Impact of permafrost degradation on debris flow initiation – a case study from the north Italian Alps

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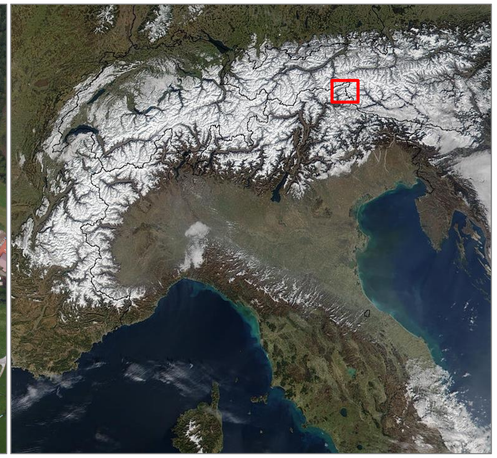

Fig. 1 (left hand): The August 2005-debris flow deposits of the Klammbach creek in Antholz-Mittertal village, Antholz valley (source: Autonomous Province of Bozen, flood protection office). The event was substantially controlled by permafrost degradation in the Klammbach basin, where mean annual air temperature rose by 1 K since 1940. The increase of MAAT caused a rise of the lower permafrost limit of most likely 100–180 m, using a mean thermal gradient of 0.57 K/100 m.

Fig. 2 (right hand): European Alps with the location of the study area Rieserferner-Ahrn Nature Park (box) and the adjacent areas in South Tyrol, Italy (source: NASA).

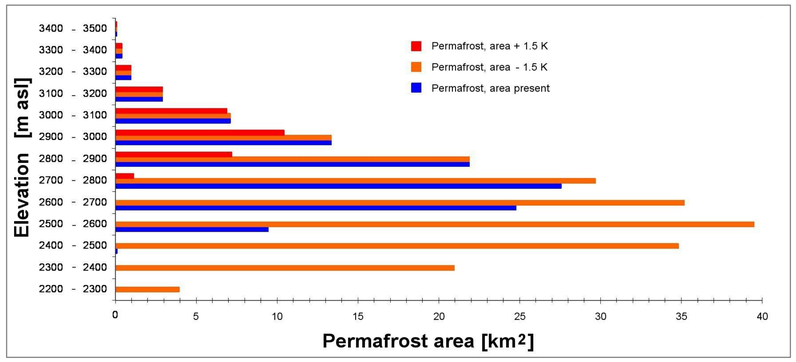

Fig. 3: Present-day extent of permafrost area in the Rieserferner-Ahrn Nature Park related to altitude and different thermal scenarios with lower (-1.5 K) and higher (+1.5 K) mean annual air temperature.

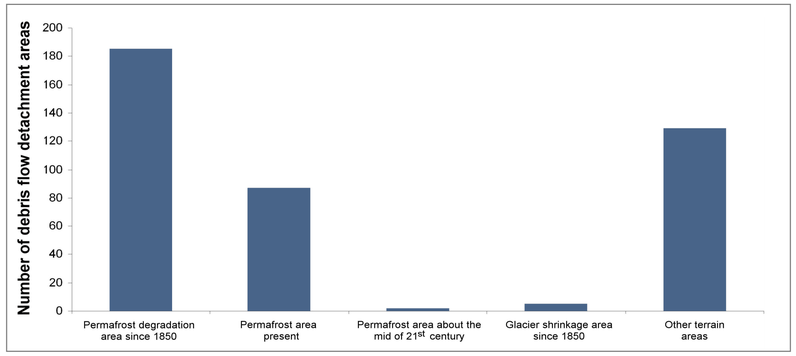

Fig. 4: Debris flow detachment areas in the Rieserferner-Ahrn Nature Park related to temporal variability of permafrost distribution and glacier extent.

Atmospheric warming in high mountain environments causes a range of impacts, including glacier recession, reduction of permafrost extent and distribution as well as changes in thermal permafrost properties. Furthermore, it is likely that climate change affects the occurrence of natural hazards, like shallow landslides and debris flows, as their initiation is related to the degradation of the cryosphere (fig. 1).

The present study demonstrates the importance of recent atmospheric warming for the spatial distribution of debris flow initiation in a central alpine area of the Italian Alps (Europe). It is primarily based on the modelling of the spatial distribution of permafrost using a database of geomorphologic, hydrologic, and physical permafrost indicators and the CRYOSNOW-approach. The variability of the lower permafrost limit was calculated using a thermal gradient of 0.57 K per 100 m in the study area.

