MAPPING AND MONITORING OF PERMAFROST PHENOMENA IN THE AUTONOMOUS PROVINCE OF BOLZANO, ITALY

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INTRODUCTION

Permafrost is highly sensitive to changes of the climatic conditions. During the last summers, increasing intensities and higher frequencies of both rock fall and debris flow processes in high alpine areas have been observed throughout the Alps. In 2005, the authorities responsible for natural hazards and risk management in the Autonomous Province of Bolzano started a project which aims at monitoring the impact of environmental changes on mountain permafrost areas and gains to develop an information basis for the assessment of natural hazards related to the degradation of permafrost zones.

METHODS

In this project, different methods of permafrost detection and mapping were combined. For the whole territory an inventory of rockglaciers was compiled on the basis of information derived from orthophotos, stereo pairs of aerial photos, the laserscan DEM and recent field mapping for the geological map of the Autonomous Province of Bolzano at 1:10.000 scale (project "CARG"). A harmonized data model for the rockglacier inventory was developed. Multi-temporal analyses were used to derive an inventory of perennial snow patches from orthophotos and to establish an inventory of slope movements in mountain permafrost areas by means of SAR interferometry (DiffSAR) applied to spaceborne C- and L-band data starting from 1993 until 2007. The radar interferometry data provided the basis for classifying the activity of each rockglacier of the whole inventory. Additionally to the regional investigations, detailed geophysical, hydrological (water temperature, electrical conductivity, discharge), geochemical and morphological measurements were carried out in five specific test-sites. At one test-site BTS-measurements, which originally started in 1994 were repeated annually. On specific rockglaciers, georadar measurements (GSS SIR System 2000 with a multiple low frequency antenna; frequency 35 MHz, constant antenna spacing in point mode) provided information on the internal structure and thickness of active rock glaciers. Surface flow velocities of rock glaciers were measured by using the differential GPS technique and, in one case, by laser tacheometry. The high precision terrestrial survey results were compared with the results of the DiffSAR slope movement measurements. Based on the inventory of perennial snow patches, the rock glacier inventory and a simplified permafrost distribution model, a synthesis map of permafrost distribution has been elaborated. This map provided the starting point for delimiting the areas of potential rockfall processes and debris flows triggered in permafrost areas and for the elaboration of a hazard index map. It was then possible to generate the map of specific risk by intersecting the hazard index map with the development plans for local real estate.

RESULTS AND CONCLUSIONS

Combining detailed investigations at local scale with regional-scale mapping methods enabled to cross-validate the various approaches and to extrapolate the geomorphologic characteristics of the different test-sites to entire regions. The multi-temporal approach revealed the different trends of permafrost areas due to changing environmental conditions since the mid 1990ies such as increasing

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slope movements, areas of preferred melt out and related processes. Now, the permafrost distribution in South Tyrol is known and the actual state of permafrost is measured in some cases. The rockglacier inventory was a role model for the rockglacier inventory of the Alps, elaborated in a successor project.

