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The Open Air Lab Kitzsteinhorn (OpAL) – Open Innovation in High Altitude

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Abstract

The Open Air Lab Kitzsteinhorn (OpAL) was established in 2010 and since then has grown into Austria's most extensive monitoring site for bedrock permafrost and high-alpine rockfall. Surface, subsurface, and atmospheric conditions are monitored based on a combination of borehole measurements, electrical resistivity surveys, terrestrial laserscanning, geotechnical recordings, and measurements at automated weather stations. We understand OpAL as an innovative pool of ideas and as a provider of valuable long-term data, open to everyone interested in investigating high-mountain environments and their response to climate change.

Keywords

Permafrost, Rockfall, Long-Term-Monitoring, Climate Change, High-Alpine Infrastructure

Introduction

Since 1880, mean annual air temperatures in Austria have risen by 2 °C, an increase that is more than twice as high as the average global warming of 0.85 °C during the same time span (APCC 2014). Rising temperatures have led to a dramatic retreat of alpine glaciers, and, far less visible, have caused significant degradation of high-alpine permafrost bodies (FISCHER et al. 2015, PERMOS 2016). Both, glacial thinning and bedrock permafrost warming, have a considerable destabilizing effect on high-alpine rock walls (WEGMANN et al. 1998, KRAUTBLATTER et al. 2013). However, quantitative data on the response of frozen rock faces to recent climatic changes is scarce (KENNER et al. 2011), leaving fundamental knowledge gaps and thus impeding adequate adaptation measures. Aggravating the situation, the temporal responses of frozen rock faces to recent warming can differ drastically, reaching from immediate effects to heavily lagged feedbacks that become evident only after long time periods (GRUBER et al. 2004). To grasp the full spectrum of responses, long-term measurements are therefore vital. The Open Air Lab Kitzsteinhorn (OpAL) has addressed this important issue by establishing a long-term monitoring in the summit region of the Kitzsteinhorn, which is briefly introduced in this contribution.

Objectives & Key Contributors

OpAL is focusing on the combined observation of surface, subsurface and atmospheric processes, to better understand the interaction between climate change, mountain permafrost, and the occurrence of rockfall. While many relevant rock- and ice-mechanical processes are well understood within the controlled and isolated confines of laboratories, the transferability of lab evidences to more complex, natural conditions remains problematic. By implementing an extensive high-alpine monitoring, OpAL strives to reduce the scientific gap between the rock **sample** scale and the rock **mass** scale, contributing to the lab character of OpAL.

The monitoring at the Kitzsteinhorn was initiated in 2010 within the research project MOREXPERT, guided by the alpS – Centre for Climate Change Adaptation (FFG funding). Since then, several committed partners provided substantial financial, logistical, and intellectual support, such as the Gletscherbahnen Kaprun, the University of Salzburg, and the Geoconsult ZT GmbH. Over the following years the monitoring was constantly expanded and has now become one of the best instrumented long-term monitoring sites for permafrost and rockfall in the entire Alps. In 2015, remediation measures to stabilize the cable car summit station were carried out under the lead of Geoconsult, strengthening the focus of the monitoring on high-alpine infrastructure safety. A year later the newly founded GEORESEARCH Forschungsgesellschaft was assigned with the lead of OpAL. Among other international networks, OpAL is integrated into the Munich Alpine Hazards and Mitigation Cluster (AlpHaz) and regularly provides temperature data to the Global Terrestrial Network for Permafrost (GTN-P).

Monitoring Structure & Key Results

The monitored area covers the entire summit pyramid of the Kitzsteinhorn, extending from the Schmiedingerkees glacier (2.950m) to the summit (3.203 m). Its isolated position and horn-type shape make the Kitzsteinhorn an ideal site to study responses to climatic changes. The monitored area primarily consists of calcareous-micaschists belonging to the Glocknerdecke (HÖCK et al. 1994). The local tourism infrastructure (cable car, ski lifts, ski slopes etc.) provides easy access and convenient transportation of measuring equipment, an essential prerequisite for an extensive long-term monitoring program.

The OpAL combines permanent surface, subsurface, and atmospheric measurements, which include five deep bedrock boreholes (up to 30 m deep) to measure permafrost temperatures, over 30 shallow bedrock boreholes (up to 1 m deep) to examine near-surface frost weathering dynamics, two permanently installed geoelectrical arrays to investigate subsurface thermal changes provided by Geolog2000 and the Geological Survey of Austria, a network of passive seismic sensors to detect acoustic emissions triggered by rockfall, numerous laserscanning positions to identify rockfall detachment zones, crackmeters and automatic rock anchor load plates to register deformations along bedrock fractures, and several fully automated weather stations that record changes of meteorological conditions (see Fig. 1).

