Impact of active rock glaciers on solute chemistry in Alpine headwaters

Ulrike Nickus, Institute of Meteorology and Geophysics, University of Innsbruck, Austria
Hansjoerg Thies, Institute of Geology, University of Innsbruck, Austria
Karl Krainer, Institute of Geology, University of Innsbruck, Austria
Kathrin Lang, Service for Geology and Material Testing of the Autonomous Province Bozen, Italy
Volkmar Mair, Service for Geology and Material Testing of the Autonomous Province Bozen, Italy
Richard Tessadri, Institute of Mineralogy and Petrography, University of Innsbruck, Austria
Monica Tolotti, IASMA Research and Innovation Centre, Edmund Mach Foundation, Italy
David Tonidandel, Service for Geology and Material Testing of the Autonomous Province Bozen, Italy

Mountain permafrost is abundant in the European Alps where mean annual air temperature (MAAT) is below -3°C, but there are also sites with MAAT around -1°C. Studies based on borehole soundings have revealed a warming of mountain permafrost of up to 1°C during recent decades. An important form of mountain permafrost in the European Alps are active rock glaciers, lobate- or tongue-shaped bodies of unconsolidated rocks and debris with an ice core or ice-matrix structure, which makes active rock glaciers sensitive indicators of climate change. There is evidence that the increase in air temperature has recently favored the solute release from active rock glaciers, and pronounced changes in water quality of headwaters in the Alps have been described (Thies et al. 2007, 2013).

Here, we report on the seasonality of solute concentrations in selected rock glacier streams in the Central Eastern Alps (Austria, Italy). Bedrock at the sites consists of paragneiss and micaschist of the Oetztal metamorphic complex. Only negligible anthropogenic impacts were observed at the selected sites (e.g. minor summer grazing of cattle). Substance concentrations of most streams revealed a strong increase up to a factor of 5 through the summer season, and thus reflected the seasonally varying contributions of the melting winter snow pack, summer precipitation, groundwater and ice melt to the discharge of active rock glaciers. Dominating ion species were sulfate, calcium and magnesium, which comprised about 98% of the total ion load. High concentrations of metals like aluminum, nickel or manganese were found in acidic streams at pH values of 4.4 to 5.2. Reference streams without any impact of active rock glaciers, on the contrary, revealed no seasonality in solute concentrations and values remained one to two orders of magnitude below those of rock glacier streams. We show vertical solute profiles in the ice of a 40 m long core drilled at an active rock glacier in the Italian Alps, where distinct layers of extremely high ion and metal concentrations were detected and peak values of electrical conductivity exceeded 1000 µS/cm.