

Goelectrical measurements for permafrost monitoring at the Hoher Sonnblick, Salzburg, Austria

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Introduction/Background

Global warming induced permafrost degradation in Alpine regions causes negative effects on environment and engineering problems. Sub-terrain processes in such permafrost degrading environments are still not completely understood. One of the main objectives of the project ALPCHANGE, is to quantify landscape dynamics in alpine regions caused by climate change in the past and at present (cf. www.alpchange.at and Lieb et al. 2007).



Currently about ~2,000 km² of Austria are underlain by permafrost. Climate warming will cause warming or/and thawing in these permafrost areas and consequently will favour mass-wasting processes, which may effect even valleys below the periglacial belt. Permafrost thawing will produce serious and farreaching environmental and engineering problems in permafrost regions and beyond (Harris et al. 2001).

Geophysical investigations - in particular the geoelectric method have been applied for many years for permafrost characterisation (e.g. Hauck 2001, Kneisel 2006). Within the framework of the project ALPCHANGE, initial geoelectric measurements have been carried out at the summit area of the Hoher Sonnblick (Hohe Tauern, Salzburg, Austria) by the Geological Survey of Austria in summer 2006 (Fig. 1).

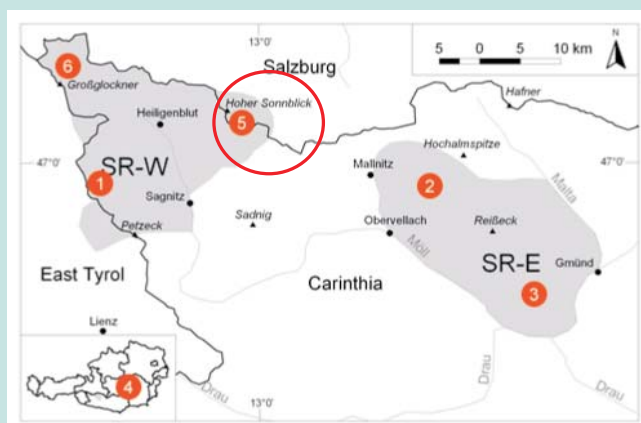


Fig. 1: location of Investigation area Hoher Sonnblick

This project is granted by the Austrian Science Fund, Project Number: FWF P18304-N10, for the period 2006-2009.



Geoelectric Monitoring/Requirements

The geoelectric method is intended to determine the distribution of the specific electrical resistivity within the subsurface. This parameter depends mainly on porosity, water saturation, conductivity of pore fluid and clay content and to a minor extent on particle shape and pore geometry. So if porosity and clay content are assumed to remain constant, resistivity methods can be used to map changes in the subsurface due to variations in water saturation and pore fluid conductivity (also true for freezing water, significant high electrical resistivity). Interpretation of resistivity changes deduce locations of freezing and thawing processes. Up to now the repetition of the data acquisition is done manually, measurement repetition roughly every couple of weeks.

So within this project a permanent geoelectric monitoring should be established. The GEOMON4D is a measuring console, a proprietary development by the Geological Survey of Austria. Fig. 2 shows a photo of the GEOMON4D. To establish a geoelectrical monitoring, several requirements have to be considered.



Fig. 2: GEOMON4D system

Fig. 3 outlines this premises and the resolution approach with the GEOMON4D system.

Requirements	Solution	GEOMON4D
high resolution	high data coverage	3000 data points
snapshot of underground	short measuring time	3000 data points in 30 min.
high reliability	quality control (signal/noise)	surveillance of each single measurement
quick availability of data	online access maintenance of system	GPRS access

Fig. 3: geoelectrical monitoring requirements and the GEOMON4D implementation

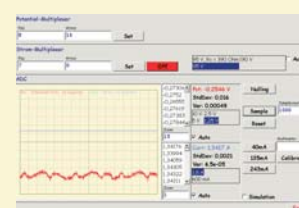


Fig. 4: screen shot from aquisition software

The GEOMON 4D system allows remote controlled automatic measurements of geoelectric pseudosections with a far better data density in the ground. This is realized e.g. with a profile of 41 electrodes where each section consists of 3000 single measurements, each one sampled for 1000 times. The acquisition time for such a section (30 min.) allows to derive a point shot of the subsurface structure times to get seasonal variabilities of freezing and thawing processes.

