Conference Volume | 4th Symposium of the Hohe Tauern National Park for Research in Protected Areas | pages 81-84
September 17th to 19th, 2009, Castle of Kaprun

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

Barbara Ebohon[1], Felix Keller[2], Lothar Schrott[1], Jan-Christoph Otto[1]

[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 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, replacing previously applied "hard" lower borderlines and therefore raises the quality of the assesment. 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.

	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.

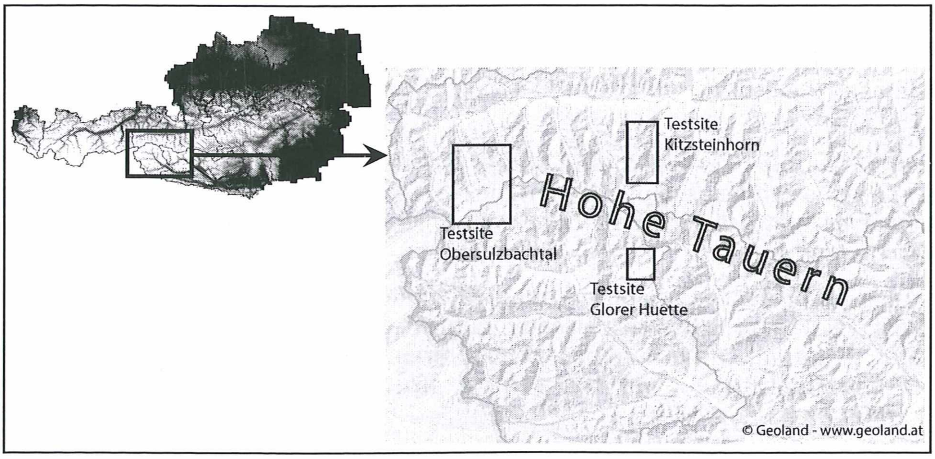

Figure 1: Study Site and preliminary defined local test sites of the project *permalp.at*; Data: BEV, Geoland

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 (Glorer 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 Ωm) 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 modells 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 fist digital permafrost-model was realised in 1994 by F. KELLER. Since then modelling approaches where 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.

Acknowledgments

Data of the pilot study were kindly provided by:

Karl Krainer (University of Innsbruck): data from basal snow temperature measurements (BTS)

Gerhard Karl Lieb (University of Graz): data from basal snow temperature measurements (BTS) and spring water temperature measurements

Wolfgang Schöner (ZAMG) Project PERSON (Permafrostmonitoring Sonnblick) GZ BMLFUW-UW.1.3.2/0528-V/5/2005 by order of Lebensministerium

DTM: BEV

Special thanks to my working group for helping me with data acquisition and interpretation and the input and ideas of Dr. Marcia Phillips (WSL, Davos, CH) are gratefully appreciated.

References

EBOHON B. & SCHROTT L. (2008): Modeling Mountain Permafrost Distribution. A New Permafrost Map of Austria. – In: Kane, D. & K. Hinkel (Eds.): Proceedings of the Ninth International Conference on Permafrost, Fairbanks, Alaska, 397-402.

HAEBERLI W. (1973): Die Basis-Temperatur der winterlichen Schneedecke als möglicher Indikator für die Verbreitung von Permafrost in den Alpen, Zeitschrift für Gletscherkunde und Glaziologie, Bd. IX, Heft 1-2, 221-227.

HAEBERLI W. & EPIFANI F. (1986): Mapping the Distribution of Buried Glacier Ice – An Example from Lago delle Locce, Monte Rosa, Italian Alps, Annals of Glaciology 8, 78-81.

HAEBERLI W. & GRUBER S. (2008): Research challenges for permafrost in steep and cold terrain: an alpine perspective. – In: In: Kane, D. & K. Hinkel (Eds.): Proceedings of the Ninth International Conference on Permafrost, Fairbanks, Alaska, 597-605.

HAUCK C. & KNEISL C. (2008): Applied Geophysics in Periglacial Environments, University Cambridge Press, Cambridge, S 240.

KELLER F. (1994): Interaktionen zwischen Schnee und Permafrost, Eine Grundlagenstudie im Oberengadin, Mitteilungen der Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie der ETH Zürich, Band 127, Hrg. Prof. DDr. Vischer, Zürich, 145 S.

KIRKBY M.J. (1996): A Role for Theoretical Models in Geomorphology?, The Scientific Nature of Geomorphology: Proceedings of the 27th Bingham Symposium in Geomorphology, Rhoads B.L. & C.E. Thorn (Eds.), John Wiley & Sons Ltd., 257-272.

KNEISL C., Hauck C., Fortier R., Moorman B. (2008): Advances in Geophysical Methods for Permafrost Investigations, Permafrost and Periglacial Processes, 19, Wily InterScience, 157-178.

LIEB G. K. (1998): High Mountain permafrost in the Austrian Alps (Europe); In: A.G. Lewkowicz and M. Allard (Editors), 7th International Conference on Permafrost, Proceedings, Collection Nordicana 57, Centre d'Etudes Nordiques, Université Laval, Yellowknife, Canada 7th International Permfrost Conference, Yellowknife (Canada), S 663-668.

SCHROTT L. & SASS O. (2008): Application of flied geophysics in geomorphology: Advances and limitations exemplified by case studies, Geomorphology, Vol. 93, Issues 1-2, Special Issue: Challenges in geomorphological methods and techniques, Elsevier, 55-73.

WASHBURN A.L. (1973): Periglacial processes and environments, Quaternary research Centre, University of Washington, Edward Arnold Ltd, London, 320 S.

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