

Synchronization of High-Resolution Imageries Acquired by NOAA and SUOMI NFP Satellites for Active Fire Detection over Etna Volcano [†]

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Abstract

Mount Etna is considered as one of the world's most active volcanoes located in Europe. In this study, we propose to characterize and model physically the geohazard area recently caused by the active Etna volcano. An advanced image processing method is presented, in which the scene is acquired simultaneously by two high-resolution remote sensors NOAA and SUOMI NFP. The proposed experimental protocol for data visualization and analysis is as follows. First, the images are processed with the same spectral reflectance using VIIRS I-bands at 375 m spatial resolution. More in details, the spectral signatures of pixels confirm the environmental changes according to a color visualization coding. In this context, the volcano clouds widespread over Etna mount are estimated approximately through a signal processing measurement algorithm. Second, the images are acquired by two high-resolution sensors, which are the NOAA and SUOMI NFP in the visible Spectrum wavelength. The synchronization of both sensors gives more details about the area occupied by the volcano fires. A spectral wavelength analysis is presented in both cases: (1) non-synchronized (i.e., each sensor separately) and (2) synchronized (i.e., combination of two sensors). Third, the protocol of active fire detection applied to the geohazard Etna Volcano is displayed: fire area detection and estimation, spectral measurement, synchronization of remote sensors, and assessment of the fire spread. Finally, the strengths and limitations of satellite-based active fire detection are presented with respect to the synchronization of different sensors. A theoretical and experimental studies will be presented.

Keywords: active fire; spectral reflectance; volcano remote sensing; image processing

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1. Introduction

Volcanoes are known as complex dynamic systems. Monitoring and supervising their activity timely pose several challenges, particularly for frequently and randomly erupting volcanoes in densely populated areas [1–4]. The advanced technologies dedicated to the observation of natural hazards as the volcanoes require the techniques of data fusion. Specifically, the combination of heterogeneous information derived from multiple

sensors operating at different spectral, spatial, and temporal resolutions generate a more complete and reliable characterization of volcanic processes.

In this work, we propose an advanced data-driven approach applied to an active fire viewed on Etna volcano eruption. This hot topic is founded on several points of views in the societies [4–6]. The multiple remote sensors could provide several information about the distant volcanoes or hazards worldwide [5,6]. In this context, we propose studying the synchronization of two sensors operating on equivalent spectral bands to visualize and analyze the data captured over Etna.

2. Study Area

The Mount Etna is located on the east coast of Sicily. It is one of the most active volcanoes in the world. The volcano is considered as a source of active fire in summit craters. The volcano activity consists of the degassing, explosive phenomena and lava flows movement. Moreover, the recurrent effusive eruptions caused by winds could extend the lava flows moving widespread over several kilometers that significantly impact the landscape. Figure 1 shows the studied area, depicting the Etna volcano go-located in the Sicilian Island, Italy in last eruption at 2 June 2025.



Figure 1. Study area. Etna mount located in Sicily, Italy (spatial resolution is 50 km).

3. Satellite Sensors: S-NPP and NOAA-20

The Visible Infrared Imaging Radiometer Suite (VIIRS) is an instrument onboard the Suomi National Polar-Orbiting Partnership (S-NPP) [5]. Known as an experimental satellite. It launched by the Joint Polar Satellite System (JPSS) and coordinated by both NASA and NOAA-20 or N20 platforms. The VIIRS (S-NPP and NOAA-20) platforms are placed in a polar orbit at a nominal altitude of 824 km. Both sensors have a FOV of 112.56°, with a swath width of 3060 km. The sensors provide a full coverage of the globe at both daytime and nighttime [7]. The data are collected across 22 spectral bands, from 0.412 μm to 12.01 μm of wavelengths [8–11].

The characteristics of the SNPP and NOAA-20 sensors, used in this study, are summarized in Table 1. Particularly, we are focused on the imaging (I4 and I5; 375 m) spatial resolution to assess and visualize the volcanic activity [11].

Table 1. The specifications of sensors experimented in the study: SNPP and NOAA-20.

Product Latency (hours)	1–4	1–4
Sensor	VIIRS (M-bands)	VIIRS (I-bands)
Satellite	SNPP NOAA-20	SNPP NOAA-20
Equator Crossing	13.30 LT 12.40 LT	13.30 LT 12.40 LT

Time		
Global Coverage	Every 12 h	Every 12 h
Spectral region	MIR, TIR	MIR, TIR
Pixel resolution at nadir	0.75 km	0.375 km
Spectral range (μm)	3.973–4.128	3.550–3.930
	10.26–11.26	10.56–12.43
ID	M-13	I-4
Bands (s)	M-15	I-5

4. Experiments and Results

We investigated the Etna volcano, which is characterized by its volcanic heat sources and its frequent eruptive events. The data are acquired at the last eruption by 2 June 2025.

