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RiskNat: a cross-border European project taking into account permafrost-related hazards

The RiskNat B1-C1 team

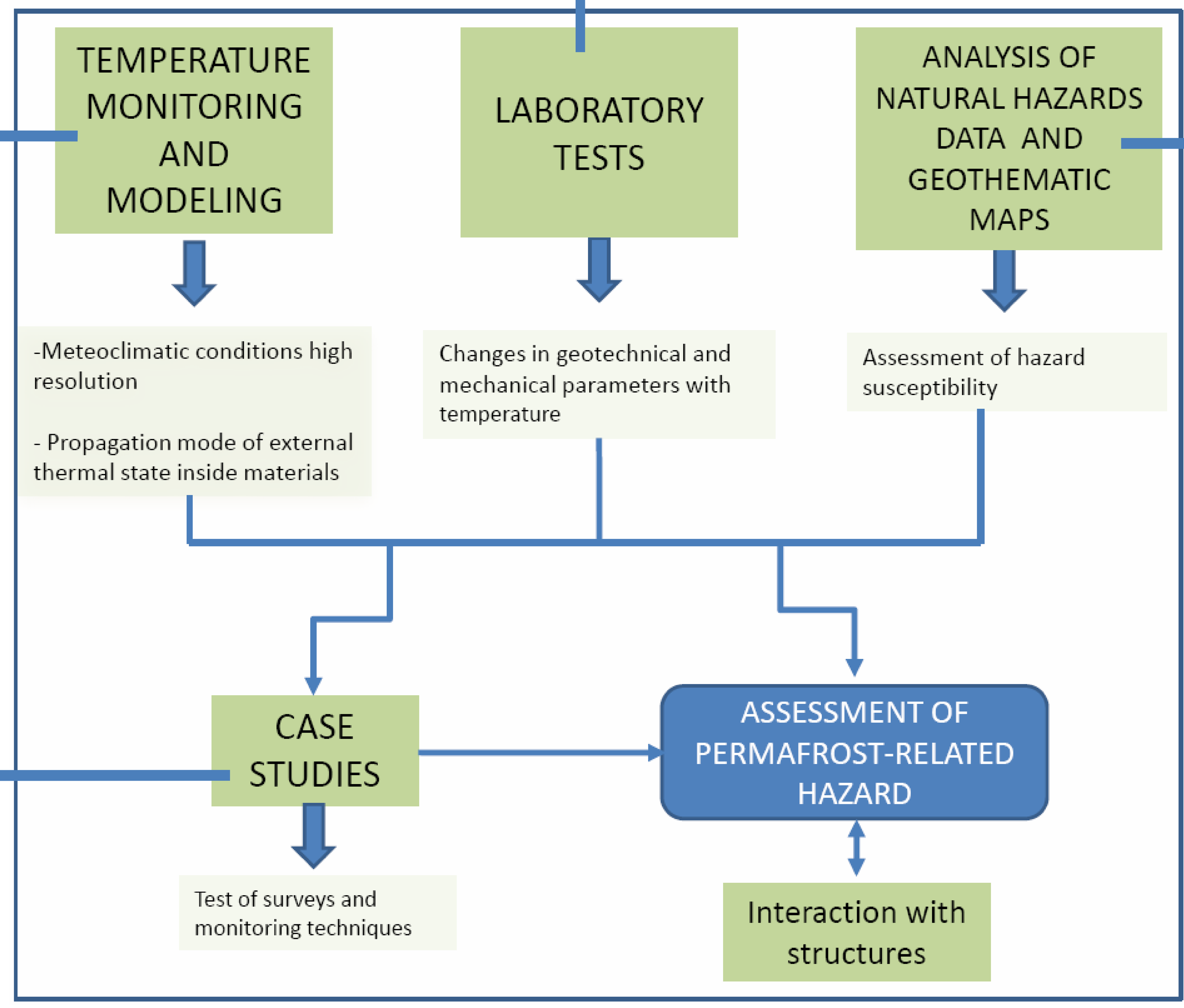
INTRODUCTION

Natural hazards and management of risks related to permafrost degradation in mountain areas are still poorly known and considered.

