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Other Conference Item

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Publication date:
2018-06

Permanent link:
https://doi.org/10.3929/ethz-b-000309262

Fracture kinematics in steep bedrock permafrost, Aiguille du Midi (3842 m a.s.l., Chamonix Mont-Blanc, France)

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Abstract

Permafrost-affected rockwalls can suffer from mechanical fatigue related to thermo-cryogenic processes. However, these processes, the rock slope kinematics, and the links between both remain largely unclear. This study reports five years of crackmeter measurements at 2-hours resolution from six of the main perennially ice-filled rock clefts at the Aiguille du Midi (3842 m a.s.l., Mont Blanc massif). Seasonal and inter-annual variations as well as response of fracture kinematics to thermo-cryogenic process are analyzed.

Keywords: permafrost, fracture kinematics, thermo-cryogenic processes, irreversible displacement, extensometry, Mont Blanc massif.

Introduction

In the current context of climate change, permafrost-affected rockwalls are increasingly affected by rockfalls (Ravanel *et al.*, 2017a) but processes that control climate-dependent rockfalls from these rockwalls are still poorly understood (Draebing *et al.*, 2017). In this study, we analyze crackmeter measurements installed in 2012 in the steep rockwalls of the Aiguille du Midi (AdM, 3842 m a.s.l.) within a Wireless Sensor Network (Ravanel *et al.*, 2017b), and their relationship with air temperature.

Study site

The AdM is located on the NW side of the Mont Blanc massif. This part of the massif is formed by an inclusion-rich, porphyritic granite and is bounded by a wide shear zone. The highest area of the AdM is steep, with few large fractures. The lower parts are gentle and more fractured. The AdM consists of three granite peaks (Piton Nord, Piton Central, and Piton Sud).

We chose the AdM as a monitoring site because: (i) permafrost is largely present; (ii) thermal monitoring (at surface and depth) is carried out since 2005; (iii) peaks offer a large range of aspect, slope angle and fracture density; (iii) its easy access by cable car from Chamonix and the availability of services (*e.g.* electricity) at the summit station; (iv) the possible easy data transmission; and (v) the risk related to permafrost for the infrastructure.

Monitoring system

The two main peaks have been equipped with crackmeters in 2012. Four crackmeters have been placed inside four major fractures at the Piton Nord, and two crackmeters have been installed along a major fracture at the Piton Central, equipped with three 10-m-deep boreholes with 15 temperature sensors since 2009. Data transmission is carried out thanks to a Wireless Sensor Network (Beutel *et al.*, 2009).

First outcomes

Common patterns can be identified throughout the dataset with a partly reversible seasonal displacement. In order to analyze crackmeter data, the methods proposed by Weber *et al.* (2017) were used.

First, a regression analysis between temperature and facture displacement is performed. Crackmeter measurements are divided into groups of 70 days where temperature variations must be of at least 8°C. For each group, the absolute value of the Pearson coefficient is computed.

The regression analysis between temperature and fracture displacement shows that every crackmeter record exhibits reversible displacement due to thermo-elastic strains related to annual temperature variations. Highest negative correlations between displacement and temperature mostly occur at the end of winter and the beginning of spring. In order to estimate timing and amplitude of plastic strain-induced irreversible displacement, we subtract the reversible component from the recorded displacement. From the irreversible displacement, we compute the irreversibility index (Weber *et al.*, 2017), that quantifies irreversibility within fracture kinematics.

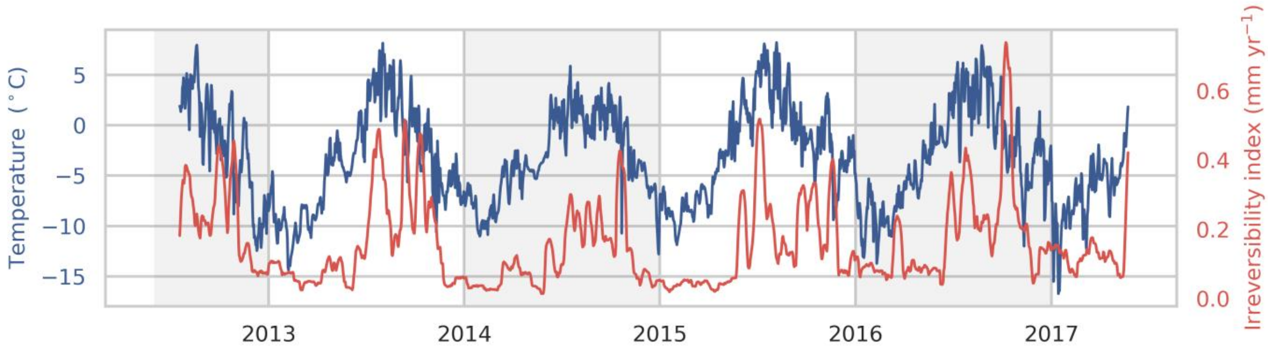

Figure 1: Irreversibility index for one of the crackmeters installed at the Piton Nord (South Face, Aiguille du Midi) and local air temperature (2012–2017)

First results show onset of highest irreversibility index when air temperature becomes > 0°C. This increase in irreversibility index seems related to increase in temperature and highlights thawing-related processes as the main generators of irreversible displacement.

During winter, lower peaks of irreversibility index are observed, widely contributing to overall annual irreversible displacement, and appear to be linked to rapid variations of local temperature conditions. Ice thermal expansion and contraction processes are thought to be responsible for the onset of such irreversible displacement.

Some sensors record high peaks of irreversibility index during autumn, when air temperature is lowering below 0°C. These peaks are the result of ice formation within the clefts.

In a next step, every crackmeter recording will be compared to temperature measured in the boreholes in order to better understand the scale variance of thermo-cryogenic processes affecting high alpine permafrost.

Acknowledgments

This research is part of the Swiss *PermaSense,* French ANR *VIP Mont-Blanc*, and ALCOTRA *PrévRisk Haute Montagne* and *AdaPT Mont Blanc* projects. We thank the Compagnie du Mont Blanc for allowing access to the site.

References

Beutel, J. *et al.*, 2009. The PermaSense remote monitoring infrastructure. *In*: *Proceedings of the International Snow Science Workshop Davos 2009*, pp. 187-191.

Draebing, D., Krautblatter, M. & Hoffmann, T., 2017. Thermo-cryogenic controls of fracture kinematics in permafrost rockwalls. *Geophysical Research Letters* 44: 3535–3544.

Ravanel, L., Magnin, F. & Deline, P. 2017a. Impacts of the 2003 and 2015 summer heat waves on permafrost-affected rockwalls in the Mont Blanc massif. *Science of the Total Environment* 609: 132-143.

Ravanel, L., Malet, E., Duvillard, P.-A., Magnin, F., Deline, P., Guillet, G., Troilo, F., Pogliotti, P., Morra di Cella, U., Beutel, J. & Gruber, S., 2017b. Instrumentation thermique et cinématique des parois à permafrost du massif du Mont Blanc. *Collection EDYTEM* 19: 27-38.

Weber, S., Beutel, J., Faillettaz, J., Hasler, A., Krautblatter, M. & Vieli A., 2017. Quantifying irreversible movement in steep, fractured bedrock permafrost on Matterhorn (CH). *The Cryosphere* 11: 567-583.