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Can we model lava flows faster than real-time to assist on a first volcanic emergency response?

Carlos Paredes[1], Marcos David Márquez[1], and Miguel Llorente[2]
[1]Universidad Politécnica de Madrid, School of Mines and Energy, Dpt. Geological & Mining Engineering, Spain (carlos.paredes@upm.es)
[2]Department of Geological Risks and Climate Change, Spanish Geological Survey (Centro Nacional Instituto Geológico y Minero de España, IGME) Consejo Superior de Investigaciones Científicas, CSIC (m.llorente@igme.es)

Remote sensing data and numerical simulation models of lava flows have been combined to assess the possibility of rapid, real-time response during the effusive crisis of the recent Cumbre Vieja (Sep 19 - December 13, 2021) eruptive episode. Here, we use the monitoring products openly distributed by COPERNICUS through the Emergency Management Service (EMSR546) and by the Cabildo Insular de la Palma (daily-updated polygons of the extent of the lava flow) and the lava flow emplacement as simulated with VolcFlow, during the first seven days of the eruption, and supported by the location of the effusive foci provided by the IGN. The morphometric analysis of the satellite data has allowed us to estimate, assuming a non-Newtonian behaviour of the lava, the flows emitted, and their viscosities, using expressions based on the morphological dimensions, their advancing speed, and their density. The morphometric values thus obtained have been used as initial conditions for the numerical calibration, which has been done by minimising the Jaccard coefficient used as the objective function, but other geometric measures can be used as functionals to be minimised. Although we have designed and presented a task flow as a procedure to perform a dynamic numerical semiautomatic calibration over time of the rheological parameters necessary to simulate the day-to-day evolution of the lava flooding zone, based on the remote information recorded, for its validation we have carried out the search for the solution to the optimisation problem manually.

The results have allowed us to obtain a Jaccard coefficient between 85% and 60% with a calculation time, including calibration, of less than 7 days of simulated lava flow. Also, an emission rate of about 140 m^3/s of lava flow has been estimated, during the first 24 h of the eruptive process, which decreased asymptotically to 60 m^3/s. This value can be cross-checked with information from other remote sources using TADR. Viscosity varied from 8×10^6 Pa s, or a yield strength of 42×10^3 Pa, in the first hours, to 4×10^7 Pa s and 35×10^3 Pa, respectively, during the remainder of the seven days. In addition, the modelling allowed mapping the likely evolution of the lava flow fields until 27 September, with an acceptable lava height distribution for the highest values and a Jaccard coefficient of 85%, in order to determine the behaviour of the available response time, according to the computational cost, for the numerical estimation of the rheology and to generate real-time forecasts of the evolution.

This integration of satellite data with numerical model calibration for parametric estimation of the La Palma 2021 eruption holds great promise for providing a real-time response system to other

future volcanic eruptions and providing the necessary information, mainly in the form of dynamic evolution maps, for efficient emergency preparedness and management.