with a condensation particle counter (CPC, TSI Model 3025). The marker at the bottom of the graph indicates the times when the AMS was connected to the CVI. During the rest of the time, background aerosol was measured during cloud free periods, and interstitial aerosol during cloud events. The concentrations vary significantly and are relatively low, as expected for free tropospheric background. When the AMS is connected to the CVI, the mass concentrations decrease markedly because of the lower number density of cloud droplets compared to aerosol particles. The enrichment of the CVI (≈ 10) can not compensate this effect.

a)



b)



c)

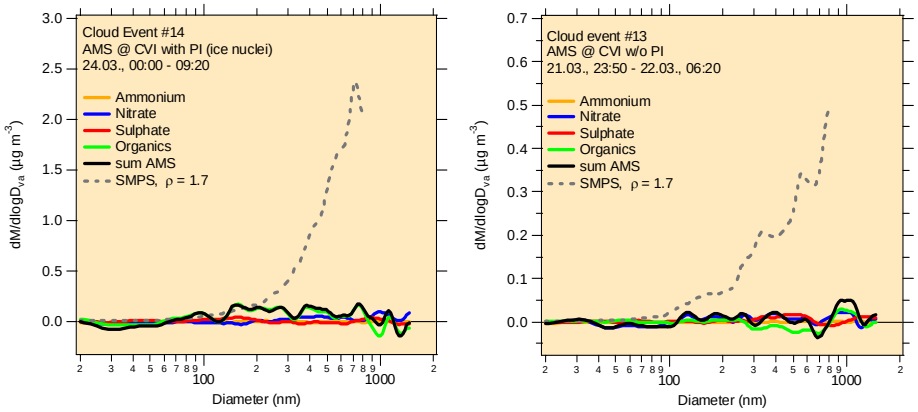


Figure 2: AMS mass concentrations during two cloud events (a) and selected size distributions (b, c)

Figure 2a shows aerosol mass concentrations measured during two cloud episodes. The light blue cloud marker was set when a liquid water content > 0.02 g m^{-3} for 85% of the 10 minute averaging period was observed (measured with PVM). Additionally, several size distributions have been selected in order to represent examples of droplet residuals (CVI without pre-impactor), ice residuals (CVI with pre-impactor), background and interstitial aerosol.
The residual particles (ice nuclei as well as liquid droplets mixed with ice nuclei, shaded graphs in Figure 2c) sampled by the CVI show negligible mass concentrations in the AMS compared to SMPS data. Obviously they consist of refractory material, e.g. black carbon or mineral dust.

The mass distribution (SMPS) of residual particles is remarkably different from the mass distribution of background/interstitial aerosol. Larger particles (> 600 nm) dominate the mass distribution of the residuals. The relative contribution of this size range is smaller in the interstitial than in the background aerosol.

The background aerosol (Fig. 2b) was composed to about 95% of non-refractive material (SMPS and AMS show almost the same mass concentration), having a density of about 1.4 g cm^{-3} (deduced from different sizing techniques). The interstitial aerosol contains more refractory material (AMS measures only 50 - 70% of the SMPS), with densities between 1.4 and 1.7 g cm^{-3}.

Key words:

aerosol mass spectrometry, cloud chemistry, ice nuclei

Collaborating partners/networks:

E. Weingartner et al., Laboratory of Atmospheric Chemistry, Paul Scherrer Institut, Villigen
S. Mertes, Institute for Tropospheric Research, Leipzig
K. Bower et al., Atmospheric Science Research Group, University of Manchester
E. Barthazy et al., Institute for Atmospheric and Climate Science, ETH Zürich
S. Henning et al., University of Copenhagen
S. Weinbruch et al., Institut für Mineralogie, TU Darmstadt
A. Petzold, Institute for Atmospheric Physics, German Aerospace Centre

Scientific publications and public outreach 2004:

Conference papers/contributions

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Magazine and Newspapers articles

“Zwischen den Wolken“ by Eva Opitz, Süddeutsche Zeitung, May 26, 2004.

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