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Towards assessing thermal and dynamic reaction scenarios of different permafrost sites in the European Alps: One action within the PermaNET project

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Summary

A large part of permafrost in the European Alps is at or close to melting conditions and is therefore very sensitive to degradation caused by atmospheric warming. Knowledge regarding permafrost distribution and its climatologically driven dynamics in the entire European Alps is still far from being complete. The project "PermaNET – Permafrost long-term monitoring network" attempts to close some of these major gaps in permafrost knowledge. One action of this project is concerned with the assessment of the thermal and dynamic reaction scenarios of 20 permafrost study sites distributed over the European Alps. Study sites and research strategy are presented here. Some of the study sites are located within national parks and other protected areas.

Keywords

European Alps, permafrost, reaction scenarios, climate change.

Background

High altitude and high latitude regions are generally recognized as being particularly sensitive to the effects of the ongoing climate change. A large part of permafrost in the European Alps for instance is at or close to melting conditions and is therefore very sensitive to degradation caused by atmospheric warming. Knowledge regarding permafrost distribution and its climatologically driven dynamics in the entire European Alps is still far from being complete.

The project PermaNET

The new European Union co-funded project "PermaNET – Permafrost long-term monitoring network" was launched in July 2008 and attempts to close some of the major gaps in permafrost knowledge in the European Alps (for details please visit www.permanet-alpinespace.eu). The main motivation for carrying out PermaNET might be seen from two different points of view:

Scientific view: e.g. consolidation and regional compilation of existing knowledge, standardisation of monitoring, set-up of an alpine wide permafrost monitoring system (comparable to the permafrost monitoring program PERMOS in Switzerland)

View from practice: e.g. How to deal with permafrost related hazards in natural risk assessment and management? What is going on in areas affected by permafrost degradation caused by present global change?

Based on this motivation the following three main objectives have been formulated:

Alpine-wide permafrost monitoring network

Alpine-wide permafrost map and database

Common strategy for dealing with permafrost and related hazards under changing climatic conditions

Assessment of thermal and dynamic reaction scenarios of different permafrost sites

One out of seven work packages of PermaNET focuses on the assessment of the relationship between permafrost and climate change (i.e. WP5). Within WP5, one action is concerned with the assessment of the thermal and dynamic reaction scenarios of different permafrost typologies in the European Alps. Research in this action is carried out in two steps:

Step 1: Establishment of the relationship between measured climate data and observed thermal and geomorphic permafrost reactions (Table 1) using available datasets collected during the last years and decades in many study sites (*cf.* Chapter 4) located within the European Alps. Such datasets include for instance ground temperature measurements (at the surface and in shallow and deep boreholes), rock glacier displacement rates or observations on mass movement events triggered in areas affected by permafrost (e.g. rock falls).

Step 2: The established relationships in the first step of this action in combination with data from predictive climate models will form the basis for simulations and estimations of changes in permafrost distribution (vertically and horizontally), in the active layer thickness or in the rates of rock glacier displacement.

Table 1: Possible thermal and geomorphic permafrost reactions relevant for PermaNET.

Possible thermal permafrost reactions
Increasing ground temperature (in bedrock, fine and coarse sediments) and hence permafrost warming
Thawing of Permafrost with three effects: (1) reduction in the spatial extent of permafrost, (2) active layer thickening, and (3) increasing ground-water circulation and pressure
Changes in the number of freeze/thaw cycles and magnitude (duration and intensity) of freezing and thawing periods
Possible geomorphic permafrost reactions
Changes in the rate of rock glacier displacement (vertically and horizontally)
Changes in displacement mode of rock glaciers (initiation of basal sliding, collapse)
Changes in solifluction rates*
Changes in cryogenic weathering (freeze/thaw cycles, ice segregation)*
Changes in the volume and extend of unstable/unconsolidated materials
Changes in frequency and magnitude of mass movement events (e.g. rock fall, rock slide, debris flow)*

*not strictly related to only permafrost but to periglacial environments in general

Selected study sites

The assessment of thermal and dynamic reaction scenarios of different permafrost sites is carried out at 20 sites within the European Alps. Figures 1 and 2 depict, respectively, the location of the study sites within the European Alps as well as visual impressions of some of the study sites. Table 2 gives an overview for each of these study sites.

