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The Graz permafrost monitoring network in the Hohe Tauern National Park (Austria)

Das Grazer Permafrost-Monitoring-Netzwerk im Nationalpark Hohe Tauern (Österreich)

Gerhard Karl Lieb, Andreas Kellerer-Pirklbauer, Viktor Kaufmann & Michael Avian

2 Figures and 2 tables

Abstract: Based on the project ALPCHANGE researchers from both the University of Graz and Graz University of Technology established a permafrost monitoring network at five different monitoring areas in the Hohe Tauern National Park, Central Austria, in 2006. Methodically this network is primarily based on ground temperature measurements, geodetic surface velocity measurements of rock glaciers and surface change detection (e. g. rock fall) using terrestrial laser scanning. For the period 2013/14 the first report on these activities was delivered to the national park authorities indicating very permafrost-unfavourable conditions for the reporting year. Additionally, the paper discusses the concept for the documentation of gravitational processes which is going to be implemented in the next years.

Zusammenfassung: Auf der Grundlage des Projekts ALPCHANGE wurde im Jahr 2006 von Forschenden der Universität Graz und der Technischen Universität Graz ein Permafrost-Monitoring-Netzwerk in fünf Untersuchungsgebieten im Nationalpark Hohen Tauern eingerichtet. Methodisch umfasst dieses Netzwerk primär Bodentemperaturmessungen, geodätische Bewegungsmessungen an Blockgletschern und die Erfassung von Oberflächenveränderungen (z. B. Steinschlag) durch terrestrisches Laserscanning. Für den Zeitraum 2013/14 wurde erstmals ein Bericht über diese Aktivitäten der Verwaltung des Nationalparks übergeben, welcher aufzeigt, dass dieses Beobachtungsjahr sehr ungünstig für Permafrost ausfiel. In der Arbeit wird auch ein Konzept für die in den nächsten Jahren geplante ergänzende Dokumentation von gravitativen Prozessen diskutiert.

Key Words: Permafrost; Long-term monitoring; Rock glacier; Effects of climate warming; Hohe Tauern National Park.

Schlüsselworte: Permafrost; Langzeitmonitoring; Blockgletscher; Auswirkungen des Klimawandels; Nationalpark Hohe Tauern.

1. Introduction

Systematical research on permafrost in the Hohe Tauern National Park started already in the early 1990s and was intensified in the period 2006–2011 during the project "ALPCHANGE" which was funded by the Austrian Science Fund (FWF). Within this project the research areas, which are still used for the ongoing monitoring program, were initially instrumented with different types of measurement devices. Later, these monitoring activities were continued within the framework of the Alpine Space project "PermaNET" funded by the European Union. PermaNET aimed at establishing a permafrost monitoring network across the entire Alpine Arc also providing a manual for this purpose (Mair et al. 2011). "PermaNET" was followed by the project "permAfrost", which was nationally funded by the Austrian Academy of Sciences and was running until 2013. The continuation of the monitoring activities was endangered due to the lack of funding. Fortunately, since 2016 the Hohe Tauern National Park is financially supporting the maintenance of the previously established monitoring network while on the national level (Austria) this problem is still unsolved (Kellerer-Pirklbauer et al. 2015a).

Permafrost as a natural phenomenon is a sensitive indicator for climate change and its variations affect a lot of processes (such as rock fall or debris flows) in high mountain areas (e. g. Schoeneich et al. 2014). Different to e. g. water, weather and glacier variations, permafrost is not monitored on a regular basis by certain institutions or organizations in Austria. This is a further reason why the Hohe Tauern National Park in the Austrian Federal State of Carinthia has decided to support our already established monitoring of permafrost.

2. Methods

The methods used in our monitoring network are well established methods of permafrost research which cannot be explained in detail here (e. g. Mair et al. 2011). Table 1 gives an overview of these methods and the five study areas where they have been applied. The methods can be grouped into three categories (cf. Lieb et al. 2014) as follows: (a) ground temperature measurements aiming to achieve information on the ther-

mal regime at the surface and at near-surface layers in different substrates (GST, GT, RST, RT; for abbreviations see Tab. 1); (b) surface velocity measurement of creeping permafrost (active rock glaciers, TS, AS); (c) detecting changes in surface morphology (TS, AS). Additional information is derived from two automatic weather stations (AWS), visual interpretation of daily terrestrial photographs taken by remote digital cameras (RDC) and documentation of natural geomorphic events, the latter being in preparation (see below).

