Long-term Geoelectrical Monitoring of bedrock permafrost in the Kammstollen, Zugspitze (Germany/Austria)

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In the last decades, electrical resistivity tomography (ERT) became the standard technique for permafrost monitoring. Changes in resistivity allow to quantify the response of permafrost to the recent climate change. In high alpine environment, especially in steep bedrock walls, consequences can be critical, putting infrastructures and people at high risk. Numerous locations are monitored along the Alps, mainly installed at the rock surface, and measured once a year. In a few cases, automatic systems have been installed to monitor changes all-year around, but this often implies bad coupling of electrodes, high costs and/or repeated failures.

In 2007, we instrumented a former touristic tunnel at about 2800 m asl on the Mount Zugspitze (D/A) in a unique setup for ERT and temperature measurements. (i) The location can be easily reached by cable car and is accessible all year around, independently from weather conditions. (ii) Measures are taken from the inside towards the rock surface. (iii) An ideal compromise between continuous automatic systems and single annual measurements is achieved with monthly repeated measurements: this allows detailed interpretation of bedrock permafrost reactions to seasonal variations as well as of long-term changes, without the burden of fix costs and the complications of automatic setups. (vi) Standard procedures and permanently installed electrodes allowed the collection of a unique dataset of consistent monthly measurements since 2014. (v) Resistivity-temperature calibration (see Krautblatter et al., 2010) enable an advanced quantitative interpretation of the results.

Results from 25 rock temperature loggers show an increase of rock temperatures in the last decade, with a gradient decreasing with depth - in good agreement with other locations in the Alps. Inversion results from the ERT fit well to this trend, especially in the summer months where a steady decrease of resistivities is measured. Winter months are strongly influenced by the duration and depth of snow cover, showing therefore more variations.

Krautblatter, M., Verleysdonk, S., Flores Orozco, A., Kemna, A. (2010): Temperature-calibrated imaging of seasonal changes in permafrost rock walls by quantitative electrical resistivity tomography (Zugspitze, German/Austrian Alps). Journal of Geophysical Research. 115. https://doi.org/10.1029/2008JF001209.

Figure: from up left, clockwise.
a) Measurements with ABEM Terrameter.
b) Frozen part of the side tunnel in March 2020. c) Outside view of the steep walls and the location of the tunnel in red. d) Main tunnel with pipelines for logistic and communication. Authors: Scandroglio, Leinauer