Activity Report of the
Laboratory of Technologies for Volcanology
(TechnoLab)
Etna Volcano Observatory (EVO)
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Space Technologies Reveal Etna's Awakening: Eruptive Activity from February 8 to March 1, 2025

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Introduction

After about three months of quiescent stage showing ordinary passive degassing from their summit crater, on February 8, 2025, Etna volcano commenced a new effusive eruption, marked by the opening of an eruptive fissure at approximately 3,050 meters above sea level, situated between the Bocca Nuova (BN) and Southeast (SEC) craters. The activity led to lava emissions that flowed along the southwestern flank of the volcano toward Monte Frumento Supino. This activity report of the TechnoLab presents an overview of the eruption based on satellite observations and derived products, complemented by additional monitoring data (Fig. 1).

Figure 1 *– View of Etna's 2025 eruption: (right) February 14, (left) February 18.*

Satellite Observations

The eruptive activity of Etna has been closely monitored using satellite data from multiple sensors, providing high-resolution thermal, optical, and ultraviolet imagery. The key observations from these sensors are summarized below:

- **MODIS (Moderate Resolution Imaging Spectroradiometer) and VIIRS (Visible Infrared Imaging Radiometer Suite)**: These sensors provided continuous monitoring of the thermal activity. The radiant power estimates indicated a significant increase in heat output starting from February 8, with peak values exceeding 1.87 GW on February 17.
- **Sentinel-2 MSI**: High-resolution imagery from Sentinel-2 was used to map the evolution of the lava flow field. Observations between February 10 and February 28 revealed an expansion of the flow, with its front reaching an altitude of approximately 1,840 meters by mid-February.
- **Landsat 9 OLI**: Data acquired on February 28 allowed for a detailed assessment of the active lava field, showing an area of approximately 0.27 km² with thermal anomalies corresponding to the effusive vents and flow paths.
- **SEVIRI (Spinning Enhanced Visible and InfraRed Imager)**: This geostationary sensor, with its high temporal resolution (15-minute intervals), recorded fluctuations in thermal activity. The effusion rate was estimated at 18 m³/s during peak activity, with a cumulative lava volume of approximately 8.44 Mm³ by March 4.

- **TROPOMI (Tropospheric Monitoring Instrument)**: This imaging spectrometer onboard the Sentinel-5 Precursor satellite provides atmospheric column measurements of sulfur dioxide (SO_2) and other gases with a pixel resolution of 3.5 × 7 km^2. SO_2 emissions began increasing significantly on February 11, reaching a peak of nearly 7.0 kt/day on February 25.

Thermal Activity

Etna's thermal activity was monitored using a variety of satellite images with different temporal, spatial, and spectral resolutions. Figure 2 shows the estimates of radiant power from August 27, 2024, to March 4, 2025, calculated using MODIS, VIIRS, and Sentinel-3 SLSTR multispectral images. At the beginning of 2025, the thermal activity observed from satellites was generally low (< 10 MW). Starting on February 8, 2025, with the onset of the effusive eruption, the thermal activity observed in the summit area increased significantly, ranging from high (> 100 MW) to very high (> 1000 MW). The maximum thermal flux value of 1.87 GW was recorded by MODIS on February 17, 2025, at 08:45 UTC. However, poor visibility due to cloud cover may have influenced the satellite image analysis.