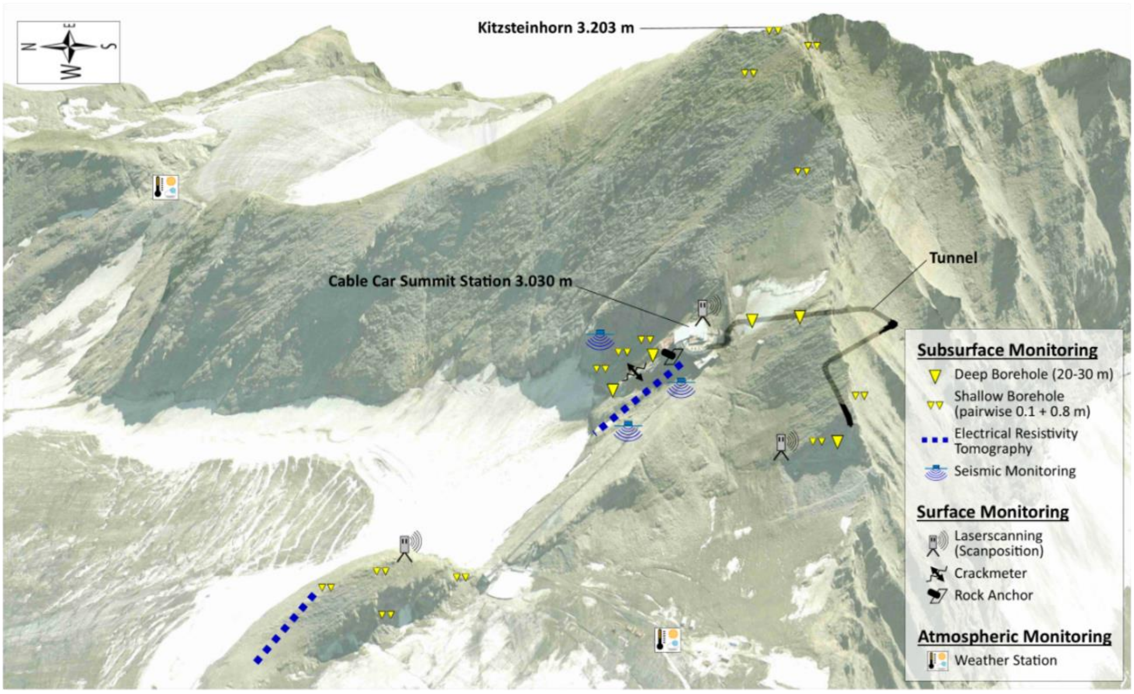

Figure 1: Overview of the long-term monitoring installations in the summit region of the Kitzsteinhorn. © GEORESEARCH

Data from deep boreholes (20-30 m) located at 3.000 m a.s.l. demonstrate permafrost core temperatures of -1.8 °C for north facing rock slopes and warmer temperatures for other slope aspects. The south-face of the Kitzsteinhorn is permafrost-free, as evidenced by measurements performed in the interior of the summit pyramid ('Hanna-Stollen') and by near-surface temperature measurements.

Electrical Resistivity Tomography (ERT) measurements are carried out along two profile lines on north-facing rock slopes. ERT data is well-suited to differentiate between frozen and unfrozen subsurface regions and is furthermore capable of identifying fluid flow in fractures. ERT measurements conducted during snow melt in June suggest that meltwater, seeping through open fractures, might have a strong and sudden destabilizing effect, despite the presence of subzero bedrock temperatures (KEUSCHNIG et al. 2016).

To detect changes occurring at the rock surface extensive terrestrial laserscanning (TLS) surveys were performed. Analysis of the TLS data obtained from 2011 – 2016 displays the dramatic impact of glacial thinning on adjacent headwalls: around 80 % of the detected rockfall volume was triggered from areas located less than 20 m above the current glacier surface. Overall, more than 400 rockfall release zones were identified, the total rockfall volume exceeded 2.400 m³. With continuing warming, the significance of rockfall from deglaciating headwalls as a considerable threat to man and infrastructure is expected to grow throughout the foreseeable future.

Conclusions & Outlook

By combining data on external forcing (climate), internal responses (rock temperatures) and surface changes (rockfall), the Open Air Lab Kitzsteinhorn provides valuable insights on the correlation between climate warming and rock mass destabilization in high-alpine rock faces. GEORESEARCH understands OpAL as an innovative pool of thoughts and ideas, open to everyone interested in high-mountain research and open to new and interdisciplinary contributions. In this context, OpAL has already evolved into an important platform for partner projects which contribute their own research questions and at the same time utilize the existing monitoring infrastructure (e.g. SeisRockHT, GlacierRocks). In the future, GEORESEARCH plans to further strengthen OpAL's role as a provider of valuable information for scientists as well as the interested public.

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