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Debris-flow observations in the Zermatt Valley

Christoph Graf
Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Mountain Hydrology and Mass Movements, Birmensdorf, Switzerland (christoph.graf@wsl.ch)

In the Alps, a multitude of unstable slopes is located at altitudes of ~2700 m asl, where sediment transfers typically happen outside the range of humans or their infrastructure. The situation is slightly different in the Zermatt Valley, a high-elevation, north-south oriented glacial valley in the Swiss Alps, where the detachment of melting permafrost results in rock falls on steep slopes and debris flows in high-gradient gullies through which till is transferred directly to the inhabited valley floor at elevations between 1100 (N) and 1600 m asl (S). As a result of the excellent database on past disasters in the valley, recent developments and measurements in the local rock glacier bodies and current torrential events, I show data from some debris-flow torrents to document impacts of past, ongoing and possible future changes of debris flows originating from periglacial environments.

Debris flows are typically initiated by the abrupt input of considerable quantities of water. The water-saturated masses of fragmented rock and soil slump down mountainsides into gullies which in turn mobilize stored sediment in the channels. In addition to triggering by extreme rainstorms, debris flows have also been reported to be released by rapid snowmelt, rain-on-snow storms, or the sudden emptying of glacier water bodies or through the rupture of landslide dams. More frequently, debris flows occur as a result of high-intensity, convective rainstorms of short duration or low-intensity advective precipitation events over several days.

Displacement rates and instability of rock glaciers have increased further recently to show movement rates without historical precedents. At Grabengufer (Dorfbach) e.g., increasing air and ice temperatures have favoured the development of annual displacement rates from just a few decimetres in the past decades to 80 m in 2010. Similar behaviour was observed in catchments nearby. As a consequence of the enhanced movement of these permafrost bodies and related slide and fall processes, increasingly large amounts of loose sediment are delivered into debris-flow systems.

Extensive till, scree slopes and rock glaciers represent the principal and extensive sediment sources for debris flows which are commonly triggered at elevations between 2000 and 3000 m asl. Here, high annual and daily thermal ranges favour frost weathering and regolith production delivered to scree slopes. Slope angles in the initiation zones range from 27 to 41° and are dominated by permafrost in all of the catchments. Debris flows are triggered either through the wetting of material continuously delivered by the permafrost body to the channel or due to release at the rock glacier fronts during exceptional water input. The wetting typically occurs during rainstorms, but debris flows at these sites also happen when sediment shear resistance is reduced by the melting of ice particles, by snow melting and/or a combination of both.

In the Dorfbach torrent near Randa, WSL operates an automated debris-flow observation station, measuring the typical parameters such as flow heights and velocities since several years. As part of an interdisciplinary project on data acquisition and numerical modelling of debris flows for hazard mapping, we monitor several other debris-flow prone torrents in the valley and combine these data with observations of ongoing processes in the headwater of the catchments.

Several debris-flow events in some of the torrents could be observed and measured in the last years. Total volume, discharge per surge, frontal speed, run out length and impact on the inhabited fans varied considerably. Typically one first event cluster is dominated by snow melting controlled conditions starting late May until end of June and a second cluster are the rainstorm dominated events in midsummer. The largest events are expected in late summer or in fall, when long-lasting advective precipitation events over several days prevail.