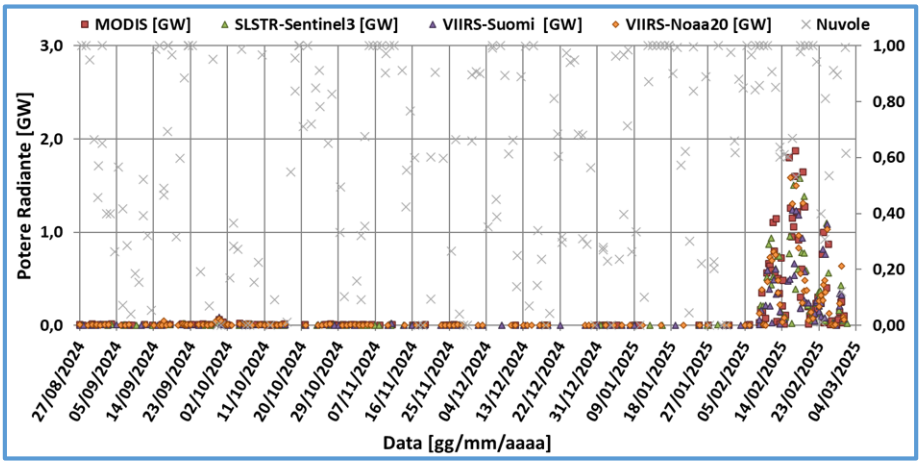

Figure 2 *– Radiant power calculated from MODIS data (red square), SENTINEL-3 SLSTR (green triangle), and VIIRS (purple triangle and yellow diamond) from August 27, 2024, to March 4, 2025.*

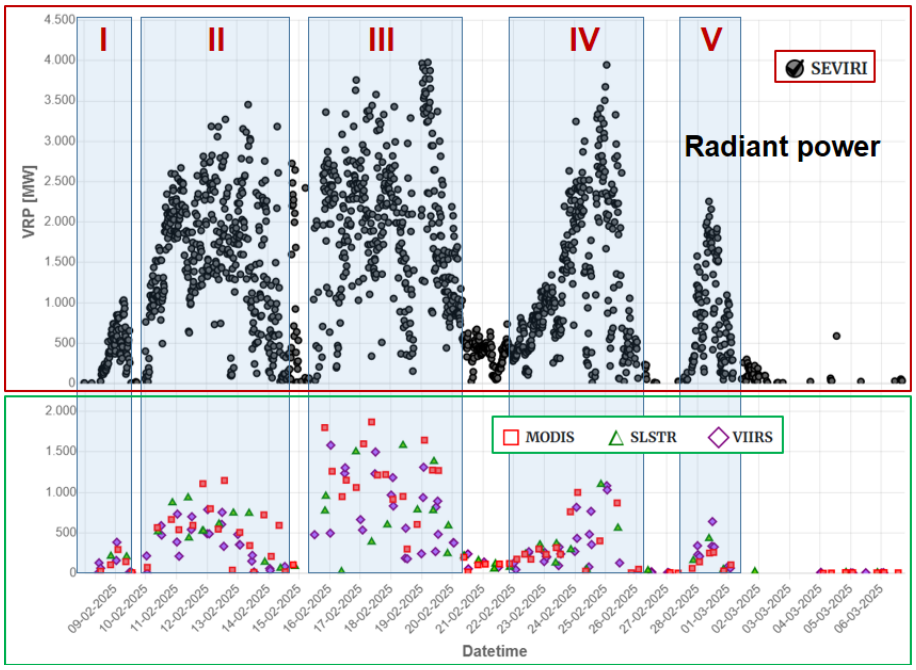

Figure 3 *– (Top) Radiant power calculated from SEVIRI (gray circle). (Bottom) Radiant power calculated from MODIS data (red square), SENTINEL-3 SLSTR (green triangle), and VIIRS (purple triangle and yellow diamond) from February 8 to March 4, 2025.*

Thermal activity in the summit area was also monitored using SEVIRI images with high temporal resolution (15 minutes), which recorded in detail the thermal activity of the eruptive event (Figure 3). The thermal flux measurements throughout the effusive and explosive activity, except for meteorological constraints, highlight five phases. The peak thermal flux values recorded by SEVIRI and the maximum values of the mean effusion rate (TADR) derived for each phase are shown in Table 1.
The estimated cumulative volume as of March 4, 2025, at 08:12 UTC, is approximately 8.44 $Mm^3 \pm 4.22$ Mm^3 (Figure 4). This value may be overestimated due to the explosive activity that characterized this period.

