Geophysical Research Abstracts
Vol. 19, EGU2017-12369, 2017
EGU General Assembly 2017

Thermal preconditioning of mountain permafrost towards instability

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Warming permafrost has been detected worldwide in recent years and is projected to continue during the next century as shown in many modelling studies from the polar and mountain regions. In mountain regions, this can lead to potentially hazardous impacts on short time-scales by an increased tendency for slope instabilities.
However, the time scale of permafrost thaw and the role of the ice content for determining the strength and rate of permafrost warming and degradation (= development of talik) are still unclear, especially in highly heterogeneous terrain.

Observations of permafrost temperatures near the freezing point show complex inter-annual responses to climate forcing due to latent heat effects during thawing and the influence of the snow-cover, which is formed and modulated by highly non-linear processes itself. These effects are complicated by 3-dimensional hydrological processes and interactions between snow melt, infiltration and drainage which may also play an important role in the triggering of mass movements in steep permafrost slopes.

In this contribution we demonstrate for the first time a preconditioning effect within near-surface layers in mountain permafrost that causes non-linear degradation and accelerates permafrost thaw. We hypothesise that an extreme regional or global temperature anomaly, such as the Central European summers 2003 and 2015 or the Northern European summers 2006 and 2014, will enhance permafrost degradation if the active layer and the top of the permafrost layer are already preconditioned, i.e. have reduced latent heat content. This preconditioning can already be effectuated by a singular warm year, leading to exceptionally strong melting of the ground ice in the near-surface layers. On sloping terrain and in a context of quasi-continuous atmospheric warming, this ice-loss can be considered as irreversible, as a large part of the melted water will drain/evaporate during the process, and the build-up of an equivalent amount of ice in following cold years does not happen on similar time-scales as the melting. Joint thermal and geophysical observations from permafrost sites in the Swiss Alps and Scandinavia suggest that the above process applies mostly to sites with low to intermediate ice contents, where singular anomalies can lead to sustained ice loss even at larger depths.