Name of research institute or organization:

Department of Geography, University of Zurich

Title of project:

Permasense

Project leader and team:

Dr. Stephan Gruber, UZH, project leader
Dr. Lucas Girard, UZH
Dr. Jan Beutel, ETH Zurich
Roman Lim, ETH Zurich

Project description:

Topic: Understanding freezing induced rock damage in-situ.
The progressive damage and fracture of porous media exposed to freezing is a fundamental problem for both scientists and engineers, as it can affect natural rock slopes, landscape development through physical weathering of bedrock and debris production, as well as concrete structures. In steep terrain, this process may be crucial for the slow preconditioning of rock fall from warming permafrost areas. As frost cracking operates slowly in the field, it has been mostly approached by laboratory experiments and theoretical studies. Such studies have documented empirical relationships between frost sensitivity of rocks and environmental controls (temperature, moisture, rock properties). They have also demonstrated that frost weathering can result from the operation of two different mechanisms, (i) the 9% volumetric expansion of freezing water and (ii) ice segregation, a mechanism comparable to frost heave in soils, yielding slow growth of ice inside rock under sustained freezing conditions. While these phenomena are now understood rather well for the controlled and idealized conditions of laboratory experiments, transferring these insights to field conditions remains a difficult task.

The goal of our research is to fill the gap between laboratory/theoretical insights on frost weathering and field conditions. In order to achieve this we carry out in-situ observations of freezing-induced rock damage, along with simultaneous monitoring of relevant environmental parameters. Through a first pilot experiment carried out at Jungfraujoch in 2010, we have demonstrated the possibility of using accoustic emission (AE) monitoring to capture freezing-induced rock fracture under natural conditions (Amitrano et al. 2012). AE monitoring consists in detecting transient elastic waves that are generated by the rapid release of energy within a material, through crack formation or friction between solid surfaces. This pilot study demonstrated that AE generated by freezing-induced stresses can indeed be detected and that the statistical properties of AEs correspond to that of micro-fracturing. However, the short duration of the experiment did not allow to detail the sensitivity to different controls of environmental parameters (rock temperature, moisture content) on the frost cracking activity.

In order to extend these first results, we have deployed, during summer-fall 2011, two continuous measurement systems on a rock wall close to the Jungfraujoch research station (Figure 1). Each measurement system is composed of a custom-built AE acquisition system, detecting AE at 10 and 50cm depth in the rock, a 1m-long temperature probe, as well as a capacitance probe intended to estimate variation in rock liquid water content (Girard et al. 2012).

Figure 1 - Field deployment at Jungfraujoch, close-up of the measurement site, and detail of measurement system M2.

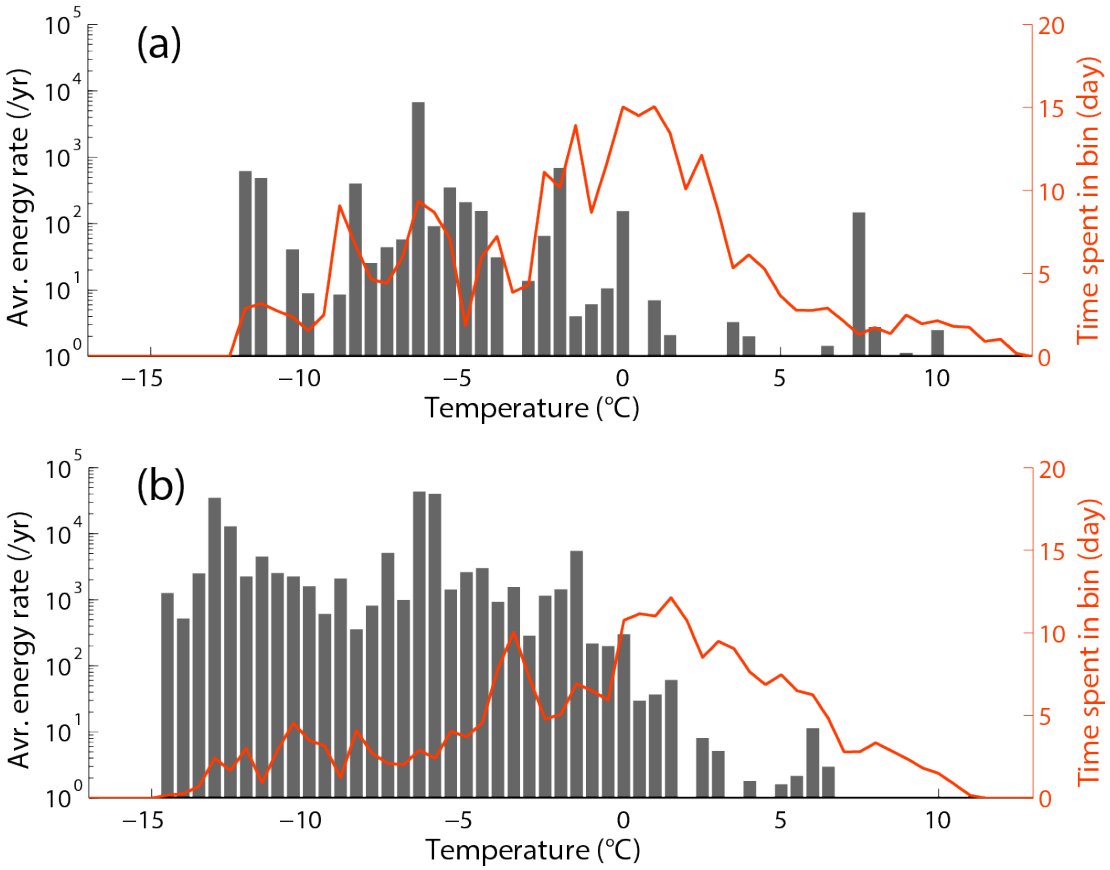

Figure 2 – Average rates of AE energy detected at both measurement sites, at 50cm depth, as a function of the rock temperature.