Phase	Duration	Thermal flux peak	TADR
I	February 8–9	1.03 GW on February 9, 2025, at 07:27 UTC	4.78 m^3/sec
II	February 10–14	3.45 GW on February 13, 2025, at 08:42 UTC	15.99 m^3/sec
III	February 15–20	3.98 GW on February 19, 2025, at 05:12 UTC	18.42 m^3/sec
IV	February 22–26	3.94 GW on February 25, 2025, at 00:57 UTC	18.27 m^3/sec
V	February 27–March 1	2.25 GW on February 28, 2025, at 08:57 UTC	10.44 m^3/sec

Table 1 *– Duration, thermal flux peak, and TADR for each of the five phases characterizing the eruptive activity from February 8 to March 1, 2025.*

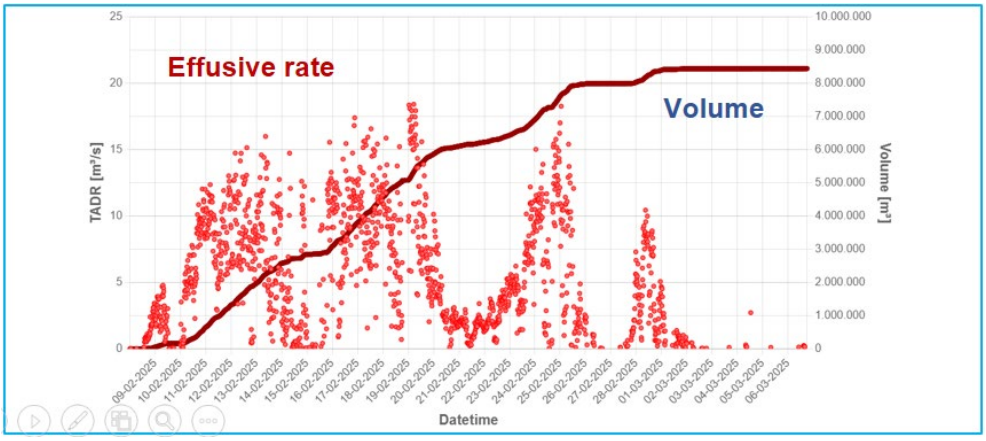

Figure 4 *– TADR and cumulative average volume estimated by SEVIRI during the effusive event that began on February 8, 2025, and ended on March 2, 2025.*

Lava flow mapping

Using Sentinel-2 MSI images (20 m spatial resolution) and Machine Learning algorithms, we monitored the evolution of the lava field since February 10 and quantified its extent in the latest acquisition on February 17, 2025:

- February 10, 2025, at 10:00 UTC: area 0.23 km^2, lava front elevation 2420 m (Fig. 5a)
- February 12, 2025, at 09:41 UTC: area 0.32 km^2, lava front elevation 2200 m (Fig. 5b)
- February 17, 2025, at 09:40 UTC: area 0.62 km^2, lava front elevation 1840 m (Fig. 5c)
- Lava field evolution mapped from February 10 to 17, 2025 (Fig. 5d)

After this phase, the lava flow field began to be a complex system of ephemeral vents with secondary flow overlapping on the previously main channel, that resulted less fed and cooling. The lava flow field started to expand laterally in the upper portion due to new flow spread up next to the southern edge. Using a Landsat 9 OLI image (with a spatial resolution of 30 m) from February 28 and Machine Learning algorithms, it was possible to map both the effusive activity at the fissure at the southern base of the Bocca Nuova crater (0.21 km^2, reaching a maximum altitude of 2680 m) and the modest lava overflow (0.06 km^2) from the Southeast Crater (bottom of Figure 5). Therefore, the total extent of active lava flow in the latest acquisition on February 28 at 09:42 UTC is approximately 0.27 km^2. The total cumulative area related to the effusive activity that began on February 8, 2025, is approximately 0.85 km^2. It is worth noting that the variations in the active lava flow area during the entire effusive period, as expected, reflect the fluctuations in the discharge rate.

