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Remobilization of Alpine Holocene debris fans: do climate change impacts increase debris flow hazards?

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Debris fans are a widespread landscape element across the Alps and many other alpine mountain regions. The fans are a result of mass movement, and in particular debris flow, activity during the Holocene. Geometry and sedimentology of many large fans suggest they were formed by repeated debris flows that were up to an order-of-magnitude larger than those observed today. Present-day debris flows typically deposit material on the fan. When the flows enter the fan, shear stresses are usually not high enough to erode any significant amounts of sediment of the fan. However, recently debris flow events have been observed in the Swiss Alps that developed sufficient erosive power to remobilize large sediment volumes on Holocene fans.
A model case is the 2005 debris flow in Guttannen, central Swiss Alps, which has been the largest event in Switzerland for about 20 years. From the total 500,000 m3 material ∼300,000 m3 were entrained on the fan, and thus, the debris flow magnitude was increased by a factor of more than 2 by erosion on the fan. The debris flow initiated in extensive sediment that was uncovered by the recession of Homad Glacier during the past decades. Permafrost contributed to hydrological conditions favoring rapid surface runoff. As observed with previous debris flows, glacier retreat since the Little Ice Age and associated uncovering of large amounts of sediment was an important factor for particularly large debris flows in the Alps. Here we hypothesize that such exposed, poorly consolidated sediment, that will be increased with future glacier recession and possibly from permafrost degradation, could facilitate the generation of large debris flows with little or no historical precedence. Such large debris flows could exceed a critical threshold of shear stress when entering Holocene fans, and transform the so far typical deposition-dominated into erosion-dominated flow.
Massive, unprecedented erosion on debris fans is likely to have important implications in terms of hazards and risks since debris volumes can be increased by a factor of 2 or more, as observed at Guttannen. Current numerical debris flow models can simulate erosion using parameterizations but reference case studies are needed to achieve reasonably realistic scenarios. Dendrogeomorphological studies from active debris flow fans in southern Switzerland provide evidence of several centuries of debris flow activity and related flow volumes, and are used here to study climate change – flow magnitude effects.