Name of research institute or organization:

Alpine Cryosphere and Geomorphology, Department of Geosciences, University of Fribourg

Title of project:

Geophysical monitoring of the evolution of permafrost on Stockhorn

Project leader and team:

Dr. Christin Hilbich (PostDoc Uni Zürich, lead geophysical measurements)
Prof. Christian Hauck (Uni Fribourg, lead geophysical measurements)
Prof. Martin Hoelzle (Uni Fribourg, lead boreholes and meteo station)
Dr. C Fuss (Geolog, maintenance of the automated geoelectrical system)
David Sciboz (technician Uni Fribourg, maintenance of boreholes and meteo station)
Etienne Rosset (MSc. Student Uni Fribourg)
Susanne Dängeli (MSc. Student Uni Fribourg)

Project description:

Within the Swiss Permafrost Monitoring Network PERMOS, the Stockhorn plateau represents the highest monitoring site (3410 m a.s.l.) and one of the two sites with deep (100 m) permafrost boreholes within the network. It is thus a very important site for the observation of permafrost evolution at high elevations.

The Stockhorn plateau is located between the Gornergrat and the Stockhorn summit separating the steep and glacier-covered northern rock face from the non-glaciated and gently inclined south face. Significant amounts of ground ice could be observed in large ice-filled cracks during construction works of a new ski lift in summer 2007. In summer 2000 two boreholes (100 m and 30 m deep) have been drilled on the plateau for regular subsurface temperature logging, and a meteorological station was installed to complement the information by air temperature, wind speed and direction, incoming and outgoing long- and shortwave radiation, humidity and snow height.

In addition, a permanent 2D geoelectrical profile (Electrical Resistivity Tomography, ERT) was installed from the northern edge of the plateau in north-south direction 96 m to the south in summer 2005. The profile covers an investigation depth of about 15-20 m. The aim is a long-term observation of temporal changes in the ground ice and liquid water content of the subsurface in response to climate change. This is possible by relating the change in measured electrical resistivities to freeze and thaw processes, as liquid water in the pore space of the subsurface material serves as electric conductor, whereas it acts as electric isolator in frozen state, causing much higher resistivities than unfrozen material.

After five years of manual and therefore sporadic geoelectric measurements on Stockhorn plateau, we installed an automatic geoelectrical monitoring system in summer 2010, which in principle allows the measurement of the 2D resistivity distribution with a daily resolution, and helps to understand the observed resistivity changes as a function of seasonal processes. The automated monitoring system was developed in collaboration with Geolog/Germany and is installed at the permafrost station at Stockhorn, but remotely controlled via direct antenna link from Gornergrat research station. As physical access to the Stockhorn plateau is logistically complicated (2 hours one-way from Gornergrat) and unsafe in difficult weather and snow conditions, the remote access via Gornergrat greatly facilitates system tests and the operational monitoring.

After installation and set up of the new instrument in summer/autumn 2010 first test series were finished 2011. These tests showed satisfying results regarding the new geoelectrical system, however, the remote control was – and still is - severely affected through electromagnetic interference from a still unknown source. Extensive tests and surveys among the institutions utilizing the surrounding antennae systems on Gornergrat could not yet identify the source of interference. Further tests are currently in progress aiming at the improvement of the signal strength of the antennae. However, this problem strongly retarded the beginning of the operational automatic geoelectrical monitoring on Stockhorn plateau.

In addition to the (intended) remotely controlled geoelectrical measurements, seismic and further geoelectrical validation measurements were conducted in summer 2011 on Stockhorn plateau. Figure 1 shows the resulting inversion models illustrating the electrical resistivity distribution along a 120m transect with the 100m permafrost borehole at its centre. Together with the seismic P-wave velocity results these data can be combined within the so-called 4-phase model (Hauck et al. 2008) to estimate the ice and liquid water contents of the subsurface. This work is currently in progress within a master thesis at the Department of Geosciences of the University of Fribourg (S. Dängeli).