Noise considerations

Noise is not linear
Noise is not symmetric

Fig. 5 shows an example of the measured electrical potential [Volt] (red line) for about 1 second. It is obvious that a 50 Hz noise is superimposing the signal.

Also drifting potentials can be detected, see fig. 6, allowing a very well-founded data quality control, so that all unstable data can be eliminated.

Fig. 7 shows an example with a very unstable measured electrical potential, which should be eliminated before inversion.

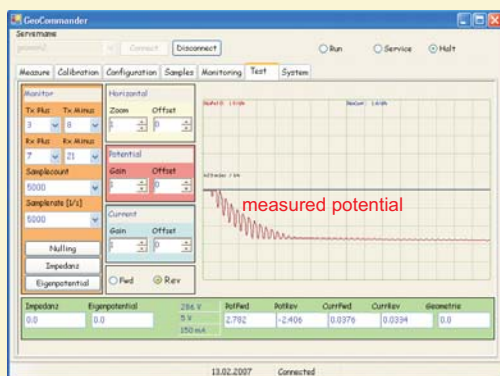


Fig. 6: drifting electrical potential

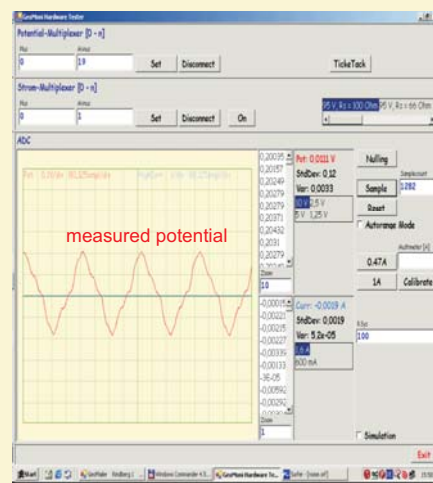


Fig. 5: data example 1 with 50 Hz noise

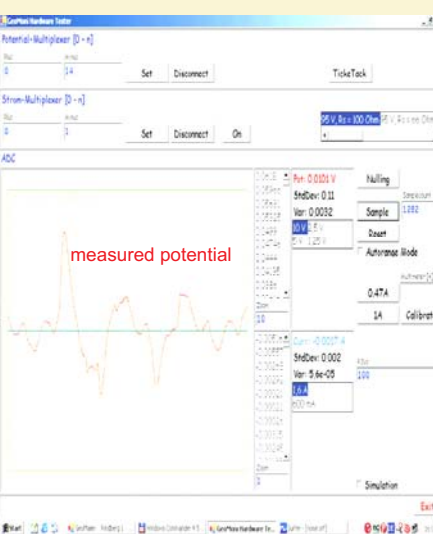


Fig. 7: unstable electrical potential

The advantage of the GEOMON 4D geoelectric system is that it allows full control of the measurement data to optimize data quality. That means all samples of the single measurements are saved, containing full information of the inherent noise and therefore allowing follow-up noise filtering in a post-processing step. So only data with good data quality can be used.

Fig. 8 gives an example of good data quality, with very stable current input and noise free electrical potential.

A Fast-Fourier-Transformation module allows determining the frequency Content of the noise.

To map changes in the subsurface due to variations in water saturation and pore fluid conductivity, resistivity methods can be used.

Data quality and data optimization before the inversion process is necessary for the interpretation of resistivity changes.

