THE CHRISTMAS 2018 ETNA ERUPTION: REAL TIME MONITORING USING GEOSTATIONARY AND POLAR ORBIT SATELLITES SYSTEMS AND PRODUCTS VALIDATION

Corradini S.(1), Guerrieri L.(1), Stelitano D.(1), Merucci L.(1), Salerno G.(2), Scollo S.(2), Picchiani M.(3), Theys N.(4)
Lombardo V.(1), Silvestri M.(1), Musacchio M.(1), Caltabiano, T. (2), Prestifilippo M.(2)

(1) Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Nazionale Terremoti, via di Vigna Murata 605, 00143 Rome, Italy
(2) Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Piazza Roma 2, 95125 Catania, Italy
(3) GEO-K s.r.l., University of Rome Tor Vergata Via del Politecnico 1, 00133 Rome, Italy
(4) Belgian Institute for Space Aeronomy (BIRA-IASB), Ringlaan-3-Avenue Circulaire B-1180 Brussels, Belgium

ABSTRACT

In this work data observed by the geostationary MSG-SEVIRI and the polar NASA-Terra/Aqua-MODIS orbiting satellite instruments, have been used for the proximal and distal monitoring of the 24-30 December 2018 Etna eruption. The combined use of the SEVIRI high repetition time and the MODIS high spatial resolution allows a reliable near real time volcanic characterization from the source to the atmosphere. For the proximal monitoring the parameters estimated are the eruption starts and duration and the volcanic plume top height, while the distal monitoring was inverted relying on the determination of the volcanic cloud altitude and the ash/SO_2 retrievals. Achieved products were validated by comparing these results with those observed remotely by ground based networks.

Results obtained in this study show the ability of satellite-based systems to entirely follow eruptive events in near real time, offering a powerful tool to mitigate volcanic risk on both local population and airspace.

Index Terms— Volcanic Monitoring, natural hazard, remote sensing, satellite data, validation

1. INTRODUCTION

Mt. Etna (Sicily, Italy) is one of the most active volcano of the world. Since 2011, Etna has showed an intense sequence of explosive activity which spanned from strombolian to short-lasting but astonishing episodes of lava fountains [1]. This eruptive regime gradually switched since 2016 to long-lasting mild explosive strombolian activities coupled with isolated episodes of lava flows from the summit crater of the volcano. On the morning of 24th of December at about 10:00 UTC, this eruptive style suddenly increased and an eruptive fracture opened at the base of the South East summit crater, spilling out a lava flow towards the Valle del Bove in the eastern flank of the volcano. The eruption produces a vigorous ash column which spread up to about 9 km above the sea level (asl) dispersing south-eastwards of the volcano. The explosive regime decreased since late afternoon of the 24th of December instead lava flow gradually ended on the 27th of December. The eruptive episode was preceded and accompanied by a seismic swarm and an increase in both seismic tremor and SO_2 flux degassing. From the 27th December significant emissions of SO_2 and ash were detected from satellite. Figure 1 shows the 24 and 27 December Etna activities.

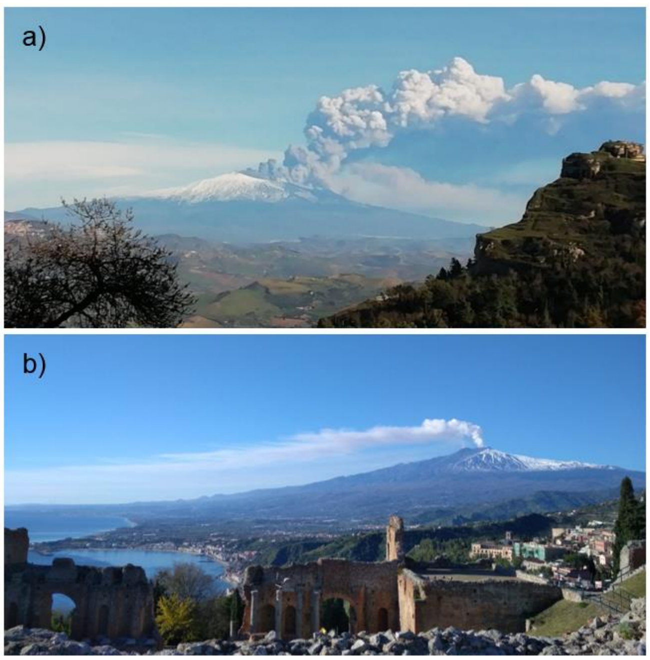

Fig. 1: 24 (a) and 27 (b) December 2018 Etna activities seen from Enna and Taormina (credits Truscia L. and Ponzo C.)

In this work data collected from the Spinning Enhanced Visible and InfraRed Imager (SEVIRI) instrument, on board the Meteosat Second Generation (MSG) geostationary satellite, and the Moderate Resolution Imaging Spectroradiometer (MODIS) on board the NASA-Terra/Aqua polar orbit satellites, were inverted for the near-real time proximal and distal characterization of the Etna eruption.

