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Biennial report for Permanent Supersite/Natural Laboratory

Mt. Etna Supersite: August 2018 – May 2020

History	***https://geo-gsnl.org/supersites/permanent-supersites/mt-etna-volcano-supersite/***
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1. Abstract

Mt. Etna is one of the most active volcanoes on Earth that in the past few decades has erupted virtually every year. The current Etnean volcanism results from the interaction between magma ascent in the rather complex plumbing feeding system and the local tectonic regime controlled by the volcano edifice's eastern flank instability, whose driving conditions (e.g., structural setting, tectonic forces) and cause-effect relationships are not completely understood yet. At the surface, the combination of the two factors produces eruptions along fissures that open on the flanks (e.g., in 2001, 2002-03, 2004-05, 2018) or at the summit craters (e.g., in 2011-'13; 2015). Eruptions might be either strongly explosive (e.g., in 2002; 2011-'13; 2015) or quietly effusive (e.g., in 2004-05). Explosive eruptions have produced volcanic ash plumes, sometime reaching also the stratosphere, that likely disrupt air traffic for hours to weeks (e.g., 5 January 2012), whereas effusive eruptions have fed lava flows capable of invading the populated areas of the volcano edifice, thus threating human property and vital infrastructures. Flank eruptions are often linked to seismic swarms with thousands of earthquakes having maximum magnitude of medium intensity (Mw = 4-5) and local severe damages to artifacts.

During the reporting period, the dynamic of the volcano was dominated by the December 2018 flank eruption and the associated seismic crisis. In this context the scientific production was focused on the interpretation of the ground deformations related to this event. Beside the scientific objective, Mt. Etna Supersite data (both EO and in-situ) were largely used to support the volcano surveillance and the activity of the Italian Civil Protection (both at local and regional level).

The management of the Etna Supersite contributed to the GEO-GSNL initiative, by participating to the periodic meeting organized by the Coordinator and providing inputs to the GEO documents. Furthermore, a few focused actions have been achieved to structure the management of the Supersite and enlarge its impact, as anticipated in the report of the previous two-year period. A relevant part of the management activity of the Supersite was devoted to consolidate the outcomes and products of the EC FP7 MED-SUV project, to improve the governance structure in the frame of the EPOS European Infrastructure, and to consolidate and open new perspectives of the impact of the Etna Supersite in the different scientific domains.

At the present day the MED-SUV Data Portal is moving into a new e-infrastructure. Projects like EPOS or EUROVOLC suggested creating a data Hub for European volcanoes and so many existing web portals will be managed inside the ongoing Volcano Observations Gateway Data Hub (http://vo-tcs.ct.ingv.it:8088/). In order to maintain a specific way to search data and metadata concerning the Supersites, a specific MED-SUV Data Search is still running at the following link (http://med-suv.essi-lab.eu/web/portal).

2. Scientists/science teams

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Scientists/science teams issues

The organization of the science team mainly inherits that implemented in the EC-FP7 MEditerranean SUpersite Volcanoes (MED-SUV) project. The participants listed above had declared the interest in using the Supersite data and thus, they are registered users of the MED-SUV portal, as well as of the EO data sets that require proper registration (e.g. CSK or TSX data). The main issue concerns the capacity to maintain an adequate level of cooperation and scientific benefit in the future, and possibly to enlarge the number of users, although the lack of steady financial support. To face this issue, the team has encouraged the exploitation of the Mt. Etna Supersite resources and the use of the MED-SUV data portal in the framework of international and national projects and initiatives. This is the case of EUROVOLC project as well as the EPOS and ENVRI infrastructures. This point will be detailed in section 7 of this report.

3. In-situ data

The in situ data are recorded from the INGV monitoring networks of Mt. Etna, which are listed below.

Seismic	Permanent:	37 stations	Mobile:	12 stations
Accelerometric	Permanent:	6 stations		
Infrasonic	Permanent:	11 stations		
GPS benchmarks	Permanent:	38 stations	Periodic surveys:	80
Leveling benchmarks			Periodic surveys:	38
Tilt & strainmetric	Permanent:	13+2 stations		
Gravimetric	Permanent:	4 stations	Periodic surveys:	106 stations
Magnetic and SP	Permanent:	9 + 3 stations		
Dilatometric	Permanent:	4 stations		
Geochemical	Permanent:	38 stations		
Visible & Thermal IR Imagery	Permanent:	6 stations		

The table below shows the in-situ available data and the access is offered through Web Rest Services. Metadata are available in the most common data format

