Name of research institute or organization:

Institute for Atmospheric and Climate Sciences, ETH Zurich

Title of project:

Field measurements of aerosols acting as ice nucleating particles and their influence on mixed-phase clouds

Part of this programme:

GAW CH +

Project leader and team:

Dr. Zamin A. Kanji (project leader)
Dr. Jan Henneberger, Larissa Lacher

Project description:

Clouds containing ice play an important role in the Earth's system, but some fundamental knowledge on their formation and further development is still missing. The phase change from vapor or liquid to ice in the atmosphere can occur heterogeneously by primary ice formation in the presence of ice nucleating particles (INPs) at temperatures warmer, and supersaturations lower than required for homogeneous freezing. Only a small fraction of particles in an environment relevant for the occurrence of ice- and mixed-phase clouds are INPs, and their identification and quantification remains challenging.

Mixed-phase clouds are thermodynamically unstable because of the co-existence of water drops and ice crystals in the same environment can lead to the Bergeron-Findeisen process. In addition, a large gap between the measured ice crystal number concentrations (ICNCs) (> 1000 $stdL^{-1}$) and ice crystal contributions from primary ice nucleation (< 10 $stdL^{-1}$) is not fully understood. As such our goal is to quantify ICNCs in mixed-phase cloud environments by measuring the phase and cloud water content as well as INP concentrations.

We measure INP concentrations with the Horizontal Ice Nucleation Chamber (HINC; Lacher et al., 2017) at the High Altitude Research Station Jungfraujoch (JFJ) during several field campaigns in different seasons and years. The measurements are performed at 242 K and above water saturation, representing mixed-phase clouds conditions. The site is regularly within mixed-phase clouds, and in addition, due to its elevation of 3480 m a.s.l., it provides mostly free tropospheric conditions (Lugauer et al., 1998; Zellweger et al., 2003; Collard Coen et al., 2011; Griffiths et al., 2014, Herrmann et al., 2015). As such the INP concentrations measured at the JFJ are relevant not only on a local, but also on a regional to global scale.

In winter 2017 INP measurements at the JFJ were conducted as part of the joint INUIT/CLACE 2017 campaign, which took place from 22nd January to 21st February 2017. In order to improve the instrument's limit of detection to quantify the naturally very low INP concentrations at the JFJ, HINC sampled after the Portable Aerosol Particle Concentrator (PAPC; Gute et al., in preparation), which is based on the virtual impaction method (Sioutas et al., 1995). With the use of the PAPC, the lower end of INP concentrations during the winter 2017 field measurements could be quantified to be below 0.1 $stdL^{-1}$ (Figure 1). Elevated INP concentrations above 10 $stdL^{-1}$ could not be connected to the occurrence of Saharan dust events and events of marine air mass origin, an observation which has been made during previous field campaigns. In order to get an in-depth understanding on the variability of INP concentrations, a comparison to the aerosol particle chemistry, as measured in parallel with the mass spectrometer ALABAMA, will be done in an upcoming study.

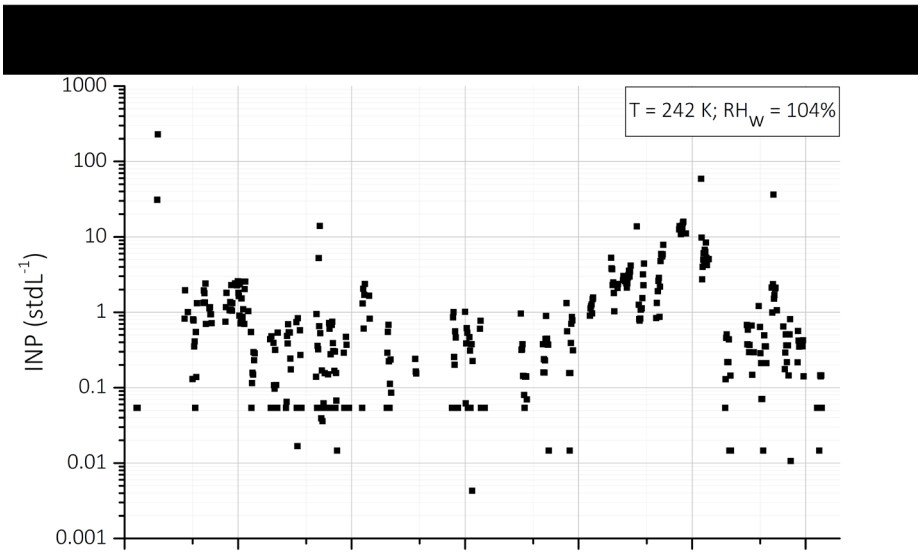

Figure 1. INP concentrations during winter 2017 at 242 K and RH_w = 104%.

