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The influence of rheology on the interaction of lava flows with obstacles

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Lava flows present a serious hazard to infrastructure in volcanic regions. Lava flows commonly interact with obstacles on the order of flow thickness or taller, including natural obstacles such as bounding faults, channel banks, past flow edges, and human-constructed buildings and diversion structures. When lava flows interact with obstacles, their advance velocity, width, thickness, and topology (split/merge) changes. We investigate this interaction using analogue fluid experiments and numerical models. Our fluid experiments use a Newtonian viscous fluid (sugar syrup), a solidifying fluid (polyethylene glycol, PEG), and molten basalt with temperature-dependent viscosity. All materials interact with upslope-pointing triangular obstacles, with varying head angles. All our experiments show an increase in the thickening of the flow directly upslope of the obstacle relative to the steady-state thickness (?H), and a slower advance rate after hitting the obstacle. The material type influences the magnitude of this relationship: Experiments using the Newtonian fluid reveal a linear relationship between obstacle angle and ?H/V^0.69 (V is the pre-obstacle flow velocity). For PEG, in contrast, ?H/V^0.69 keeps an almost constant value regardless of obstacle angle. In addition, PEG flows reach a constant finite flow width, while flows of syrup and molten basalt widen over time, as expected for Newtonian fluids. The experimental observations provide an excellent dataset for testing numerical codes that simulate lava flow emplacement. We simulate the experiments using a set of existing flow codes, ranging in their assumptions and dimensionality. By comparing the accuracy of the simulation and the computational cost between codes, we highlight the pros and cons of different simulation approaches. We find that more complex (and thus slower) codes are required to accurately model flow thickening behind obstacles, while simpler codes are sufficient to model flow advance rate, width, and length.