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Rapid topographic changes in a glacierised and permafrost-affected high-mountain flank caused by large slope failures

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In this study, slope instabilities and rapid topographic changes in a glacierised high-mountain flank with widespread permafrost occurrence are investigated with respect to the current climatic change. The study is conducted at the east face of Monte Rosa, one of the highest periglacial rock faces in the European Alps, where strongly increased rock and ice avalanche activity has been observed since around 1990. In a new approach for steep mountain faces we combine digital aerial-photogrammetry and airborne LIDAR for the generation of multi-temporal high-resolution digital terrain models (DTM). DTM comparisons reveal a total volume loss of more than 20×10^6 m^3 over the past 50 years including both bedrock and glacier ice, with the majority of the loss since the 1990's. Single large slope failures could be precisely quantified, such as an ice avalanche with a volume of more than 1×10^6 m^3 in 2005, and a rock avalanche of 0.3×10^6 m^3 in 2007.

Our study shows that changes in surface geometry and surface cover of the partially glacierised rock wall can be rapid, and vary considerably in process, magnitude and timing over the entire wall. The DTM comparisons and additional imagery analyses showed that the unstable areas and failure zones are strongly spatially connected and a strong slope stability coupling between permafrost bedrock and adjacent hanging glaciers exists.

Meteorological data were considered for the interpretation of observed mass movement activity. The coincidence of the begin of the intense terrain changes with increased mean annual temperatures around 1990 suggests an influence of the changes in thermal conditions and percolating meltwater on the stability of the steep glaciers as well as the bedrock. External factors such as climatic changes may trigger the onset of significant changes in ice and hydraulic properties. However, topographic change can lead subsequently to a self-reinforcing and irreversible process chain with increasing mass movement activity, potentially resulting in large-volume rock and ice avalanches, as observed in the Monte Rosa east face.