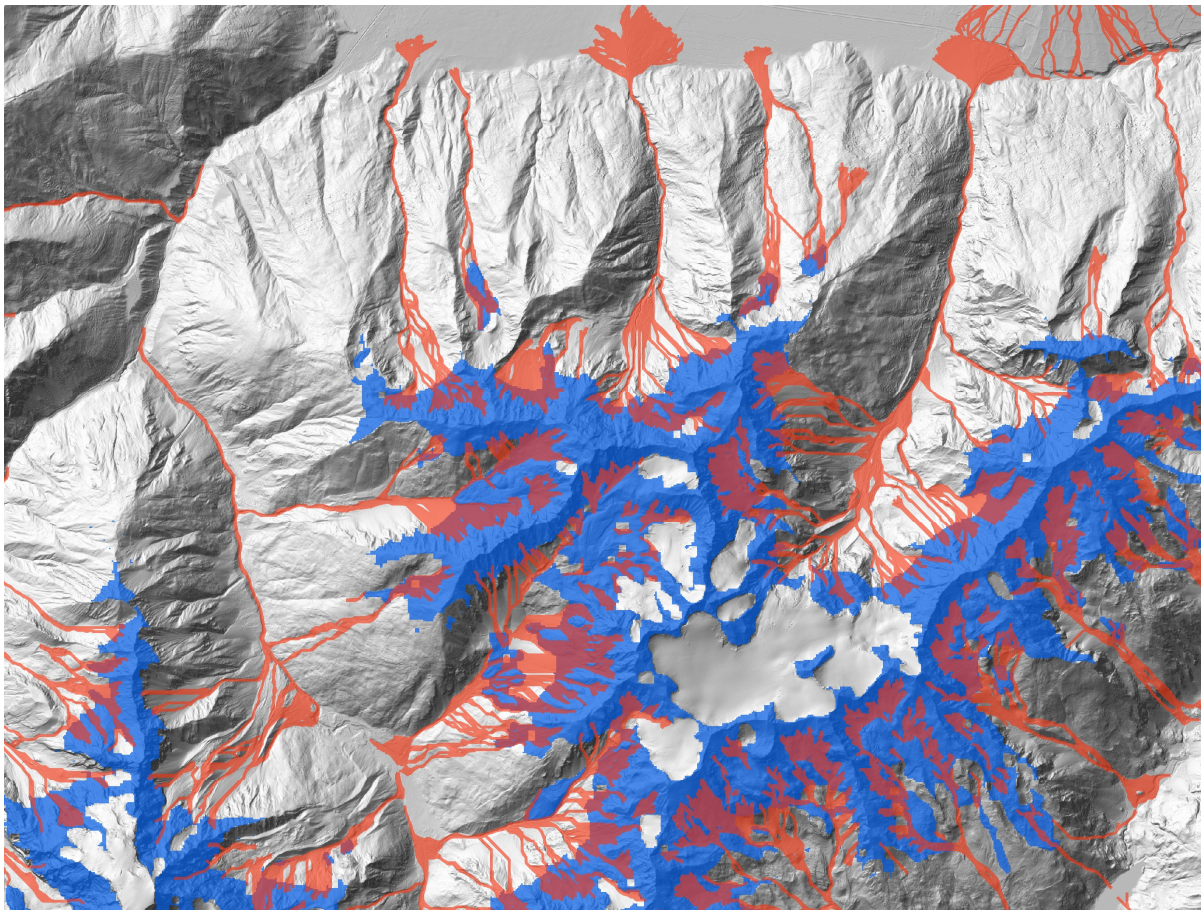

Fig. 1 Hazard index map of torrents eroding quaternary sediments located in permafrost areas. The red colour shows the hazard index map of debris flow processes, the blue colour shows the permafrost distribution map. Example from the Ortles Alps, South Tyrol.

The analyses pointed out that about 20% of all alpine torrent catchments in South Tyrol have a remarkable percentage of the catchment area lying in permafrost areas. About 1.4 % of the settlement areas - corresponding to more than 900 buildings and about 4000 persons living therein - are potentially exposed to debris flows from these torrents eroding quaternary sediments located in permafrost areas. Rockfalls from permafrost areas do not only affect hiking trails and some mountain huts, cable cars or ski lifts in the high mountains but potentially even about 50 persons in buildings and about 2.5 km of the road infrastructure. The datasets provide a valuable basis for decision-making in risk management regarding permafrost related processes. The exposed infrastructures could be identified and detailed investigations about the related risks could be initiated. The integrated approach of permafrost investigation and monitoring lead to the development of an information system for permafrost detection and monitoring which is based on reliable and cross-validated information. The database provides the required information for the elaboration of hazard zone maps in high mountain areas.

Keywords: permafrost, climate change, risk assessment, rockfall, debris flows