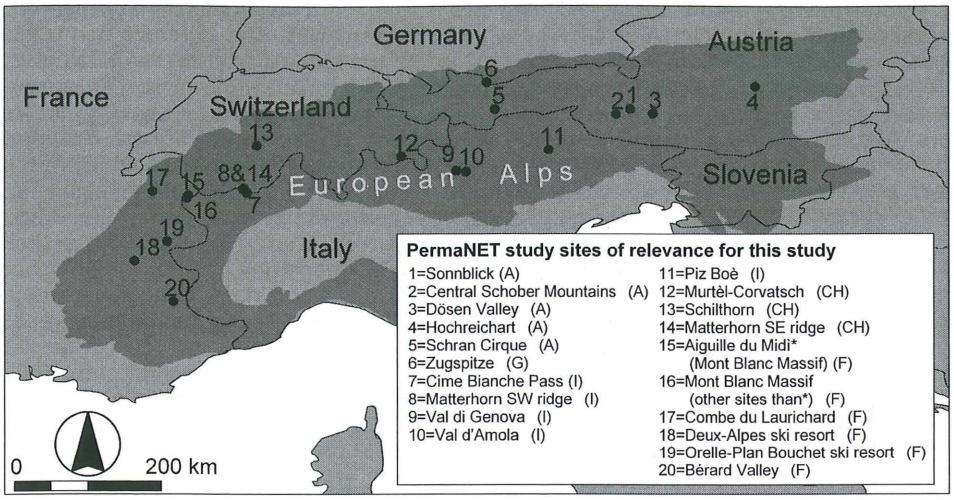

Figure 1: Location of the 20 PermaNET study sites relevant for the assessment of thermal and dynamic reaction scenarios of different permafrost sites in the European Alps.

