

Modelling water-related processes in rock wall permafrost

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Rock wall permafrost has been increasingly regarded since the early 2000s in reason of the growing frequency and magnitude of bedrock failures from mountain permafrost areas. One of the main current challenges to better assess its degradation and the failure mechanisms is the quantification of hydric processes, *i.e.* water infiltration and circulation in the fractures. Indeed, since the pioneer studies, the thermal and mechanical behavior of saturated frozen rock media has been deeply investigated (*e.g.* Noetzli *et al.*, 2007; Krautblatter *et al.*, 2013; Mamot *et al.*, 2018), allowing a better understanding of the mid- to long-term (decadal to millennial) permafrost evolution and rupture of ice-filled joints. However, thermal and mechanical processes acting on the short term (seasonal to pluri-annual) remain poorly understood due to the lack of consideration for hydric processes acting into non-saturated bedrock fractures. However, these processes have been evidenced by the presence of water alongside ice bodies in several rock fall scars worldwide.

In this communication, we will present a first attempt to model hydric processes in high-alpine bedrock permafrost. This entails designing a new modelling approach accounting for heterogeneous (fractures) and non-saturated areas in the rock media. We use the Finite Element simulation system Feflow (DHI-WASY) to model variably saturated flow and advective-conductive heat transports combined with phase change processes. We simulate heat transports in a 2D geometry (vertical cross-section) reflecting the Aiguille du Midi settings (3842 m a.s.l., Mont Blanc massif, European Alps), where heat conduction models in similar geometry have been already successfully applied to reconstruct and predict permafrost evolution since the Little Ice Age to the end of the 21st century (Magnin *et al.*, 2017). The water circulation is enabled in the upper part of the model geometry through a partially saturated domain, whereas the lower part is saturated. Water circulation in unfrozen zones is allowed by two outlets on each side of the cross section, one of them being under the Géant glacier (accumulation zone of the Mer de Glace), and by active layer thawing when the hydraulic conductivity is sufficient. Finally, the fractures intersection is also necessary to allow water circulation considering that massive rocks have low permeability also at positive temperature. We test two numerical approaches to design this fracture network and implement the related heat transports, applying the Richards equation and the Hagen-Poiseuille laws.

These novel modelling approaches bear strong potential to address thermal and mechanical effects of water infiltration (from snow melting and rain) and circulation in the frozen

bedrock, and to draw hypotheses on the periglacial processes and paraglacial slope adjustment affecting steep bedrock slopes.

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