2. SEVIRI AND MODIS DATA AND RESULTS

SEVIRI has 12 spectral channels from visible (VIS) to Thermal InfraRed (TIR), a nadir spatial resolution of 3 km and a high temporal resolution (15 min for the Earth full disk and 5 min for the rapid scan mode over Europe and Northern Africa). MODIS has 36 channels in the same spectral range and a spatial resolution of 1 km. Retrieved parameters for the proximal monitoring are the eruption start and duration (ESD) and the Volcanic Plume Top Height (VPTH), while for the distal monitoring, the Volcanic Cloud Top Height (VCTH), ash and SO_2 retrievals are computed. ESD is retrieved by comparing the radiance difference computed from the SEVIRI 3.9 μm radiances of the pixel centered on craters and the mean value from the 5x5 pixels around it (DR(t)), with reference values (DT(t)) [1], while VPTH is carried out by applying a simplified procedure based on the 11 μm brightness temperature computation [2, 3]. The ash and SO_2 volcanic cloud retrievals have been realized by using the Volcanic Plume Retrieval (VPR) procedure [4, 5] based on the computation of the volcanic cloud transmittance of the channels centered at 8.7, 11 and 12 μm, and a Neural Network (NN) approach [6]. VCTH is realized from different techniques based on the following of the volcanic cloud center of mass by exploiting the SEVIRI measurements [5] and a modified CO_2 slicing procedure applied to the MODIS data.

2. PRELIMINARY RESULTS AND VALIDATION

In Figure 2, the SEVIRI images at 3.9 μm collected on the 24th December were used to compute DT(t) and DR(t) represented by the dashed and solid lines respectively. When DR(t) becomes greater than DT(t) the eruption start [1] and this happened at about 11:15 UTC.

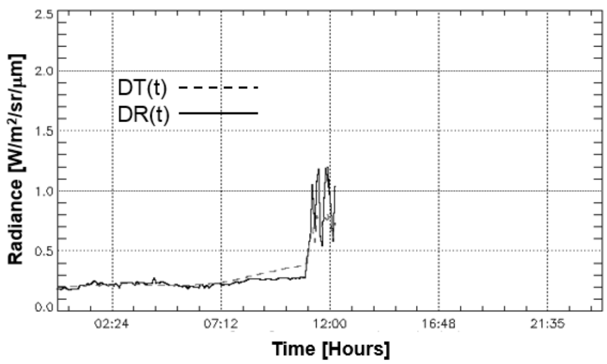

Fig. 2: SEVIRI data collected the 24 December 2018. The dashed and solid lines represent DT(t) and DR(t) respectively.

After this time the trend of the two curves shows fluctuations due to the volcanic activity and the start of the formation of the eruptive plume.

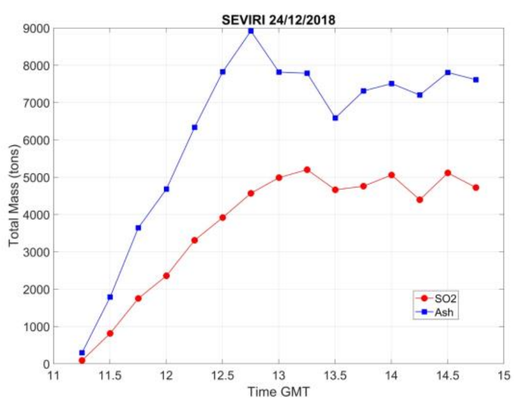

Fig. 3: Ash and SO_2 total mass temporal evolution for the 24 December 2018 event using SEVIRI data.

Figure 3 shows the temporal evolution of the 24th December ash and SO_2 emissions computed every 15 minutes. The gas and particles emission starts at about 11:15 UTC and reach the maximum values at 12:45 and 13:15 UTC for ash and SO_2, respectively. Figure 4 shows the ash and SO_2 maps retrieved from MODIS-Aqua images collected the 27, 28 and 29 December at 12:20, 11:25 and 12:05 UTC respectively. Differently from the December 24th event, between 27 and 29 December the SO_2 emission was always significantly larger than the ash emission.

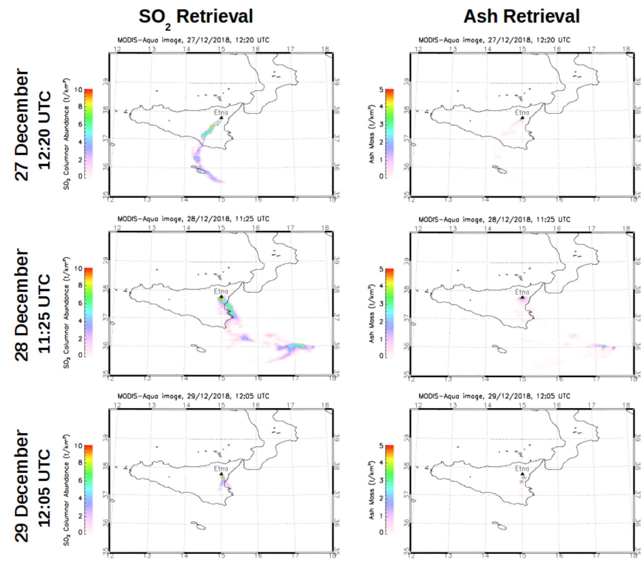

Fig. 4: Ash and SO_2 maps obtained from MODIS-Aqua images collected the 27, 28 and 29 December 2018.