Type of data	Data provider	How to access	Type of access
Seismic waveform	*INGV*	*Link to Network Italian Seismic Network Web Service through MED-SUV Portal Search*	*Open to anonymous users*
Seismic events	*INGV*	*Link to Network Italian Seismic Network Web Service through MED-SUV Portal Search*	*Open to anonymous users*
GPS data	*INGV*	*Due to a server failure and to the end of the support by UNAVCO, GSAC services are moving into a new standard (GLASS) adopted inside EPOS framework. Part of the network is discoverable at the INGV RING direct link http://ring.gm.ingv.it/*	*Open to anonymous users*
GPS data survey (1994- 2013)	*INGV*	*Same as above*	*Open to anonymous users*
GPS coordinates / displacement vectors	*INGV*	*Same as above*	*Open to anonymous users*

Hydrophone / OBS waveform	*INGV*	*MED-SUV File Manager*	*Limited to registered users*
Thermal cameras	*INGV*	*MED-SUV File Manager*	*Limited to registered users*
Tilt	*INGV*	*MED-SUV File Manager*	*Limited to registered users*

In-situ data issues

The in-situ data are provided by INGV. They are discoverable and accessible through the e-infrastructure implemented in the framework of EC-FP MED-SUV project.

The first version of the e-infrastructure, issued at the end of the project, included the data sets defined in the project consortium agreement - i.e. the seismic (raw and products), GPS (raw and products), video-cameras, and tilt data from the 2005 - 2011 Mt. Etna record.

Throughout the July 2018 – May 2020 reporting period, the MED-SUV infrastructure adopted appropriate initiatives (from both technical and strategic point of view) to integrate its activity in the frame of other initiatives and to stabilize the services and extend the in-situ data sets to data of more recent years. Seismic data have been also extended.

In this frame, the most relevant initiative is the participation to the European Plate Observing System (EPOS) infrastructure and to the EUROVOLC project. By using MED-SUV portal, and in the next future the Gateway Portal, a new variety of in-situ data and products will be managed inside EPOS Volcano Observations Thematic Core Services (VO- TCS) (e.g. geochemical data). Indeed, the MED-SUV infrastructure will be integrated into the first European Volcanology Gateway planned in the EUROVOLC activities. The goal is to foster new initiatives in order to upgrade, complete and extend the original data set by adopting open science paradigm.

The current data policy of the in-situ data adopts the access rules defined in the frame of the MED-SUV project. In the forthcoming months INGV will complete data policies rules that will be extended also to the MED-SUV datasets.

4. Satellite data

<In the table below please list all satellite data types available for the Supersite>

Type of data	Data provider	How to access	Type of access
ERS-1/ERS-2	ESA	Direct link to http://eo-virtual-archive4.esa.int/?q=Etna or through the MED-SUV Portal	Registered public
ENVISAT	ESA	Direct link to http://eo-virtual-archive4.esa.int/?q=Etna or through the MED-SUV Portal	Registered public
Sentinel	ESA	Direct link to https://scihub.copernicus.eu or through the MED-SUV Portal	Registered public
TerraSAR-X	DLR	Direct link to https://supersites.eoc.dlr.de or through the MED-SUV Portal	GSNL scientists
COSMO-SkyMed	ASI	Through the ASI server of the MED-SUV Portal	GSNL scientists
RADARSAT-2	CSA	PoC requests access from CSA for individual users; a specific CSA server is under implementation on the MED-SUV Portal	GSNL scientists
Landsat 8	USGS	Direct link to http://earthexplorer.usgs.gov MED-SUV will update the ending points for grant access	Registered public
AVHRR	NOAA	Direct link to http://earthexplorer.usgs.gov MED-SUV will update the ending points for grant access	Registered public
MODIS	NASA	Direct link to http://modis.gsfc.nasa.gov/data/ MED-SUV will update the ending points for grant access	Open

Satellite data issues

During the reporting period, the scientific use of EO data sets has reduced with respect to the past. The reason of that mainly relates to the ending of same big scientific projects supporting the volcanological researches (i.e., MED-SUV). Such effect suggests adopting more effective strategies to promote the use of the Supersite in-situ and the EO data (see section 7).

From the management point of view, the main efforts have concerned the consolidation of the e-infrastructure to manage the data (both EO and in situ); about this activity details are in Section 3. In this frame, the agreement between ASI and ESA to distribute CSK data through the ESA GEP (Geohazards Exploitation Platform, https://geo-gsnl.org/access-to-cosmo-skymed-supersite-sar-imagery/) is fruitfully exploited. Due to ongoing activity on the e-infrastructure, some severe issues occurred in the update of the databases, e.g., the TSX data, as well as in the addition of new type of EO data, e.g., optical data. These issues will be solved in the forthcoming months as the e-infrastructure will be fully operational. A further issue was encountered in acquiring Radarsat-2 data, owing the difficulties in receiving feedback from CSA about the update of the agreement.

Furthermore, during the biennial period, some users express interest in using Pleiades data. Considering the continuous volcanic activity of the volcano, Mt. Etna Supersite is interested to include in the EO provision also one Pleiades tri-stereo acquisition / year (at minimum), of an area 20x20 Km, centered to the summit craters. Ideally, it would be more than appropriate to have a new acquisition after each main volcanic event (i.e. causing large morphological changes, as lava flow eruptions or major explosive activity).

