The Morphology and Optical Properties of Ice Particles in Mixed Phase Clouds, ISI-MICROPHYSICS

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- **Introduction and motivation**
  As part of the CLACE2013 campaign the new Ice Selective Inlet (ISI), which has been jointly developed by PSI and KIT, was deployed for the first time in natural mixed phase clouds. ISI uses a non-intrusive method to separate ice particles from supercooled liquid droplets for the subsequent analysis of the ice nuclei. The new inlet is also excellently suited to investigate mixed-phase ice particles in great detail which is difficult to achieve in situ due to the overwhelming number of supercooled droplets. In combination with in situ cloud measurements, microphysical measurements downstream the ISI opens new measurement possibilities for addressing the following scientific objectives.
- **Scientific objectives**
  - What is the frequency of hexagonal and "frozen droplet" morphologies?
  - Do we observe crystals with rough surfaces/rimed particles?
  - Is there evidence for ice multiplication processes?
  - How homogeneous are the encountered mixed phase clouds?
  - How frequent are sharp transitions between pure ice/pure supercooled liquid particles in these clouds?
- **Reason for choosing station**
  In winter the High Altitude Research Station Jungfraujoch is always located in the free troposphere and is therefore ideally suited for ground-based investigations of aerosol-cloud effects and ice particle microphysical processes in mixed-phase clouds. This project was part of the CLACE2013 campaign which gives us the possibility to analyze our data in the context of aerosol and cloud measurements performed by other groups.
- **Method and experimental set-up**
  The Particle Phase Discriminator of KIT (PPD2-KIT) was operated downstream the ISI in addition to the Small Ice Detector (SID3) and the Particle Habit Imaging and Polar Scattering (PHIPS) probe of KIT that measured in-situ in the prevailing cloud. PHIPS and SID3 were installed on a specifically designed swivel platform equipped with wind sensors and controllable pumps to achieve nearly isokinetic sampling conditions. Downstream the ISI after the extraction and sublimation of the ice particles we operated a Single Particle Soot Photometer (SP-2) and a Waveband Integrated Bioaerosol Sensor (WIBS-4) to investigate the ice residual particles with respect to the black carbon and bioaerosol content.
  The PPD2-KIT and SID3 instruments both measure high-resolution scattering (diffraction) patterns of individual cloud particles which allow a reliable discrimination between super cooled liquid droplets and ice crystals even for the tiniest cloud particles down to sizes of about 1 µm and also in case of "frozen droplet" ice geometries. This is especially important for the identification of possible ice multiplication processes and for a characterization of pure ice/pure liquid boundaries within the cloud. Moreover, the diffraction patterns of the droplets (measured by SID3) can be evaluated with a high accuracy of the order of 0.1 µm which is not possible with other light scattering or imaging instruments due to ambiguity and resolution issues. In this way accurate droplet size distributions and liquid water contents will be provided. Finally, the PHIPS instrument

will provide data sets of visible angular scattering functions of individually imaged cloud particles that will be used to derive average scattering phase functions and asymmetry parameters of the mixed phase clouds with different ice particle fractions.

- **Preliminary results and conclusions**

  The PHIPS instrument was operated continuously during five weeks on Jungfraujoch and imaged a great variety of ice particle shapes. We are currently working on linking the occurrence of pristine and rimed ice particles to certain meteorological conditions.

  Like the PHIPS, the SID3 instrument recorded several million diffraction patterns during the five weeks of CLACE2013. A case study of a 12 hour period revealed that the occurrence of small ice is followed by a completely glaciated cloud pocket with a low overall particle concentration consisting exclusively of ice particles. These findings need to be verified by further analysis and further measurements.

  A first analysis of the PPD2-KIT data acquired after the ISI, demonstrated that the ISI removes liquid droplets efficiently. During the course of the CLACE2013 campaign only a negligible low number of droplets transmission events were detected by the PPD2-KIT. However on the other hand the ice transmission efficiency varied between 10-30%. Comparing the diffraction patterns recorded by the PPD2-KIT and the SID3 we recognized deviating patterns. The ice particles imaged by the PPD2-KIT seemed to have sublimated on their way through the ISI. In order to increase the ISI ice transmission efficiency and to avoid ice morphology changes in the ISI modifications of the ISI ice separation section are currently under way.

- **Outcome and future studies**

  First results of our findings from CLACE2013 were presented at the ***Davos Atmosphere and Cryosphere Assembly*** (***DACA2013***, 08.07.-12.07.2013)

  In situ characterization of mixed phase cloud ice particles

  Paul Vochezer, Martin Schnaiter, Ahmed Abdelmonem, Thomas Leisner, Piotr Kupiszewski, Ernest Weingartner, Poster

  Cloud chamber investigations and field observations of ice crystal growth instabilities

  Martin Schnaiter, Ahmed Abdelmonem, Paul Vochezer, Alexei Kiselev, Robert Wagner, Ottmar Möhler, Zbigniew Ulanowski, Carl Schmitt, Andrew J. Heymsfield, Poster

  Design of an ice selective inlet for the characterization of ice in mixed-phase clouds

  Ernest Weingartner, Piotr Kupiszewski, Alessandro Bigi, Urs Baltensperger, Paul Vochezer, Martin Schnaiter, Poster

  Cloud microphysics and physico-chemical characterization of ice residuals in mixed-phase clouds: CLACE 2013

  Piotr Kupiszewski, Ernest Weingartner, Urs Baltensperger, Paul Vochezer, Claudia Fuchs, Martin Schnaiter, Talk

  We plan to deploy of the same set of instruments during winter 2013/2014 on Jungfraujoch. The identical set of instruments should lead to improved findings because:

  - The optical fibre setup of the PHIPS was redesigned which allows now the measurement of the angular scattering function of mixed phase clouds.
  - We are convinced that the ice transmission efficiency of the ISI will be improved by a modified version of the ISI ice separation unit.