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The lava flow invasion hazard map at Mount Etna and methods for its dynamic update

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PREFACE

This special issue of Annals of Geophysics contains seventeen peer-reviewed papers that cover a wide variety of topics related to the V3-LAVA Project funded by the Italian Dipartimento della Protezione Civile in the framework of the 2007–2009 Agreement with the Istituto Nazionale di Geofisica e Vulcanologia (INGV). The frequent eruptions of Mount Etna can produce lava flows that can cover distances long enough to invade vulnerable areas on the flanks of the volcano. These require improvements to our forecasting tools for the effective assessment of lava-flow hazards, to help the local authorities to make the necessary decisions during a volcanic eruption. The LAVA Project aims to develop, validate and unify methods for mapping the areas around Etna that are threatened by lava invasion within the next 50 years, and also within the immediate days after an eruption has begun. Both timescales of lava-hazard mapping call for estimations of the probabilities of vent openings – using geological evidence over the long-term, and monitoring data over the short-term. The application of numerical models to the simulation of lava-flow paths represents the central part of the extensive methodology for long-term hazard assessment at Etna. These numerical simulations of lava-flow paths are based on our knowledge of past Etnean eruptions, and are derived from the integration of historical and geological data, and from adopting an updated digital representation of the topography on which the lava flow will be emplaced. The short-term maps are dynamic instruments that can be rapidly modified by consideration of the signals collected by the monitoring networks, the temporal evolution of the eruption, and the weighted opinions of the experts. Probabilities of vent opening can be estimated using a Bayesian approach and expert elicitation (BET-EF). Once vents are assumed (or known), three flow models for simulating lava paths have been compared – DOWNFLOW, SCIARA and MAGFLOW. A fourth modeling approach, known as Smoothed Particle Hydrodynamics, has also been introduced. Its implementation on graphic processing units poses significant mathematical and computer-science challenges. It is not yet ready for side-by-side comparisons with the three other models, but the method has gained much favor in other applications, and it will probably be competitive in the not-too-distant future.

Since physics-based models to simulate lava-flow paths require their effusion rates as an essential input parameter for real-time scenarios, much effort has also been applied to the estimation of effusion rates in real time. The primary tools are infrared remote sensing (SEVIRI, AVHRR and MODIS, with SEVIRI providing the best time resolution, and MODIS the best spatial resolution). Satellite techniques are focused on hot-spot detection and effusion-rate estimation, to drive numerical simulations of lava-flow paths during ongoing eruptive events. The various images are compiled in the LAV@HAZARD web-GIS framework, from which information can be fed directly into MAGFLOW, and presumably into other models as well. As satellite-derived lava eruption rates can be obtained in real time and simulations of several days of eruption can be calculated in a few minutes, such a combined approach has the potential to provide timely predictions of areas likely to be inundated with lava, which can be updated in response to changes in the eruption conditions. The interactive capability of this architecture appears to be excellent – indeed, it is leading the way in dynamic hazard mapping.

In summary, we believe that the LAVA Project has made major progress towards reliable long-term and short-term lava-hazard maps. All of the methods in this project – for the estimation of vent-opening probabilities, effusion rates, and flow scenarios – will undoubtedly continue to evolve. However, they are already useable and are providing a great service to the population around Mount Etna. Many parts of the LAVA Project are at the cutting edge of volcanology worldwide. It is an outstanding project, and we thank and congratulate all of the contributors.

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