No.	Name of local study area	GST	GTx	RST	RTx	TS	AS	AWS	RDC
1	Dösen-Säuleck	X	X	X	X	X	X	X	X
2	Hinteres Langtalkar-Kögelekar	X	X	X	X	X	X	X	X
3	Hochtor-Fallbichl	X	X			X			
4	Pasterze-Burgstall	X	X	X	X	X	X		
5	Weißenkar	X	X			X	X		

Tab. 1: Measured parameters at the five local study areas in the Hohe Tauern National Park. GST: ground surface temperature, GTx: ground temperature at different depths in shallow soil boreholes or in voids of coarse sediments, RST: rock surface temperature, RTx: rock temperature at different depths in shallow boreholes, TS: terrestrial survey (geodesy, terrestrial laserscanning, differential GPS), AS: airborne survey (aerial photographs, airborne laserscanning), AWS: automatic weather station, RDC: automatic remote digital camera.
Tab. 1: Gemessene Parameter in den fünf lokalen Untersuchungsgebieten im Nationalpark Hohe Tauern: GST: Bodentemperatur an der Oberfläche, GTx: Bodentemperatur in unterschiedlichen Tiefen in seichten Bodenbohrlöchern oder in Hohlräumen von grobblockigen Sedimenten, RST: Felstemperatur an der Oberfläche, RTx: Felstemperatur in unterschiedlichen Tiefen in seichten Felsbohrlöchern, TS: terrestrische Vermessung (Geodäsie, terrestrisches Laserscanning, differential GPS), AS: luftgestützte Vermessung (Luftbilder, luftgestütztes Laserscanning), AWS: automatische Wetterstation, RDC: automatische Digitalkamera.

Figure 1 shows the location of the monitoring areas and their relation to the modelled permafrost distribution, glaciers and rock glaciers. The best information on permafrost and permafrost variations provide boreholes with temperature sensors in different depths. Currently no deep borehole (i. e. deeper than the active layer thickness; in Austria in the range of several meters) in the Hohe Tauern National Park is run by the institutions involved in the presented monitoring activities. However, at Hoher Sonnblick (Fig. 1) three 20 m deep boreholes in permafrost are operated by the Central Institute for Meteorology and Geodynamics (Schöner et al. 2012).

3. Results

A comprehensive report on the monitoring activities outlined above has been prepared for the period 2013/14 (Kellerer-Pirklbauer et al. 2015b). In this short communication, however, the results cannot be provided in detail. Instead of this and as an example, the evolution of the mean annual ground surface temperatures for 2006–2014 for two selected sites is shown in Figure 2.

