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Seasonal and daily freeze-thaw dynamics of a rock glacier and their impacts on mixing and solute transport: a case study from the Val d'Ursé, Bernina Range, Switzerland

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The aim of this study was to quantify the seasonal to daily freeze-thaw cycles of a rock glacier (RG) located in the Val d'Ursé catchment (Bernina Range, Switzerland) and their role in controlling the dynamic of the connected groundwater system. We combined digital image correlation techniques (Bickel et al., 2018) and time series analysis of discharge rates and physicochemical properties of springs and streams influenced by the RG, as well as changes in hydraulic head in nearby deep boreholes. The results indicate an acceleration of creep since 1990 due to rising temperatures, with the most active regions exhibiting horizontal velocities of ~1 m/yr. Distinct geochemical signatures of springs affected by RG discharge reflect different mixing rates with groundwater. Observed variations in discharge and dilution/enrichment cycles (based on the electrical conductivity signal) reveal an afternoon onset linked to the diurnal freeze/thaw cycle of the RG ice. This daily signal is superimposed on a seasonal trend that combines the effect of the changes in temperature and recharge/discharge dynamics of the deep groundwater system. Based on the results of a FFT-based analysis performed on the electrical conductivities and temperature signals of springs, we discuss the evolution of flow and transport mechanisms involved at the seasonal timescale. Specifically, the analysis of the phase lag between the signal of electrical conductivity with respect to the air temperature reveal key information on transport properties and timescales. Further investigations using a cryo-hydrogeological model (HEATFLOW-SMOKER code, Molson and Frind, 2019) allowed us to investigate the coupled processes governing groundwater-meltwater mixing on daily to seasonal time scales, supporting the interpretations of our field observations.