Ice nucleating particles and ice multiplication at moderate supercooling

Franz Conen[1], Claudia Mignani[1], Lukas Zimmermann[1]

[1]Department of Environmental Sciences, University of Basel, Basel, Switzerland

franz.conen@unibas.ch

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1. Project description

This project contributes to a better understanding of ice formation in mixed-phase clouds, an unstable colloid that frequently shrouds Jungfraujoch during winter.

In 2018 we were lucky to have Dr. Jessie Creamean from CIRES joining us for a measurement campaign on Jungfraujoch lasting from 14 February to 12 March. CIRES, the Cooperative Institute for Research in Environmental Sciences, is a partnership of NOAA and the University of Colorado Boulder. Jessie's visit was funded by the SNF Scientific Exchanges scheme (grant number IZSEZ0_179151). She had brought a range of instruments from her laboratory which we used during the campaign, among others for an intercomparison with instruments and procedures we have been using at the site for several years now. Both sets of instruments produced comparable results in terms of ice nucleating particle (INP) concentrations at moderate supercooling in snow and rime. They have resulted in a valuable set of data on INP in snow (39 samples), cloud droplets (26 samples) and in interstitial aerosol (18 samples), which are currently discussed in *Atmospheric Chemistry and Physics Discussions* (https://www.atmos-chem-phys-discuss.net/acp-2018-1082/). Overall, INP concentrations were 3 to 20 times higher for all three kinds of samples when air masses had been in contact with land surfaces southeast of Jungfraujoch, compared to surfaces in other directions.

A second line of investigation had already started several months before the joint campaign in form of method developments. It is the study of secondary ice formation. Earlier studies on Jungfraujoch by other groups have suggested that many of the ice crystals found in mixed-phase clouds at Jungfraujoch originate from local surfaces covered with hoar frost when in clouds. Our approach to evade this issue was to sample relatively large (millimetre-size) snow crystals with regular shapes that are unlikely to not have formed within a cloud itself. One of these shapes (dendrite) develops in conditions supersaturated with respect to water, characteristically between -12 °C and -17 °C. Melting a dendrite and then supercooling the resulting droplet to a temperature below -17 °C is a way to interrogate it regarding its primary or secondary origin. If the supercooled droplet freezes within the temperature range where a dendrite typically forms, the crystal must have contained an insoluble INP that has most likely caused its growth by initiating a primary ice particle, which then grew into a dendritic snow crystal through vapour deposition within the mixed-phase cloud. If the analysed dendrite did not contain an INP active between -12 °C and -17 °C, it probably has formed through the growth of a secondary ice particle, such as an ice splinter generated by the collision of two larger ice particles with different deposition velocities within the cloud. During the campaign in February and March 2018 we were able to analyse 190 dendrites, of which one in eight was judged as being of primary, and seven in eight as being of secondary origin. There are, as in every experimental study, several assumptions on which these judgements are based. As the approach is new, it has to weather through fierce peer review before we may claim it provides meaningful insights. For more details please see: https://www.atmos-chem-phys-discuss.net/acp-2018-829/.

Collaborating partners / networks

Dr. J. M. Creamean, Colorado State University, CIRES, Boulder, CO, USA
Dr. M. Gysel and Dr. N. Bukowiecki, Laboratory of Atmospheric Chemistry, Paul Scherrer Institute, Villigen, Switzerland
Dr. S. Reimann, Dr. C. Hüglin, Dr. M. Steinbacher, Ms. C. Zellweger-Fäsi, and Dr. A. Fischer, Laboratory for Air Pollution/Environmental Technology, Swiss Laboratories for Material Science and Technology (Empa), Dübendorf, Switzerland
Dr. C. E. Morris, Institut national de la recherche agronomique (INRA), Pathologie vegetale, Montfavet, France

