

Name of research institute or organization:

**Leibniz-Institut für Troposphärenforschung, Leipzig, Deutschland
(IfT)**

Title of project:

Sampling and physico-chemical characterization of ice nuclei in mixed phase clouds

Project leader and team:

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Project description:

The nucleation of ice particles in middle and lower tropospheric clouds can initiate precipitation and change cloud radiative properties, thus affecting the climate forcing of tropospheric clouds. In the lower and middle troposphere heterogeneous nucleation which is triggered by a subset of atmospheric aerosol particles, named ice nuclei (IN), is the main process to initiate ice formation inside supercooled clouds.

Field studies investigating the physico-chemical properties of ice nuclei in tropospheric mixed-phase clouds are needed to improve the understanding of heterogeneous ice nucleation. By means of the unique Ice-CVI sampling system it is feasible to extract particles that have nucleated ice particles in mixed-phase clouds for the determination of their physical and chemical properties. The analysis of the international joint field campaigns CLACE-4 (2005) and CLACE-5 (2006) at the high alpine research station Jungfraujoch using the novel Ice-CVI inlet generally showed that super-micron particles preferentially serve as IN, although in absolute terms the IN concentration is dominated by submicron particles. This finding is consistent with the qualitative identification of mineral dust, non-volatile organic matter and black carbon as IN components. However, the used instrumentation for the chemical IN characterization was either non-sensitive for refractory particles, or integral mass but not number related, or pure qualitative due to the low abundance of IN.

Since the influence of heterogeneous ice formation on precipitation and radiative cloud properties is a number based phenomenon, it is the main objective at present to determine the chemical composition of single IN, and if possible, size resolved, quantitatively and with sufficient statistical significance. Therefore, it was the main goal to achieve a chemical single particle characterization of the ice nuclei sampled by means of the Ice-CVI during the field campaign CLACE-6 at the Jungfraujoch in February/March 2007. Thus, during this joint experiment, which was led for the second time by the German collaborative research centre TROPEIS, the Ice-CVI was coupled with the single particle mass spectrometers ATOFMS (ETH Zürich) and SPLAT (University of Mainz) and the single particle soot photometer SP-2 (University of Manchester). Further instrumentation for the characterization of IN was similar to CLACE-3, CLACE-4 and CLACE-5 (cf. activity reports 2004, 2005 and 2006).

The residual mass spectra measured with SPLAT verify the dominance of mineral dust particles serving as IN. A first classification of the obtained mass spectra reveals that mineral dust (detected as Si) was found in 74 % of the identified ice particle residuals. 63 % of the residuals contained sulphate and 37 % of the residuals

contained mineral dust and sulphate. The latter implies that half of the mineral dust particles had a sulphate coating most likely originating from the cloud condensation nuclei matter of frozen drops. The SPLAT mass spectra analysis of the background aerosol particles yielded that 15 and 85 % of these particles comprised mineral dust and sulphate, respectively. Thus, the mineral dust component was strongly enriched in the ice nuclei whereas sulphate was depleted. Another chemical element, which was detected quite often in the ice particle residuals by the coupling of Ice-CVI and SPLAT is lead (Pb) with a relative number contribution of 42 %. Although, this is less than the contribution of mineral dust, Pb seems to have a similar atmospheric IN efficiency, because the fraction of Pb containing particles of the total aerosol reservoir was measured to be only 9 %.

Another approach was additionally carried out during CALCE-6 in order to obtain information about the dominating heterogeneous ice nucleation mechanism. Therefore, the IN-counter FINCH (University of Frankfurt) was connected downstream the Ice-CVI in order to study how many of the atmospheric IN that are coming out of the Ice-CVI as residual particles could be activated to ice particles inside FINCH. Fig.1 (left panel) shows a time series of IN number concentration measurements with FINCH at the 8th of March connected to the Ice-CVI (15:50-16:26) and thereafter connected to the total inlet (16:28-16:50). Moreover, the temperature and the saturation ratio with respect to ice adjusted inside FINCH are given (the latter is most likely 20 % to high according to a revised calibration).

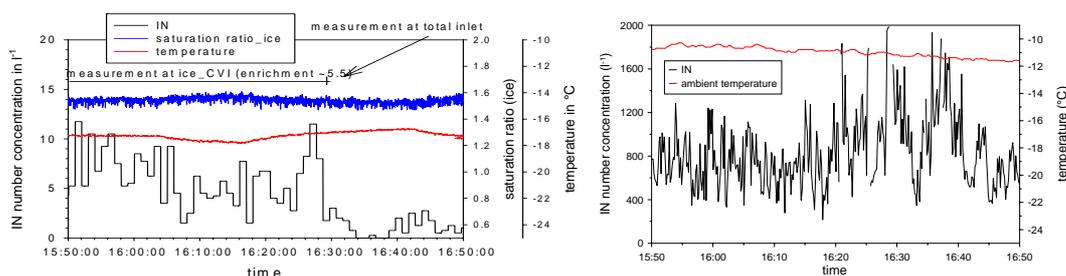


Fig.1: Left panel: time series of IN number concentration measured with FINCH connected to the Ice-CVI and total inlet (change at 16:26) and adjusted temperature and saturation ratio with respect to ice inside FINCH. Right panel: simultaneous time series of IN number concentration sampled with the Ice-CVI and ambient temperature.

IN number concentration sampled by the Ice-CVI and ambient temperature are illustrated on the right side of Fig.1. The IN number concentration measured with FINCH downstream the Ice-CVI is not corrected for the CVI enrichment, which was 5.5, and thus the absolute mean value is about 1.2 L^{-1} (and not about 7 L^{-1} as indicated in the left hand side of Fig.1). The residual number concentration was much higher with about 760 L^{-1} although the ambient temperature was slightly higher than the FINCH chamber temperature. Indeed, residuals coming from ice particle fragments created by collisions of precipitating or wind-blown ice crystals could have been sampled that did not serve as ice nuclei. But as shown already during CLACE-3 these residual particles are small ($< 50 \mu\text{m}$) and do not account for more than 60 % of the complete residual particle concentration. Thus, this effect could by far not explain the discrepancy between the FINCH and Ice-CVI number concentration results, which is still at least a factor of hundred. It is more likely that this difference in number

concentration is related to the heterogeneous ice nucleation processes. The Ice-CVI samples IN inducing all heterogeneous mechanisms whereas the heterogeneous ice particle formation inside FINCH is restricted to deposition and condensation freezing. Consequently, these processes seem to be negligible with respect to contact and immersion freezing of supercooled drops in the investigated clouds. Another finding visible from the left panel of Fig.1 is that FINCH detected the same amount of IN at the Ice-CVI and at the total inlet (taking into account the CVI enrichment factor) which is an independent indication that the Ice-CVI collects IN that induce ice particle formation via deposition and condensation freezing quantitatively.

Key words:

aerosol cloud interactions, mixed-phase clouds, heterogeneous ice nucleation, ice nuclei

Internet data bases:

http://cloudlab.tropos.de/physik_CVI1.html

Collaborating partners/networks:

Paul Scherrer Institute Villigen; ETH Zurich; Max Planck Institute Mainz; University of Mainz; Technical University of Darmstadt; University of Frankfurt; University of Manchester

Scientific publications and public outreach 2007:

Refereed journal articles

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