The uncertainty affecting the retrieved results was explored using data obtained by ground-based networks. In particular, the SO_2 estimations was compared with the results obtained from the polar orbit hyperspectral measurements of the TROPOspheric Monitoring Instrument (TROPOMI) on board the Copernicus Sentinel-5 Precursor (S5P) satellite and those achieved by the ground-based ultraviolet scanning spectrometer FLAME-Etna network installed on the flanks of Mt. Etna [7]. The timing of the eruption (start/duration) and the VPTH was compared with VIS-TIR ground based cameras also placed at Mt. Etna [2]. Figure 4 shows the 27 December TROPOMI SO_2

retrieval. Taking into account the greater sensitivity of the UV measurements than the TIR, the SO_2 volcanic cloud, in the region covered by the MODIS image, appears similar and the mass retrieved consistent.

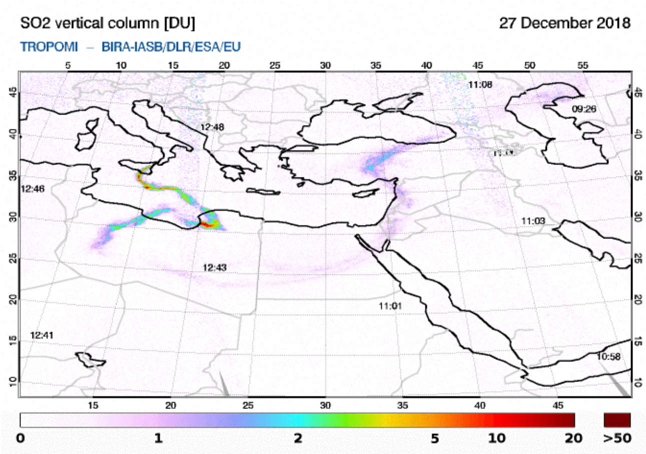

Fig. 4: SO_2 maps obtained from TROPOMI images collected the 27 December 2018.

The SEVIRI and MODIS VPTHs vary from 8 to 5 km asl from 24 to 29 December. These values are comparable with those obtained from the VIS-TIR ground based cameras network at Mt. Etna.

Results gathered from the validation process indicates a good agreement between the satellite and ground based retrievals and confirms the effectiveness of the satellite measurements to fully characterize the eruption from the source to the atmosphere.

5. REFERENCES

[1] S. Corradini, L. Guerrieri, V. Lombardo, L. Merucci, M. Musacchio, M. Prestifilippo, S. Scollo, M. Silvestri, G. Spata, D. Stelitano, "Proximal monitoring of the 2011-2015 Etna lava fountains using MSG-SEVIRI data", MDPI Geosciences, Special Issue on Volcanic Plumes: Impacts on the Atmosphere and Insights into Volcanic Processes, 8(4), 140, 2018.

[2] S. Corradini, M. Montopoli, L. Guerrieri, M. Ricci, S. Scollo, L. Merucci, F. S. Marzano, S. Pugnaghi, M. Prestifilippo, L. Ventress, R. G. Grainger, E. Carboni, G. Vulpiani, M. Coltelli, "A multi-sensor approach for the volcanic ash cloud retrievals and eruption characterization", Remote Sensing, Special Issue on Volcano Remote Sensing, 8(1),58, 2016.

[3] S. Scollo, M. Prestifilippo, E. Pecora, S. Corradini, L. Merucci, G. Spata, M. Coltelli, "Eruption Column Height Estimation: the 2011-2013 Etna lava fountains", Annals Of Geophysics, 57, 2, 2014.

[4] S. Pugnaghi, L. Guerrieri, S. Corradini, L. Merucci, "Real time retrieval of volcanic cloud particles and SO2 by satellite using an improved simplified approach", Atmos. Meas. Tech., 9, 1–10, 2016.

[5] L. Guerrieri, L. Merucci, S. Corradini, and S. Pugnaghi, "Evolution of the 2011 Mt. Etna ash and SO_2 lava fountain episodes using SEVIRI data and VPR retrieval approach", JVGR, Vol. 291, pp. 63-71, 2015.

[6] M. Picchiani, M. Chini, S. Corradini, L. Merucci, P. Sellitto, F. Del Frate, S. Stramondo, "Volcanic ash detection and retrievals from MODIS data by means of Neural Networks", Atmos. Meas. Tech., 4, 2619-2631, 2011.

[7] G. G. Salerno, M. R. Burton, C. Oppenheimer, T. Caltabiano, D. Randazzo, N. Bruno, V. Longo, "Three-years of SO_2 flux measurements of Mt. Etna using an automated UV scanner", J. Volcanol. Geotherm. Res. 183, 76–83, 2009.