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Quantifying water and ice content variability in ice-rich permafrost using piezometer measurements

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Mountain permafrost ground that consists of rock debris supersaturated with ice can deform under its own weight and form rock glaciers, a creeping periglacial landform. Over the past decades, much research has been dedicated to examining the dynamics of rock glaciers and identifying their main drivers across different spatiotemporal scales and their coupling to climate. Creep causes deformation within the rock glacier body and, dominantly, shearing in a discrete horizon commonly at about 15-30m depth. However, current understanding of the driving forces of these processes is limited. Rock glacier surface velocity time series highlight the effect of temperature on creep rates at inter-annual to multi-decennial timescales. Seasonal velocity variations also point out a thermally driven effect, even if there is no temperature change at the depth of the shear horizon. A temperature change within the rock glacier body potentially alters the water content. Increasing water pore pressure in the shear horizon of rock glaciers could have an accelerating effect. We aim to investigate (i) how changes in water content taking place at shallow depths within the permafrost could affect the shear process occurring lower down (ii) how and where water infiltration is occurring within the permafrost. Direct insights into the internal hydrology of rock glaciers have yet to be quantitatively described using field data.

In this study, we measured relative changes in pore water pressure in different layers of a rock glacier using piezometers, which allowed us to describe the water-to-ice ratio variability and investigate its effect on kinematics. Seasonal pore water pressure variations can be attributed to phase change, as indicated by parallel ground temperature measurements and cross-borehole electrical resistivity tomography (ERT) data. To improve the understanding of piezometer measurements in permafrost field environments, we carried out laboratory tests to validate piezometers in ice-rich ground undergoing phase change. To do this, we created an experimental setup in which we froze and thawed a mixture of sand, gravel and water containing Keller PAA-36XiW piezometers under controlled laboratory conditions. The results of the laboratory experiments, their implications on the interpretation of field data, and the advantages and limitations of piezometer measurements in ice-rich permafrost with variable water contents will be presented.