Scientific publications and public outreach 2018

Refereed journal articles and their internet access

Conen, F., N. Bukowiecki, M. Gysel, M. Steinbacher, A. Fischer, S. Reimann, Low number concentration of ice nucleating particles in an aged smoke plume, Q. J. R. Meteorol. Soc., **144**, 1991-1994, doi: 10.1002/qj.3312, 2018. https://rmets.onlinelibrary.wiley.com/doi/epdf/10.1002/qj.3312

Conference Papers

Mignani, C., J.M. Creamean, L. Zimmermann, and F. Conen, Examining single snow crystals for ice-nucleating particles – a new approach to investigate primary versus secondary ice formation, BACCHUS Final Meeting, Zurich, Switzerland, April 24-26, 2018.

Creamean, J.M., C. Mignani, and F. Conen, Using spectra characteristics to define ice nucleating particle populations from north and south of the Alps, 6th Workshop – Microphysics of ice clouds, Vienna, Austria, April 7, 2018.

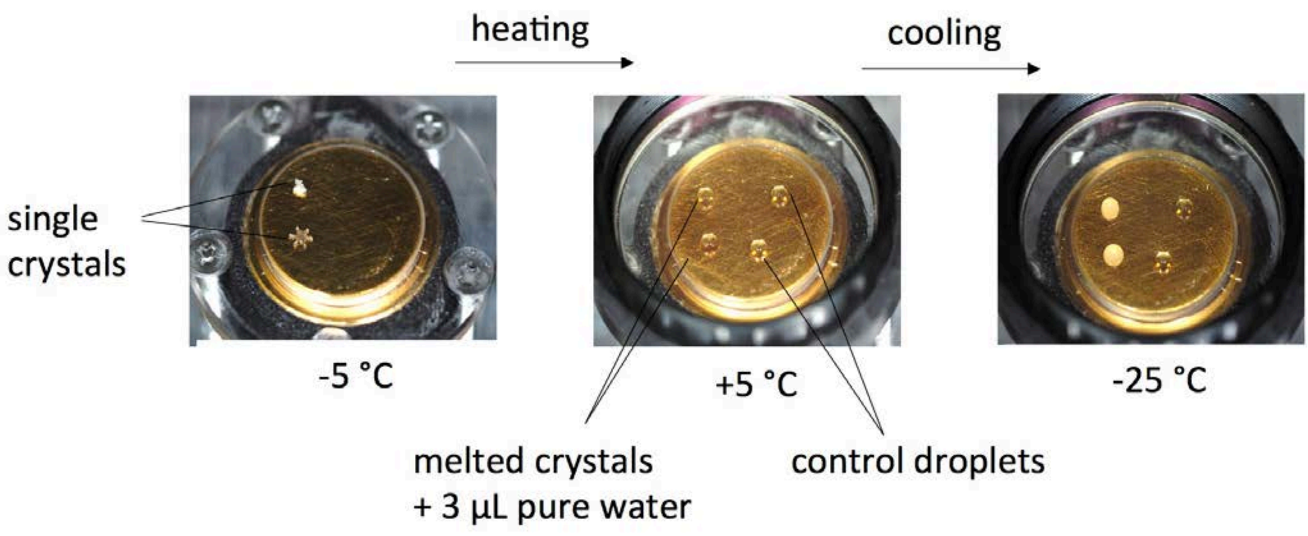

Figure 1. Illustration of the procedure to interrogate single snow crystals regarding the presence of an insoluble INP. Two crystals (here a graupel particle and a dendrite) are placed on a coldstage (diameter 18 mm) and molten (left). The resulting droplets are increased in size by adding 3 l of high purity water to ease visual detection of the freezing event. Two control droplets of the same water are added next to them (middle). The temperature of the coldstage decreases and the temperature at which the droplets freeze is recorded. The assay is terminated at -25 °C (right).

Address

Department of Environmental Sciences
University of Basel
Bernoullistrasse 30
CH-4056 Basel
Switzerland

Contacts

Dr. Franz Conen
Tel.: +41 61 207 0481
e-mail: franz.conen@unibas.ch