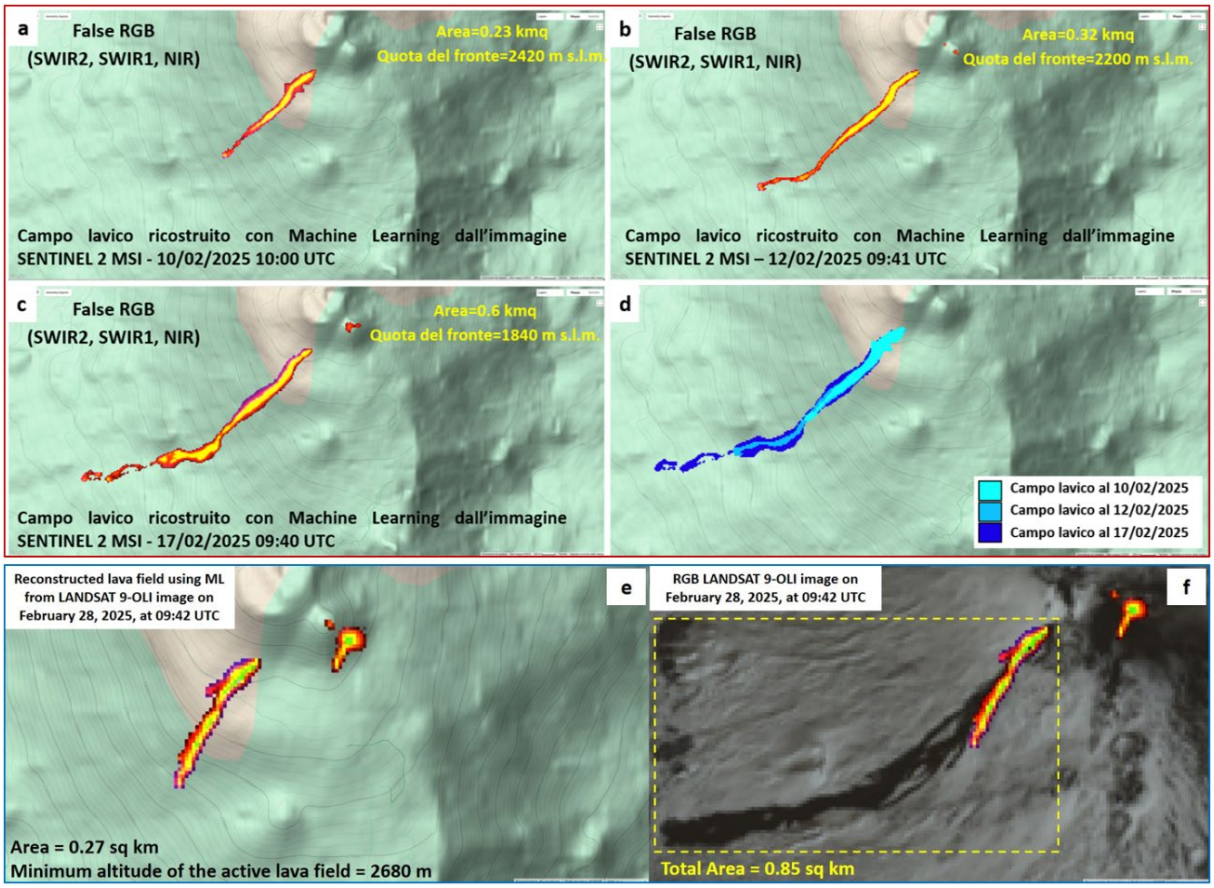

Figure 5 *– (Top) Lava field observed by Sentinel-2 MSI with a spatial resolution of 20 m. Map of thermal anomalies associated with the active lava field on (a) February 10 at 10:00 UTC, (b) February 12 at 09:41 UTC, and (c) February 17 at 09:40 UTC. The intensity levels correspond to the values of the False RGB image (SWIR2, SWIR1, NIR). (d) Sequence of lava fields mapped on February 10, 12, and 17, 2025, for the entire effusive activity that began on February 8, 2025. (Bottom) Lava field observed by LANDSAT 9 OLI with a spatial resolution of 30 m. (e) Map of thermal anomalies associated with the active lava field on February 28, 2025, at 09:42 UTC. The intensity levels correspond to the values of the False RGB image (SWIR2, SWIR1, NIR). (f) Corresponding RGB image highlighting the cooling lava field from the effusive activity that started on February 8, 2025, overlaid with the active lava field as of February 28, 2025.*