5. Research results

After a sort summary of the Mt. Etna volcanic activity, we report below the recent research results based on the use of Mt. Etna Supersite data. Most of the researches focused on the dynamic of the volcano related to the December 2018 eruption.
Additionally, results of researches carried out during physical accesses to the facilities of the Supersite Etna, in the frame of the ENVRIPlus project are also briefly reported. These studies mainly focused on the impact of volcanic activity on the atmosphere.

5.1. Summary of the Volcanic Activity.

During the biennial reporting period, Mt. Etna's volcanic activity consisted in summit and flank eruptions. From July 2018 to September 2019 the activity at the Summit Craters focused at the South-East Crater (SEC). The activity was mainly degassing or slightly explosive (strombolian) even if SEC fed a series of short-lasting effusive eruptions (in August, November and December 2018 and May-June 2019) with lava flows spreading on the southern and eastern flank of the SEC cone, which produced small compound lava fields nearby it. Early on September 2019, deep strombolian explosions began also at the North-East Crater (NEC) and Voragine (VOR) vents. During the 2019 fall, the activity at VOR increased and an almost continuous strombolian and effusive activity was observed from January to April 2020, which produced internal morphological changes, e.g. a cinder cone and a compound lava flows within the Summit Craters (Bocca Nuova area). On December 24th, 2018, Mt. Etna volcano showed sudden signals of unrest, marked by a seismic crisis beneath the summit and upper southern flank of the volcano, accompanied by significant ash emission from the Summit Craters. Seismicity also affected the SW flank of the volcano and the NE sector, with significantly energetic events along the Pernicana fault system. Eruptive fissures opened at the SSE base of Summit Craters, propagating SE-wards. The lateral eruption lasted until December 27th, 2018, producing a relatively small lava flow field. The peculiarity of the seismic swarm accompanying the eruption was that almost all the volcano-tectonic structures lying on the flanks of the volcano were active; this phenomenon was never observed before with such high energy release, even during very high energetic eruptions (e.g. on 2001 or 2002). Beside from the seismic swarm localized beneath the upper part of the volcano, a sudden Mw=4.9 earthquake struck the lower SE flank of Mt Etna on December 26th at 02:19 GMT. This event produced severe damages to many villages on SE lower flank of the volcano, causing many injuries but, luckily, no casualties.

5.2. Ground Deformations and morphological changes

The December 2018 eruption

On December 24th, Mt. Etna volcano underwent a seismic crisis beneath the summit and upper southern flank of the volcano, accompanied by significant ash emission. Eruptive fissures opened at the base of summit craters, propagating SE-wards. This lateral eruption lasted until December 27th. Despite the small eruption, seismic swarm and ground deformation were very strong (Bonforte et al 2019)

Moreover, the swarm involved some of the shallow volcano-tectonic structures located on the Mount Etna flanks and culminated on 26 December with the strongest event (M-L 4.8), occurred along the Fiandaca Fault. [De Novellis et al. 2019]