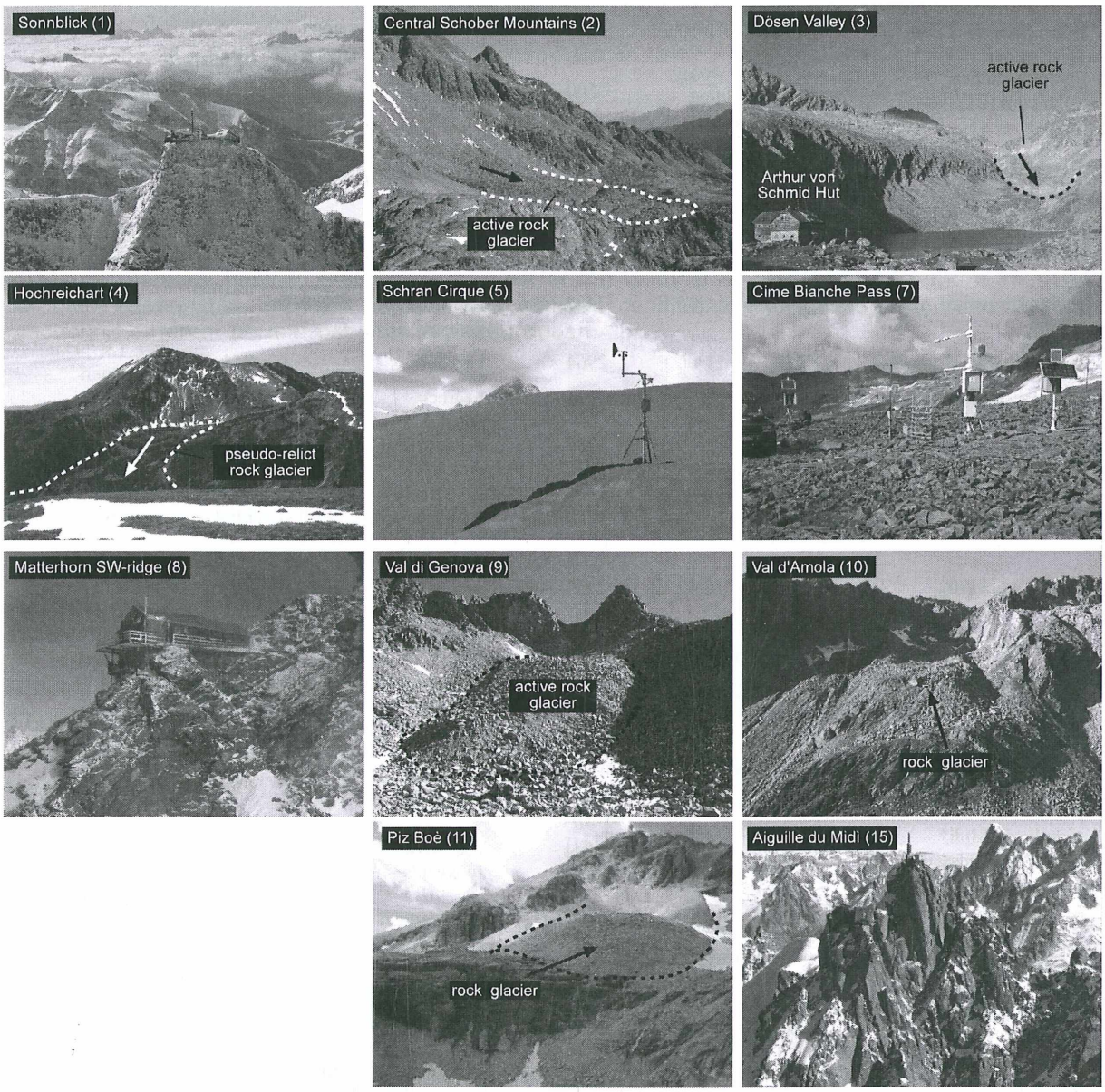

Figure 2: Visual impressions of 11 of the 20 PermaNET study sites relevant for the assessment of thermal and dynamic reaction scenarios. The numbers in brackets refer to the numbers in Fig. 1 and Table 2. The study sites range from just below 2000 m a.s.l. (study site Hochreichart) to about 4000 m a.s.l. (study sites in the Mont Blanc Massif). All photographs provided by the authors of this paper.

Table 2: Overview of the study sites relevant for the assessment of thermal and dynamic reaction scenarios of different permafrost typologies in the European Alps within the project PermaNET. The different permafrost monitoring sites are: **PF-bedrock**=Permafrost in bedrock (from near-vertical rockwalls to flat morphologies); **PF-fine**=Permafrost in fine-grained material (relatively flat morphology); **PF-coarse**=Permafrost in coarse-grained and blocky material; scree slopes, rock glaciers (from slopes to rather flat morphologies); Project partners and collaborators: **LfU**=Bavarian Environment Agency, Department 10: Geological Survey, Economic Geology, Soil Protection, Munich, Germany; **ARPA VdA**=Regional Agency for the Environmental Protection of Valle d'Aosta, Aosta, Italy; **ARPAV**=Environment Protection Regional Agency of Veneto; **GeoVE**=Regione del Veneto, Direzione Geologia e Attività Estrattive, Servizio Geologia, Venezia, Italy; **GST-PAT**=Autonomous Province of Trento, Civil and Territory Protection Department, Geological Survey, Trento, Italy; **UIBK**=Institute of Geography, University of Innsbruck, Innsbruck, Austria; **IGRS**=Institute of Geography and Regional Science, University of Graz, Graz, Austria; **ZAMG**=Central Institute for Meteorology and Geodynamics, Regional Offices for Salzburg and Upper Austria, Salzburg, as well as Vienna, Austria; **IGA-PACTE**=Institut de Géographie Alpine, University of Grenoble, France; **EDYTEM**=EDYTEM Lab, Université de Savoie, CNRS, Le Bourget-du-Lac, France; **Uni Trento**=University of Trento, Department of Civil and Environmental Engineering, Trento, Italy; **Uni Zurich**=Department of Geography, University of Zurich, Zurich, Switzerland; **Uni Pavia**=Earth Science Department, University of Pavia, Pavia, Italy ; **Uni Bonn**=Department of Geography, University of Bonn, Bonn, Germany.