Alpine permafrost is rather different from permafrost in arctic or northern lands. Thermal regime largely depends on microclimate effects, dealing with altitude, aspect and geographic position; moreover, thermal regime inside of materials depends on material type itself (rock, debris, soil), slope steepness, exposure to solar radiation, water circulation and presence of snow. Because of the complexity of these parameters, permafrost distribution is discontinuous and difficult to detect. Furthermore, alpine permafrost affects areas traditionally characterized by few inhabitants and infrastructures. Thus, until now there has been no need of a good understanding of alpine permafrost-related phenomena from a practical point of view.

Landslide and debris flow phenomena occurred in recent years in alpine regions, triggered in high mountain areas, sometimes reaching the distal valley areas and involving man-made works and inhabited zones. High mountain is characterized by an high level of natural hazard due to high energy and frequency of the involved processes. Rock falls, debris flows, debris avalanches and others more or less huge processes are increasing their consequences in a climate change framework. Warming temperatures in high mountain areas cause modifications in glacial environment and the degradation of the alpine permafrost in periglacial realm. On the other hand, high elevation zones get more and more interested by human activities and structures (mainly for tourist trade).

In the next future, the great challenge is to evaluate the possible scenarios linked to natural hazards in high mountain environment in order to assess consequences and risk mitigation strategies. That's why not only the scientific community but also public administrations involved in land use planning, in civil protection and in risk management had increased their interest to permafrost-related phenomena, becoming more important as strictly related to climate change. **Activity B.1 – C.1 "Hazards deriving from high mountain environment evolution"** of *RiskNat* project is an example of this increasing response to new needs; the activity is presented in this poster.



TEMPERATURE MONITORING AND MODELING

Due to the complexity of high mountain topography the direct measure of surface rock temperature is fundamental for the detection of permafrost state at local scale (Fig 1). On the selected case-study sites the rock temperature is monitored by mini-datalogger installed in the representative sectors of the study area (Fig 2). Such data are used for roughly define permafrost occurrence probability and for calibration of a physical model (*GEOtop*) used for the projection of surface temperature in depth (Fig 3). Meteorological parameters coming from local regional monitoring network are used for driving the model and for defining the local climate of the study sites.

Fig1. Example of an high-mountain infrastructure affected by permafrost degradation (Carrel Hut – Matterhorn). The complex topography strongly affect rock thermal regime. In the small picture the mini-datalogger used for the monitoring of rock and air temperature.

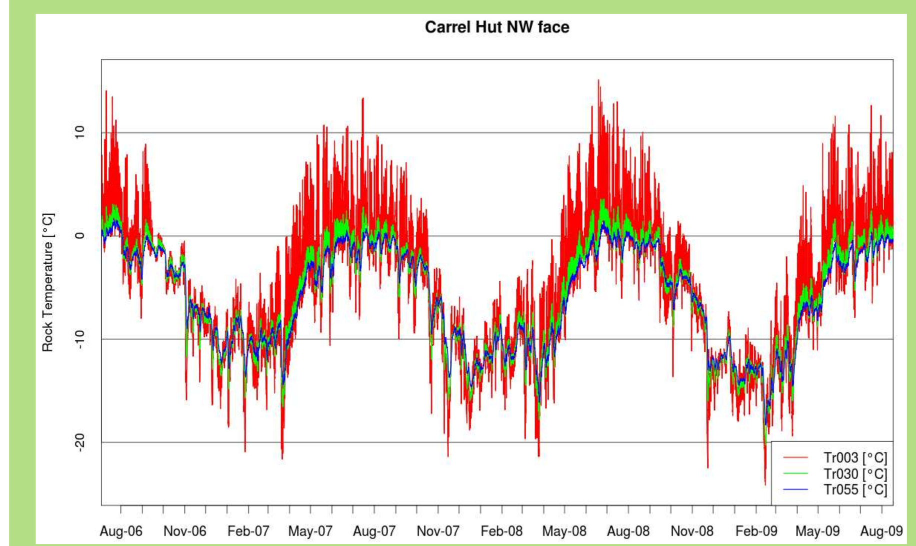


Fig2. Example of surface rock temperature dataseries.