Both eruptive and seismic event was imaged by Sentinel 1 SAR images, and the DInSAR
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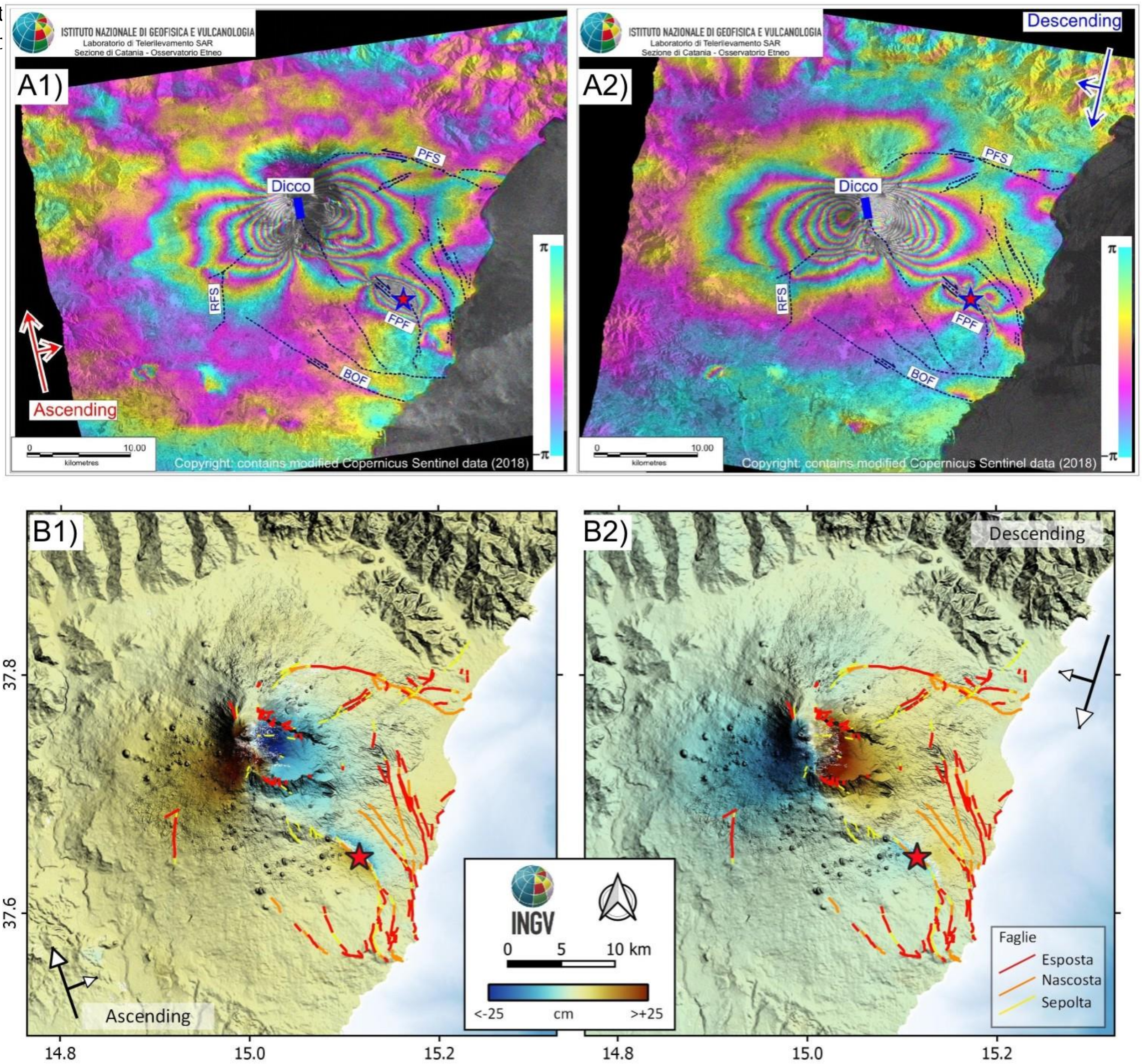

Figure 1. Ascending and descending Sentinel 1 interferogram (phase) and corresponding LOS deformation maps in cm. Into (A1) and (A2) the ascending and descending Sentinel 1 interferograms relevant to 22122018 – 28122018 time spanning are reported; (B1) and (B2) LOS deformation maps corresponding to interferograms. [Comunicato CNR-IREA & INGV]

De Novellis et al., (2019), used the Sentinel 1 DInSAR data coupled with the seismic data, in order to detect the magmatic sources and to study the cause-effect relationship between dikes intrusion and the movement which affected some of the seismogenic structures of the volcano. They modelled the Sentinel 1 DInSAR data in order to detect the volcanic and

tectonic sources parameters, and after they performed a Coulomb Stress analysis to study the stress change scenario. The results revealed that the intrusion encouraged, with a positive loading, the seismic activation of the faults in all the volcano edifice (Figure 2).
Furthermore, De Novellis et al., (2019), performed also a geomorphological analysis by using the COSMO-SkyMed ascending SAR amplitude images; this analysis was aimed at defining the geometry of the eruptive fissure and the lava flows (Figure 3).