Name of study site (code see in Fig. 1)	Co	Latitude	Longitude	Elevation range/max. (m a.s.l.)	Main studied landform or process	Re-search initia-tion	Permafrost monitoring site	Involved project partners and collaborators
Hoher Sonnblick (1)	A	47°03'N	12°57'E	3106	bedrock, detritus	2007	PF-bedrock PF-coarse	ZAMG
Central Schober Mountains (2)	A	46°57-59'N	12°47-49'E	2500-2725	rock glacier, rock wall,	1997	PF-bedrock PF-fine PF-coarse	IGRS
Dösen Valley (3)	A	46°59'N	13°17'E	2400-3000	rock glacier, rock wall	1995	PF-bedrock PF-fine PF-coarse	IGRS
Hochreichart (4)	A	47°22'N	14°41'E	1920-2416	rock glacier, rock wall, detritus	2004	PF-bedrock PF-coarse	IGRS
Schran Cirque (5)	A	47°04'N	11°06'E	2400-3496	rock glacier, morainic deposits	2008	PF-fine PF-coarse	UIBK
Zugspitze (6)	G	47°25'N	11°00'E	2964	bedrock		Pf-bedrock	LfU, Uni Bonn
Cime Bianche Pass (7)	I	45°55'N	07°42'E	3100	bedrock, detritus	2006	PF-bedrock PF-coarse	ARPA VdA
Matterhorn SW ridge (8)	I	45°58'N	07°39'E	3750 - 3830	near-vertical rockwalls	2005	PF-bedrock	ARPA VdA
Val di Genova (9)	I	46°13'N	10°34'E	2750-2860	rock glacier	2001	PF-coarse	GST-PAT, Uni Trento, Uni Pavia
Val d'Amola (10)	I	46°12'N	10°42'E	2330-2480	rock glacier	2001	PF-coarse	GST-PAT, Uni Trento, Uni Pavia
Piz Boè (11)	I	46°30'N	11°50'E	2900-2950	rock glacier	2005	PF-coarse PF-bedrock	GeoVE, ARPAV
Murtèl-Corvatsch (12)	CH	46°25'N	09°49'E		rock glacier, bedrock	1980s	PF-coarse	Uni Zurich
Schilthorn (13)	CH	46°33'N	07°51'E	2973	mountain top	1980s	PF-bedrock	Uni Zurich
Matterhorn SE ridge (14)	CH	45°58'N	07°39'E		near-vertical rockwalls		PF-bedrock	Uni Zurich
Aiguille du Midi* (Mont Blanc Massif) (15)	F	45°53'N	06°53'E	3840	near-vertical rockwalls	2005	PF-bedrock	ARPA VdA, EDYTEM, Uni Zurich, Uni Bonn
Mont Blanc Massif (other sites as*) (16)	F	45°50'N	06°52'E	3000-4000	near-vertical rockwalls	2006	PF-bedrock	ARPA VdA, EDYTEM
Combe du Laurichard (17)	F	45°56'N	06°24'E	2450-2630	rock glacier	Ca 1980	PF-coarse	IGA-PACTE
Deux-Alpes ski resort (18)	F	44°59'N	06°09'E	2650-2720	rock glacier	2007	PF-coarse	IGA-PACTE
Orelle-Plan Bouchet ski resort (19)	F	45°15'N	06°36'E	2780-3050	rock glacier	2007	PF-coarse	IGA-PACTE
Bérard Valley (20)	F	44°26'N	06°41'E	2500-2850	fine grained rock glacier	2007	PF-fine	IGA-PACTE

Research strategy

Monitoring of permafrost temperature are performed on four different kind of permafrost sites primarily using miniature temperature dataloggers (MTD), thermistor-chains lodged in boreholes (from very shallow to deep) or calm-grid areas:

Permafrost and active layer in bedrock (from near-vertical rock walls to flat morphologies)

Permafrost and active layer in fine grained material (rather flat morphology)

Permafrost and active layer in coarse grained and blocky material (scree slopes, rock glaciers; from steep slopes to rather flat morphologies)

Thermal state of Little Ice Age moraines above 3000 meters of altitude (ice-cored)

Climate conditions at permafrost sites are monitored by meteorological stations.

Monitoring of dynamic conditions in permafrost environments is carried out by geodetic, photogrammetric, terrestrial laserscanning (LiDAR), DInSAR and DGPS techniques as well as visual observations and calculations. This monitoring focuses on:

Mass movement (e.g. rock fall) frequency and magnitude

Rate of rock glacier displacement (vertically and horizontally)

Rate of solifluction rates

Physical weathering (freeze/thaw cycles)

Numerical models for the estimation of deep temperature or spatial permafrost distribution will be used and calibrated using the field data and will complement the research strategy.

Outlook

This paper gives a brief overview of the planned and partly already initiated research activities within this project part of PermaNET. The project running period of PermaNET is until summer 2011. By then, we hope to understand in most of the study sites presented here more about the complex relationship between climate and climatic conditions and the thermal and dynamic reaction of different permafrost sites in the European Alps.

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