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Preferential loss of trace elements from melting Alpine snow and glacier ice

Anja Eichler (1,3), Jürg Trachsel (4,5), Jacinta Edebeli (1,5), Sabina Brütsch (1), Thorsten Barthels-Rausch (1), Martin Schneebeli (4), Margit Schwikowski (1,2,3), Sven Avak (1,2,3)

(1) Laboratory of Environmental Chemistry, Paul Scherrer Institute, Villigen PSI, Switzerland, (2) Department of Chemistry and Biochemistry, University of Bern, Bern, Switzerland, (3) Oeschger Centre for Climate Change Research, University of Bern, Bern, Switzerland, (4) WSL-Institute for Snow and Avalanche Research SLF, Davos Dorf, Switzerland, (5) Department of Environmental Systems Science, ETH Zürich, Zürich, Switzerland

Cold high-Alpine glaciers are invaluable archives of past climate and atmospheric composition. Especially, trace element (TE) records from high-Alpine ice cores and snow pits contain comprehensive information about paleo atmospheric changes (Schwikowski et al., 2004). Due to the current global climate warming, many high-Alpine glaciers are increasingly in danger to significantly suffer from melting. Meltwater percolation has been shown to substantially alter the information stored in these environmental archives (Eichler et al., 2001). To further use TE records as paleo atmospheric archives, the influence of melting on the preservation of TEs in snow and ice needs to be thoroughly understood.
Here, we present an extensive investigation of the impact of melting on the preservation of 35 TEs of natural and anthropogenic origin in high-Alpine snow and glacier ice. Analysis of an ice core from upper Grenzgletscher, Switzerland, including a 16 m section in the firn part affected by meltwater percolation, revealed a fractionation of TEs depending on water solubility and location at the grain scale. Ba, Ca, Cd, Co, Mg, Mn, Na, Ni, Sr, and Zn revealed significant concentration depletion, while Ag, Al, Bi, Cu, Cs, Fe, Li, Mo, Pb, Rb, Sb, Th, Tl, U, V, W, Zr, and the rare-earth elements (Ce, Eu, La, Nd, Pr, Sc, Sm, Yb) were well preserved. TEs likely to originate from water-insoluble minerals were found to be mostly preserved, even though typically enriched on grain surfaces, due to their immobility with meltwater. Water-soluble TEs revealed variable meltwater-mobility. While TEs occurring in ultra-low concentrations tend to be preserved due to incorporation into the ice crystal interior, abundant TEs were prone to meltwater-induced relocation mainly from ice crystal surfaces. In addition, a snow pit campaign at the 180 km distant Weissfluhjoch test site in Switzerland was conducted with regular sampling from January to June 2017, to monitor the behavior of TEs during melting of the snow pack. Comparison of snow pit profiles representing dry (insignificant occurrence of melting) and wet conditions (snowpack heavily soaked with meltwater) revealed a preferential loss of certain TEs that largely matched the elution behavior at upper Grenzgletscher. Thus, our study revealed a variety of TEs that are still robust environmental proxies even in melt-affected ice core and snow pit records from the entire Alpine region.

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