INP concentrations during winter 2017 were on average lower as compared to previous measurements at similar conditions and in the same season (Figure 2). During the winter 2014 (Boose et al., 2016) and winter 2015 and 2016 (Lacher et al., 2017), median INP concentrations were 2.2 stdL^{-1}, 2.7 stdL^{-1}, and 4.7 stdL^{-1}, respectively, excluding peak INP concentrations as measured during SDEs, marine events, and air masses with considerable anthropogenic influence. During the winter 2017 field campaign the median INP concentrations were lower with a value of 0.5 stdL^{-1}, a difference which might be explained by the non-occurrence of SDEs and marine events, leading to a general decrease in the background INP concentrations.

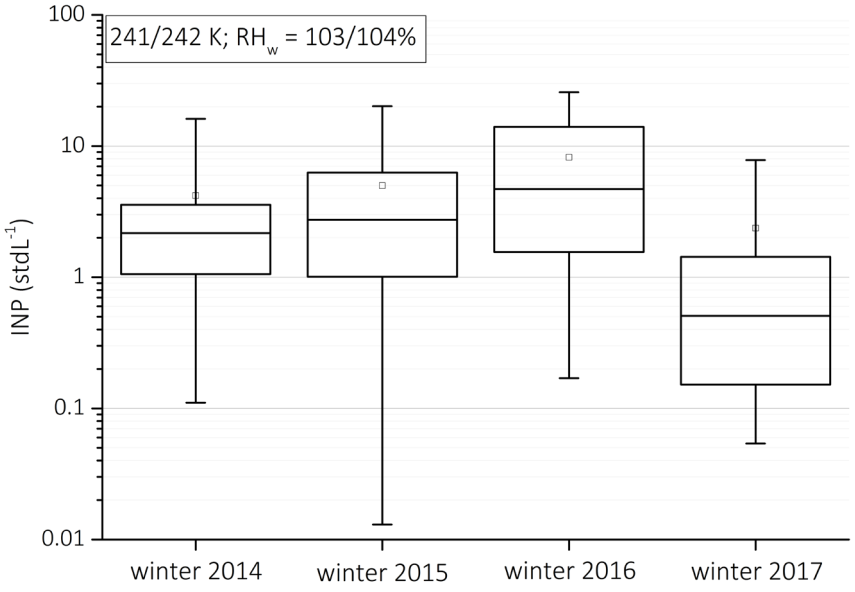

Figure 2. Averaged INP concentrations observed above water saturation, as measured with PINC (winter 2014; 241 K and RH_w = 103%) and HINC (winters 2015 - 2017; 242 K and RH_w = 104%). Data used to produce the distributions include INP below the instrument's limit of detection; data exclude contributions from measurements during periods of known air masses arrived at the JFJ with anomalously high INP concentrations (see Lacher et al., 2017 for a detailed description). Median: middle bar, mean: open square data point, box: IQR (25th to 75th percentile), whiskers: 5th and 95th percentile.

The holographic imager HOLIMO (Henneberger et al., 2013) was employed at the JFJ from January until March 2017. HOLIMO measures the phase resolved size distribution and the concentration of hydrometeors from which the water content of cloud particles can be derived. The goal is to observe the microphysical properties of orographic clouds in particular in the mixed-phase regime, where a mixture of supercooled liquid droplets and ice crystals are present. The measurements and collected holograms collected at JFJ in 2017 will be analysed to yield information on how ICNCs change with temperature and other meteorological variables.

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Collaborating partners/networks:

Paul Scherrer Institute (PSI)
EMPA
Hebrew University of Jerusalem
University of Toronto
Max-Planck Institute for Chemistry, Jacob Fugal, Mainz

Scientific publications and public outreach 2017:

Refereed journal articles and their internet access

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Henneberg, O., Orographic mixed-phase clouds in the Swiss Alps - occurrence, persistence and sensitivity, PhD Thesis, ETH Zürich, 2017.

Lacher, L., Measurements of Ice Nucleating Particles at the High Altitude Research Station Jungfraujoch, PhD Thesis, ETH Zürich, 2017.

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