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Single-particle characterization of ice-nucleating particles and ice particles residuals sampled by three different techniques

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During January/February 2013, at the High Alpine Research Station Jungfraujoch a measurement campaign was carried out, which was centered on atmospheric ice-nucleating particles (INP) and ice particle residuals (IPR). Three different techniques for separation of INP and IPR from the non-ice-active particles are compared. The Ice Selective Inlet (ISI) and the Ice Counterflow Virtual Impactor (Ice-CVI) sample ice particles from mixed phase clouds and allow for the analysis of the residuals. The combination of the Fast Ice Nucleus Chamber (FINCH) and the Ice Nuclei Pumped Counterflow Virtual Impactor (IN-PCVI) provides ice-activating conditions to aerosol particles and extracts the activated INP for analysis. Collected particles were analyzed by scanning electron microscopy and energy-dispersive X-ray microanalysis to determine size, chemical composition and mixing state. All INP/IPR-separating techniques had considerable abundances (median 20 – 70 %) of instrumental contamination artifacts (ISI: Si-O spheres, probably calibration aerosol; Ice-CVI: Al-O particles; FINCH+IN-PCVI: steel particles). Also, potential sampling artifacts (e.g., pure soluble material) occurred with a median abundance of < 20 %. While these could be explained as IPR by ice break-up, for INP their IN-ability pathway is less clear. After removal of the contamination artifacts, silicates and Ca-rich particles, carbonaceous material and metal oxides were the major INP/IPR particle types separated by all three techniques. Soot was a minor contributor. Lead was detected in less than 10 % of the particles, of which the majority were internal mixtures with other particle types. Sea-salt and sulfates were identified by all three methods as INP/IPR. Most samples showed a maximum of the INP/IPR size distribution at 400 nm geometric diameter. In a few cases, a second super-micron maximum was identified. Soot/carbonaceous material and metal oxides were present mainly in the submicron range. ISI and FINCH yielded silicates and Ca-rich particles mainly with diameters above 1 μm, while the Ice-CVI also separated many submicron IPR. As strictly parallel sampling could not be performed, a part of the discrepancies between the different techniques may result from variations in meteorological conditions and subsequent INP/IPR composition. The observed differences in the particle group abundances as well as in the mixing state of INP/IPR express the need for further studies to better understand the influence of the separating techniques on the INP/IPR chemical composition.