Field data, numerical simulations and probability analyses to assess lava flow hazards at Mount Etna

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Supplementary Information to the EtnaHazard.kmz file

The EtnaHazard.kmz file contains the geological data (location coordinates are in decimal degrees) and hazard maps presented in Del Negro et al. (2013). While traditional maps are static, Google Earth provides a dynamic interface in which the users can interact and explore the different layers included in each map.
To access data and maps on your PC, please download and click on the EtnaHazard.kmz file, and it will automatically open to Google Earth. Once Google Earth starts, click the checkbox to select and navigate through the many layers of each map:

1) Volcano-tectonic data, containing dykes, faults, pre-1600 eruptive fissures and post-1600 eruptive fissures. These latter can be clicked both from the left panel and the map to view information regarding the corresponding eruption.
2) Vent opening probability map, one for flank eruptions and one for the summit eruptive activity;
3) Lava flow hazard map, one for flank eruptions and one for the summit eruptive activity. These maps are extremely dynamic, since it is possible to see them both as a whole and as single layers of probability of inundation by lava flows, by selecting each level individually in the left panel.

Supplementary Information to the EtnaFlank.dat file

The EtnaFlank.dat file contains all flank eruptions occurring between 1610 and 2012 at Mt. Etna, which were considered to classify the expected eruptions for the flank eruptive activity. For each lava flow field, we collected the main quantitative volcanological data, concerning the eruption onset and duration, the lava volume emitted, the Mean Output Rate (MOR), the area covered by flows, and the fissure producing the lava flow [Behncke et al., 2005; Vicari et al., 2007; Del Negro et al., 2008; Hérault et al., 2009; Neri et al., 2011; Cappello et al., 2012; 2013; Ganci et al., 2012b] .

From an accurate analysis of the distribution of flow durations and lava volumes, we selected a time barrier at 30 days and two divisions for the total volume emitted, at 30 and 100 × 10^6 m^3 (Figure 1). Thus we obtained six eruptive classes, five of which are populated (Table 1).

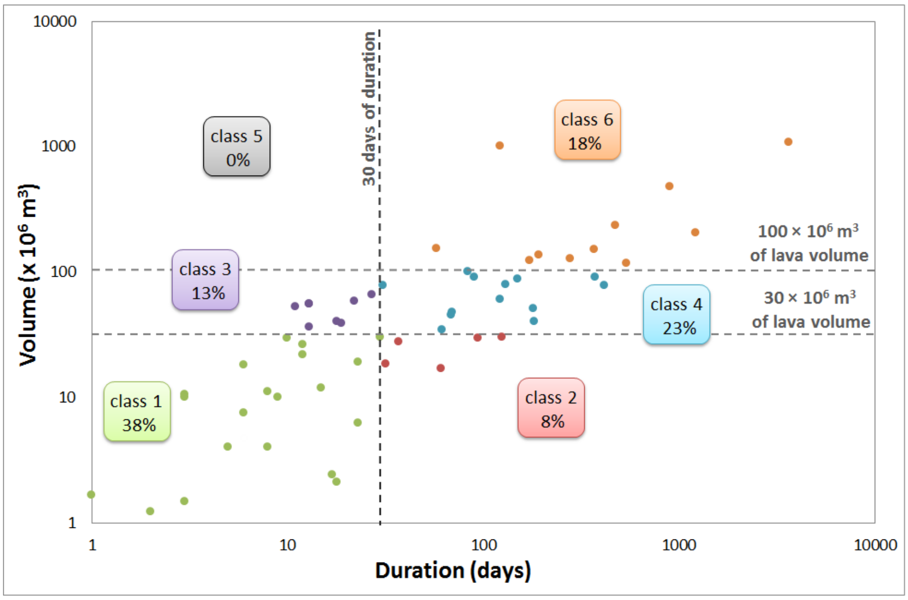

Figure 1 – The six eruptive classes obtained by analysing duration and lava volume of eruptions at Etna volcano in the last 400 years. The dashed vertical line suggests the time barrier (30 days) for duration, while the two dashed horizontal lines show the lava volume divisions (30 and 100 x 10^6 m^3). The percentage of occurrence for each eruptive class is also reported.

Lava volume (× 10^6 m^3)	**Duration (days)**	
	[<= 30]	**[> 30]**
[< 30]	Class I (38%) MOR ≈ 15 m^3s^{-1}	Class II (8%) MOR ≈ 5 m^3s^{-1}
[30 – 100]	Class III (13%) MOR ≈ 31 m^3s^{-1}	Class IV (23%) MOR ≈ 8 m^3s^{-1}
[> 100]	Class V (0%)	Class VI (18%) MOR ≈ 16 m^3s^{-1}

Table 1 – Classification on durations and lava volumes of flank eruptions occurring at Etna from 1610 to 2012. The MOR is calculated as the final volume of erupted lava divided by total eruption duration.