The study area covers the Rieserferner-Ahrn Nature Park in South Tyrol, Italy and adjacent areas of the Hohe Tauern National Park, Austria (fig. 2). Highest peaks in the study area reach up to 3,500 m a.s.l. Since the end of the Little Ice Age about AD 1860 the glacier area decreased by 50 to 65 % in the Rieserferner-Ahrn Nature Park. Strong glacier recession was recorded during the last three decades when the ELA partially rose up to 3100 m a.s.l. The present permafrost area in the study area and that related to the thermal conditions at the end of LIA is calculated to be 109 km² and 211 km², respectively.

Compared to present conditions the permafrost area would decrease by approximately 72 % by the middle of the 21st century (fig. 3) with regard to an increased air temperature of +1 to +2 K. Moreover, glaciers widely disappear in this scenario. This may presumed to be a moderate increase of temperature in relation to the predicted climate development of the IPCC. Ongoing glacier recession and permafrost degradation increase the amount of instable debris as well as the potential of debris flow detachment zones in the future.

There is first evidence that it is possible to quantify the regional debris flow hazard potential for different climate scenarios and variable geomorphic stability (fig. 4). In particular, permafrost degradation due to increasing mean annual air temperature (MAAT) since the end of the Little Ice Age (LIA) caused mechanical instabilities of sediments and slopes (fig. 5). In the study area it can be shown that almost half of the debris flow initiation zones originate in areas with loose rock that were still stabilized by glacier ice and/or permafrost about 150 years ago (fig. 6).

Fig. 5: Permafrost degradation in frozen till of a LIA terminal moraine at 2700 m a.s.l. (left hand) and internal ice of talus and till deposits uncovered by sliding at 2750 m a.s.l. (right hand). Thickening of the seasonally unfrozen active layer and the loss of internal ice by permafrost degradation destabilize loose rock and favour the detachment of debris (photo: B. Damm)

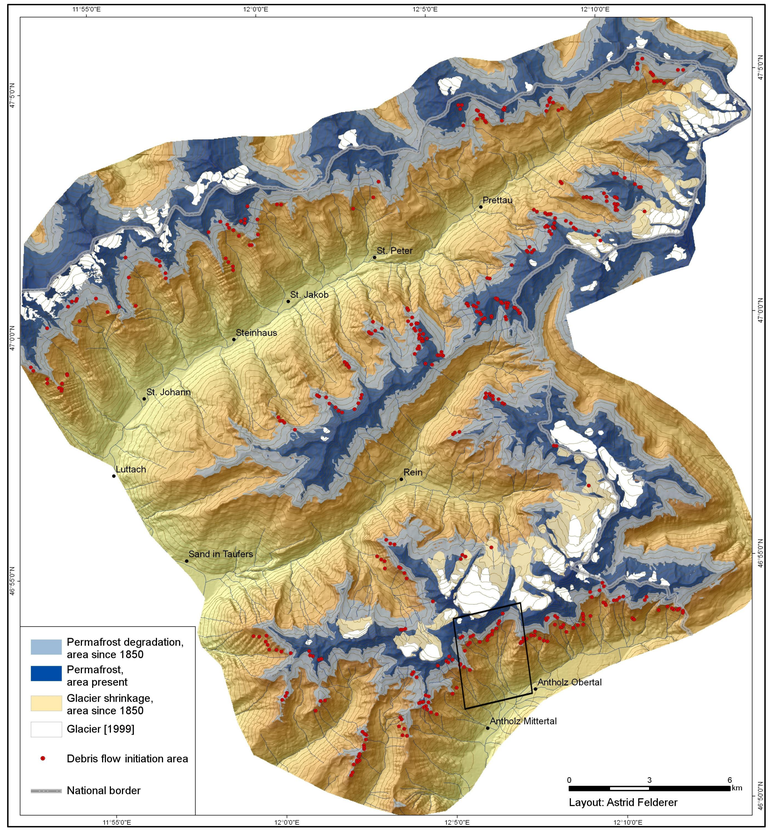

Fig. 6: General map of glacier extent, permafrost distribution and debris flow initiation areas in the Rieserferner-Ahrn Nature Park. In total, 408 debris flow initiation zones were mapped. The Klammbach drainage area (cf. fig. 1) is located in the box.

References

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