

Modelling of permafrost in the region of the "Hohe Tauern", Austria

Barbara Ebohon¹, Felix Keller², Lothar Schrott¹, Jan-Christoph Otto¹

¹ Department of Geography and Geology, University of Salzburg, Austria

² Academia Engiadina & Pädagogische Hochschule Graubünden, Samedan, Switzerland

Summary

Alpine permafrost responses very sensitive to climate change. Thus, it is of great interest to estimate and assess its distribution in high mountain areas. In densely populated and developed mountain areas (e.g. ski resorts, etc.) mapping and modelling of permafrost distribution is an important prerequisite to assess and prevent natural hazards and risks. Furthermore, permafrost related topics have to be more present within the media to gain the interest of the public.

A pilot study shows that possible and probable permafrost areas of the Austrian Alps comprise 1600 km², which corresponds to an area of approximately 2 % of the federal territory. In some regions a significantly higher proportion of permafrost can be expected. The new project permafrost.at is focused on the accurate modelling of permafrost distribution within the area of the Hohe Tauern based on a new approach. By analysing the relation between slope, altitude, aspect and visible permafrost indicators, a new map showing the probability of permafrost occurrence in the Hohe Tauern will be developed, replacing previously applied "hard" lower borderlines and therefore raises the quality of the assessment. This map will be based on field data of permafrost distribution gathered throughout the mountain range in several test sites. Data acquisition includes BTS, ground-temperature measurements and field-geophysics.

Keywords

Alpine Permafrost, Hohe Tauern, Indexed Simulation

Introduction

Permafrost (permanently frozen ground) is defined on the basis of temperature and time. In permafrost areas ground temperature remains at or below 0°C for at least two consecutive years (WASHBURN, 1973).

The Intergovernmental Panel on Climate Change predicts a significantly higher temperature rise for the Alps compared to the average. Within the context of changing climate conditions, detailed knowledge about permafrost becomes more and more important since steep talus slopes and rock walls can become instable.

Permafrost research in Austria is still a young scientific field compared to Switzerland, where the first permafrost related topics were already published in the 70s of the last century. Besides intensive data gathering, international collaboration and exchange of significant data and knowledge is important to enlarge the sample size (HAEBERLI & GRUBER, 2008) and compare meaningful results.

Pilot Study

Until recently, the permafrost distribution in Austria has been mapped and modelled only for a few local regions. Previous studies in the Austrian Alps have shown that on average permafrost occurrence must be expected above 2500 m (LIEB, 1998). It is obvious that in Austria permafrost areas have their maximum extensions in the western federal states due to a decline of absolute heights of mountain ranges from west to east.

Since empirical values for the simulation, namely lower limits of possible and probable permafrost distribution related to altitude, aspect, slope and slope foot were originally deduced and calibrated for the Upper Engadine in the eastern Swiss Alps, they have been adjusted to the eastern Alps using empirical values of probable permafrost distribution in Austria generated by LIEB (1998) for the pilot study.

Table 1: Values used for the simulation in the pilot study. www.biologiezentrum.at

| | Permafrost possible (sporadic) | | Permafrost probable (discontinuous) | |
|---------------------|--------------------------------|----------------------|-------------------------------------|----------------------|
| | Steep Slopes | Foot-slope positions | Steep Slopes | Foot-slope positions |
| N | 2300m a.s.l. | 1690m a.s.l. | 2500m a.s.l. | 2410m a.s.l. |
| NE | 2450m a.s.l. | 2100m a.s.l. | 2600m a.s.l. | 2500m a.s.l. |
| E | 2575m a.s.l. | 2220m a.s.l. | 2720m a.s.l. | 2520m a.s.l. |
| SE | 2700m a.s.l. | 2230m a.s.l. | 2850m a.s.l. | 2630m a.s.l. |
| S | 2900m a.s.l. | 2340m a.s.l. | 2900m a.s.l. | 2690m a.s.l. |
| SW | 2650m a.s.l. | 2230m a.s.l. | 2850m a.s.l. | 2630m a.s.l. |
| W | 2600m a.s.l. | 2160m a.s.l. | 2700m a.s.l. | 2510m a.s.l. |
| NW | 2530m a.s.l. | 2120m a.s.l. | 2580m a.s.l. | 2470m a.s.l. |
| Flat areas | Permafrost possible (sporadic) | | Permafrost probable (discontinuous) | |
| Wind-exposed | | 2590m a.s.l. | | 2710m a.s.l. |
| Sheltered from wind | | 2640m a.s.l. | | 2900m a.s.l. |

First modelling results show that in Austria 1600 km² can be assigned to mountain permafrost (EBOHON et al., 2008). This corresponds to an area of approximately 2 % of the federal territory but in some regions a significantly higher proportion of permafrost can be expected. Although a small scale regional map has inherently a limited accuracy, it allows approximations of the permafrost distribution on a nation wide scale. For the simulation routines of PERMAKART and PERM were used applied on a DEM with a resolution of 50 m.

The first results were promising but a lot of questions still remain and some problems unsolved. Therefore more data has to be gathered and a DEM with a higher resolution is needed for the simulation.

The new project “*permalp.at*”

A major objective of the project *permalp.at* is focused on the accurate modelling of permafrost distribution within the area of the Hohe Tauern based on a new approach:

By analysing the relation between slope, altitude, aspect and visible permafrost indicators, a new map showing the probability of permafrost occurrence in the Hohe Tauern will be developed. This map will be based on field data of permafrost distribution gathered throughout the mountain range in several test sites. Data acquisition includes BTS, ground-temperature measurements and field-geophysics.

