Name of research institute or organization:

Leibniz-Institut für Troposphärenforschung (TROPOS) Leipzig, Deutschland

Title of project:

Composition analysis of ice particle residuals combining aerosol mass spectrometry and counterflow virtual impactor technique (INUIT2-RP2-TROPOS)

Part of this programme:

INUIT (research unit of the German research foundation DFG)

Project leader and team:

Dr. Stephan Mertes, project leader
Udo Kästner, Stephan Günnel, Maik Merkel, Oliver Welz

Project description:

This research activity is part of the research unit INUIT (research project 2) of the German research foundation DFG. It should contribute to a better understanding of the heterogeneous nucleation of ice particles in middle and lower tropospheric super-cooled clouds. A question closely related to the different heterogeneous ice nucleation mechanisms is the nature of the IN with respect to their chemical composition and microphysical properties. Especially the anthropogenic influence on tropospheric ice formation is hardly known as well as the atmospheric relevance between mineral dust and biogenic aerosol particles. In order to tackle these questions, INUIT organized a joint field campaign in real atmospheric mixed-phase clouds at the High Altitude Research Station Jungfraujoch, called INUIT-JFJ 2017.

The possibility to measure in real atmospheric mixed-phased clouds allows the characterization of ice particle residuals (IPR). For the IPR there exists no direct proof that they actively contribute to ice formation. But they are found in real atmospheric ice particles, which implies that they are closely related to atmospheric ice nucleating particles (INP). Thus, the objective is the physico-chemical characterization of IPR within natural mixed-phase clouds at the High Altitude Research Station Jungfraujoch in the Swiss Alps. The determination of the IPR aerosol properties requires the coupling of the counterflow virtual impaction (CVI) techniques with single particle mass spectrometry.

In order to investigate the scientific objective described above, the unique Ice-CVI inlet system was setup on the Sphinx platform, which consists of a virtual impactor (VI), a drop pre- impactor (PI) and a standard CVI, respectively. Under mixed-phased cloud conditions this sampler extracts small, freshly produced ice particles from all other solid/liquid components of the cloud by consecutively pre-segregating large ice aggregates, super-cooled drops and interstitial particles. In the PI supercooled drops freeze on the cool impaction plates whereas the small ice particles bounce off and remain in the sampling flow. Inside the Ice-CVI the ice water of the sampled ice particles is evaporated releasing the IPR for analysis. Restricting the collection to ice particle sizes between 5 and 20 µm by means of the combination of VI and standard CVI the IPR can be attributed to the original ice nuclei, because in this size range ice particles grow only by water vapor deposition. The IPR are size-resolved analyzed within this research project for number concentration and size distribution by an optical particle sizer (OPS, 0.3 – 10 µm), an optical particle counter (Sky-OPC, 0.25 – 30 µm) and an ultra-high- sensitivity aerosol spectrometer (UHSAS, 0.08 – 1 µm). For a more detailed chemical characterization of the IPR the single particle mass spectrometer ALABAMA (MPI Mainz) and an impactor for offline electron microscopy (TU Darmstadt) was additionally coupled to the Ice-CVI.

Up to now 16 different cloud events during the INUIT-JFJ 2017 campaign were identified, some of them further subdivided into separate time periods.

Figure 1 shows the mean sub- and super-micrometer IPR number concentration determined by the different aerosol sensors for a selection of cloud events. For the same size range the results from the three different sensors agree quite well for the small concentration range between 1 to 30 L^{-1}. The higher values are observed during Saharan dust occurrence at the Jungfraujoch, but the variability for dust and non-dust cloud periods depends mainly on the meteorological conditions. Moreover, it is obvious from Fig. 1 that the sub-micrometer IPR concentration exceeds the super-micrometer one by a ratio of 80% to 20% on average. This means, although it is expected that larger aerosol particles are the more efficient INPs, the IPR number concentration is dominated by sub-micrometer particles.

