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# The role of warm extreme events as triggers for high-mountain slope failures: recent evidence and future scenarios

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In recent years an increase of large slope failures was observed in some high mountain regions such as the European Alps. There is concern that recent climate change and related impacts on glacier decay and permafrost degradation is a cause behind the slope failures, thereby possibly exacerbating the hazard in the future. While the effects of gradual temperature rise on glaciers and permafrost has been intensively studied, the impacts of short-term, unusually warm temperature events on high-mountain slope stability remain largely unexplored.
Here we describe several large slope failures in rock and ice that occurred in recent years in Alaska, New Zealand and the European Alps, and analyze the corresponding air temperature evolution days and weeks before failure. Although we did not find one general temperature pattern, all the events were related to unusually warm periods before failure, and some showed a sudden drop to freezing temperatures immediately before failure.
To assess the frequency of warm extremes in the future we analyzed eight Regional Climate Models (RCM) from the recently completed EU-programme ENSEMBLES for the central Swiss Alps. Results show a clear trend of higher frequency of high-temperature events for the 2001-2050 period, as compared to the past reference period of 1951-2000. 5-, 10- and 30-day warm events are projected to increase by factors of about 1.5 to 4 but also up to 10 in some models.
The role of warm extremes for triggering large slope failures in temperature-sensitive high mountains is primarily through the enhanced production of melt water from snow and ice, and rapid thaw processes, resulting in reduced slope strength. However it must also be considered within the local geological, glaciological and topographic context of a slope. Our studies indicate that large slope failures in high mountains may increase in the future with a higher number of warm extremes, which can have severe consequences for populated mountain regions.