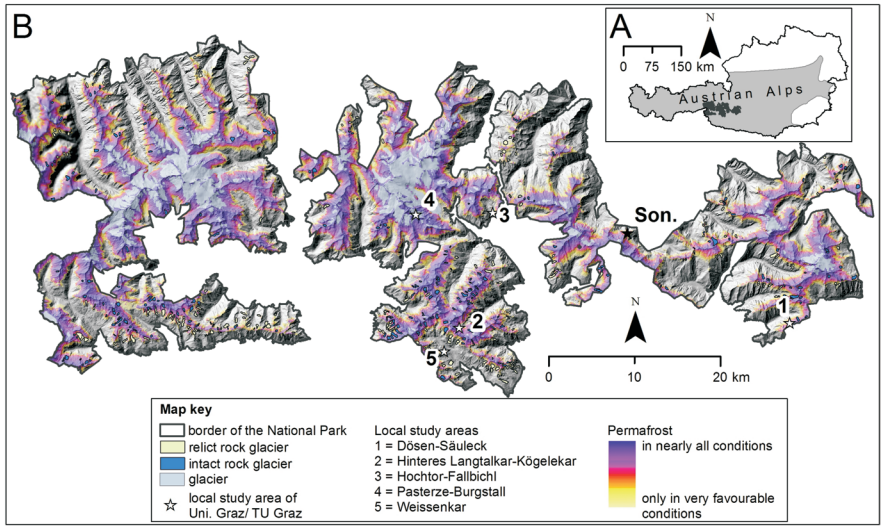

Fig. 1: Study areas: (A) Location of the Hohe Tauern National Park in Austria and the Austrian Alps; (B) Spatial distribution of modelled potential permafrost and glaciers (Boeckli et al. 2012), intact and relict rock glaciers (Kellerer-Pirklbauer et al. 2012a) as well as the location of the five monitoring areas of the Graz permafrost monitoring network within the Hohe Tauern National Park. Furthermore, the Hoher Sonnblick (Son.) site with three deep boreholes is indicated.
Abb. 1: Untersuchungsgebiete: (A) Lage des Nationalparks Hohe Tauern in Österreich und den österreichischen Alpen; (B) Räumliche Verbreitung von modelliertem potenziellem Permafrost und Gletschern (Boeckli et al. 2012), intakten und reliktischen Blockgletschern (Kellerer-Pirklbauer et al. 2012a) sowie die Lage der fünf lokalen Untersuchungsgebiete des Grazer Permafrost-Monitoring-Netzwerkes im Nationalpark Hohe Tauern. Weiters ist der Hohe Sonnblick (Son.) mit drei tiefen Bohrlöchern verortet.

While the left diagram in Figure 2 shows a clear warming trend (interpreted as a result of the ongoing global climate change) at a permafrost site, the right diagram indicates more variable mean annual temperatures which is related to variable seasonal snow cover conditions from year to year at a site most likely lacking permafrost. Taking into account all the results documented in the above mentioned report, the following conclusions can be drawn:

Ground temperatures: The period 2013/14 was comparatively warm leading to new maxima of GST at some measurement points and to very unfavourable conditions for conservation or aggradation of permafrost. 2013/14 thus fits to the long-term development of GST visible in Figure 2.

Surface velocity of rock glaciers: The values recorded in 2013/14 were higher than in all previous years which can be explained by high deformation rates typical for relatively warm permafrost and the increased existence of liquid water. This parameter is also characterized by a clear trend towards higher velocities in the last decade reflecting global warming too (cf. Schoeneich et al. 2014).

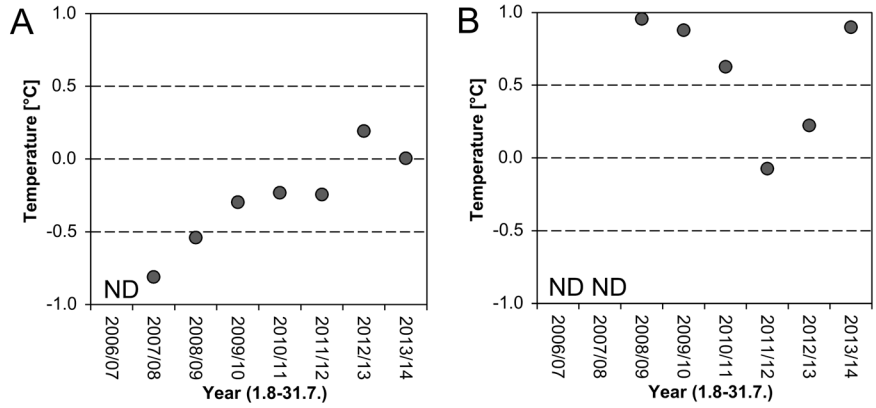

Fig. 2: Mean annual ground surface temperature (GST) at two selected monitoring sites in the Hohe Tauern National Park. One is a permafrost site (A) and one is characterized by seasonal frost (B): (A) site HLC-UP-N in the monitoring area Hinteres Langtal Cirque (HLC) at 2693 m a.s.l. indicating a clear warming trend; (B) site FAL-UP in the monitoring area Hochtor-Fallbichl (FAL) at 2345 m a.s.l. indicating no clear trend related to variable seasonal snow conditions. ND = no data.
Abb. 2: Die Jahresmitteltemperatur an der Oberfläche (GST) an zwei ausgewählten Monitoringstandorten im Nationalpark Hohe Tauern; ein Permafroststandort (A) und ein Standort mit saisonalem Bodenfrost (B): (A) Standort HLC-UP-N im Untersuchungsgebiet Hinteres Langtal Kar (HLC) auf 2693 m ü.A. mit einem klaren Erwärmungstrend; (B) Standort FAL-UP im Untersuchungsgebiet Hochtor-Fallbichl (FAL) auf 2345 m ü.A. ohne Trend bedingt durch eine stark variierende winterliche Schneedecke. ND = keine Daten.

