NEAR REAL TIME FORECASTING OF LAVA FLOW PATHS USING MAGFLOW MODELDRIVEN BY THERMAL SATELLITE DATA

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1. INTRODUCTION

Timely predictions of the areas likely to be inundated by lava flows are of major interest to hazard managers during a volcanic eruption. To this aim several models have been developed, which deal with various aspects of flow emplacement and cooling. That challenge has inspired the INGV-CT to develop the MAGFLOW Cellular Automata model to simulate lava flows [6]. It is based on a steady state solution of the Navier-Stokes equations coupled with a heat transfer model that takes into account radiative heat losses [1, 4]. The effects of core cooling on flow rheology are modeled via the temperature-dependent viscosity model, derived for Etna. MAGFLOW was applied with satisfactory results to simulate flow fields formed during the 2001 and 2004 eruptions at Mt Etna, Sicily [1, 4, 6]. For a given composition, the volumetric flux of lava from the vent (i.e. the lava discharge rate) is the principal parameter controlling final flow dimensions [3]. Direct field measurements of lava discharge rate can be made. However, in most situations, measurements, especially regular measurements, are difficult-to-impossible due to safety and logistical reasons. For example, during the early phases of an eruption, lava flows spread at high velocities, and explosions, fountaining and lava spattering may occur at the master vent, making close approach to the master channel hazardous and discharge rate measurement unsafe.

The timely and synoptic view afforded by satellite-based sensors can be used to estimate time-averaged discharge rate throughout an eruption [2,4]. To this end, we have developed a software tool that uses near-real-time infrared satellite data acquired by different sensors (MODIS and SEVIRI) to estimate discharge rates. These time-varying discharge rates are then used to drive MAGFLOW simulations to chart the spread of lava as a function of time. We tested our thermal monitoring system (Fig. 1) on Etna volcano during the first 40 days of May 2008 eruption. The good agreement between simulated and mapped flow areas indicates that model-based inundation predictions, driven by time-varying discharge rate data, provide an excellent means for assessing the hazard posed by on-going effusive eruptions.

2. MODEL RESULTS AND DISCUSSION

Etna's 2008 eruption provided the opportunity to verify the performance of the whole monitoring system, as proposed in this paper. The eruption started on the morning of 13 May 2008 and it still going on. After a seismic swarm of more than 200 earthquakes and significant ground deformation an eruptive fissure opened in the summit area immediately to the east of Etna's summit craters. On the afternoon of the same day, a new eruptive fissure opened with a number of vents displaying Strombolian activity and emission of lava flows toward the Valle del Bove (a wide depression that cuts the eastern flank of the volcanic edifice). An helicopter survey carried out on 14 May at 13:00 (local time) showed the two eruptive fissures: a first one opened on the east of the summit craters (3000 m asl) spreading along North-South direction, and a second fissure started from the east flank of South-East Crater summit cone of Mt Etna (2900- 2500 m asl) spreading with ENE-WSW orientation toward the Valle del Bove. During the following 24 hours the lava traveled approximately 6 km to the east, but thereafter its advance slowed and stopped, the most distant lava fronts stagnating about 3 km from the nearest village, Milo. Between 16 and 18 May, ash emissions became more frequent and produced small but spectacular clouds, whereas the rate of lava emission showed a gradual diminution. During late May and the first week of June, the activity continued at low levels, with lava flows advancing only a few hundred meters. On 8 June, there was a considerable increase in the vigor of Strombolian activity and lava output rate. During the following week, lava flows advanced up to 5 km from the source vents. Thermal anomalies have been observed by MODIS and SEVIRI since 13 May with an evident increase in the number of detected hotspots and almost continuously over the Mt Etna flank for the whole studied period. In particular, the opening of the new fissure with a consequent lava effusion has been clearly confirmed by a strong increase of number of detected hotspots over the volcanic area.

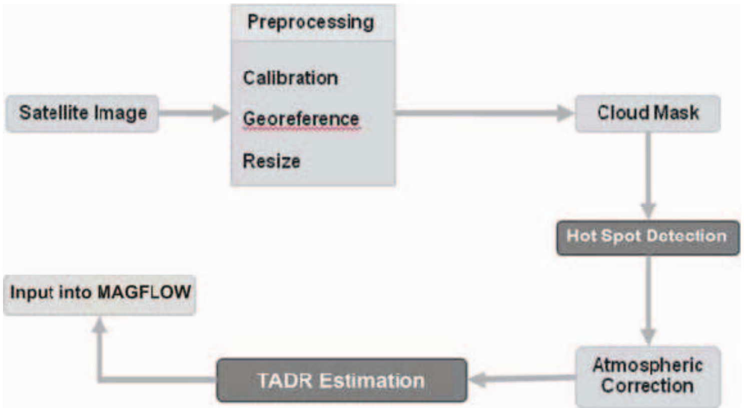

Fig. 1: Flow diagram illustrating the operations of the automated system to detect thermal anomalies and to compute discharge rate

For each hot pixel detected, the thermal analysis is carried out to give an estimate of the area and radiated heat flux of the thermal feature contained within the pixel. To achieve this aim, we assume a three component thermal surface within the pixel, and fixing reasonable bounds on the temperature of the lava crust, cracks and ambient background. The total thermal flux measured using satellite infrared data can be converted to time-averaged discharge rate (TADR) at the time the image data were collected, by using:

$$TADR = \frac{Q_{TOT}}{\rho\left(C_p \Delta \mathrm{T} + \mathrm{C_L} + \Delta\phi\right)}$$

where Q_{tot} is the total thermal flux, ρ is the lava density, C_p is the specific heat capacity, ΔT is the eruption temperature minus solidus temperature, C_L is the latent heat of crystallization, and ΔΦ is the volume percent of crystals that form while cooling through ΔT [5].

These time-varying discharge rates were used to drive lava flow simulations using the MAGFLOW cellular automata algorithm. We simulated step-by-step the whole effusive activity, during the period of 13 May – 21 June 2008, produced by two vents opened on 13 May on the eastern part of the summit craters. The simulated scenario well reproduces the observed lava flow field.

3. REFERENCES

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