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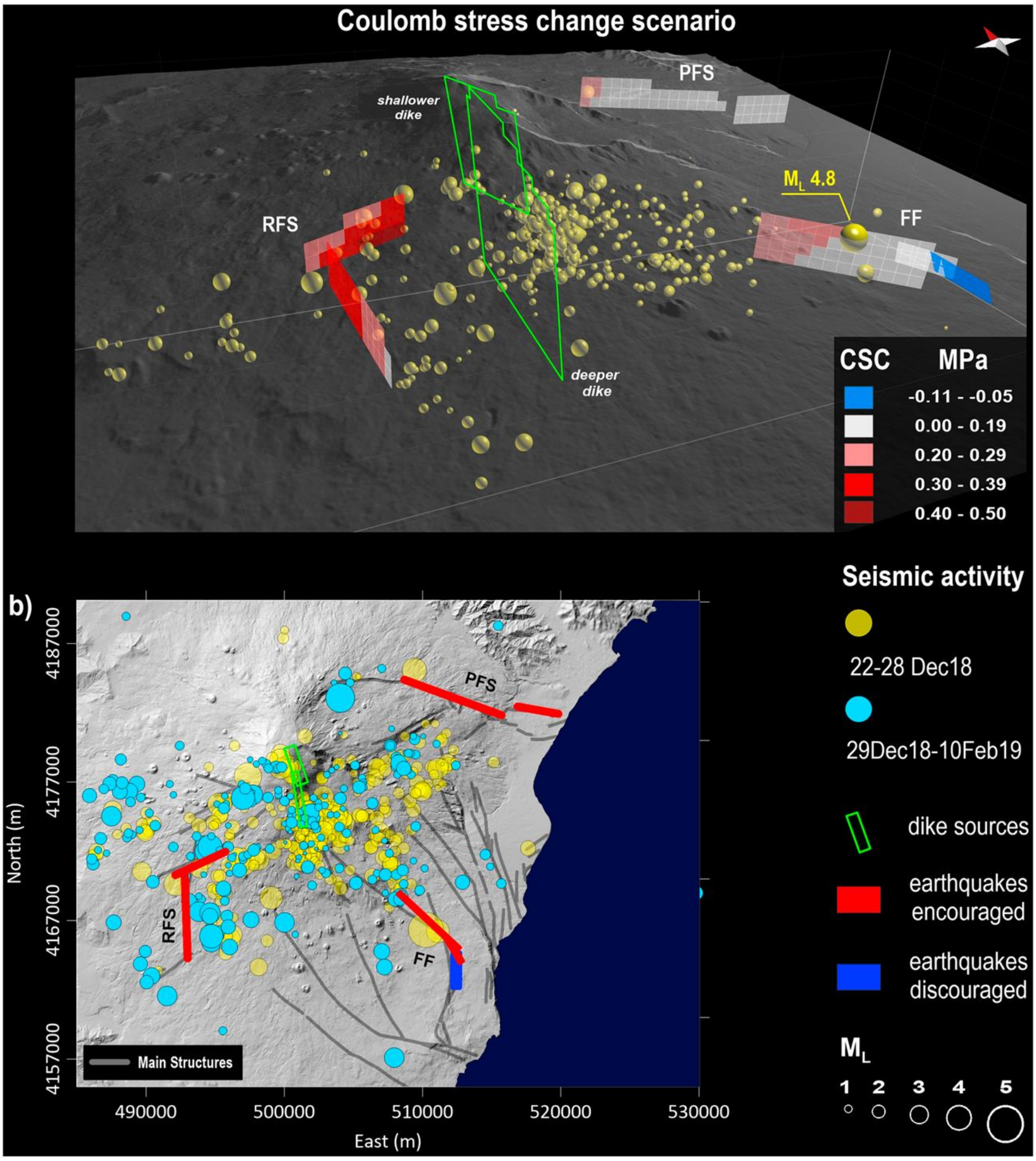


Figure 2. Coulomb stress change (CSC) results. (a) CSC values retrieved along the investigated structures;. (b) Map where the encouraged (red) and discouraged (blue) motions are reported; the main structures (black lines) and the surficial projection of the two dikes (green polygons) are also shown. The seismicity recorded from 22–28 December 2018 (yellow circles) and from 29 December 2018 to 10 February 2019 (light blue circles) is also reported as a function of magnitude. [from De Novellis et al., 2019]