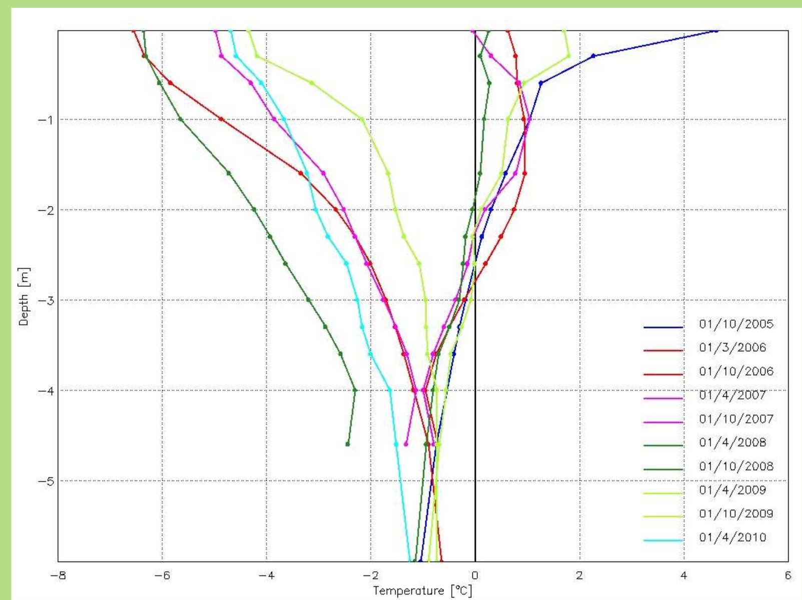


Fig3. Example of sub-surface temperature profiles.

LABORATORY TESTS

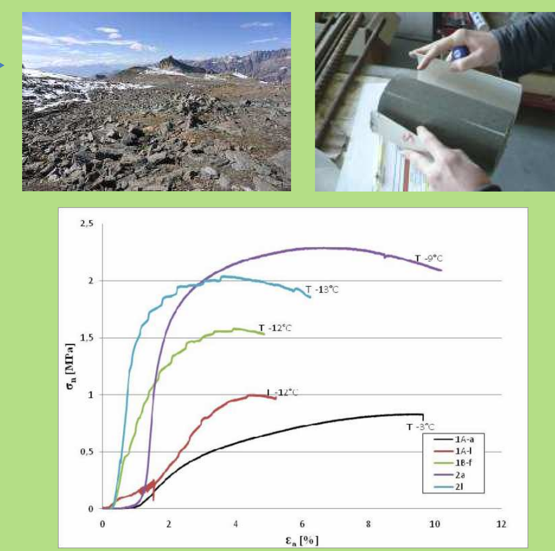
In order to assess changes of mechanical properties of materials with temperature, some laboratory tests have been performed. These involve some difficulties, dealing with (i) difficulty in reproducing natural phenomena related to permafrost degradation, (ii) the availability of test apparels working with artificially induced temperature and (iii) problems related to get representative samples in very heterogeneous materials.

How do mechanical characteristics of material (rock, debris) change with temperature?

Debris/loose materials → **UCS test at different temperatures**

Rock mass → Intact rock → **Point Load Strenght Test on cores after different freeze-thaw cycles**

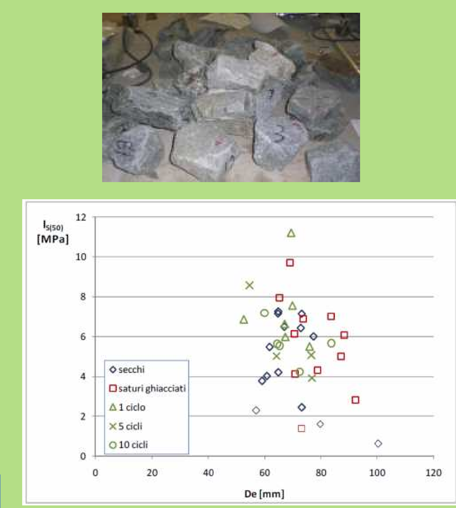
Rock mass → Joints → **Shear test**: Freeze-thaw cycles → Weathering and mechanical damage of joints → Decrease of roughness → Base friction angle



