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A comparison of laboratory and field observations of superelevation in debris flows

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Post-event estimation of debris-flow velocity is a central part of hazard analysis. Estimates of debris-flow velocity are useful for e.g. dimensioning mitigation measures, calibrating or testing debris-flow runout models, constructing intensity-based hazard maps, and designing warning systems. However independent field observations of velocity are rare and it is often necessary to indirectly estimate flow velocity. The difference in mud elevation on either side of a channel through a bend of a constant radius can be used to estimate the flow velocity using a vortex method developed for a Newtonian fluid. In 2015 we reported on the application of the vortex method to calculate the front velocity of debris flows in the laboratory (Scheidl et al., 2015). In the laboratory experiments, we found a statistically significant correction factor k for the application of the vortex equation to debris flows under supercritical flow conditions, with somewhat more scatter for subcritical flows. Nevertheless, it was possible to derive a forced-vortex equation, without a correction factor, after considering active and passive earth pressures within the flow. Herein, we compare the laboratory results with field data from the Illgraben and Schipfenbach torrents in Switzerland. Using video recordings and flow trajectory data for 17 debris flows at the Illgraben debris-flow observation station in Switzerland, we were able to independently test the application of the new forced vortex equation against field data. The general trend observed in the laboratory are confirmed using the field data: the correction factor k decreases with increasing Froude number of the flow. However the field data show a much larger degree of scatter in the vortex-equation correction factor in comparison with the laboratory data. The debris flows in the field differ from the laboratory channel in many ways. Although the observation section at the Illgraben was fairly uniform in terms of the surface width of the flow ($\sim$10 m) and radius of curvature (71 m), the local variability in both parameters is certainly larger than in the laboratory. The laboratory channel was a regular half-pipe with uniform roughness lining the channel bed. In the field the channel is approximately trapezoidal, with local topographic variability produced by the presence of bars and large boulders on the channel bed, which were observed to change between debris flows. Similarly, the local roughness within the channel, which locally influences the speed of the flow, is also spatially variable. Differences in the grain-size distribution among the debris flows in the field are almost certainly present, although field measurements of grain size are not available for every event. While it would have been possible to derive the relation of Scheidl et al. (2015) independently of the laboratory experiments, it would not have been possible to validate the method without high-quality laboratory data.