Long-term Monitoring of Borehole Temperatures and Permafrost-related Data for Climate Change Research, and Natural Hazard Management: Examples from the Mattertal, Swiss Alps

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Mattertal and neighbouring Saastal are certainly amongst the best investigated areas in the Alps concerning permafrost distribution and natural hazard management. An extremely steep topography and traffic routes to touristic sites (e.g. Zermatt, Saas Fee) have led to intense research efforts by the authorities and scientists in order to minimise risks for the population and tourists and to gain the data necessary for natural hazard assessment and protection. Moreover, the long term temperature monitoring in deep boreholes and continuous climate measurements provide valuable data for permafrost distribution modelling and climate change research.

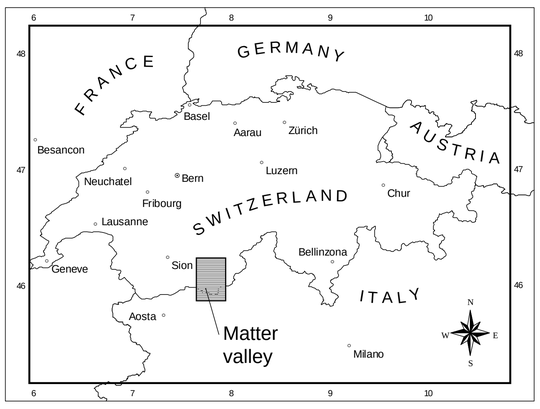

Figure 1: Location of the research area

1 Borehole Monitoring for Climate Change Research

Three boreholes have provided us with significant data concerning subsoil rock temperatures: The locations and the characteristics of the two boreholes on the Stockhorn plateau and the borehole at Ritigraben are shown in Table 1. The temperature curves vary considerably mainly due to their respective positions and surface structures. The permafrost thickness is expected to be approximately 170 meters (Stockhorn plateau) and more than 30 meters (Ritigraben), respectively. The temperature curves show evidence for climatic warming during the last decades, however, the separation of topographic from transient effects in complex topography is a challenging task. The two boreholes at the east-west running crest of the Stockhorn show a very strong effect of exposure on the permafrost characteristics. On the plateau and close to the northern face of the ridge –2,5° C have been measured at 30 metres depth, however, only –0,9° C were recorded at the southern borehole.

Table 1: Borehole Stockhorn Plateau and Ritigraben, location and borehole characteristics

	Stockhorn	Ritigraben
Co-ordinates	45°59'00" N	46° 10' 27'' N
	07°49'05'' E	07° 50' 56'' E
Altitude	3410 m a.s.l.	2615 m a.s.l.
Slope inclination	8° S	14° NW
Date of Drilling	August 2000	October 2001
Borehole depth	100 m / 30 m	30 m
Permafrost thickness	170 m (approx.)	>30 m
Active layer depth	3.1 m	3.8 m
ZAA / MAGT	17.7 m/-2,5°C	14 m/-0,37°

Figure 2: Drilling operations at Stockhorn plateau (3410 m a.sl.) in August 2000, with view to the Liskamm

The Stockhorn and Ritigraben boreholes provide data for long term monitoring of permafrost temperatures, an important source of data for climatic change research. In the high mountain areas of Europe, this idea was initiated by the EU-project PACE (Permafrost And Climate in Europe) and the network is maintained by its ESF sponsored continuation PACE-21. The data is also integrated into international or national databases as GTN-P or PERMOS (PERmafrost MOnitoring Switzerland) forming a base for global comparative research..

