



The existence of warm permafrost in unstable rock slopes in western and northern Norway

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During the last decade there has been an increased interest to monitor mountain permafrost slopes. Climatically-driven permafrost warming and degradation may influence the future magnitude and probability of potentially hazardous events on cold mountain slopes, and pose a risk to people and infrastructure. Extensive studies since the 1980's have shown that permafrost is discontinuous in the higher mountains of central southern and eastern Norway. However up to now sparse information is available on the distribution of mountain permafrost, its thermal state and the general mountain climate in the high-relief alpine areas in western and northern Norway. A permafrost and climate monitoring programme was initiated in 2001-2004 in some selected areas in Møre og Romsdal (western Norway) and Troms (northern Norway), where several unstable rock slopes exist. The goal was to increase the knowledge of permafrost distribution and seasonal frost in some of the most hazardous rockslide areas in Norway and to assess whether the potential presence of permafrost can lead to increased stability problems.

In these areas displacement measurements indicate that large volumes (often several million cubic metres) of rock are moving several cm/year at some sites. Some may pose serious consequences to inhabited areas due to their potential of generating disastrous tsunamis in fjords and damming of rivers in valleys, with subsequent risk of major flooding. A series of temperature data loggers were installed in altitudinal transects for monitoring of ground-, surface and air temperatures. To optimise comparability and to ensure that the thermal properties were not extensively complex, most sites were located at exposed sites, in the main ridge-crest or plateau locations, where winter-snow accumulation is minimal. At 1474 m a.s.l. on Dalsnibba, Møre and Romsdal, a 16 m deep borehole was drilled in 2001 and in Troms two 30-32 m deep boreholes were drilled in 2004 at altitudes of 786-850 m a.s.l.

Results suggest that several of the unstable rock slopes in Troms are located in warm permafrost or just below the present altitudinal limit of permafrost. The lower permafrost limit is located at about 800-900 m a.s.l. in the outermost areas along the coast, decreasing to 600-700 m a.s.l. in the inner fjord- and valley areas. In the valley areas in Møre and Romsdal the lower permafrost limit is located at 1300-1400 m a.s.l., but permafrost is probably present at lower altitudes in steep north-facing rock walls. The 6-10 year data series from the three boreholes show a general increase in ground temperatures. At 11 metres depth on Dalsnibba ground temperature increased by more than 1 °C between 2001 and 2009, suggesting that permafrost in this area at present may be subject to fast change and degradation.