Changes in surface morphology: There was little dynamics in rock falls and rock face denudation at the relevant monitoring sites which most likely can be explained due to the lack of long lasting heat waves in 2013/14. However, numerous and extensive rock falls have been reported in the previous years (e. g. Kellerer-Pirklbauer et al. 2012b).

4. Documentation of natural geomorphic processes

Permafrost in the Alps exists in high mountain areas which are prone to gravitational processes of different types. Especially permafrost degradation which is proved by the results of our monitoring leads to destabilization of substrate when this substrate was rich in ice before melting. The processes triggered by this effect such as rock fall or debris flows are a potential hazard for humans and infrastructure, a problem which has been addressed in the Hohe Tauern National Park e. g. by Kern et al. (2012). In order to document such potentially hazardous processes a questionnaire (Tab. 2) is in preparation which will be provided to the staff of the Hohe Tauern National Park from summer

2017 on. This questionnaire aims at gathering information on large areas of the national park and will also provide information on processes which occur in permafrost-free areas.

Question	Parameter	Example
Which event has taken place?	e.g. rock fall, ice avalanche, debris flow, inundation	rock fall
Who has observed the event?	person, profession, address	Lieb and monitoring team, gerhard.lieb@uni-graz.at
When was the observation?	date, time	2012-09-10; 08.00-10.00 h
Where has the event taken place?	location, elevation a.s.l., slope aspect	Kellersberg-NE-crest, ca. 2650-2700 m, aspect NE; 12°43'19"E, 47°04'09" N
What was the lower extent and range of the event?	area affected, type of substrate, estimated volume	valley near Hofmannskees, rock fall reaching downward to 2200 m a.s.l.; ca. 1.000 m^3 rock
When did the event took place?	approximation of date and time	during the observation, main event 9.35-9.36 h
When was a similar event observed here before?	statement on singularity or frequency of the event	never
Who or what was affected by the event?	damage to persons, infrastructure, animals, plants	none
What else is worth mentioning concerning the event?	additional observations of any kind	series of rock falls; huge cloud of dust developed
How is the event documented?	map, photograph, video (upload)	https://www.youtube.com/watch?v=io2GwoCiWQswww.uni

Tab. 2: Parameters to be documented in the questionnaire of natural geomorphic events (working table).
Tab. 2: Parameter, welche im Erfassungsbogen für geomorphologische Ereignisse erfasst werden (Arbeitsdokument).

5. Conclusions

The results of the Graz permafrost monitoring network presented in this contribution lead to a clear statement on the current development of permafrost: The climatic conditions in 2013/14 as well as in the entire time span since the establishment of the monitoring network (2006) are unfavourable for permafrost which is especially proved

by increasing ground temperatures and surface velocities of rock glaciers. The continuation of the measurements which seems to be secured for the years to come will provide further insight to the process of permafrost degradation which will most likely occur as judged from predicted climate change.

Acknowledgments

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Authors addresses:
Gerhard Karl Lieb
University of Graz, Department of Geography and Regional Science, Working Group Alpine Landscape Dynamics (ALADYN), Heinrichstrasse 36, 8010 Graz
gerhard.lieb@uni-graz.at

Andreas Kellerer-Pirklbauer
University of Graz, Department of Geography and Regional Science, Working Group Alpine Landscape Dynamics (ALADYN), Heinrichstrasse 36, 8010 Graz
andreas.kellerer@uni-graz.at

Viktor Kaufmann
Graz University of Technology, Institute of Geodesy, Working Group Remote Sensing and Photogrammetry, Steyrergasse 30, 8010 Graz
viktor.kaufmann@tugraz.at

Michael Avian
AIT Austrian Institute of Technology GmbH
Energy Department, Environmental Resources & Technologies
Konrad-Lorenz-Straße 24, 3430 Tulln
michael.avian@ait.ac.at