Size distribution and black carbon content of ice residual particles in mixed-phase clouds at the high-alpine site Jungfraujoch

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Keywords: mixed-phase cloud, heterogeneous freezing, ice nucleating particles, black carbon
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Supercooled liquid clouds do occur at temperatures below 0 °C as homogeneous freezing of cloud droplets only occurs at approximately –38 °C. Heterogeneous freezing of supercooled cloud droplets can be caused by ice nucleating particles (INP) at temperatures above –38 °C. If present, INPs can trigger ice formation and with that also the Wegener-Bergeron-Findeisen process, which transforms supercooled liquid clouds to mixed-phase or fully glaciated clouds. However, the number of INPs in the temperature range –10 °C to –20 °C (typical for wintertime conditions at the high-alpine site Jungfraujoch), is several orders of magnitude lower than total particle number. Understanding the properties and abundance of INPs is an important piece of information required to assess the effect of heterogeneous freezing processes on cloud optical properties and precipitation efficiency.

In this study (Kupizewski *et al.*, 2016), we applied a sophisticated inlet named "Ice-CVI" (Mertes *et al.*, 2007), which exclusively extracts ice crystals with diameters between 5 and 20 µm from mixed-phase clouds, in order to study INPs in ambient clouds encountered at the high-alpine Jungfraujoch site (3'580 m asl). The selected small ice crystals are dried such that the ice residual particles (IRP), which are expected to be INPs, can be characterized and contrasted with the total aerosol. We measured the size distribution using scanning mobility particle sizers and optical particle sizers, and determined the fraction of black carbon (BC) containing particles using single particle soot photometers (SP2).

Results

The ice activated fraction (IAF), defined as the ratio of IRP to total particle number concentration at a certain size, was found to be strongly size dependent with values as low as $3 \cdot 10^{-4}$ for particles with diameters below 100 nm and values reaching about 0.6 in the diameter range above 1 µm. Nonetheless, in absolute terms, the submicron IRPs still dominated the total number of IRPs.

The SP2 measurements further revealed that BC-containing particles are about one order of magnitude less active as heterogeneous ice nuclei compared to BC-free particles with equal overall particle optical diameter. This is in disagreement with a previous study (Cozic *et al.*, 2008). However, we consider the result of our study, which is based on BC particle number rather than BC mass, to be more relevant. We conclude that BC particles likely play a minor role for the glaciation of supercooled clouds in the temperature range covered in this study (~ –8 to –26 °C).

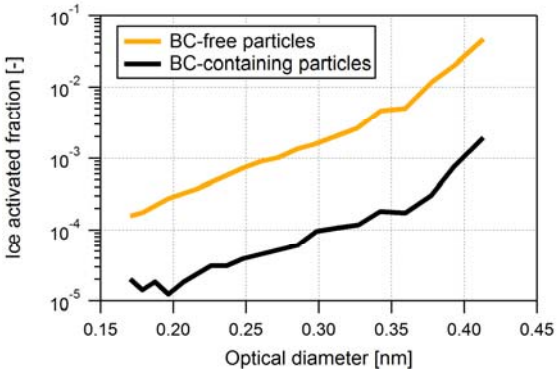

Figure 1. Ice activated fraction of BC-free and BC-containing particles as a function of total optical diameter of the particles as measured by the SP2 downstream of the Ice-CVI inlet operated in mixed-phase clouds at the high-alpine site Jungfraujoch.

This project was supported by the SNSF (grant 135356), the DFG (HALO, INUIT and grant SCHN 1140/2-1), MeteoSwiss (GAW-CH program), the European Research Council (ERC-CoG 615922-BLACARAT) and the EU FP7 projects ACTRIS and BACCHUS. We also thank the International Foundation High Altitude Research Stations Jungfraujoch and Gornergrat (HFSJG).

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