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What is the velocity profile of debris flows?

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The distribution of flow velocity within a debris flow is difficult to determine at full scale in the field due to the large forces and inherently destructive nature of the flow. However, knowledge of the distribution of velocity within a flow would be helpful to constrain rheological models and to better understand the internal dynamics of such flows. Here we describe recent efforts to determine the velocity of debris flows as a function of distance from the channel bed.

Measurements were made at the Illgraben, Switzerland, which exhibits a wide variety of flows, ranging from turbulent debris floods to flows which resemble laminar mud flows to more classical debris flows with a clear granular front. The Illgraben observation station is therefore an ideal location to investigate debris flow dynamics. Our measurements were made using sensors embedded on a 14 m long, 2.5 m tall steel-reinforced concrete wall constructed flush with the torrent channel walls. The main instrumentation consists of 18 geophones (10 Hz natural frequency) installed on square steel plates with a side length of 0.3 m. Each steel plate is acoustically isolated from the wall and the other plates through the use of elastomer elements. The geophone plates are arranged in six rows of three sensors with a dimension of 1.8 m in the vertical direction and 1.5 m in the horizontal direction (i.e. parallel to the flow direction). A sensorless plate separates each plate in the horizontal direction. The data are collected at 2 kHz using a high-speed (synchronous) capture card in a pc. The elevation of the flow surface is determined at a cross-stream distance 1 m away from the wall, using a laser sensor installed on a bridge above the wall.

We present a processing approach for the geophone data with the goal to track particle sliding across the sensor plates. For signals near or above the sensors' natural frequency (10 Hz), the measured time series are poorly correlated between sensors. Therefore, we use a cross-correlation scheme after calculating the signal envelope and low pass filtering it. In this sense, we do not target individual particle impacts. Rather, we measure debris flow velocities by tracking activity bursts across sensor triplets sharing the same height. Our method is therefore ideally applied to debris flows, whose geophone records show long-term modulations of signal amplitudes.

For certain debris flow records our procedure provides vertical flow velocity profiles. We compare these with independent measurements of debris flow front speeds and flow depths. Furthermore, we discuss important limitations of the shear wall set up. Specifically, the channel bed below the instruments is erodible and thus varying with time. Moreover, debris deposits near the channel wall may locally perturb the debris flow and thus divert it from the direction parallel to the channel centerline. Nevertheless, we believe that our vertical flow profile results are the first of their kind and shed light on the interior of a debris flow, which is usually shielded from direct observations.