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Measurement of debris flow entrainment at the Illgraben torrent, Switzerland

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Debris flows often entrain significant amounts of sediment from the channel bed when flowing along a channel, sometimes substantially increasing their volume. This has important implications for hazard assessment and must also strongly influence the flow dynamics. Here we report on debris flow entrainment measurements from the Illgraben debris flow observation station in the Swiss Alps. The Illgraben catchment, which has been monitored for debris flows since 2000, is characterized by steep slopes, abundant sediment, and frequent debris flow activity. Our objective was to measure the timing and magnitude of erosion during debris flows and compare the observations with other measurements such as total normal and shear stress. Measurements during flood events were analyzed for comparison.

Five erosion sensor columns, developed for this project, were installed vertically and flush with the surface of the channel bed at the distal end of the torrent channel (slope 8 to 10%). The columns were arranged in a T-shaped pattern with a spacing of 2m in the downstream direction and 1m in the lateral direction. Each sensor column consisted of 20 5-cm long aluminium tube elements stacked in a column; each element contained a resistor and the total resistance of the column was logged outside of the channel. As a debris flow eroded one or more cells of a sensor column, the decrease in total resistance was measured, corresponding to the change in the length of the sensor column and therefore the depth of erosion. Additionally pore water pressure was measured at 1 and 1.2m depths close to the sensors columns. Automatically-triggered photogrammetric cameras were installed to relate the timing of eroded elements to the stage of a flow. Flow depth, total normal and shear stress were recorded at a large force plate on the channel bed at the observation station 80 m downstream and extrapolated to the erosion sensor site. Additionally, the changes of the channel bed after an event were surveyed.

Several debris flow and flood events occurred between June and August 2008. During flood events or hyperconcentrated flows, erosion occurred stepwise over several minutes. During the two debris flows, erosion was recorded at the front of the debris flow and within the first 10-20 seconds. The timing coincided with a short and intense increase in pore water pressure and with the maximum values for flow depth, shear and total normal stress. The occurrence of erosion at the debris flow front may be important in the dynamics of flow propagation because the sediment on the bed has to be detached and entrained into the flow, thereby extracting momentum from flow and decreasing the front velocity. The presence of debris flow erosion at only the debris flow front also suggests that the properties of the debris flow front (rather than the entire debris flow) should be considered for modelling bedrock erosion due to debris flows.