The synchronization of both sensors using comparable mid-infrared and thermal infrared bands provides a more accurate visualization of the studied area. In our case, the images of Mount Etna were analyzed using VIIRS I-bands at 375 m spatial resolution. The lava flows are depicted in Figure 1 with red and yellow colors, corresponding to images captured by NOAA-20 and S-NPP satellites.

A macro-visualization the eruption phenomena is obtained by selecting the near-real time specifications focused at the same location and synchronizing both sensors wavelengths to collect more spectral information about the intensity of lava. The corresponding color-based data analysis is displayed in Figure 2.

For estimating the severity of the volcano activity, both sensors are employed at a larger spatial resolution, which corresponds to the adjustments of the optical view camera. For a better understanding, we present an experiment in Figure 3, in which the spatial resolution is equal 10 km. It is clearly seen that the severity of the eruption is regionally labeled from yellow (low) to orange (high). Such results allow a better human-monitoring of the hazard.

The enlarged area is based on the mixed pixel phenomena, which highlights in depth the severity of the volcano (from low to high) according to pixel reflectance. This strategy is presented in Figure 4 as a zoomed image of Figure 3.



Figure 2. The visualization of the lava flows of Etna volcano (green = NOAA-20, blue = S-NPP). The spatial resolution is 1 km).

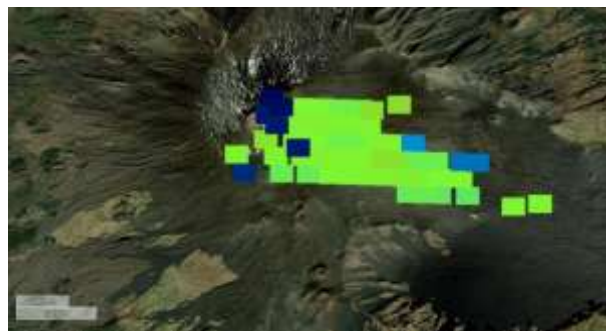


Figure 2. The macro-visualization of the lava flows of Etna volcano (green = NOAA-20, blue = S-NPP). The spatial resolution is 1 km.



Figure 3. The macro-visualization of Etna volcano (the spatial resolution is 10 km). All green-blue color nuances (seen in Figure 2) are clearly displayed. The severity of the eruption volcano are labelled by yellow (low) and orange color (high).

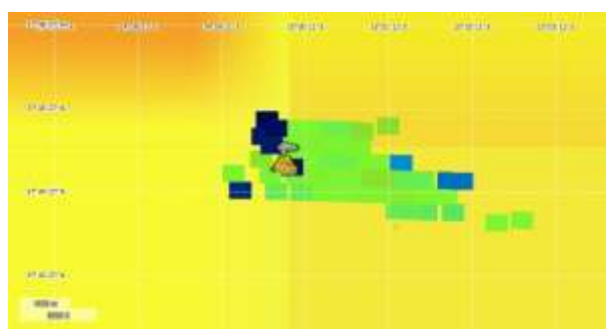


Figure 3. The enlarged visualization of Figure 3 (the spatial resolution is 1 km) highlighting in depth the severity of the eruption volcano (low to high).

5. Conclusions and Future Insights

In this study, we presented an experimental study to estimate the severity of the Etna volcano eruption through the synchronization of NOAA-20 and S-NPP with the same wavelength. The lava flows are remotely visualized over an active volcano. The visualization was performed at two spatial resolutions (1 km and 10 km), which allows complementary perspectives on the volcanic activity. The mixed pixels in the images highlighted in depth the severity and the intensity of the heat and the lava flow in the landscape, according to their pixel reflectance.

As perspectives, we will investigate the estimation of the air quality impacted by the latent heat flux transfer in a thermally active volcanic area of Mount Etna. For extending our proposed technique, we plan to apply a technique recently cited in [12] and [15]. Experimentally, we propose to capture direct measurements of vapor flow to quickly identify thermal anomalies [16]. In the context of signal processing, we will model the images captured from both sensors and study the overlaying of their squared-pixels on the same location (i.e., overlap), with partial overlap and with no overlap.

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