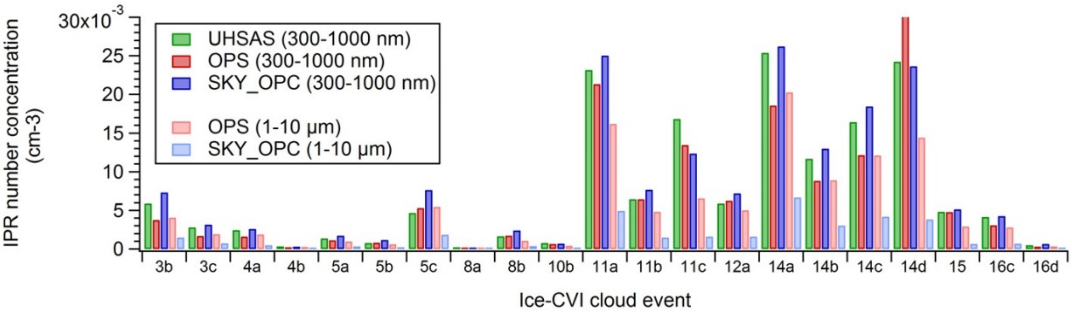

Figure 1. Mean sub- and super-micrometer IPR number concentration determined by the different aerosol sensors for a selection of cloud events during INUIT-JFJ 2017.

In Figure 2 the IPR size distributions for cloud event 1a and 1c derived from the UHSAS and OPS measurements are exemplary shown. The distributions from both instruments show a good agreement in the overlap region between 0.3 and 1 µm. Overall, the IPR number size distributions are very broad in comparison to those of the prevailing total aerosol particles which indicates that larger IPR are more enriched in the ice particles and thus are preferred to act as ice nucleating particle. However, the IPR number is dominated by sub-micrometer aerosol particles with maxima in the number size distribution that can vary between 0.2 to 0.5µm.

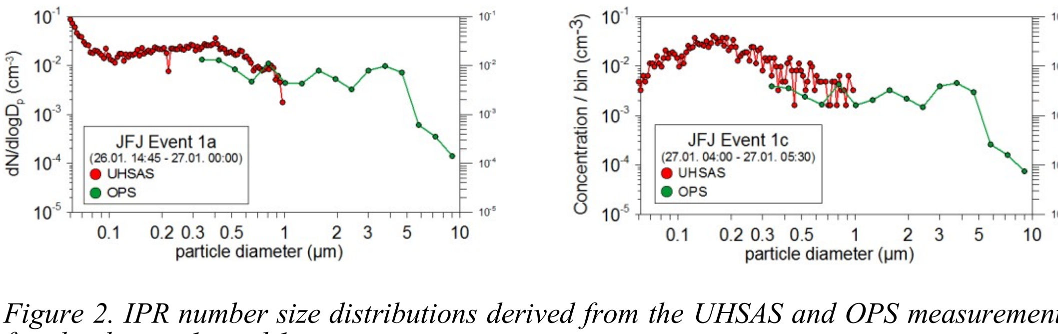

Figure 2. IPR number size distributions derived from the UHSAS and OPS measurements for cloud event 1a and 1c.

Key words:

Aerosol cloud interactions, mixed-phase clouds, heterogeneous ice nucleation, ice particle residuals

Internet data bases:

http://www.tropos.de/en/research/aerosol-cloud-interaction/process-studies-on-small-spatial-and-temporal-scales/aerosol-cloud-interaction/heterogenous-freezing-in-lab-and-field/ice-nulei-in-atmospheric-clouds/

Collaborating partners/networks:

Max Planck Institute for Chemistry, Mainz, Germany
University of Frankfurt, Germany
Technical University of Darmstadt, Germany
Karlsruhe Institute of Technology, Germany
Paul Scherrer Institute, Villigen, Switzerland
University of Manchester, United Kingdom

Scientific publications and public outreach 2017:

Refereed journal articles and their internet access

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/

Book sections

Cziczo, D. J., L. Ladino, Y. Boose, Z. A. Kanji, P. Kupiszewski, S. Lance, S. Mertes and H. Wex, Chapter 8: Measurements of ice nucleating particles and ice residuals. Ice formation and evolution in clouds and precipitation: Measurement and modeling challenges, AMS Meteorological Monographs, **58**, 8.1-8.13, doi: 10.1175/AMSMONOGRAPHS-D-16-0008.1, 2017. http://journals.ametsoc.org/doi/abs/10.1175/AMSMONOGRAPHS-D-16-0008.1

Conference papers

Schneider, J., S. Mertes, A. Roth, S. Schmidt, H. Clemen, T. Klimach, O. Eppers, F. Köllner and S. Borrmann, Single particle analysis of residues from cloud droplets and ice crystals, European Aerosol Conference (EAC), Zurich, Switzerland, August 27 - September 1, 2017.

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