A quantitative approach for evaluating lava flow simulation reliability: the LavaSIM code applied to the 2001 Etna's eruption

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Many numerical codes have been developed to simulate the emplacement of lava flows for evaluating their possible evolutions and for defining, by a statistical approach, hazard maps useful for risk assessment and land planning. Although many examples of lava flow simulation can be found in literature, just a few of them attempted to quantify the correspondence between observed and simulated flows, nevertheless this is a crucial point especially if the codes are applied in real-time for risk managing.
The aim of this work was to define a methodology to quantitatively evaluate the reliability of simulation codes. In particular, it applied the LavaSIM code (Hidaka et al., 2005) to simulate the main lava flow emplaced on the South flank of Mt. Etna (Italy) between 18 July and 9 August 2001 which represents an ideal test case for validating numerical codes (Coltelli et al., 2007). It is a single flow both for its geometry and its temporal evolution and, many data are available to be used as input of the simulations (lava composition, pre- and post-eruption topographies, final flow volume and thickness and temporal evolution of average volumetric flow rates) and for checking their results (2D temporal evolution).
LavaSIM is the only full 3D model, thus able to account for the vertical variation of lava properties (temperature, viscosity, velocity and liquidus or solidus state). It is based on the 3D solution of the Navier-Stokes and the energy conservation equations and provides the most complete description of the lava cooling by considering radiation, conduction and convection. Its greatest peculiarity is to take into account crust formation by evaluating the enthalpy of every cell and by adopting an empiric threshold parameter (the solidification fraction of liquidity loss) to discriminate liquid and solid cells.
Different values of input parameters (viscosity, solidification fraction of liquidity loss, eruptive enthalpy and lava emissivity) have been adopted for evaluating their influence on the simulated lava distribution and cooling. A simulation with constant lava discharge, averaged on the whole eruption, was also run for checking how the feeding affects the lava spreading and cooling.
The results were first analyzed by comparing the planar expansions of real and simulated flows. A quantitative analysis was then carried out adopting two parameters for constraining both the lengthening and the planar expansion. For quantitatively verifying the correspondence between simulated and observed lengths, the Percent Length Ratio (PLR) was defined as the percentage ratio between simulated and observed lengths measured along the main flow direction. The second control parameter was the fitness function (e_1) defined by Spataro et al. (2004) as the square root of the ratio between the intersection and the union of real and simulated areas. Since the e_1 factor allows quantifying the simulated lateral spreading while PLR the flow lengthening, it is important to jointly analyze these two parameters.
This work showed that by combining the fitness function of Spataro et al. (2004) with the Percent Length Ratio, here defined, it is possible to constrain both the lateral spreading (by e_1) and the flow lengthening (by the PLR). The analysis here presented also demonstrated the capability of the LavaSIM simulation code to account for the vertical variation of the lava properties and to simulate the crust formation.

References

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