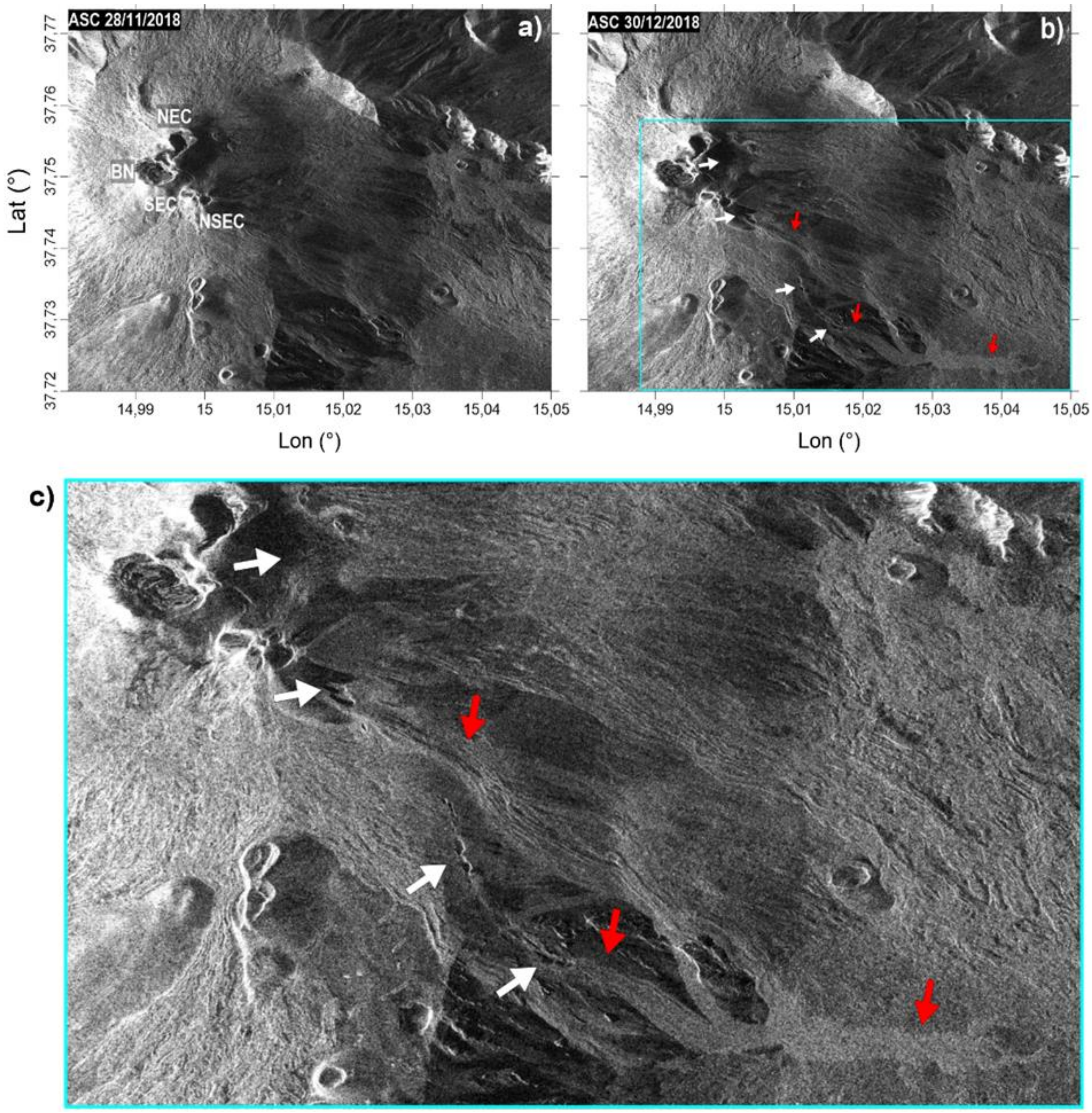


Figure 3. Geomorphological evidences of the EE2018. a) pre- (28 November 2018) and b) post- (30 December 2018) eruption COSMO-SkyMed ascending SAR amplitude images. These SAR images allowed us to identify a 2800 m long fissures, which start from the base of the NSEC and propagate southwards within the VdB depression (see red arrows). These fissures were also responsible for the 24 December lava emission (see white arrows). c) This is the zoom area of panel b) where the eruptive fissures and lava field are represented. . [from De Novellis el al. 2019]. NSEC: New South-East Crater; NEC: North-East Crater; SEC: South-East Crater; BN: Bocca Nuova Crater;

Bonforte et al., (2019) modelled the Sentinel 1 DInSAR data focusing their efforts on the magmatic system. In this way, they defined the magmatic sources triggering the succession of eruptive and seismic phenomena, resolving the discrepancy between the large ground deformation and the small eruption occurred. Their results shown that the erupted magma was drained from the upper plumbing system by a shallow radial dyke and not from the deeper eccentric intrusion, furthermore they estimated that a large volume of magma (~30 × 106 m^3) has not been erupted and stopped beneath the volcano, running out of its energy, activating peripheral faults . The fault slip discharges the energy and so the eruption aborted (Figure 4).