SO2 fluxes from TROPOMI

Using TROPOMI images from January 21 to March 4, 2025, we calculated the daily average volcanic SO_2 fluxes from Mount Etna. To overcome the challenges associated with SO_2 monitoring, we developed an Artificial Intelligence (AI) algorithm capable of detecting and quantifying volcanic SO_2 emissions in near real-time. Our approach employs a Random Forest (RF) model, a supervised Machine Learning (ML) algorithm, to identify volcanic SO_2 emissions and integrates Cloud Top Height (CTH) data to improve the accuracy of SO_2 mass quantification during intense volcanic eruptions. This AI algorithm, fully implemented in Google Earth Engine (GEE), leverages TROPOMI data to automatically retrieve daily volcanic SO_2 plumes and CTH measurements. We validated the model's performance against the Radius classifier, a state-of-the-art tool, and extended its application to various volcanoes (Etna, Villarrica, Fuego, Pacaya, and Cumbre Vieja) with different degassing activities, SO_2 emission rates, and plume geometries.

Our findings (Fig. 6) show that the proposed AI approach effectively detects and quantifies SO_2 plumes emitted from Mount Etna during the eruption began on February 8, enabling the analysis of SO_2 emission time series that reflect volcanic dynamics in upper part of the plumbing system (< 4 km). In particular, the higher value it is associated with a more intense phase of strombolian activity at the SEC with explosions occurred from three vents.

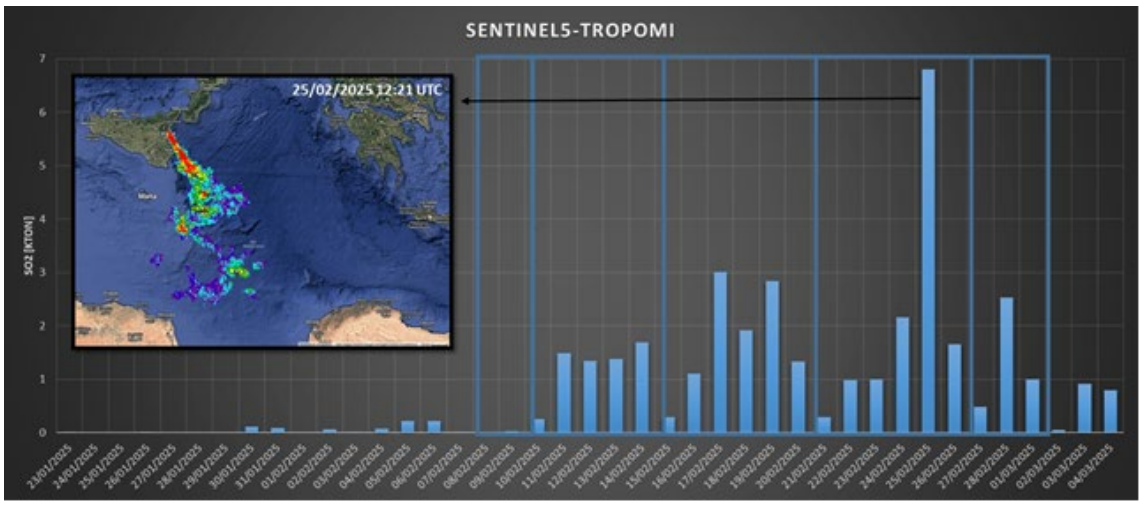

Figure 6 *– Time series of SO2 fluxes between January 21 and March 04. Daily means of SO2 fluxes began increasing significantly on February 11, reaching a peak of nearly 7.0 kt/day on February 25. (insert) TROPOMI data acquired on 25 February 2025 12h21 UTC with the native grid resolution, showing the SO2 corrected by altitude in kt/day.*

Effusive and Explosive Activity

The effusive activity was primarily concentrated at the fissure near Bocca Nuova, with lava advancing in multiple branches. The emission point varied slightly, shifting from 3,070 m to approximately 2,980 m by February 22-23 due to the development of lava tubes. The longest lava flow reached approximately 4.3 km in length. In addition to the effusive activity, mild strombolian explosions occurred at the Southeast Crater (SEC), with sporadic ash emissions. A more significant explosive phase between February 12 and 16 produced an ash plume reaching up to 5,500 meters above sea level, necessitating the issuance of a Red VONA alert (Fig. 7).