Throughout the year 2012, these two monitoring systems have operated almost uninterruptedly, yielding an unprecedented data set which allows us to revisit the characteristics and controls of field frost weathering. These important results will be the focus of a new publication currently in preparation. In brief, the measurements highlight:

- The strong sensitivity of frost cracking to rock liquid water content, as suggested by laboratory experiments.
- The fact that periods of sustained freezing yield stronger frost weathering activity than freeze-thaw cycling.
- The operation of frost weathering on a wide range of sub-zero temperatures, down to the lowest temperature detected (-15°C) (Figure 2).

These new insights allow us to revisit an important and controversial question of frost weathering studies: through which mechanism does frost weathering operate in the field. Our results suggest that both candidate mechanisms debated in literature operate in the field, although ice segregation may be seen as the prevailing mechanism. A striking aspect of our results is that the range of temperatures over which frost cracking was detected goes beyond what was expected in earlier studies that attempted to transfer laboratory/theoretical knowledge to real natural conditions.

Finally, the year 2012 has also seen the beginning of a new collaboration with a group of researchers from SLF, Davos, led by Dr. Marcia Phillips. This collaboration takes place within the scope of the PhD thesis of Anna Haberkorn, dealing with properties of snow in steep rock walls. As part of this work, a first measurement campaign was carried out together with the PermaSense team in November 2012. Further planned research steps include analyses based on the 4-year timeseries of rock temperature acquired near the Jungfraujoch research station as part of the PermaSense project.

Key words:

Rock mechanics, accoustic emission, weathering, permafrost

Internet data bases:

www.permasense.ch
www.data.permasense.ch

Collaborating partners/networks:

Dr. David Amitrano, ISTerre, CNRS / Université J. Fourier, Grenoble, France
Dr. Marcia Phillips, SLF Davos, Switzerland

Scientific publications and public outreach 2012:

Refereed journal articles and their internet access

Girard, L., J. Beutel, S. Gruber, J. Hunziker, R. Lim, S. Weber, A custom acoustic emission monitoring system for harsh environments: application to freezing-induced damage in alpine rock walls, Geosci. Instrum. Method. Data Syst., **1**, 155–167, doi: 10.5194/gi-1-155-2012, 2012.
http://dx.doi.org/10.5194/gi-1-155-2012

Amitrano, D., S. Gruber, L. Girard, Evidence of frost-cracking inferred from acoustic emissions in a high-alpine rock-wall, Earth and Planetary Science Letters, **341**, 86–93, doi: 10.1016/j.epsl.2012.06.014, 2012. http://dx.doi.org/10.1016/j.epsl.2012.06.014

Book sections

Weber, S., S. Gruber, L. Girard, Design of a Measurement Assembly to Study In-Situ Rock Damage Driven by Freezing, in Proceedings of the tenth international conference on Permafrost, Russia, June 2012.

Conference papers

Amitrano, D., S. Gruber, L. Girard, Cryo-induced cracking in high-alpine rock-wall, evidences from acoustic emissions monitoring, European Geophysical Union, General Assembly, Vienna, Austria, 2012.

Girard, L., S. Gruber, S. Weber, J. Beutel, Continuous monitoring of near-surface damage in a freezing rock-wall, 10th Swiss Geoscience Meeting, Bern, Switzerland, 2012.

Gruber, S., L. Girard, D. Amitrano, J. Beutel, S. Weber, Can improved understanding of frost cracking help anticipating focal zones for rockfall from degrading permafrost? The Geological Society of America, Annual meeting, Charlotte, North Carolina, USA, 2012.

Weber, S., S.Gruber, L. Girard, J. Beutel, Acoustic emission measurement system to investigate rock damage driven by freezing, 10th Int. Conference on Permafrost, Salekhard, Russia, 2012.

Weber, S., S. Gruber, L. Girard, J. Beutel, Let rock crack, let crack rocks, AK Permafrost meeting, Potsdam, Germany, 2012.

Address:

Glaciology, Geomorphodynamics & Geochronology
Dep. of Geography, University of Zurich
Winterthurerstr. 190
CH-8057 Zurich, Switzerland

Contacts:

Lucas Girard
Tel.: +41 44 63 55 219
E-mail: lucas.girard@geo.uzh.ch
URL: http://www.geo.uzh.ch/~girard/

Stephan Gruber
Tel.: +41 44 635 51 46
E-mail: stephan.gruber@geo.uzh.ch
URL: http://www.geo.uzh.ch/~stgruber/