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Comparison of field interpretations and numerical predictions of debris flow dynamics

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Numerical models of mass flow processes are a crucial tool for the understanding and management of risk to exposed populations and infrastructure. For effective use as a decision-making tool, the accuracy and limitations of these models need to be quantified. Current quantifications of model performance typically compare simulated deposits or flow outlines with observations (e.g. through a confusion matrix Bennett et al., 2013; Charbonnier et al., 2017). However, these methods conflate location and quantification error and are sensitive to map geometry. Comparisons to dynamic flow characteristics such as velocity or travel time are also needed to give confidence to hazard metrics estimated from simulated flow velocities. Field-based data at a level of accuracy suitable for comparison is also affected by limited acquisition, uncertainties and data assumptions. As a result, quantitative evaluations of model performance for real-world debris flows and their dynamics are rare.
In this study, we evaluate the performance of several debris flow numerical models using the 2012 debris flow from the Upper Te Maari crater, Tongariro Volcano. The Te Maari debris flow is reasonably well documented by aerial remote sensing (Hyperspectral imaging, LiDAR), seismic records and field investigations. Model performance in predicting static debris flow properties of flow outline and deposit depth are evaluated using fuzzy set theory and multiscale comparisons to identify the level of both location and quantification error. This performance is then evaluated in the context of the debris flow dynamics inferred from analytical run-up and superelevation estimates, seismic records and field observations. A lack of direct measurement and the unsteady, inhomogeneous and three-dimensional characteristics of debris flows complicates quantitative comparisons of debris flow dynamics. Instead, we qualitatively compare model performance during three stages of the debris flow: initiation, flow, and deposition; identifying key assumptions, deficiencies and differences between models. This approach establishes bounds of confidence in dynamic hazard predictions and is used to highlight current needs and limitations for quantitative evaluation of model performance in predicting debris flow dynamics.