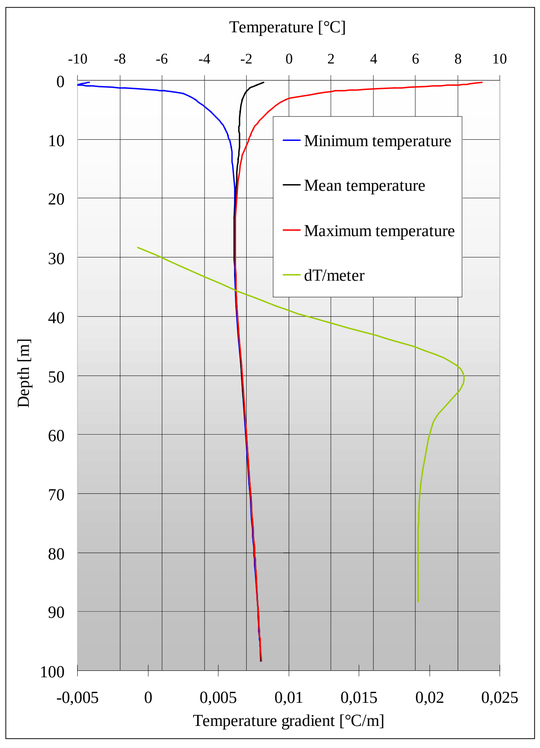

Figure 3: Ground temperature envelope of the 100 meter deep borehole at Stockhorn plateau

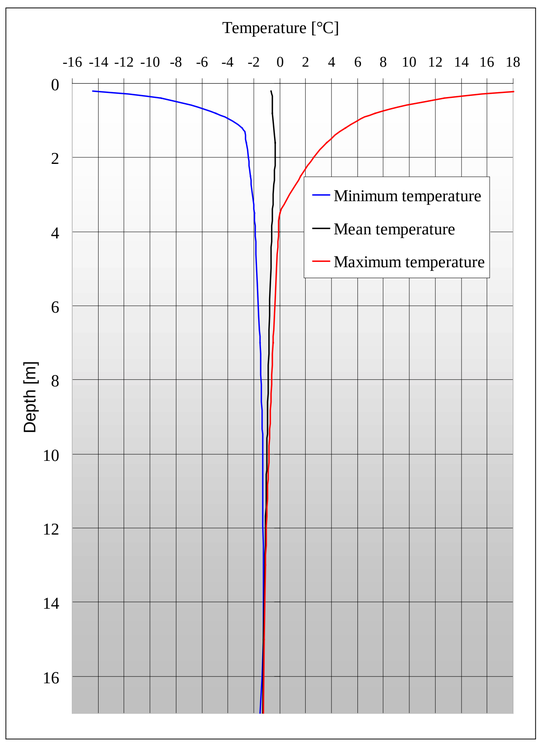

Figure 4: Ground temperature envelope of the 30 meter deep borehole at Stockhorn plateau

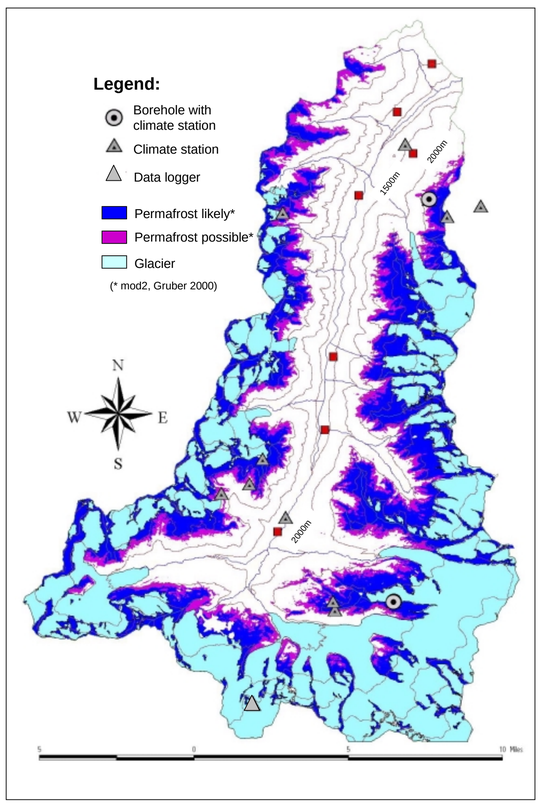

Figure 5: Location of the boreholes Stockhorn plateau and Ritigraben and climate stations in the Matter valley (cp. Table 2)

