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Sediment transfer and connectivity at the front of active rock glaciers

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The overall aim of this thesis is to study active rock glaciers as sediment sources for the torrential network systems of high alpine hillslopes. Active rock glaciers act as efficient sediment conveyors in periglacial mountain environments, transferring large quantities of debris from their rooting zone (upslope area) to their fronts. Active rock glacier fronts are typically steep, reach up to several tens of meters height and are composed of coarse elements (pebbles, boulders) embedded in a matrix of finer-grained debris. Because of instabilities induced by the motion of the landforms, active rock glacier fronts are expected to be frequently affected by sediment reworking processes. In some cases, mobilized debris can accumulate on subjacent slopes and gullies where they become available for further transport, for instance via debris flow events. Rock glaciers can thus represent important sources for torrential sediment transfer processes. However, still very little is known about the mechanisms governing the erosion of the fronts, and the transport of sediments downwards in the torrents. In addition, only several cases of rock glaciers connected to torrents have been observed but no regional scale inventory able to indicate the location and the number of such type of rock glacier exist. These questions are thus addressed in the present study with a particular focus on the understanding of the erosion and sediment transfer processes.

For that purpose, the sedimentary connection between rock glaciers and torrential channels was studied into more details at three study sites located in the western Swiss Alps, namely Dirru, Gugla and Tsarmine between 2013 and 2017. At each site, the occurrence of erosion and sediment transfer processes was observed by the means of in situ webcams and multi-temporal Digital Elevation Models (DEMs) were obtained using terrestrial laser scanning in order to identify and quantify sediment transfer activity and calculate sediment budgets and sediment transfer rates. In addition, an inventory of all catchments in which at least one rock glacier (or slope movement in general) is connected to the torrential network system was developed for a 2000 km^2 region in the south-western Swiss Alps.

The general results of this study indicate that only specific topographic conditions lead to the occurrence of a sedimentary connection between rock glaciers and torrential channels and appear to be relatively rare. When such type of configuration exists, typical sediment transfer rates between rock glacier fronts and torrents range from less than 100 m^3/y to more than 1000 m^3/y. Therefore, rock glaciers can in some cases act as substantial sediment sources for torrential transfer processes, leading to the transfer of large amounts of sediment within torrents. At the seasonal scale, the erosion of the fronts is mainly controlled by weather conditions, while at the inter-annual or pluri-annual scale, both weather conditions and the displacement rate of the landform represents the main controlling factors. In general, the erosion of the fronts leads to the recharge of torrential channels with sediments. The sediment transfer activity is continuous in time as the rock glacier motion is constantly bringing new sediments forward. The remobilization of these sediments by debris flows has been observed to be then strongly dependent on water availability. This research showed that better assessment of the potential frequency-magnitude of debris flow events asks for the identification and the characterization of such types of sedimentary connection. In addition, the most important site specific parameters to investigate are surface velocity, channel recharge rate and the potentiality for enhanced water availability in the torrent.

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