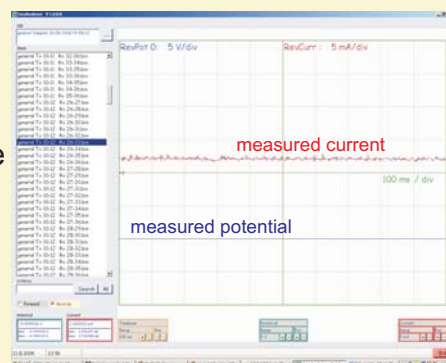


Fig. 8: data example with good data quality

Geoelectric Monitoring/Preliminary Results

The research Area is located at the Hoher Sonnblick (Salzburg, Austria) The meteorological observatory at Hoher Sonnblick (3,106m asl., Goldberg Group) - see Fig. 9 - has been operating continuously since 1886. Data from this high altitude station are used within the ALPCHANGE project. The red circleshow the positions of the drill holes with temperature logger. The white line indicates the location of the geoelectric monitoring profile.



Fig. 9: meteorological observatory at Hoher Sonnblick, locations of geoelectric and drill holes

Fig. 10 and fig. 11 show the inversion results of the geoelectric profiles from August 2006 and March 2007 respectively.

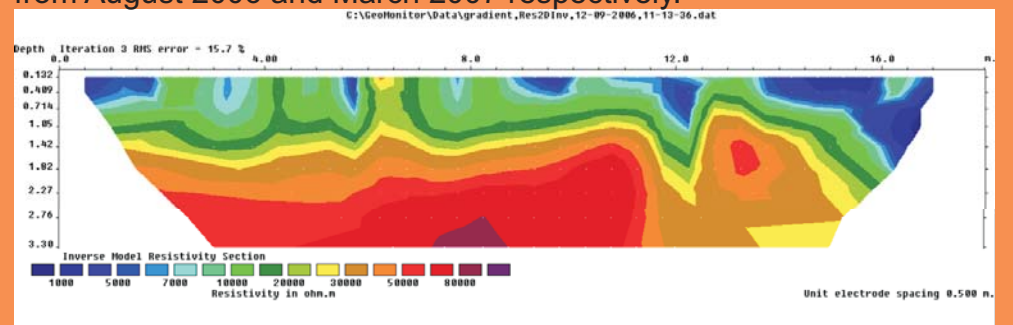


Fig. 10: geoelectric result from August 2006

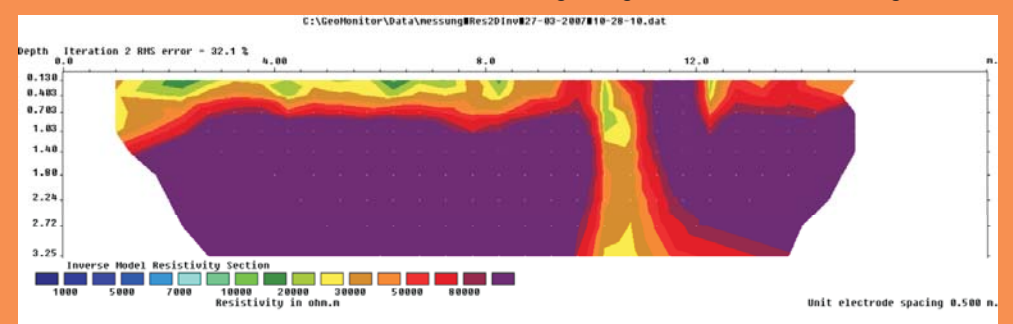


Fig. 11: geoelectric result from March 2007

Although the two profiles were measured at slightly different locations, the increase of the electrical resistivities during winter is apparent. The high electrical resistivities (red area) represent the bedrock or alternatively the frozen underground, whereas the blue/green regions mark the zone of freezing and thawing processes. So a change of depth of the permafrost could be interpreted from 1.5 m in August to 0.5 m in March.

Resistivity changes should allow observing seasonal freezing and thawing processes leading to a better understanding of related processes.

References

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