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A model of lahars for hazard assessment

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Lahars are complex fluid flows exhibiting diverse characteristics. Despite substantial advancements gained through field observation and experimentation on large and small scales, the physical processes governing the dynamics of lahars is incompletely understood. Physics-based models of lahars have typically been developed with the aim of gaining quantitative understanding of the various physical processes governing lahar dynamics, and have yet to be widely applied as tools in hazard management. Here we present a new model of lahar dynamics developed explicitly to be used as a tool in hazard assessment. As such, our model includes only the dominant physical processes and adopts bold parameterizations. We adopt a shallow-water framework, and model the transport of a mixture of water with entrained solid material. The flow of the mixture is resisted by a basal stress whose form evolves with the composition of the flow. Erosion of the bed and deposition of the solid material alter the local topography that feeds back into the mobility of the flow. The predictions of the model are made under uncertainty, and the quantification of uncertainty is essential for making robust predictions. Uncertainty in model parameters can be readily propagated through the model, and the uncertainty due to interpolation of coarse topographic data incorporated. Structural uncertainty arising from the neglect of processes known to occur in lahars from our simple model can also be characterized and incorporated into the overall model uncertainty. We discuss the use of uncertainty quantified as part of model calibration as method for incorporating uncertainty estimates into rapid hazard assessments. We demonstrate the calibration of our lahar model using field observations and reconstructed hydrographs for recent secondary lahars on Tungurahua and Cotopaxi volcanoes in Ecuador.