

# Deep-seated rock slope failures in mountain permafrost: Pizzo Cengalo and Piz Kesch (Canton Grisons, Switzerland)

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## INTRODUCTION

Two deep-seated rock slope failures occurred recently in Canton Graubünden, the first in the Northeast face of Pizzo Cengalo (with a volume of around 1.5 million m<sup>3</sup>) in December 2012 and the second in the North face of Piz Kesch, where a 150'000 m<sup>3</sup> rock buttress collapsed in February 2014 (Phillips et al. 2015). The Pizzo Cengalo event did not directly affect any underlying infrastructure but debris flows subsequently triggered in the sediments deposited in Val Bondasca reached the village of Bondo and caused damage to hydroelectric infrastructure. At Piz Kesch the rock material was deposited on the Porchabella glacier and had no negative effects. In both cases massive ice was present in the detachment scar, providing evidence of permafrost conditions prior to failure.

## METHODS

To understand the processes involved in the occurrence of large rock slope failures, their interaction and their relative importance, all data available for the events at Pizzo Cengalo and Piz Kesch is being investigated in a pilot project funded by ARGE Alp. In particular, the roles of the geological structure, of ice and/or water in joints and of short- and long-term changing thermal regimes in rock walls are the object of further investigation.

At both sites the geological structure and the volumes of the failure events could be determined using high resolution photographs and the SwissALti3D digital terrain model in combination with airborne and/or terrestrial laser scanning. Due to a lack of in-situ rock temperature measurements, the thermal regime of these rock walls is modelled using the numerical 1D model SNOWPACK and compared with data obtained in instrumented SLF boreholes located at sites with similar elevations in the Swiss Alps. Data from nearby automatic

weather stations is used for statistical analysis of the effect of antecedent meteorological conditions at various (recent) time scales preceding the events. Modes of collapse, flow dynamics and run-out distances are simulated using the rapid mass movement simulation software RAMMS.

## PRELIMINARY RESULTS

Progressive failure of rock bridges and gradual aggradation of ice in joints induced by cryogenic suction appear to be the main factors leading to failure at Pizzo Cengalo and Piz Kesch. These processes may occur over several millennia: organic matter found in the permafrost ice on the Piz Kesch rock material was dated at around 6000 years BP using the 14C method. The timing of failure (winter in both cases) is not exceptional: the SLF rock fall data base indicates that in mountain permafrost regions large events exceeding 100'000 m<sup>3</sup> occur at any time of year, whereas smaller ones tend to take place during periods of high air temperatures, in the summer months. Despite their magnitude, the events at Pizzo Cengalo and Piz Kesch were not directly observed and were only registered due to seismic data and later observations.

## OUTLOOK

At Pizzo Cengalo the rock wall continues to show signs of activity and rock wall dynamics are being monitored regularly using terrestrial laser scanning and a portable interferometric radar, which allows detection of millimetre scale movements (Fig. 1). Crackmeters and thermometers will be installed in the active part of the rock wall in summer 2015 to allow direct monitoring of joints. The timing of failures can be determined using seismic data and an automatic camera, which is located on the Sciora moraine.

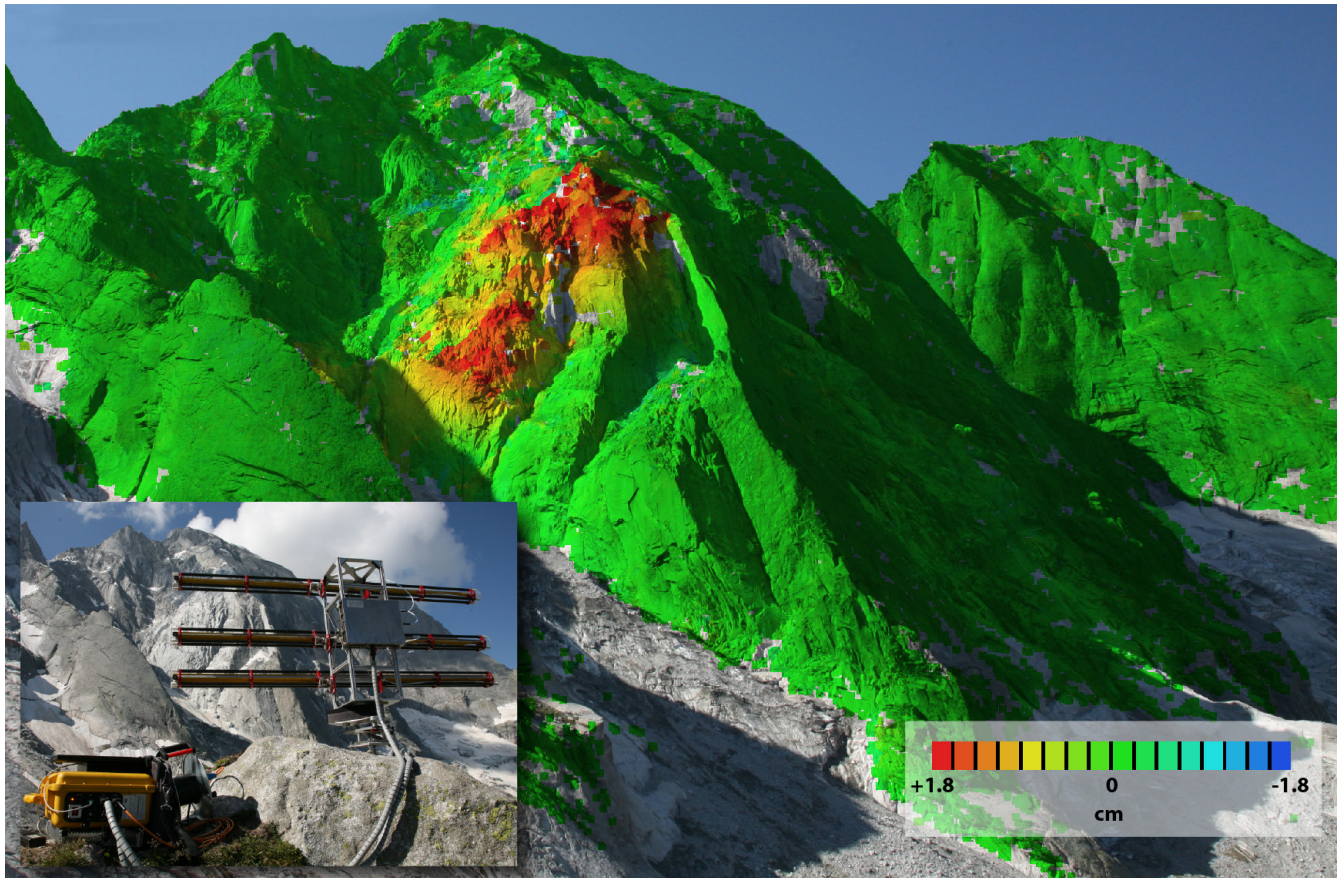


Figure 1. Total displacements on Pizzo Cengalo for a 2 year period (2012-2014) measured with a portable radar interferometer (Terrasense Switzerland)

## CONCLUSIONS

Large rock slope failures can occur at any time of year in mountain permafrost regions. The role of permafrost ice in the progressive failure of large rock masses over several millennia is the object of further investigation.

## REFERENCE

Phillips M., Lüthi R., Kenner R., Barblan R. (2015). Felssturz am Piz Kesch, Winter 2014. Bündner Wald, 68, 46-49.

## KEYWORDS

Deep-seated rock slope failures; permafrost ice; structural geology; monitoring techniques; rockfall database.

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