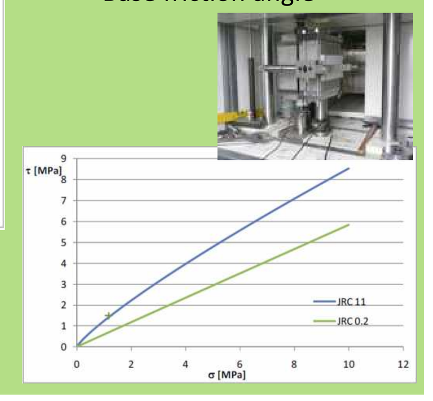
Results of test on rework debris cores from "Cime Bianche" site W ≈ 10% (≈ in situ water content).

Very low T (≈ -15°C)
- higher UCS
- "elastic-brittle" behaviour

Higher T (≈ -5°C)
- lower UCS
- "plastic" behaviour



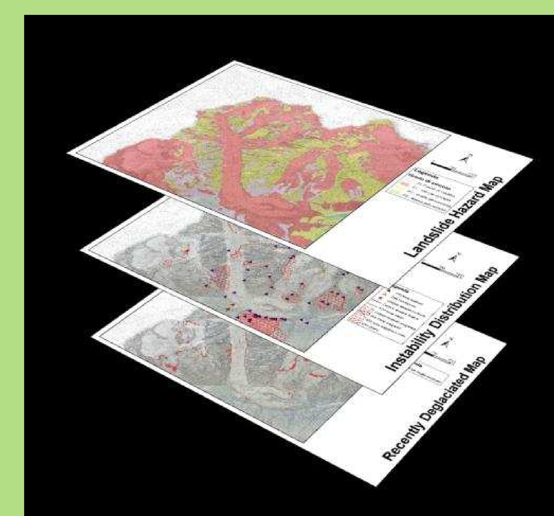
No significant correlation between strength and freeze-thaw cycles



ANALYSIS OF NATURAL HAZARDS DATA AND GEOTHEMATIC MAPS

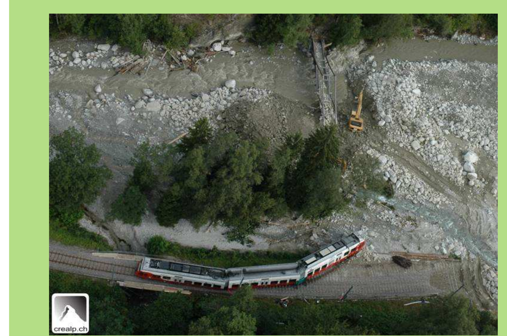
Starting from the available data and maps (e.g. permafrost distribution, deglaciated areas, landslide distribution, land-use, etc.), the relationships among different layers and information will be analyzed.

For example, it is important to understand the relationships between permafrost and landslide distributions, and the behaviour of different kinds of landslides linked to permafrost evolution. Not only the paroxysmal phase of a sudden process is considered in this analysis but also the very slow movements linked to the creeping permafrost that cause damages to the high mountain works (like alpine shelters and cableways).

