Name of research institute or organization:

Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology

Title of project:

Characterization of ice nucleating aerosol particles by single particle mass spectroscopy and filter sampling, INUIT-CLACE-2017

Part of this programme:

ACTRIS

Project leader and team:

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Project description:

Introduction and scientific objectives

Only a minor fraction of atmospheric aerosol particles acts as a trigger for heterogeneous ice formation in clouds. Nevertheless, the activity of these ice nucleating particles (INPs) controls primary ice formation, followed sometimes by secondary ice multiplication processes, and thereby markedly influences the cloud radiative properties as well as the initiation of precipitation. Among these ice nucleating particles, mineral dust aerosol is thought to be one of the most important types on the global scale. The contribution of other aerosol species to ice formation in mixed-phase clouds is still under discussion. Laboratory measurements indicated that, for example, primary biological particles are very ice active (Hoose and Möhler, 2012), but their global atmospheric importance is unclear. Therefore, atmospheric INP measurements and field studies in clouds are required to receive quantitative information on the contribution of various atmospheric aerosol species to ice formation. The high variability of ice particle residuals chemical composition observed during previous campaigns also at the Jungfraujoch (Mertes et al., 2007, Cziczo et al., 2009, Ebert et al., 2011, Chou et al., 2011, Kupiszewski et al., 2016, Schmidt et al., 2016) asks for further in-cloud sampling to achieve the following objectives:

- Comparison of the chemical nature of total aerosol particles with interstitial aerosol particles, or ice crystal or cloud droplet residual particles.
- Validation of single particle chemical composition measurements by comparison with a second single particle aerosol mass spectrometer (ALABAMA, MPI Mainz).
- Quantification of the ice nucleation behaviour of the total aerosol particles collected at the Jungfraujoch station.
- Determination of the impact of single particle chemical composition on the ice nucleation behaviour of the aerosol particles collected in ice and mixed phase clouds at the Jungfraujoch.

Further information on the background for this project can be found on the homepages of the INUIT project: http://www.ice-nuclei.de/the-inuit-project/ and the CLACE project: https://www.psi.ch/lac/clace-gaw-plus.

Reason for choosing station/ infrastructure

The Jungfraujoch station is one of the rare stations in the world allowing direct sampling in ice or mixed phase clouds that is equipped with inlets required to probe the total, interstitial, and residual aerosol particles.

Method and experimental set-up

To achieve the scientific objectives, a laser ablation single particle time of flight mass spectrometer (LAAPTOF, AeroMegt GmbH) was deployed at the Jungfraujoch station measuring single particle composition of aerosol particles or residual particles selected by the different aerosol inlets available: total (w/o particle concentrator), interstitial, ice counter flow virtual impactor (ICE-CVI) or ice selective inlet (ISI).

Furthermore, aerosol particles were collected by the KIT filter sampler setup connected to the total aerosol inlet via a vertical sampling line. With this setup, particles were collected on filters during day and night time with a frequency of two filters per day. In total 57 filters were collected covering the time period from January 24th to February 22nd. After collection, the filters were stored at -20°C and at the end of the campaign they were transported back to KIT. There, the collected aerosol particles will be washed off and will be analysed for their ice nucleation behaviour with an immersion freezing method, which is similar to the Ice Spectrometer of the Colorado State University (Hiranuma et al., 2015).

