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:

Ice nucleation in tropospheric, super-cooled clouds is the main initiation mechanism for precipitation in middle latitudes and moreover influences the radiative properties and the chemical multiphase processes of these mixed phase clouds. Heterogeneous ice nucleation that is induced by a special subset of atmospheric aerosol particles named ice nuclei plays the decisive role for ice particle formation in the middle and lower troposphere. But up to now, the physico-chemical properties of ice nuclei (size, number concentration, chemical composition) as well as the relevance of different heterogeneous freezing mechanisms (deposition, condensation, immersion or contact freezing) have been rather exclusively studied theoretically or in laboratory experiments but hardly inside real tropospheric clouds.

A sampling system based on the principle of a counterflow virtual impactor (CVI) has been developed (ICE-CVI) in order to characterize tropospheric ice nuclei that have formed ice particles in clouds. Inside mixed-phase clouds the ICE-CVI separates ice particles smaller than 20 µm by pre-segregating large ice crystals, super-cooled droplets and interstitial particles. The collected small ice particles remain airborne in the vertical sampling system and are completely sublimated in a dry and particle free carrier air stream. In this way, the contained non-volatile aerosol particles are released as dry residuals which can be analysed by instruments coupled to the ICE-CVI. The sampled small ice particles do not incorporate particles by riming or aerosol scavenging, i.e. the ice particle residuals can be considered as the original ice nuclei (IN). Only when ice formation takes place via droplet freezing (immersion and contact freezing), the aerosol particle that formed the liquid droplet, the so-called cloud condensation nuclei should be additionally detected. Using this information it should be possible to differentiate between ice formation via droplet freezing and ice deposition nucleation.

The sampling properties of the novel ICE-CVI sampling system was successfully verified during the international field campaign CLACE-3 (cloud and aerosol characterization experiment) at the high alpine research station Jungfraujoch in February/March 2004. One year later the ICE-CVI was again operated at the Jungfraujoch during the international joint field campaign CLACE-4 in order to carry out more systematic measurements of IN. Downstream the ICE-CVI inlet several devices were connected to characterize the ice particle residuals in collaboration with other working groups. Number concentration and number size distribution of the ice nuclei were measured with a condensation particle counter (CPC, operated by IfT) and a combination of scanning mobility particle sizer and optical particle counter

(SMPS and OPC, operated by the Paul Scherrer Institute, Villigen). By means of a filter-based particle soot absorption photometer (PSAP, IfT) the mass concentration of black carbon (BC) within the IN was determined. The mass concentration of major ions and organic matter (OM) of the collected ice nuclei was derived by an aerosol mass spectrometer (AMS, operated by the Max-Planck Institute Mainz, Germany). Furthermore, an impactor was connected for the off-line single particle analysis of the impactor samples using environmental scanning electron microscopy (ESEM, operated by the Technical University of Darmstadt, Germany).

The physico-chemical properties of IN have been determined during several mixed phase cloud events during CLACE-4 by the combination of the ICE-CVI and the coupled instrumentation and related to the aerosol properties of the total aerosol population measured downstream an independent whole air inlet. From Fig.1 that shows number size distributions of the total and residual particles of four different events the variability in the shape and absolute number is obvious.

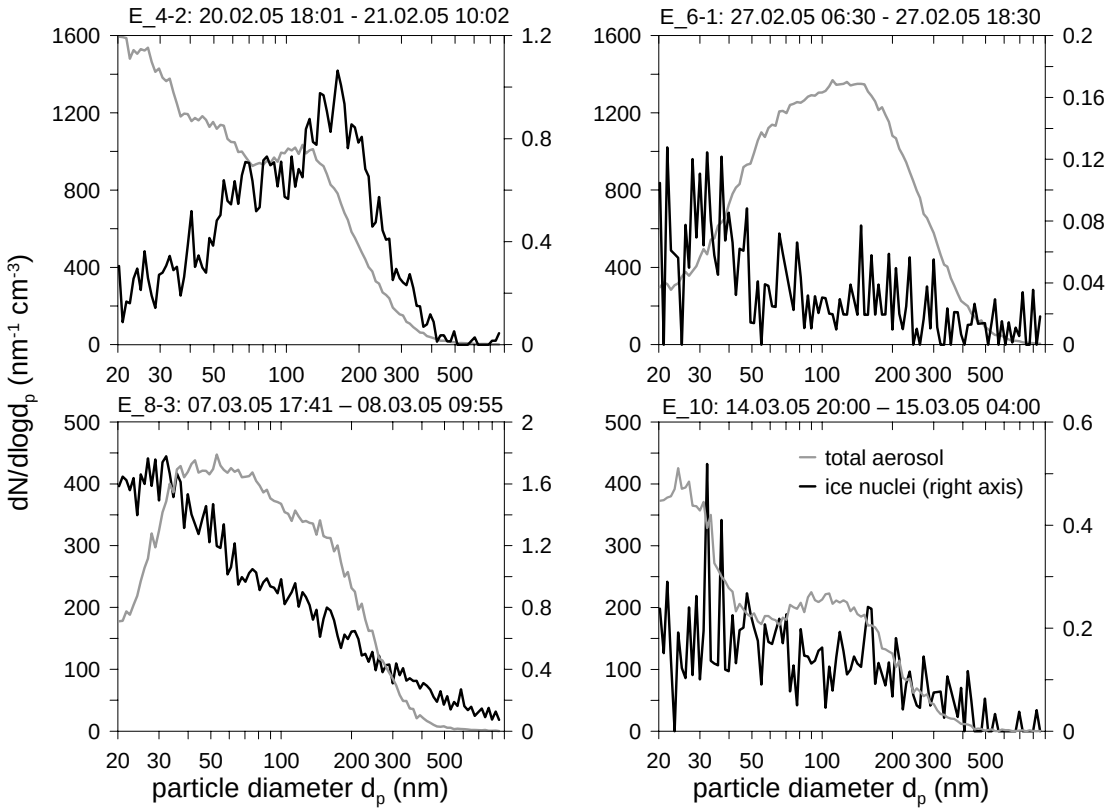

Fig.1 Number size distribution of total aerosol (grey lines, left scale) and ice nuclei (black lines, right scale) of 4 different mixed phase cloud events during CLACE-4

