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Rainfall as primary driver of discharge and solute export from rock glaciers: the case of the Col d'Olen Rock Glacier (NW Italian Alps)

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Permafrost degradation affects hydrochemistry of surface waters. In particular, evidence of modifications of water quality has been collected in mountain headwaters impacted by rock-glacier thawing. Rock glaciers are slowly flowing mixtures of debris and ice-rich permafrost, and melting ice inside them has been reported to affect surface water hydrochemistry, in some cases causing severe ecological damages.

Three hypotheses have been formulated to explain how weather and climate drive the export of solute-enriched water from rock glaciers: (1) Warm periods cause increased subsurface ice melt, which releases solutes; (2) rain periods and the melt of long-lasting snow enhance dilution of rock-glacier outflows; and (3) percolation of rain through rock glaciers facilitates the export of solutes, causing an opposite effect as that described in hypothesis (2). This lack of understanding exists because suitable studies of atmospheric parameters, hydrologic processes and physicochemical characteristics of water bodies downstream from rock glaciers are unavailable.

In this study, a rock-glacier pond in the North-Western Italian Alps was studied on a weekly basis for the ice-free seasons 2014 and 2015 by observing atmospheric forcing (air temperature, snow cover duration, rainfall) assumed to drive the export of solute-enriched waters from the rock glacier and the physicochemical response of the pond (water temperature as a proxy of rock-glacier discharge, stable water isotopes, major ions and selected trace elements).

Results revealed intra-seasonal patterns of increasing solute export associated with higher rock-glacier discharge. Specifically, rainfall (after winter snowpack depletion) was found to be the primary driver of solute export from the rock glacier during the ice-free season, likely through the flushing of stored solutes (SO42-, Mg2+, Ca2+, Ni, Mn, Co) and microbially-active sediments (NO_3-) in the rock-glacier interior.

With projected reductions in snow cover duration, and increases in air temperature and summer rainfall in the northern hemisphere and in the Alps, an increase in solute flushing from rock glaciers is likely. However, characteristics of rock-glaciers and relative catchments (e.g., ratio of rock-glacier size to catchment area, lithological setting) and characteristics of rock-glacier interior (e.g., frozen core structure and dimensions, hydrological system properties) might influence the timing and magnitude of the impacts of rock-glacier thawing on water quality.