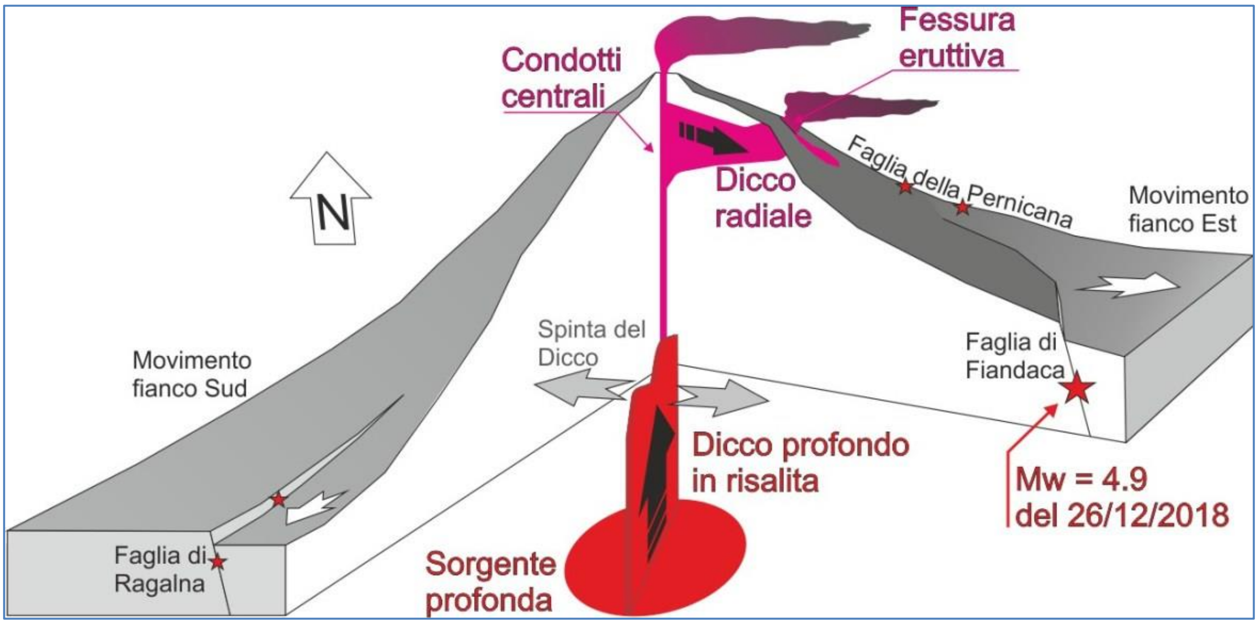


Figure 4. 3d sketch model of the Dicembre 2018 eruption [from Blog INGV-Vulcani, https://ingvvulcani.com/2019/05/13/sulle-ali-della-farfalla-delletna-cosa-e-avvenuto-durante-leruzione-del-natale-2018/]

Immediately after the eruption on 24 December, a survey was carried out using a GNSS mobile network located on the southern and south-eastern flanks, making 24-hour measurements for a week. The acquired mobile GNSS data were processed together with the data acquired by the permanent GNSS network in order to obtain a better detail. In Figure 5, the comparison with the July 2018 GNSS survey on the entire Etna GPS network are reported. The GNSS vectors show decimetric displacements, highlighting the summit deformation generated by the dike intrusion and the intense deformation due to the earthquake of 26 December occurred along the Fiandaca-Pennisi fault. This pattern is associated with the destabilization of the southern and eastern sides of the building, whose movements make clear the roles of release of the Pernicana fault in the NE and of the Fiandaca fault in the SE.
To derive high-accuracy three-dimensional surface motion maps, we applied the SISTEM method [Guglielmino et al., 2011] to integrate the July-December 2018 GNSS and Sentinel 1 DInSAR data covering same time span. The GNSS displacement relevant to July-December 2018, were integrated with the DInSAR Sentinel interferograms (ascending and descending) covering the same time span, using the SISTEM approach
The SISTEM results provide an exceptional detail of the deformation field, allowing analyzing the effects and characterizing the different deformation sources. In particular, is possible discriminate: (i) the December 24 dike intrusion occurred in the upper Valle del Bove, which produced a maximum deformation of about 30 cm westward and about 40 cm to the east; (ii) the Fiandaca-Pennisi fault (lower south-east flank) that shows a maximum relative displacement of 20 cm ; (iii) the Pernicana fault (north-east flank) with a maximum relative displacement of about 3 cm; (iv) the Ragalna fault (upper South-West flank) with a

maximum relative displacement of about 2 cm; (v) the Borello-Ognina fault (lower southern flank) which showed a maximum relative displacement of about 2 cm (Figure 6)

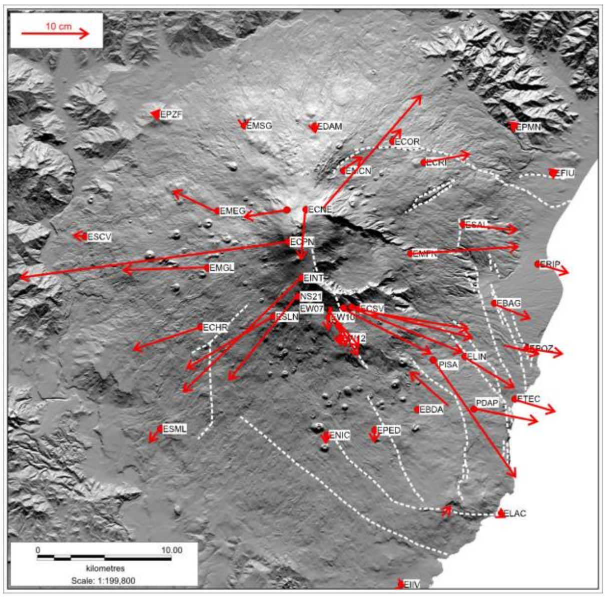


Figure 5. GPS displacements referring to the Jult-December 2018 surveys comparison