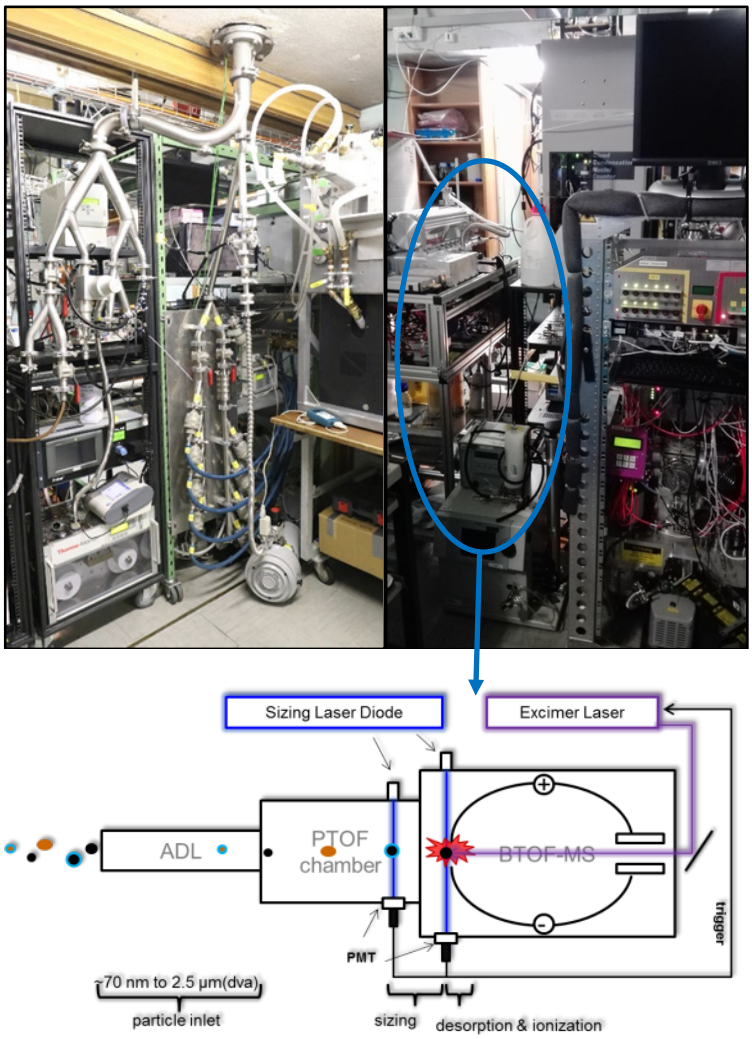

Figure 1. KIT filter sampler setup at the total aerosol inlet of the Jungfraujoch research station (lhs) and the KIT single particle mass spectrometer (LAAPTOF) which was connected to different inlets (middle) and a schematic of the mass spectrometer (rhs).

The aerosol mass spectrometer and the filter sampling system were installed, tested and calibrated at the Jungfraujoch in the week from January 16th to 20th, 2017 and were taken down on February 23rd, 2017. Depending on the meteorological conditions, measurements were performed sampling continuously or intermittently at the different inlets.

Preliminary results and conclusions

In the time period from January 22nd to February 22nd the single particle mass spectrometer LAAPTOF recorded size as well as positive and negative ion mass spectra for a total of 42404 single particles. Most of them were measured using the total aerosol inlet. The ice CVI inlet was used several times (January 30th 7 h, January 31st 14 h, February 6th 6 h), but only on February 17th mass spectra for only 9 single particles could be recorded (cf. Table 1). On February 22nd also the aerosol concentrator was used to concentrate the total aerosol for measurements with the single particle mass spectrometer.

Preliminary analysis of the total aerosol particles identified about 10 different particle classes. Some of these classes showed up almost every day, e.g., particles containing potassium, sulfate and organonitrate; particles containing elemental carbon (EC) and sulfate; and particles containing sodium nitrate (cf. Figure 2).