Figure 7 *– Explosive activity from the South-East Crater on February 11.*

Hazards Associated with the Lava Flow

The advancing lava flow interacted with the existing snow cover on Etna's slopes, leading to sporadic phreatic explosions. These explosions occurred due to the rapid vaporization of snow upon contact with the hot lava, resulting in the ejection of incandescent lava fragments over distances of several hundred meters. Such interactions underscore the potential hazards posed by lava flows, particularly when they encounter snow or ice, which can lead to explosive events and pose risks to nearby infrastructure and individuals (Fig. 8).

Figure 8 *– Explosive events occur when lava flows encounter snow. Image sequence from February 13, 2025.*

Volcanic Monitoring [Weekly Bulletins of the Etna Volcano Observatory (EVO)]

- **Volcanic Tremor and Seismicity**: The amplitude of volcanic tremor exhibited fluctuations, with peaks corresponding to increased lava effusion. Seismicity remained moderate, with most events concentrated on the eastern and southern sectors of the volcano. The strongest recorded event had a magnitude of 3.7 on February 10, 2025.
- **Ground Deformation**: GNSS data indicated minor deflation, consistent with the prolonged effusive activity. InSAR analysis showed localized displacements along fault zones near Trecastagni and Acitrezza.
- **Gas Emissions**: SO_2 emissions were elevated from February 4 to March 1, with a total degassed magma volume of ~6.8×10^6 m^3. CO_2 emissions followed a similar trend, suggesting sustained magmatic input.

Current Status and Ongoing Monitoring

As of February 18, 2025, the lava flow remained active, with the most advanced front reaching an elevation of approximately 1,850 meters. The effusive activity remained confined to the summit areas, posing no immediate threat to populated regions. By March 7, effusive activity had significantly decreased, with only residual lava flows visible in satellite images. However, continued monitoring remains necessary due to the possibility of reactivation. The Laboratory of Technologies for Volcanology (TechnoLab) continues to closely monitor the situation, integrating satellite observations with ground-based measurements to provide comprehensive assessments of the ongoing eruption (Fig. 9).

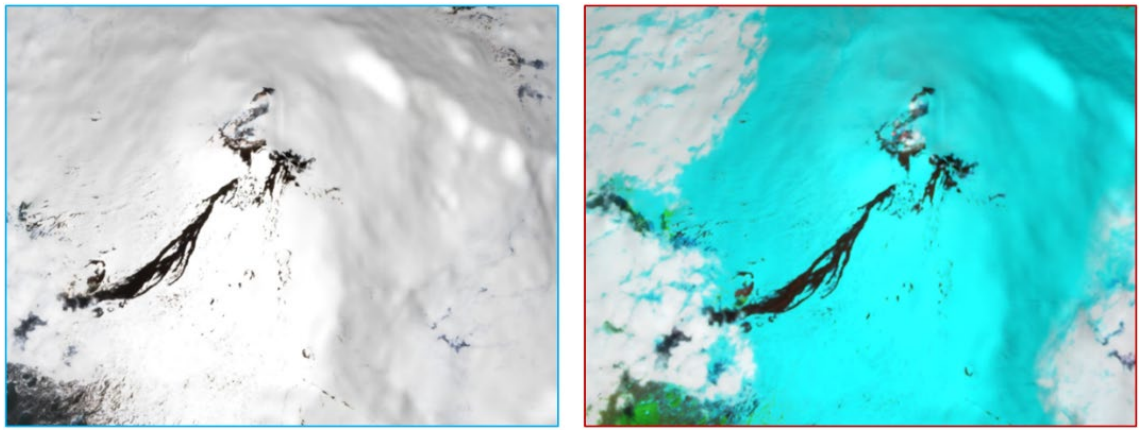

Figure 9 *– Final lava flow field on March 9, 2025 observed from Sentinel-2: (left) True colors, based on bands 8, 4, and 3; (right) SWIR image, based on bands 12, 8a, and 4.*

Conclusion

The eruption of Etna from February 8, 2025, has been effectively monitored using a variety of satellite observations. Remote sensing tools, including MODIS, VIIRS, Sentinel-2, Landsat 9 OLI, SEVIRI, and TROPOMI, have provided critical insights into the thermal dynamics and spatial evolution of the lava flows. The multidisciplinary approach to monitoring has ensured comprehensive coverage of the eruption's progression, supporting hazard assessment and response efforts.

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