Name of research institute or organization:

Max Planck Institute for Chemistry (MPIC), Mainz, Germany

Title of project:

Ice residual composition measurements by single particle mass spectrometry during INUIT/CLACE-JFJ2017

Part of this programme:

ACTRIS (EU), BACCHUS (EU), INUIT (DFG)

Project leader and team:

Dr. Johannes Schneider, project leader
Hans-Christian Clemen
Oliver Eppers

Project description:

In the framework of the DFG-funded research project INUIT (Ice Nucleation Research Unit) we conducted a field measurement campaign at the High Altitude Research Station Jungfraujoch in January and February 2017 (INUIT-JFJ 2017). The main objective of this campaign was the physico-chemical characterization of ice particle residues (IPR) sampled from mixed phase clouds as well as of ice nucleating particles (INP) sampled from ambient air. The project included nine research institutes from four different countries and was coordinated by Johannes Schneider (MPIC, Mainz, Germany). Additional support was provided by the EU-funded activities ACTRIS and BACCHUS.

The objective of the research group of MPIC Mainz was the chemical analysis of IPR by single particle aerosol mass spectrometry. Similar to the predecessor project (INUIT-JFJ 2013), we employed the Ice-CVI (Ice counterflow virtual impactor), developed and operated by the Leibniz Institute for Tropospheric Research (TROPOS, Leipzig, Germany), and the ALABAMA (Aircraft-based laser ablation aerosol mass spectrometer) which was developed at MPIC Mainz. Additionally, a Multiangle Absorption Photometer (MAAP) for the detection of black carbon and an Aerosol Mass Spectrometer (C-ToF-AMS) were deployed for the chemical analysis of the out-of-cloud and interstitial aerosol particles.

During the INUIT-JFJ 2017 measurements, the Jungfraujoch station was covered by clouds for about 135 hours. The Ice-CVI extracted small ice crystals (d < 20 µm) from the clouds and provided the residual particles to the various analysis instruments. The ALABAMA detected and analyzed 755 individual IPR during these times. Details of the cloud events are given in Table 1. For comparison, under ambient conditions the ALABAMA analyzed more than 750 000 aerosol particles sampled through the total inlet.

Event	number of analyzed particles	Start time	End time
CE1	48	27.01.17 00:00:00	27.01.17 07:40:00
CE2	37	28.01.17 02:20:00	28.01.17 04:20:00
CE3	23	30.01.17 08:30:00	30.01.17 11:00:00
CE4	173	10.02.17 01:10:00	10.02.17 16:40:00
CE5	52	12.02.17 03:30:00	12.02.17 09:10:00
CE6	261	17.02.17 02:00:00	17.02.17 20:20:00
CE7	21	20.02.17 00:30:00	20.02.17 06:30:00
CE8	30	21.02.17 11:50:00	21.02.17 14:30:00

Table 1. Cloud events with start and end times and number of analyzed particles by ALABAMA.

The composition of the IPR is clearly different from that of the ambient aerosol (Figure 1). For this comparison, a subset of 38233 particles from the ambient aerosol (one hour before and after the respective cloud event) was selected. The IPR contain mainly mineral and metallic components (Al, Na, K, Mg, Fe, Si, Ca), while the out-of-cloud aerosol is dominated by carbonaceous (EC, OC) and secondary inorganic material (sulfate, ammonium). The high abundance of potassium (K) can indicate biomass burning or primary biological material and is observed in both particle populations.

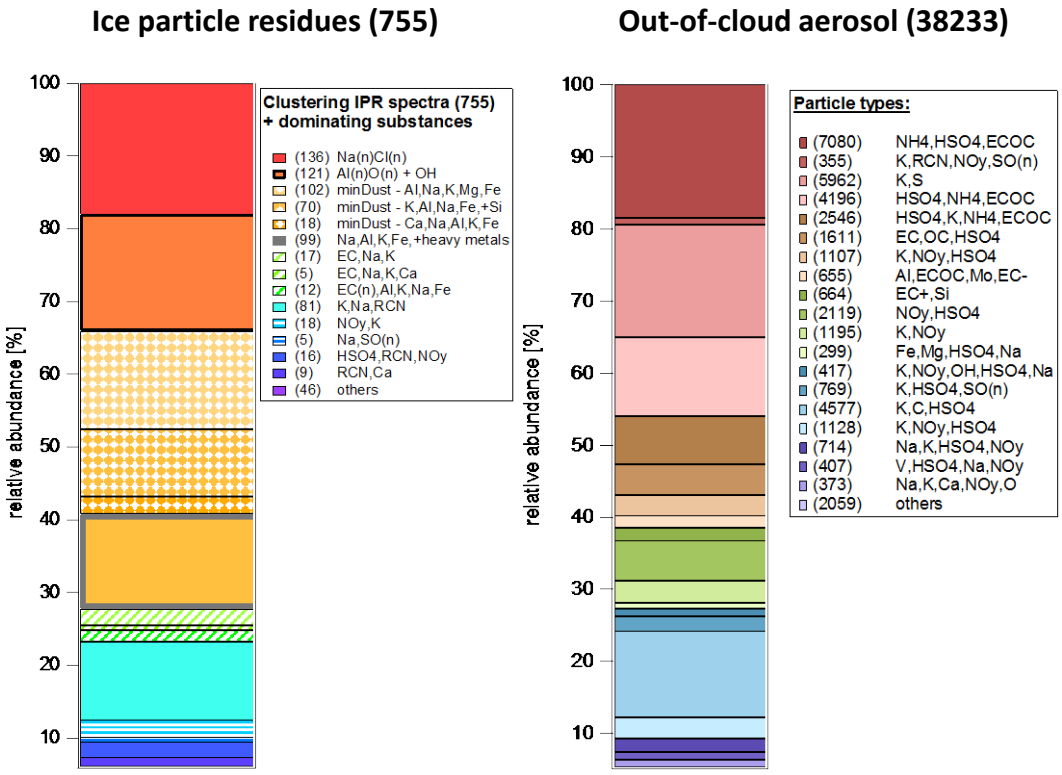

Figure 1. Comparison between the chemical composition of ice particle residuals (left) and out-of-cloud aerosol particles (right).