In a second (completed) master thesis E. Rosset used the first geoelectrical monitoring data from Stockhorn to develop an automated and site-independent data filter for A-ERT measurements. The filter automatically detects probable measurement errors by analyzing the spatial resistivity distribution, the absolute values of the electrical raw data as well as the statistical properties of the data set. This new filter routine which was specifically developed for the new A-ERT system will be presented in a scientific paper which is currently in preparation for Annals of Glaciology.

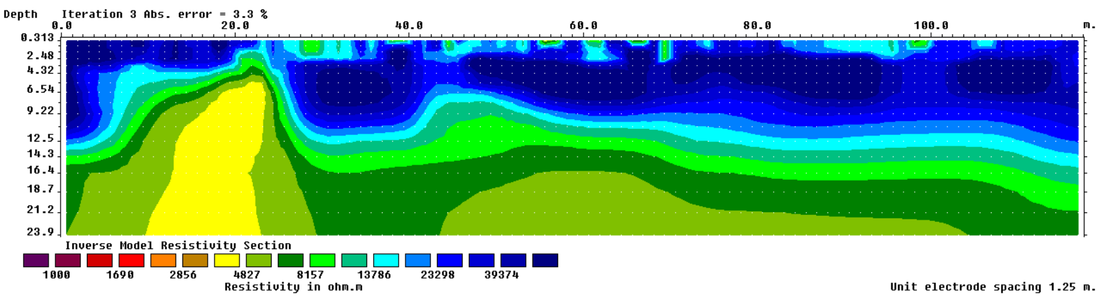

Figure 1. *ERT inversion model along the Stockhorn plateau (W to E) showing specific electrical resistivity in a 2-dimensional cross-section. High resistivity values (blue) correspond to higher ice contents within a more-weathered surface layer, reduced resistivities (green/yellow) correspond to low-porosity but still frozen bedrock below.*

Key words:

Permafrost, electrical resistivity, seismic P-wave velocity, freeze/thaw processes, automated electrical resistivity monitoring (A-ERT)

Internet data bases:

www.permos.ch;

Collaborating partners/networks:

Permafrost Monitoring Switzerland (www.permos.ch)
FNS-Sinergia project TEMPS
(http://www.unifr.ch/geoscience/geographie/acag/doku.php?id=projects:temps)

Scientific publications and public outreach 2011:

Peer-reviewed papers

Hauck, C., Bach, M., Hilbich, C. 2008. A 4-phase model to quantify subsurface ice and water content in permafrost regions based on geophysical data sets. Proceedings Ninth International Conference on Permafrost, Fairbanks, Vol. 1, Kane D.L. and Hinkel K.M. (eds), Institute of Northern Engineering, University of Alaska Fairbanks, 675-680.

Hauck, C., Böttcher, M. and Maurer, H. 2011. A new model for estimating subsurface ice content based on combined electrical and seismic data sets. The Cryosphere, 5, 453–468.

Hilbich, C., Fuss, C., Hauck, C. 2011. Automated time-lapse ERT for improved process analysis and monitoring of frozen ground, Permafrost and Periglacial Processes 22(4), 306-319, DOI: 10.1002/ppp.732.

Data books and reports

PERMOS 2010. Permafrost in Switzerland 2006/2007 and 2007/2008. Noetzli, J. and Vonder Mühll, D. (eds.), Glaciological Report (Permafrost) No. 8/9 of the Cryospheric Commission of the Swiss Academy of Sciences, 68 pp, 2010.

Theses

Rosset, E, Automatic filtering of ERT monitoring data in mountain permafrost: Filter development and quality control. MSc thesis, Department of Geosciences, University of Fribourg, 2012.

Address:

University of Fribourg
Department of Geosciences
Chemin du Musée 4
CH-1700 Fribourg

Contacts:

Christian Hauck
Tel.: +41 26 300 9011
Fax: +41 26 300 9746
e-mail: christian.hauck@unifr.ch
URL:
http://www.unifr.ch/geoscience/geographie/dokuwiki/doku.php?id=staff:hauck.christian

Christin Hilbich
Tel.: +41 63 55 224
Fax: +41 63 56 841

e-mail: christin.hilbich@geo.uzh.ch
URL: http://www.geo.uzh.ch/en/units/physical-geography-3g/about-us/staff/christin-hilbich/