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Recent high mountain rockfalls and warm daily temperature extremes

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Linkages between longer term warming of the climate, related changes in the cryosphere, and destabilisation of high mountain rockwalls have been documented in several studies. Although understanding is far from complete, a range of physical processes related to longer term warming are understood to have an effect on slope stability. More recently, some attention has turned to the possible influence of much shorter periods of extremely warm temperatures, as a contributing factor, or even trigger of slope failures. So far, studies have not extended beyond highlighting one or a few individual events, and no common approach to quantifying the 'extremity' of the prevailing temperatures has been used.

In the current study, we integrate established practices used in the climatology community in the analyses of climate extremes, together with an inventory of ca. 20 recent rock failures (1987 – 2010) in the central European Alps, to assess temporal relationships between daily air temperature extremes and rock failure occurrence. Using data from three high elevation recording sites across Switzerland, we focus on daily maximum temperatures in the 4 weeks immediately prior to each rockfall occurrence, where an extremely warm day is defined as exceeding the 95th percentile during the climatological reference period of 1971 – 2000. The 95th percentile is calculated in a 21 day moving window, so that extreme temperatures are considered relative to the time of year, and not on an annual basis. In addition, rock failures from the Southern Alps of New Zealand are analysed, although high elevation climate data are limited from this region.

Results from the European Alps show that a majority of recent slope failures have been preceded by one or more extreme, unseasonably warm days, most notably in the week immediately prior to the failure. For example, for 9 slope failures in the Valais – Mt Blanc region (based on Grand St Bernhard climate data), 6 were proceeded by extremely warm temperatures in the 7 days prior to failure, (between 6 - 9°C above average), and in three of these cases, temperatures exceeded even the 99th percentile. A further 3 events occurring in this region during the longer term heatwave of 2003 similarly were also preceded by extreme daily maximum temperatures. This relationship holds for other failures analysed in the northern, and eastern regions of the central Alps. Most interestingly, the weekly temperature anomaly, and the proportion of 'extreme' days, generally decreases as the analyses are extended from 1, 2, 3 and 4 weeks out from each failure. In other words, there is a notable warming, and conditions become increasingly extreme in the lead-up to slope failure.

In addition to extreme summer temperatures, our analyses points towards a possible role of unusually warm autumn and spring days influencing slope stability. A linkage between short term periods of extremely warm temperatures and rock failure may be reasonably facilitated through melt water operating within rock discontinues, processes that have recently been measured in high-mountain rock faces, and are considered to be particularly important in spring/early summer melt periods. It is not clear whether slope failures during warm autumn periods can be linked to the same processes. Rockfalls in the winter months remain rare, however, the 27 December 2011 rock avalanche at Piz Cengalo, Val Bregaglia, Switzerland (ca 2-3million m3), occurred following the warmest year on record, potentially reinforcing the role of longer term warming destabilising bedrock with permafrost at depth.