Analysis of the individual cloud events shows that the composition varies between the events (Figure 2). Especially during events 4 through 8 the relative abundance of mineral dust and sea spray particles is markedly higher than during the other events. This can be explained by air mass origin: Trajectory analyses (HYSPLIT) show that during the second half of the campaign the probed air masses arrived from the Sahara region. Accordingly, also in the out-of-cloud aerosol the aluminum and calcium containing particles (as indicators for dust particles) show a higher abundance than during the first half of the campaign.

These findings further emphasis the role of mineral dust particles as INP in the free troposphere and confirm the results that were obtained during the first INUIT-JFJ campaign in 2013 [1]. In that study, we observed an enrichment of mineral particle in IPR compared to out-of-cloud aerosol of a factor 30. Similar as in the present study, we observed particles of biological origin in IPR as well as in the out-of-cloud aerosol. However, particle identification in the data set of the 2013 study was hindered by the fact that only one polarity (cations) was measured. In 2017, both polarities (anions and cation) were detected simultaneously for each particle, such that particle identification is markedly more robust and reliable. The particle classification shown in Figures 1 and 2 is still a preliminary result and will be refined before final publication which is planned for the second half of 2018.

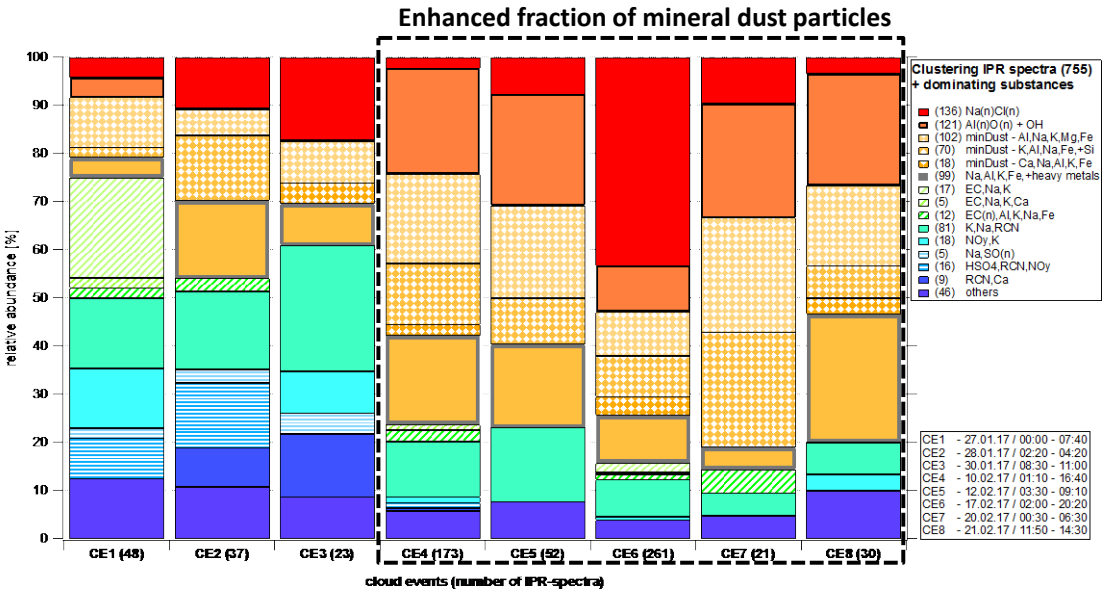

Figure 2. Ice particle residual composition separated by individual cloud events as given in Table 1.

Key words:

Ice nuclei, aerosol composition, aerosol-cloud interaction, aerosol mass spectrometry

Internet data bases:

http://www.ice-nuclei.de/the-inuit-project/

Collaborating partners/networks:

University Frankfurt, Germany
University Bielefeld, Germany
Karlsruhe Institute of Technology (KIT), Germany
Leibniz Institute for Tropsopheric Research (TROPOS), Leipzig, Germany
Technical University Darmstadt, Germany
Paul Scherrer Institute (PSI), Switzerland
ETH Zurich, Switzerland
University of Manchester, UK
University of Toronto, Canada

Scientific publications and public outreach 2017:

Refereed journal articles and their internet access

[1] Schmidt, S., J. Schneider, T. Klimach, S. Mertes, L.P. Schenk, P. Kupiszewski, J. Curtius and S. Borrmann, Online single particle analysis of ice particle residuals from mountain-top mixed-phase clouds using laboratory derived particle type assignment, Atmos. Chem. Phys., **17**, 575-594, doi: 10.5194/acp-17-575-2017, 2017. https://www.atmos-chem-phys.net/17/575/2017/

Kupiszewski, P., M. Zanatta, S. Mertes, P. Vochezer, G. Lloyd, J. Schneider, L. Schenk, M. Schnaiter, U. Baltensperger, E. Weingartner, Ice residual properties in mixed-phase clouds at the high-alpine Jungfraujoch site, J. Geophys. Res. Atmos., **121**, 12343–12362, doi: 10.1002/2016JD024894, 2016. https://dx.doi.org/10.1002/2016JD024894

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