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On the influence of geological and cryospheric factors on slope instabilities in steep high-mountain flanks

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Slope stability of steep flanks in glacierised and permafrost-affected high-alpine regions is controlled by different factors, such as topography, geological-geotechnical conditions, hydrogeology, glaciation and permafrost. Changes in one or more factors may affect slope stability and eventually lead to rock fall events. Currently, cryospheric factors are most prone to changes. Based on the analysis of recent rock fall events, this study aims to provide new aspects for the understanding of the different factors and mechanisms which may affect the stability of high-mountain rock walls, especially in view of ongoing climatic change. The complexity of slope stability problems underlying high-mountain boundary conditions demands the implementation of multidisciplinary investigations and modelling methods.

We report on an integrated assessment of the detachment zones of several recent rock fall events. Detailed site investigations were combined with comprehensive statistical analyses of rock fall events. As a case study the Tschierva rock fall event was back-calculated by means of the discrete element method (UDEC). Different parameters of the detachment zone such as the topography, lithological, geomechanical and hydrology characteristics, as well as glaciation and permafrost occurrence were investigated based on scientific field data and from imagery or meteorological data. Results from the slope stability modelling show that the glacier retreat strongly influences the stress field and causes an opening of pre-existing discontinuities in the bedrock. A second case study was performed for the Monte Rosa east face. Besides highly specified field and imagery investigations, high-resolution DTMs from LiDAR and digital photogrammetry were developed for detailed investigations of long-term topographic changes in glaciation and bedrock within the past 50 years. The results revealed the significant influence of glacier retreat on slope stability and important feedback processes.

Complementary to the findings of these two case studies, a larger number of recent high-mountain rock fall events in the European Alps were analysed. A number of different data sets and investigation techniques such as DTM and imagery analyses, geological maps, on-site field investigations, permafrost modelling as well as numerical stability modelling techniques were considered and evaluated statistically. Based on this multidisciplinary approach, the influence of the different factors and processes on slope failure was assessed. The characteristics of investigated detachment zones can be compared qualitatively and statistically and allow first integral conclusions about the effect and importance of the different investigated parameters on slope instabilities.