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Thermal regime in steep permafrost rockwalls (Aiguille du Midi, 3842 m a.s.l., Mont Blanc massif) based on borehole data and 2D numerical modelling

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Since permafrost in steep rockwalls is mainly climatically controlled, the ongoing climate warming potentially strongly impacts frequency and magnitude of rockfalls in high-alpine rock faces in the near future. However, knowledge about the role of permafrost is still limited. This is especially because of measurement difficulties (invisibility of permafrost, remoteness and harshness in high mountain areas). In addition to local measurements, numerical models have thus been used in the past years to better understand the distribution and thermal conditions of permafrost and to investigate involved physical processes.
To monitor permafrost in steep bedrock and to provide input and validation data for modeling, three 10-m-boreholes have been drilled in 2009 on the NW, NE and S faces of the Aiguille du Midi (AdM 3842 m a.s.l), a granitic peak in the Mont Blanc massif (France). Here, we study the thermal regimes at depth and heat diffusivity. Climatic parameters such as air temperature, wind speed and direction, incoming and outgoing solar radiations are also collected continuously by an automatic weather station.

In this contribution, we present the first two years of data from the boreholes, in comparison with climatic parameters and outputs from a basic conductive 2D model. We gain a qualitative understanding of the processes governing the thermal regime of the central pillar of the Aiguille du Midi: (i) the importance of short-wave solar radiations on the most exposed rock faces, and air temperature control on other aspects, (ii) the impact of the snow cover, and (iii) the role of fractures on heat diffusivity and thermal regimes.

2010 and 2011 were respectively the coldest (mean annual air temperature: -9.1°C) and the warmest (-6.7°C) years since 2007 at the AdM. Solar radiations forcing is highlighted by fast thermal response of rockwalls experienced through the variation of the maximum Active Layer Thickness (ALT) from one year to another. In the SE face directly exposed to radiations, ALT was 2.7 m thicker in 2011 than in 2010. In contrast, in the shaded NW face, the ALT only increased by 0.5 m. In a different way, the ALT on the NE side was thinner in 2011, which is likely due to summer snowfalls that occurred just before the air temperature maximum and cooled the face. This cooling effect of snow cover is detectable by comparing the near-surface temperatures from the borehole to temperatures measured at the same exposition but in steeper snow-free parts as well as by model runs. A cooling effect is also related to fractures and associated air ventilation, as displayed by the temperature profile of the NW face, locally distorted and globally cooled. Looking at heat diffusivity from one thermistor to the next reveals its high variability with temperature changes: the values vary by an order of 2.5 between frozen and unfrozen rock.