Supplementary Information to the EtnaSummit.dat file

The EtnaSummit.dat file contains the paroxysmal events and Strombolian activity at the summit craters of Mt. Etna between 1955 and 2102. For each eruptive event, we provide the eruption onset and duration, the lava volume emitted, the summit crater producing the eruption (Central Crater – CC; North-East Crater – NEC; Voragine – VOR; South-East Crater – SEC), and the MOR. Using the flow duration/lava volume distributions, we identified ten classes of expected eruptions for the summit eruptive activity of Mt. Etna.
For the paroxysmal events, we considered lava flows and lava fountains occurring at VOR and SEC [Behncke et al., 2005; Vicari et al., 2011; Ganci et al., 2012a]. We established three different duration intervals (<4, 4–8 and >8 hours), and emitted lava volumes (<1, 1–2 and >2 × 10^6 m^3), resulting in nine possible eruptive classes (Classes I–IX). The last class of expected eruptions (Class X) was identified on the basis of Strombolian activity from 1955 to 1996 (Table 2).

Lava volume (× 10^6 m^3)	**Duration (hours)**			
	[< 4]	**[4 – 8]**	**[> 8]**	**[> 300]**
[< 1]	Class I (54%) MOR ≈ 68 m^3s^{-1}	Class II (5%) MOR ≈ 27 m^3s^{-1}	Class III (18%) MOR ≈ 13 m^3s^{-1}	
[1 – 2]	Class IV (3%) MOR ≈ 136 m^3s^{-1}	Class V (5%) MOR ≈ 94 m^3s^{-1}	Class VI (3%) MOR ≈ 38 m^3s^{-1}	Class X (7%) MOR ≈ 0.5 m^3s^{-1}
[> 2]	Class VII (2%) MOR ≈ 185 m^3s^{-1}	Class VIII (3%) MOR ≈ 164 m^3s^{-1}	Class IX (2%) MOR ≈ 35 m^3s^{-1}	

Table 2 – Classification on durations and lava volumes of paroxysmal events and Strombolian activities occurring at Etna's summit craters from 1955 to 2012. The Mean Output Rate (MOR) is calculated as the final volume of erupted lava divided by total eruption duration.

References

Behncke, B., Neri, M. & Nagay, A. Lava flow hazard at Mount Etna (Italy): New data from a GIS-based study. in Kinematics and dynamics of lava flows, edited by M. Manga and G. Ventura, Spec. Pap. Geol. Soc. Am. 396, 189–208 (2005).

Cappello, A., Neri, M., Acocella, V., Gallo, G., Vicari, A. & Del Negro, C. Spatial vent opening probability map of Mt. Etna volcano (Sicily, Italy). Bull. Volcanol. 74, 2083–2094, doi:10.1007/s00445-012-0647-4 (2012).

Cappello, A., Bilotta, G., Neri, M. & Del Negro, C. Probabilistic modelling of future volcanic eruptions at Mount Etna. J. Geophys. Res. Solid Earth 118, 1925–1935 doi:10.1002/jgrb.50190 (2013).

Del Negro, C., Cappello, A., Neri, M., Bilotta, G., Hérault, A. & Ganci, G. (2013). Lava flow hazards at Mount Etna: constraints imposed by eruptive history and numerical simulations, Sci. Rep., doi: 10.1038/srep03493.

Del Negro, C., Fortuna, L., Herault, A. & Vicari, A. Simulations of the 2004 lava flow at Etna volcano by the MAGFLOW cellular automata model. Bull. Volcanol. 70, 805–812, doi:10.1007/s00445-007-0168-8 (2008).

Ganci, G., Harris, A. J. L., Del Negro, C., Guehenneux, Y., Cappello, A., Labazuy, P., Calvari, S. & Gouhier, M. A year of lava fountaining at Etna: volumes from SEVIRI. Geophys. Res. Lett. 39, L06305, doi:10.1029/2012GL051026 (2012a).

Ganci, G., Vicari, A., Cappello, A. & Del Negro, C. An emergent strategy for volcano hazard assessment: From thermal satellite monitoring to lava flow modeling. Rem. Sens. Environ. 119, 197–207 doi:10.1016/j.rse.2011.12.021 (2012b).

Hérault, A., Vicari, A., Ciraudo, A. & Del Negro, C. Forecasting lava flow hazards during the 2006 Etna eruption: Using the MAGFLOW cellular automata model. Comput. Geosci. 35 (5), 1050–1060 doi:10.1016/j.cageo.2007.10.008 (2009).

Neri, M., Acocella, V., Behncke, B., Giammanco, S., Mazzarini, F. & Rust, D. Structural analysis of the eruptive fissures at Mount Etna (Italy). Ann. Geophys. 54(5), 464–479, doi:10.4401/ag-5332 (2011).

Vicari, A., Herault, A., Del Negro, C., Coltelli, M., Marsella, M. & Proietti, C. Modeling of the 2001 lava flow at Etna volcano by a cellular automata approach. Env. Mod. Soft. 22, 1465–1471, doi:10.1016/j.envsoft.2006.10.005 (2007).

Vicari, A., Ganci, G., Behncke, B., Cappello, A., Neri, M. & Del Negro, C. Near-real-time forecasting of lava flow hazards during the 12–13 January 2011 Etna eruption. Geophys. Res. Lett. 38, L13317, doi:10.1029/2011GL047545 (2011).