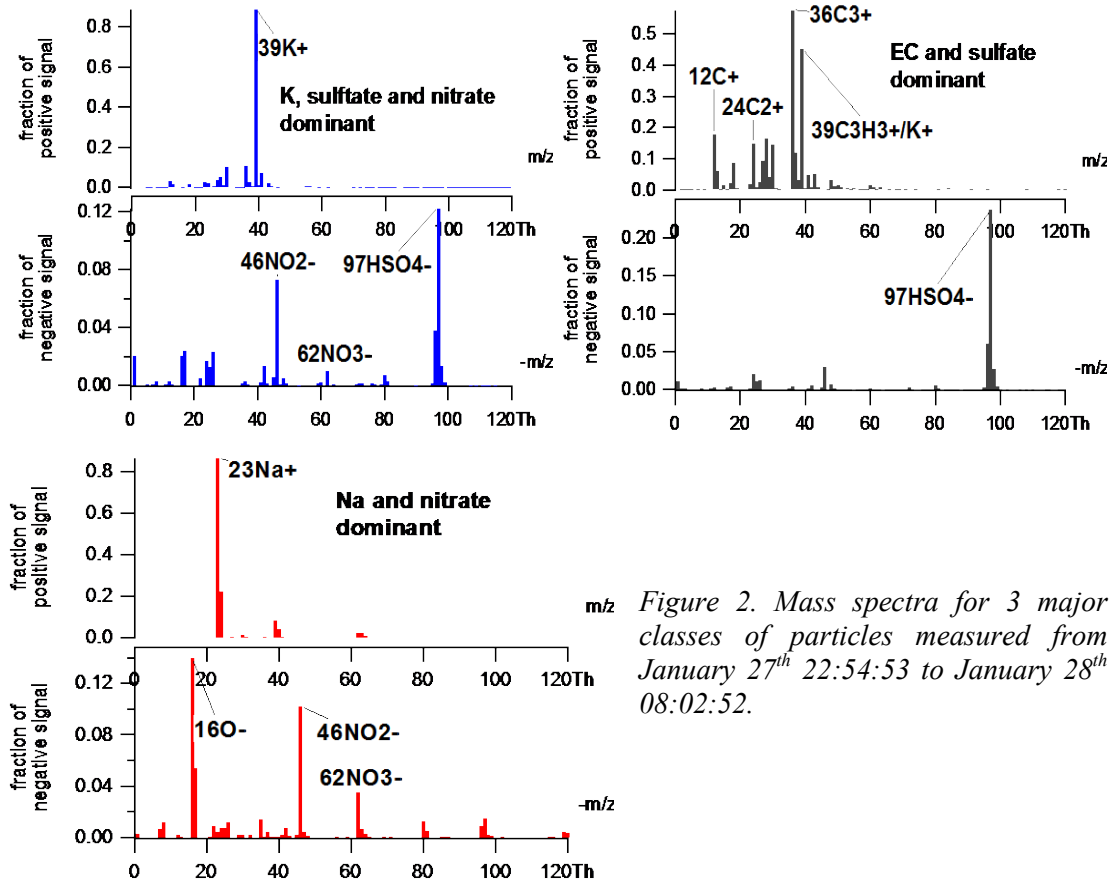

Figure 2. Mass spectra for 3 major classes of particles measured from January 27th 22:54:53 to January 28th 08:02:52.

The particle classes observed vary with particle size. As shown in Figure 3, the following particle classes dominate the submicron size range (< 1µm d_{va}): potassium – sulfate – organonitrate particles, and EC – sulfate particles, as well as ammonium – sulfate - nitrate particles. For sizes above 1 µm sodium - nitrate particles as well as mineral - nitrate particles have the largest number fraction. In addition, a particle class combining many of the different chemical components was observed and may be attributed to aged aerosol particles.

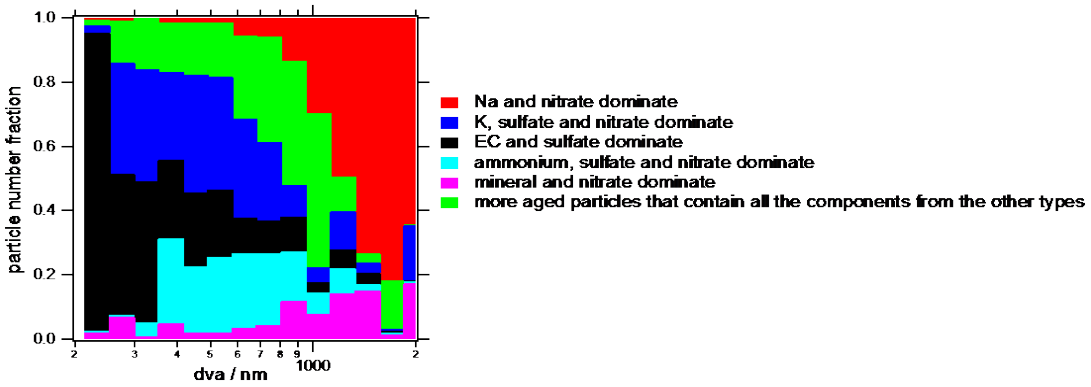

Figure 3. Preliminary particle number fraction for different particle classes as a function of vacuum aerodynamic diameter (d_{va}) as observed between January 27th 22:54:53 and January 28th 08:02:52.

For many measurement periods particle composition data can be compared to the other single particle mass spectrometer ALABAMA (MPI Mainz) for validation of the single particle sizing and chemical characterization. For some cloudy time periods the two instruments obtained complementary information with the ALABAMA measuring ice residual particles using the ice CVI and the LAAPTOF characterising the total aerosol. These data will allow comparison of the chemical nature of the total aerosol particles with the ice crystal residuals and may help determination of the impact of single particle chemical composition on the ice nucleation behaviour of the aerosol particles collected in clouds at the Jungfraujoch.

Outcome and future studies:
We will analyse the KIT filters with our immersion freezing method in order to receive atmospheric INP concentrations for the whole duration of the campaign.
A future study will be conducted in April 2017, where the KIT filter sampler is participating at the international A-LIFE campaign (organized by Univ.-Prof. Dr. Bernadett Weinzierl, University of Vienna) in Cyprus. Here, our focus is on atmospheric INP measurements in an environment, where mineral dust and marine aerosol is present.

Key words:
Single particle mass spectroscopy, ice nucleating particles

Collaborating partners/networks:
http://www.ice-nuclei.de/the-inuit-project/
https://www.psi.ch/lac/clace-gaw-plus

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