Locations and chemical compositions of micro-inclusions in EGRIP Holocene and Late Glacial ice derived by optical microscopy and Raman spectroscopy

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Abstract. Impurities deposited in polar ice allow the reconstruction of the atmospheric aerosol concentration of the past while at the same time impacting the physical properties of the ice itself such as its deformation behaviour. Impurities are thought to enhance deformation, but observations are ambiguous due to a shortage of comprehensive microstructural analyses. For the first time, we systematically analyse micro-inclusions in fast flowing ice, i.e. from the East Greenland Ice Core Project (EGRIP) ice core drilled trough the Northeast Greenland Ice Stream (NEGIS). We derive the crystal-preferred orientation, grain size, dust particle concentration, and microstructural features at eleven depths, covering the Holocene and Late Glacial, and analyse the in-situ locations and chemical compositions of inclusions in the polycrystalline, solid ice samples using optical microscopy and Cryo-Raman spectroscopy. Micro-inclusions are more variable in spatial distribution and mineralogy than previously observed, and show various distributional patterns ranging from centimetre-thick layers to clusters and solitary particles, independent of depth. At some depths micro-inclusions are preferably located at grain boundaries. Identified Raman spectra are mainly mineral dust (quartz, mica and feldspar) and sulphates (mainly gypsum), but mineralogy changes considerably with depth. A variety of sulphates dominate the upper 900 m while gypsum is the only sulphate in deeper samples, which contain more mineral dust, nitrates and dolomite. The analysed part of the core can thus be divided into two depth regimes of different mineralogy, which could originate from different chemical reactions in the ice or large-scale changes in NE-Greenland during the Mid-Holocene. We discuss how the spatial variability of micro-inclusions is related to their chemical compositions and possible effects on the microstructure, which is intensively impacted by dynamic recrystallization at all depths. However, deriving clear conclusions remains challenging and emphasises the need for holistic approaches combining microstructure and impurity analysis.