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The DOWNFLOW code for lava flow hazard mapping, with applications to the volcanoes Etna, Nyiragongo, and Cameroon

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Lava flows are a constant menace at many effusive volcanoes in the world, threatening the human settlements located on the fertile volcano flanks, and in many cases, large cities directly constructed on ancient lava fields. The case of the January 2002 fissure eruption of Mount Nyiragongo, when the city of Goma, about 500,000 inhabitants, was largely destroyed by the lava, stands as a vivid last reminder of the need for adequate urban planning at cities on effusive volcanoes. Several attempts are being done in order to map the hazard by lava flows, making large use of computational modelling resources. While the understanding of the dynamics of lava flows requires the development of increasingly sophisticated models, we show here that a simpler approach based on the probabilistic prediction of possible lava flow paths should be preferred when the aim is that of forecasting the volcanic hazard. The DOWNFLOW code presented here is based on an evolution of the steepest descent path concept, that is modified by including random perturbations in the topography to account for the capability of lava flows to surmount obstacles, fill depressions, and spread over the topography. With only two parameters that must be calibrated through comparison with real lava flows at a given volcano, we demonstrate through applications to the volcanoes Etna, Nyiragongo, and Cameroon, that the code can be used for detailed mapping of the lava flow hazard, as well as to evaluate the feasibility and effectiveness of artificial barriers in protecting sensible areas, identify the areas on the volcano flanks where venting would result in direct menace to any specific interest area, predict in real time the areas threatened by lava flows originating from any specific vent, and for several other applications in volcanic hazard. Specific analysis shows further the robustness of the predictions with comparison to real cases characterized by considerable differences in eruption parameters including mass flow-rate, substantiating the conclusion that lava flow hazard mapping is best assessed with simpler modelling that can be extensively used for probabilistic analysis.