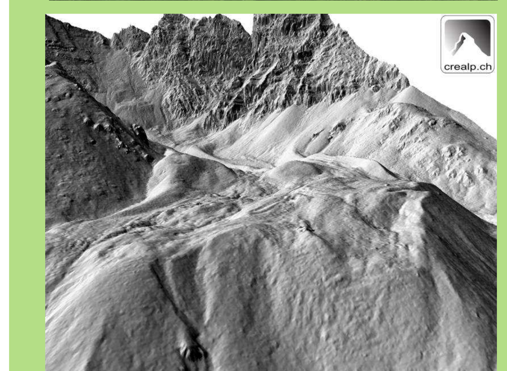


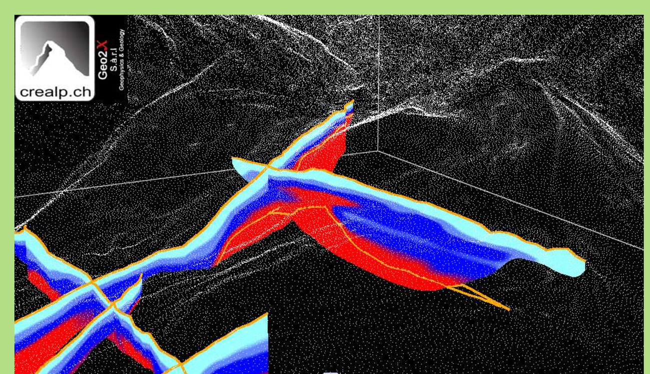
CASE STUDIES: DEBRIS FLOWS TRIGGERED IN PERMAFROST

Two sites in Wallis that have recently produced destructive debris flows originating from permafrost area are studied. Detailed surveys of these 2 areas were undertaken to better understand the role of permafrost on the dynamic of debris flow triggering.



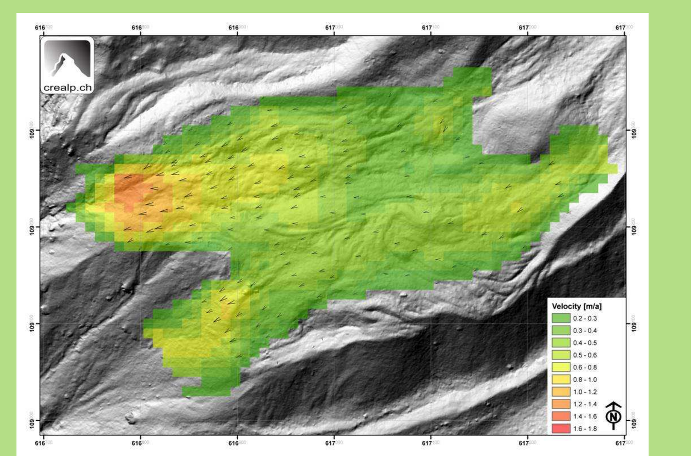
To assess the role and the future dynamic of these sites, it is necessary to reconstruct the 3D geometry of the permafrost complex. In a first stage, terrestrial & airborne LiDAR acquisition are performed to define the surface. These data allow to accurately implement geophysical measurements, as seismic refraction, GPR, or ERT. Drill holes are realized in order to calibrate the geophysical measurements too.





All these information are compiled in a 3D software (*AdHoc*©) that enables the analysis on multisources data.

In a second stage, we try to asses the dynamic of the area. For this purpose historical maps, ancient orthophotos and on site GPS measurements are analyzed.



Coupled with the knowledge from the 3Dconstitutive material of the permafrost complex, the deformation of the whole mass is a robust tool to estimated the future impact on debris flows dynamic.

The work is still in progress on these sites. Among others, long term temperature measurements will be undertaken soon.

RiskNat is a cross-border project in the framework of the program Alcotra France-Italy (2007-2013), developed between 2009 and 2012. It focuses on natural hazards that concern mountain areas: earthquakes, landslides, torrent floods, snow avalanches and hazards related to permafrost degradation. All regions of Italy, France and Switzerland in the western Alps are involved.

RiskNat aims at the constitution of an interregional platform on natural hazards by means of (i) knowledge and experience exchange between technicians, researchers and public administrations of the different regions and (ii) awareness programs about natural risks.

Regions involved in activities B1-C1 "*Hazards deriving from high mountain environment evolution*" are: Autonomous Region of Aosta Valley (IT), Piedmont Region (IT), Department of Haute-Savoie (FR), Wallis Canton (CH).