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Numerical modelling of surge-derived pyroclastic flows (25 June 1997) at Soufriere Hills Volcano, Montserrat

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Deposits from ash-cloud surges associated with dome-collapse block-and-ash flows can, under some conditions, be immediately remobilized to form dense, surge-derived pyroclastic flows (SDPF). SDPFs, such as that generated on 25 June 1997 at Soufrière Hills, Montserrat, are hazardous because they are very mobile and can follow drainages different from those affected by the block-and-ash flows. Their formation represents a key process for the understanding of the physical behavior of pyroclastic density currents.
We investigate by numerical modelling the conditions that favor the generation of SDPFs during dome-collapse events. We have developed a new version of the numerical model VolcFlow that simulates both components of a pyroclastic density current: the basal avalanche (block-and-ash flows) and the overriding ash-cloud surge. In the model, mass transfer into the ash cloud surge is caused by particle entrainment from the basal avalanche, while particle sedimentation from the ash cloud transfers mass in the opposite sense. The dense pyroclastic flows, i.e. block-and-ash flows, SDPFs and deposits, are assumed to have the same bulk rheology, that is simulated using rheological laws already proposed by previous workers: plastic rheology, frictional rheology, and frictional with variable friction coefficient rheology. If a yield criterion is exceeded (critical thickness or critical slope, depending on the rheology), the mass sedimented by the surge is remobilized and amalgamates to form a SDPF.
Source conditions and quantitative parameters of the model are extracted from field studies. Rheological parameters that govern each rheological law are estimated by trial and error, as well as empirical parameters that govern entrainment from the block-and-ash flow into the overriding ash cloud surge.
For the 25 June 1997 dome collapse at Soufrière Hills, our best-fit simulation successfully reproduces the dynamics of the block-and-ash flow, the ash-cloud surge, and the SDPFs, as well as the distribution of their respective deposits.
The model shows that SDPFs may commonly form during pyroclastic eruptions, but are difficult to distinguish from the associated surge deposits. They are particularly visible in 1997 at Montserrat due to a combination of the following factors: first, a bend of the Mosquito Ghaut valley that allowed the ash-cloud surge to detach and to sediment on steep slopes ; second, a surge deposit thick enough to be remobilized ; and third, a network of tributaries that drain all the remobilized mass into the Dyer' River valley, far outside of the Mosquito Ghaut valley affected by the surge and the primary flow.