On the other hand the scavenging fraction which is the ratio of residual to total aerosol number size distribution looks quite similar for all evaluated events, which is illustrated in Fig.2. The scavenging ratio increases for with particle diameter indicating that larger particles are preferred to act as IN. The increase of the scavenging fraction occurs between a particle size of 250 and 500 nm and at very different absolute levels. The single particle analysis with ESEM revealed a strong Si signature in the larger particles which implies that mineral dust particles are the main soured of IN. This is in agreement to the results of the aerosol mass spectrometer that did not

detect non-refractory substances in the ice nuclei. The smaller ice nuclei that control the number of ice particles show signatures of C and O which implies a contribution of low volatile organic matter and BC. In agreement to this ESEM results, an enrichment of BC was found in the IN in comparison to the total aerosol particles. Whereas a fraction of 2 – 3 % of BC was found in the total aerosol mass, the fraction of BC in the IN mass was in the range of 10 to 14 %.

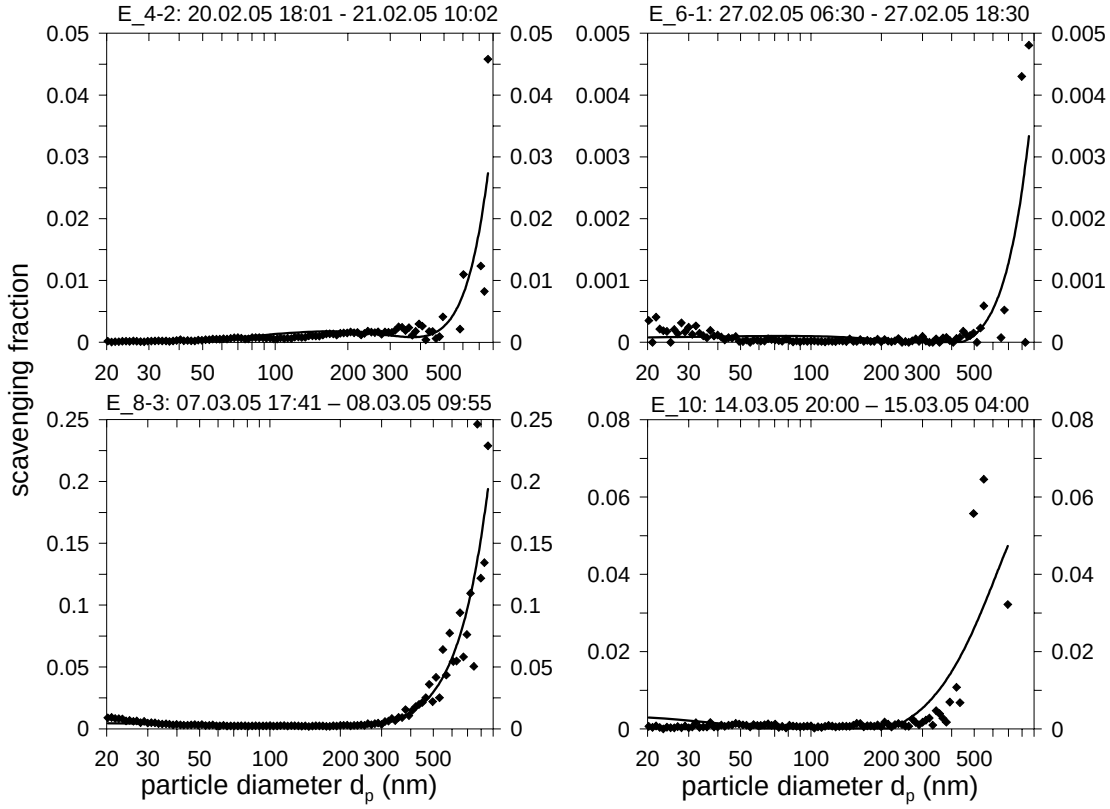

Fig.1 scavenging fraction of ice nuclei with regard to the abundant total aerosol population as a function of 4 particle size of 4 different mixed phase cloud events during CLACE-4

During CLACE-4 in 2005 the data base of ice nuclei measurements could be significantly enhanced. The results from the field experiment confirm that large particles are preferred to serve as IN. Mineral dust, non-volatile organic matter and BC were identified as ice nuclei substances. The latter ones imply an anthropogenic influence on ice nucleation in tropospheric supercooled clouds.

Key words:

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

Internet data bases:

http://www.tropos.de

Collaborating partners/networks:

Paul Scherrer Institute Villigen (PSI); Max-Planck Institute Mainz (MPI); Technical University of Darmstadt (TUD); University of Manchester (SEAES)

Scientific publications and public outreach 2005:

Conference papers

Mertes, S., B. Verheggen, J. Schneider, M. Ebert, S. Walter, A. Worringen, M. Inerle-Hof, J. Cozic, M.J. Flynn, P. Connolly, K.N. Bower, E. Weingartner, Sampling and physico-chemical characterisation of ice nuclei in mixed phase clouds at the high alpine research station Jungfraujoch (3580 m asl) during CLACE, European Aerosol Conference 2005, Ghent, Belgium, August 28-September 2, 2005, Conference Proceedings, 130, 2005

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