Chemical composition, mixing state, size and morphology of ice nucleating particles at the Jungraujoch station, Switzerland

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INTRODUCTION

An intense field campaign from the Ice Nuclei Research Unit (INUIT) was performed in January and February of 2013 at the High-Alpine Research Station Jungfraujoch (3580 m a.s.l., Switzerland). Main goal was the assessment of microphysical and chemical properties of free-tropospheric ice-nucelating particles.

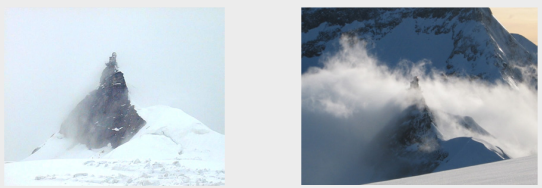

Figure 1: High altitude research station Jungfraujoch, Switzerland.

SAMPLING OF ICE NUCLEI/RESIDUALS

The ice-nucleating particles were discriminated from the total aerosol by three different devices. First device used was the 'Fast Ice Nucleation CHamber' (FINCH; University Frankfurt) and second the 'Ice-Selective Inlet' (ISI, Paul Scherer Institute) followed by a pumped counter-stream virtual impactor. The separated ice-nuclei (IN) respectively ice residuals (IR) were then collected with nozzle-type impactors.
Finally, with the ICE Counter-stream Virtual Impactor (ICE-CVI) atmospheric ice crystals are separated from the total aerosol and their water content is evaporated to retain the ice residual particles, which are then collected also by impactor sampling.

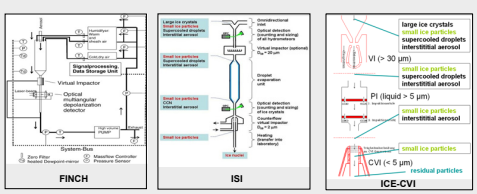

Figure 2: Sketches of the three devices (FINCH, ISI, ICE-CVI), which were used for seperation of the ice nuclei/residuals.

ELECTRON MICROSCOPICAL ICE NUCLEI AND ICE RESIDUAL ANALYSIS

All samples were analyzed in a high-resolution scanning electron microscope (SEM) equipped with an energy-dispersive X-ray microanalysis system (EDX). By this method, for each particle its size, morphology, mixing-state and chemical composition is obtained. In total 2838 ice nucleating particles were analyzed.
Based on their chemical composition and morphology the particles were classified into seven groups: silicates, metal oxides, Ca-rich particles, (aged) sea-salt, soot, secondary particles (sulphate/organic mixtures) and carbonaceous matter. Furtheron, in Figure 5 it is shown, which part of the particles were internal or external mixed.

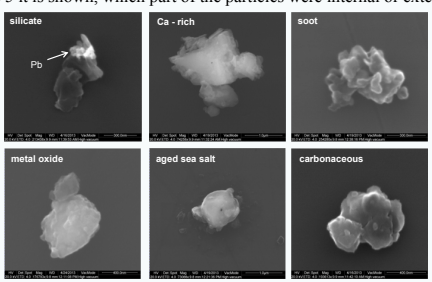

Figure 3: Secondary electron images of detected IN/IR: a)alumosilcate; b)Ca-rich; c)soot; d)metal oxide; e)aged sea salt; f)carbonaceous particle.

ARTEFACTS

Originally more than 5000 potential IN/IR were analyzed in the samples from the three IN/IR-selective pathways. SEM-EDX analysis revealed that in ICE-CVI samples about 60% of the particles were aluminium(oxides) (Figure 4b), in the ISI samples ~75% of all detected particles were silicon oxide spheres (Figure 4a) and in FINCH samples ~15% were alloy particles (Fe,Cr,Ni). These particles were identified as methodical artefacts and were not considered for further discussion.

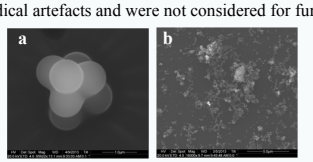

Figure 4: Secondary electron images of artefact particles within the IN/IR fraction: a)silicon oxide spheres in ISI and b)aluminium(oxide) in ICE-CVI samples.

RESULTS

The most frequent IN/IR at the Jungfraujoch station are silicates > carbonaceous particles > metal oxides. Calcium-rich particles and soot play a minor role. In the IR fraction of the ICE-CVI lead bearing particles are strongly enriched in contrast to the background aerosol. This is in agreement with prior measurements[1,2]. While FINCH also shows an Pb enrichment, this was not found in the ISI samples. All these findings are confirmed by quasi-parallel measurements with an online single particle laser ablation mass spectrometer (ALABAMA). Espacially in the fine mode (D_p< 1 µm) also higher amounts of soluble particles (sulphates/sea-salt) were detected. These particles were interpreted as sampling artefacts. In this way a further discussion of IN/IR composition seems to be most useful for particles larger than 1 µm.

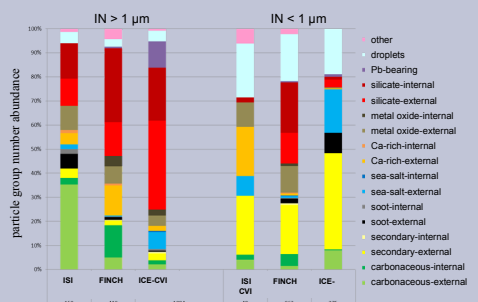

Figure 5: Average relative particle group number abundance of IN/IR at Jungfraujoch station measured by SEM-EDX. IN/IR samples were received by ISI, FINCH, and ICE-CVI devices.

CONCLUSION

All the tested techniques for measuring ice nucleating particles perform similar from a chemical point of view within the range of their uncertainties and low counting statistics due to the low particle concentrations in free-tropospheric air. Nevertheless, a high number of artefacts were observed for all IN/IR separating devices, which have to be considered. These artefacts can be identified and discarded by SEM-EDX. In this way, for the first time three different ice nucleation measurement techniques could be compared side by side under real-world atmospheric conditions.

REFERENCES

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[2]Cziczo D.J., Stetzer O., Worringen A., Ebert M., et al., Inadvertent Climate Modification Due to Anthropogenic Lead, Nature Geoscience, DOI: 10.10382009/NGEO 499, 2009.

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