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Controls on sediment transfer and storage on debris flow fans

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Debris flows are important in transporting sediment from mountain slopes to valley floors. Debris flow fans are regarded as sediment traps, but often little is known about what proportion of the input at the fan apex is stored on the fan (the fan efficiency, e_f) or how individual debris flow volumes evolve via entrainment and deposition along the flow path. It is therefore crucial to investigate the controls on debris flow volume change along the whole flow path in order to understand the role that debris flows play within the integrated sediment routing system.

We present high spatial resolution data on the volume change of debris flows due to entrainment and deposition on the Illgraben fan, Switzerland. This fan has experienced 36 debris flows since June 2000, generally in response to summer (May–October) convective storms. We compare debris flow hydrographs from fan apex and fan toe with locally measured lag rates from terrestrial laser scanning (TLS) of a 300 m study reach for several of these events. Debris flow volumes are calculated from hydrographs measured by radar sensors, and flow velocity estimates are based on geophone measurements of flow front position. The debris flow lag rate is defined as the volume change per unit channel length. We present high-resolution (0.2 m grid) change maps from successive sets of TLS topographic data along the study reach. We use the change maps to derive reach-scale lag rates of single debris flow events by projecting the volume change onto a flow axis down the channel thalweg. We use video recordings of the flow fronts and recordings of geophones and radar sensors to investigate flow properties in two locations along the flow path.

The flow hydrograph data show that flow volumes can change by up to one order of magnitude between fan apex and fan toe. Both increasing and decreasing flow volumes are observed in different events moving through the same channel. Lag rates measured in the study reach with TLS data are generally comparable to the fan-scale lag rates in both sign and magnitude, indicating that volume exchange between channel and bed is typically fairly uniform down-fan in any given flow. Accordingly, flows of similar volume at the fan apex can evolve in a divergent manner, becoming significantly larger or smaller while crossing the fan surface. Because debris-flow hazard and depositional pattern are highly dependent on the degree of flow confinement within a channel, and in turn on the volume of individual flows, the results have important implications for the short- to medium-term evolution of fan systems, and can be used to inform how we manage debris flows on fan surfaces as hazards.