Modeling Rockwall Permafrost to Understand Periglacial Rock Slope Failures

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Rockwall permafrost has been increasingly investigated since the summer heat wave that struck the European Alps in 2003 and was associated with a remarkably high number of rockfalls. Presence of ice in many rockfall scars, concomitance of periglacial rock slope failures (PRSF) with hot periods, and laboratory tests on the mechanical behavior of frozen rock suggest that the warming and alteration of ice-cement in bedrock fractures may be the predominant triggering mechanism of recently observed high occurrence of PRSF.

However, linking this hypothesis to field observations is challenged by the lack of understanding of rockwall thermal dynamics at the time of observed rockfalls, and of the complex thermo-hydromechanical processes controling rock slope stability. Here we present some recent developments in rockwall permafrost modeling to support understanding of PRSF.

By applying a simple thermal model accounting for heat conduction and latent heat processes to 209 rockfalls (>100 m³) in the Mont Blanc massif (Western European Alps) from 2007 to 2015, we showed that events with scar depth > 6 m systematically occurred in warm permafrost conditions, while shallower events were scattered within a larger temperature range. Additionally, most rockfalls were characterized by an exceptionally high temperature at depth of failure 1 day to 3 weeks earlier.

In parallel, we recently developed a fully coupled hydrothermal model applied to the Aiguille du Midi (3842 m a.s.l., Mont Blanc massif). It shows that under ice- or water-saturated conditions in the fractures and the rock matrix, permafrost degradation is first delayed into and around ice-cemented fractures due to locally enhanced latent heat consumption, but is followed by a strongly enhanced degradation within and around the fractures as soon as ice melts and water starts to flow.

These developments draw research perspectives to statistically determine areas and timing at risk of PRSF, and to quantitatively determine the primary parameters that trigger them. Current challenges are associated to the realistic parameterization (water input and fracture network) and the validation of the hydrothermal models. Recent developments in geoelectrical monitoring as possible validation approaches will be briefly introduced.