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The influence of impurities on the densification of firn -a case study from North Greenland

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Paleoclimatic records from polar ice cores provide unique information about past atmospheric conditions, like temperature from stable water isotopes and greenhouse gas concentrations. To investigate leads and lags of temperature, measured in the ice phase, with gas concentration the exact dating of gas and ice is important. However, the age difference between the air and the surrounding ice complicates the exact dating. After the deposition the age of the snow increases with depth, whereas the pores only close in a certain depth, so called close-off depth (COD). Thus, the knowledge of the COD is crucial for dating the gas. Snow accumulation rate and temperature are known as the main factors of firn densification. Recently, a possible influence of impurities enclosed in the ice was found.

Here, we present a case study to investigate which impurities could have an influence on the densification of polar firn. We have analyzed 80 cm from an unbroken firn core from north-west Greenland from a depth of $\sim$54 m, next to the firn-ice transition. Here the density is of very high variability. We can differentiate between layers of different densities in spite of the same temperatures and snow accumulation rates and its deep enough to analyse the influence of trace elements.
We measured the density using a new full core X-ray computer tomograph with a resolution of 113 μm. We analysed major ions (SO42-, $CH3SO_3$-, NH4+, NO_3-, F-, Br-, Na+, Cl-, K+, Ca2+ and Mg2+) and dust particles on discrete samples in 3-4 mm resolution and compared the obtained concentration profiles with the density of the firn. The uncertainty in depth correspondence is less than 1 mm, thus a comparison on this level is possible for the first time.

We found the highest correlations between the dust proxies (particle concentration and Ca2+-concentration), r = 0.6, indicating an influence of these impurities on the densification of firn. Correlation coefficients between other ion concentrations and the density range from r = -0.04 (F-) to r = 0.27 (NO_3-). Only sulphur components (sulphate and MSA) show also higher correlations to the density of the firn (r$\sim$0.5).
For the first time in a direct comparison in a resolution of 1 mm or less it was possible to investigate the influence of impurities on firn densification. The correlation between the density and the dust proxies indicates that the dust particle or some other process linked to the dust proxies, have an influence on the densification of firn. However, the mechanism of densification is not clearly understood yet.