Table 2: Selected IMIS and ENET-Climatic stations used for modelling purposes in the Matter valley

Name	Altitude	MAAT 2001
Gornergrat snow station	2950m	-2,1°C
Gornergrat wind station	3130m	-2,7°C
Saas Platthorn	3246m	-3,9°C
Saas Schwarzmies	2810m	-1,3°C
Saas Seetal	2480m	+0,5°C
St. Niklaus Oberer Stelli Glacier	2910m	-1,6°C
Zermatt Platthorn	3345m	-4,5°C
Zermatt Triftchumme	2750m	-0,6°C

Figure 6: Meteorological station at Ritigraben block slope, 2615 m

2 Climate Monitoring and Permafrost Modelling

Long term data gathered by the Inter-cantonal Measurement and Information System (IMIS, ENET) for avalanche warning provides permafrost-related information as air and ground temperatures, precipitation, snow depth, global radiation, wind speed and wind direction in the Mattertal. These stations are often positioned in permafrost areas, as the 0°C-isotherme in the Mattertal lies slightly above 2600 meters a.s.l. (Table 2).

In connection with information taken from DTMs, aerial photography, satellite imagery and research undertaken at the Giessen Institute for Geography (Gruber, 2000; Philippi et al., in press) this climate information forms an excellent data base for further permafrost modelling (Gruber et al, 2001) using a Geographical Information System (GIS). A field check with BTS measurements was done in March 2003. It is intended to implement this data into a neuronal network as this could prove to be a valuable tool for a better modelling of permafrost.

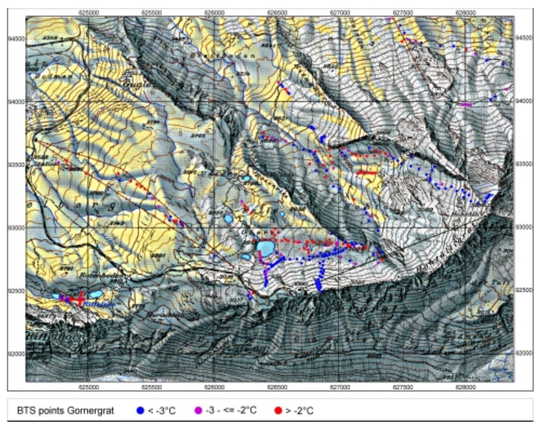

Figure 7: Results of 3 BTS campaigns in the Gornergrat area

Figure 8: BTS-measurements in the Gornergrat area (March 2003)

3 Monitoring for Natural Hazard Management

The strong variability of climatic parameters in this relatively dry and continental climate may lead to extreme climatic events that may trigger catastrophic mass wasting processes due to the extremely steep topography of the whole Valais region. The increasing frequency of natural hazard events are a matter of great concern of the local, regional and national authorities. Great attention is therefore paid to the assessment and management of natural hazards.

More and more, it is realised that permafrost plays an important direct or indirect role in the assessment and prevention of these hazards (Herz et al., in press). The responsible authorities and research organisations therefore support applied research of the mudflow origins in permafrost areas and the origin of unexpected water releases, the installation of early warning devices in mudflow canyons, the monitoring of degrading permafrost and the examination of the stability of avalanche protection constructions in permafrost areas.

An early warning device has been installed in the Ritigraben gully above St. Niklaus. In the event of a debris flow it would automatically cause the main road in the valley to be closed. In a further step it is intended to use precipitation data from the weather station at the Ritigraben borehole as an early warning parameter, that is located close to the starting point of the debris flows.

4 CONCLUSIONS

Long-term monitoring of permafrost temperatures in deep boreholes and the analysis and interpretation of climate data forms a valuable source of information for climate change research and permafrost distribution modelling. This information can also be used for natural hazard detection and protection.

Acknowledgements

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