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Magnitude-frequency relationships of debris flows – a case study based on field surveys and tree-ring records

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Debris-flow activity within a given area can be defined in terms of magnitude and frequency. The assessment of occurrence probabilities and the quantification of sediment volumes transported by debris flows are not only of crucial importance for hazard and risk assessment, but also for land use planning and the design of torrent control. Although debris flows are recognized as a frequently occuring and destructive phenomenon, relatively few studies have addressed the magnitude–frequency aspects. In the Swiss Alps, records on pre-1987 debris flows are not readily available, resulting in very fragmentary data on return periods of debris flows and magnitude is specified insufficiently.

In an attempt to further the understanding of the magnitude–frequency relationships of debris flows, this contribution tries to shed light on 150 years of debris-flow activity on a cone in the Swiss Alps by coupling results from tree-ring analyses with ground survey data and meteorological records. The specific objectives of this study are to derive magnitude–frequency relationships of debris flows for a total of 63 events reconstructed on the intermediate cone of the Ritigraben torrent (Valais, Swiss Alps) for the period AD 1858–2008. Magnitudes are reconstructed via (i) a quantification of material deposited by past debris flows; (ii) an assessment of granulometry of deposits, the spatial spread of and tree removal by past incidences as well as via (iii) an identification of the amount and type of precipitation that have lead to the release of individual debris flows.

A large majority of the reconstructed events were either small- or medium-scale events with below-decadal return periods. While most of the material deposited during these incidences was left on the cone, more recent activity continuously overprint evidence of this order of magnitude. Large-scale events occurred every 10–20 years and deposits are more easily identified in the field. There is also evidence for very large events (15–20,000 m3) in 1922, 1948 and 1993. These events occurred during convective rainfall (> 100 mm over 3–5 days) in late summer and early fall, when large amounts of loose sediment were available from the active layer of the permafrost body located in the departure zone of the torrent. These XL events did not leave too many deposits on the cone either, but deeply scoured the debris-flow channel, resulting in larger magnitudes (probably > 50,000m3) at the confluence of the Ritigraben torrent with the receiving Mattervispa River. While the frequency of debris flows is expected to decrease in a future greenhouse climate, the magnitude of Ritigraben events could increase due to melting permafrost as well as a shift in the seasonality and in the intensity of heavy-precipitation events.