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Revealing controls for debris-flow erosion using a LiDAR-based geomorphic change detection and a calibrated numerical model

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Debris flows are destructive mass movements in steep channelised alpine torrents. They threaten economic goods and human lives due to their high velocities and impact pressures. To identify appropriate hazard zones and to analyze the associated risk, debris-flow volume and runout are a key requirement. However, quantitative controls of erosion and material entrainment of debris flows are still poorly understood.

In this study we reveal controls for debris-flow erosion derived from a calibrated numerical model and a LiDAR-recorded event in the German Alps. We detect erosion and deposition areas induced by a debris flow in June 2015 using pre-event airborne LiDAR data and post-event terrestrial laser scans. Errors were considered using a spatially variable threshold based on point density and slope maps of the DEMs. A numerical one-phase model (RAMMS Debris Flow) was calibrated with detailed field records including entrainment data along the flow path. We compare flow properties of the modelled debris flow to elevation changes deciphered by the LiDAR-based geomorphic change detection.

It shows that 9,550 ± 1,550 m^3 was eroded and 650 ± 150 m^3 was deposited in the channel during the event with highest erosion rates up to 5 m^3/m^2. The linear regression models, relating debris-flow erosion rates to momentum and shear stress, show an R^2 up to 68 %. Largest erosion values occurred at transitions from bedrock to loose debris causing excessive erosion up to 1 m^3/m^2.

The results contribute to better understand controls of debris-flow erosion and entrainment. A more reliable prediction of the volumetric debris-flow growth helps to anticipate debris-flow runout and potential risks in endangered areas.