



Configuration of a High-Resolution Paraglacial Borehole Monitoring System at the Great Aletsch Glacier

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Phenomenological interactions between glacial activity and slope activity have been derived from several case studies, where slopes failed in response to retreating valley glaciers (e.g. Holm et al., 2004). Processes controlling the interactions between valley glaciers and adjacent rock slopes have been systematically investigated e.g. by Grämiger (2017) and Grämiger et al. (2017) based on numerical modeling using data from the Aletsch region. They show that glacial loading and unloading cycles in combination with thermo-hydro-mechanical (THM) effects drive progressive damage of paraglacial rock slopes, which can act as major preparatory factors for the development of large slope instabilities.

In this contribution we present a new borehole based monitoring system designed for measuring and analyzing progressive rock damage and fracture slip caused by irreversible ice-unloading, and cyclic thermo-mechanical and hydro-mechanical loading in a paraglacial environment. The monitoring system has been installed in three 50 m research boreholes drilled into fractured crystalline rock at or near the 2017 ice margin of the Great Aletsch Glacier. The three boreholes have a spacing of about 200 m and are located NE of the very active part of the large Moosfluh slope instability. First the destructively drilled 101 mm diameter boreholes were logged and tested with geophysical and hydrogeophysical methods. Borehole transmissivity at the ice contact is surprisingly high ($\geq 10^{-3}$ m²/s) and pore pressure transients are strongly influenced by glacial meltwater. The borehole drilled at a lateral distance of 45 m from the ice margin shows substantially smaller borehole transmissivity ($\sim 10^{-5}$ m²/s) and pore pressure transients mainly controlled by slope water infiltration. Differences in transmissivity measured in the three boreholes can be explained by their location relative to the Moosfluh landslide or other local instabilities. After logging and testing we equipped each borehole with a pressure sensor in a 1-2 m long sand filter at the borehole end, an SAA inclinometer chain with 0.5 m sensor spacing including temperature sensors with 1 m sensor spacing, and a pre-strained FBG axial strain - temperature sensor chain with 5 m base-length and microstrain resolution. The three borehole locations are connected by protected or suspended fiber optical cables. Power supply in this harsh environment is provided by solar panels with two 135 Ah batteries and a monitoring setup to minimize power consumption. Here we show the detailed configuration and operation of this unique monitoring system and present preliminary results of 3D borehole deformations caused by THM loading during the first few month of monitoring.

Grämiger, L. M., 2017, Beyond debuttressing: Thermo-hydro-mechanical rock slope damage during glacial cycles [PhD Thesis: ETH Zurich.

Grämiger, L. M., Moore, J. R., Gischig, V. S., Ivy-Ochs, S., and Loew, S., 2017, Beyond debuttressing: Mechanics of paraglacial rock slope damage during repeat glacial cycles: *Journal of Geophysical Research-Earth Surface*, v. 122, no. 4, p. 1004-1036.

Holm, K., Bovis, M., and Jakob, M., 2004, The landslide response of alpine basins to post-Little Ice Age glacial thinning and retreat in southwestern British Columbia: *Geomorphology*, v. 57, no. 3-4, p. 201-216.