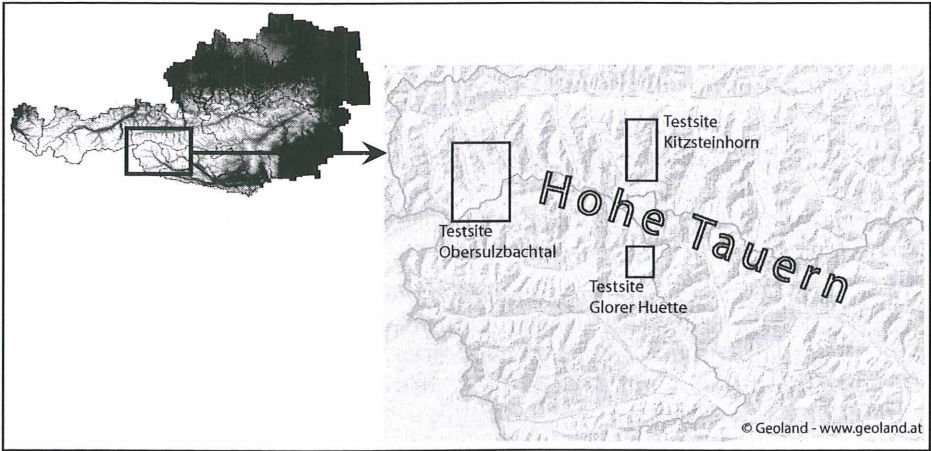


Figure 1: Study Site and preliminary defined local test sites of the project *permalp.at*; Data: BEV, Geoland

Methods

The BTS-method (basal temperature of snow cover) was firstly applied by HAEBERLI (1973, 1986). It is based on the assumption that a snow cover thickness of more than 80 centimetres insulates the ground from atmospheric influences due to low heat transfer capacity. Consequently undisturbed ground temperature could be measured at the bottom of the snow cover during the late winter. Values below -3°C indicate that permafrost in the ground is probable while values between -3°C and -2°C signal that permafrost occurrence is possible. In areas, where values above -2°C are measured, permafrost is improbable (KELLER, 1994).

In two test sites (Glörer Huette, Obersulzbachtal) UTL-data logger are already installed at different heights and aspects in fall 2008 to measure the ground temperature. Other test sites will be equipped throughout the course of the project.

Within the last decade the use of geophysical techniques has become more widespread in geomorphology, especially in the field of permafrost research. These techniques can help to understand the internal structure of the ground, as well as to detect the presence and absence of permafrost. Every method is based on the measurement and interpretation of contrasts in physical properties of the subsurface material. Consequently only a combination of two or three different geophysical methods allows conclusions of the subsurface conditions since every technique has its own limitations and particular inaccuracies (SCHROTT & SASS, 2008). Permafrost delivers characteristic parameters from the geophysical survey.

For example, the DC (direct-current) resistivity methods detect changes in electrical resistivity at different depths in the subsurface. Tomography (ERT – electrical resistivity tomography) is commonly used in high mountain areas for the detection of permafrost. Concerning separation between permafrost and its surrounding material, permafrost areas show a very high resistivity ($10^3 - 10^6 \Omega m$) since most of the pore water is frozen (HAUCK & KNEISL, 2008). It is well known, that an intense increase in resistivity can be recognised at the freezing point and that ice, in contrary to water, can be seen as electrically nonconductive (KNEISL et al., 2008).

In the project *permalp.at* BTS and long-term ground-temperature will be monitored and combined with local geophysical surveys (applying ground penetrating radar, electric resistivity tomography, seismic refraction) and detailed geomorphological mapping of permafrost related landforms. These new data serve to validate the model and adapt the Swiss “rules of thumb” to Austria.

Modelling Alpine Permafrost

In geomorphology simulation models represent one of the operative links between process studies and the study of landforms. When the relationship between landscape dynamics and causing physical or chemical processes is known, a model can be developed through simplification of these processes (KIRKBY, 1996). Model validation can help to check if the pictured processes are the driving forces or if some important variables are still missing. As soon as a model is well calibrated it also allows simulations of future scenarios up to a limited extent.

In the Alps the first digital permafrost-model was realised in 1994 by F. KELLER. Since then modelling approaches were constantly developed further. The new approach improves existing previous models in two ways: Firstly, the resulting map will include a probability index between 0 and 100 which replaces previously applied “hard” lower borderlines of the subdivision “probable”, “possible” and “no permafrost” and therefore raises the quality of the forecast. Secondly, the implementation of snow cover effects on the distribution of permafrost will be achieved to improve the accuracy of distribution modelling. Furthermore the simulation will be realized on a DEM with a resolution of 10m.

Outlook

The resulting permafrost distribution map will be an important tool for all decision makers concerning infrastructure in the area of Hohe Tauern and will inform about science-based knowledge concerning Alpine permafrost. Furthermore it is planned, to implement a web based map to make data accessible to the general public. Results of the pilot study can already be seen on the homepage www.permalp.at visualised in a web GIS. The duration of the project *permalp.at* covers a period of three years.

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Contact

Mag. Barbara Ebohon
barbara.ebohon@sbg.ac.at

Dr. Lothar Schrott
lothar.schrott@sbg.ac.at

Dr. Jan-Christoph Otto
jan-christoph.otto@sbg.ac.at

Department of Geography and Geology
University of Salzburg
Hellbrunnerstr. 34
5020 Salzburg
Austria

Dr. Felix Keller
f.keller@academia-engiadina.ch

Adademia Engiadina & Pädagogische
Hochschule Graubünden
Quadratscha 18
7503 Samedan
Switzerland

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