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Hydro-meteorological conditions responsible for the triggering of past debris flows – a reconstruction dating back to 1864

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Through their unpredictable and sudden occurrence, debris flows represent a major hazard in many mountainous regions of the world. The understanding of the triggering factors of such events is crucial for hazard assessment, the forecasting of potential future events and for early warning systems. In the recent past, many studies have been published on debris-flow triggering, rainfall conditions, minimum thresholds, duration-intensity relationships or on antecedent moisture conditions. These studies were normally based on archival records or directly observed events and therefore often covered a rather limited temporal dimension.

In the study we present here, the definition of triggering rainfall events is based on an unusually dense database and dates back to 1864. The assessment is based on tree-ring derived database of debris flows for eight torrents, three meteorological stations and four river gauging stations located in the Zermatt valley, Swiss Alps. We report on the (i) timing and (ii) duration of precipitation events, (iii) the amount of rainfall involved, (iv) changes in the seasonality of events, (v) define minimum precipitation thresholds needed for the triggering of past debris-flow events, (vi) assess the percentage of rainfall events with certain thresholds leading to the triggering of a debris-flow event and (vii) explore the differences in characteristics between triggering and non-triggering rainfall events.

Results show that the debris-flow season at the study location lasts from May to October with August being the month with the highest occurrence of events (36%) whereas events in May and October remain very scarce with 4% and 7%, respectively. More than half of the events were triggered by short-duration, high intensity convective rainfalls lasting at a maximum one day and only 11.5% of the events were released after persistent advective rainfall of more than 2 days. Towards the end of the debris-flow season in September and October, the percentage of long-lasting rainfall events considerably increases as compared to the summer months of July and August when local thunderstorms seem to represent the main triggering factor. Total precipitations sums involved in the triggering range from below 20 mm for short-duration events to up over 50 mm on average for the long-lasting events and were generally lower for events during July and August than very early or late in the debris-flow season. Significant differences in the characteristics between triggering and non-triggering rainfall events since 1981 could be seen in the total amount of rainfall involved, storm duration and in temperature. In contrast, it seems that antecedent rainfall did not affect the release of events.

Results obtained on the timing, duration and the amount of rainfall involved in the triggering of debris flows can be transferred to future climate scenarios so as to identify the possible future occurrence of debris flows.