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Magnitude-frequency relations of debris-flows on cones: evidence from tree-ring records, field surveys and meteorological data

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Debris-flow activity in a watershed is usually defined in terms of magnitude and frequency. While magnitude-frequency (M–F) relations have long formed the basis for risk assessment and engineering design in hydrology and fluvial hydraulics, only fragmentary and insufficiently specified data for debris flows exists. This paper reconstructs M–F relationships of 62 debris flows for an aggradational cone of a small (< 5 km2), high elevation watershed in the Swiss Alps since A.D. 1863. The frequency of debris flows is obtained from tree-ring records. The magnitude of individual events is given as S, M, L, XL, and derived from volumetric data of deposits, grain size distributions of boulders, and a series of surrogates (snout elevations, tree survival, lateral spread of surges). Class S and M debris flows (< 5 $\times$ 103 m3) encompass a typical size of events and have mean recurrence intervals of 5.4 (SD: 3.2) and 7.4 years (SD: 6.7), respectively. Class XL events (104 – 5 $\times$ 104 m3) are, in contrast, only identified three times over the past 150 years, and major erosional activity on the cone was restricted to two of these events in 1948 and 1993. A comparison of results with hydrometeorological records shows that class L and XL events are typically triggered by advective storms (rainfall > 50 mm) in August and September, when the active layer of the rock glacier in the source area of debris flows is largest. Over the past $\sim$150 years, climate has exerted control on material released from the source area and prevented triggering of class XL events before 1922. With the projected climatic change, permafrost degradation and the potential increase in storm intensity are likely to produce "class XXL" events in the future with volumes surpassing 5 $\times$ 104 m3 at the level of the debris-flow cone.