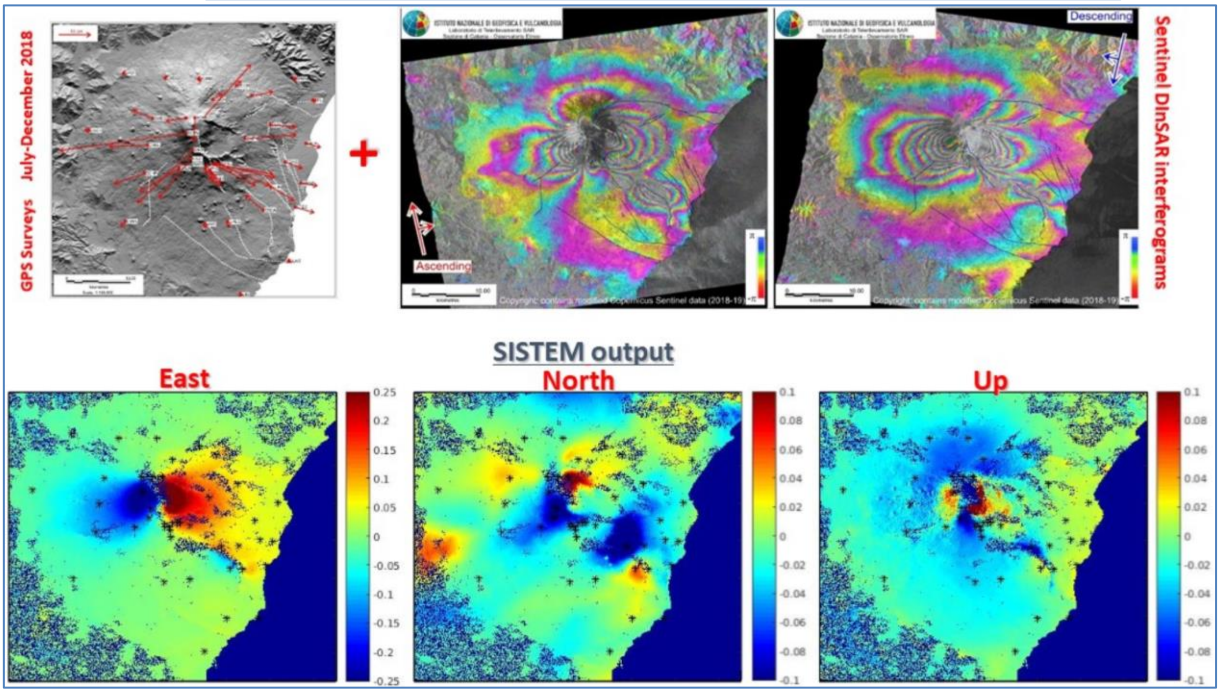


Figure 6. SISTEM input/output

These results were disseminated in same internal presentations. A paper for an international journal is in preparation.

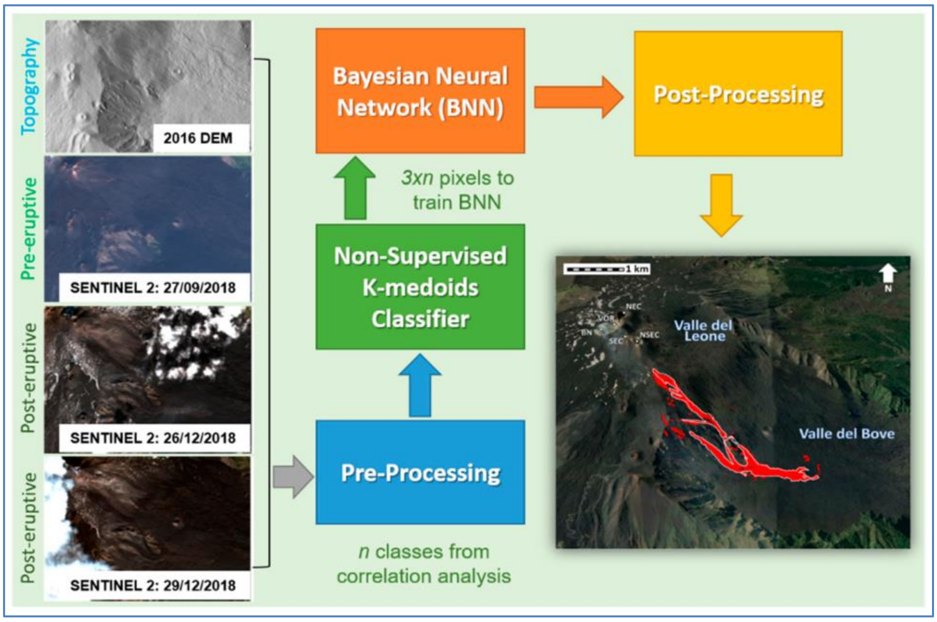


Figure 7. The workflow adopted to map lava flows using the MSI Sentinel-2 data and DEM information. The input data are firstly pre-processed and given as input to the k-medoids unsupervised clustering; then n pixels for each class are used to train the BNN. The output of the BNN is post-processed by opening the resulting image providing the areal extent of lava flow. [From Corradino et al., (2019)]

In order to map the December 2018 lava flow, Corradino et al., (2019), used a supervised classifier based on machine learning techniques to discriminate recent lava imaged in the MultiSpectral Imager (MSI) on-board Sentinel-2 satellite. The MultiSpectral Imager (MSI) onboard of Sentinel-2 acquires data in 13 spectral bands, at 3 different spatial resolutions: 10 m (bands 2, 3, 4, 8), 20 m (bands 5, 6, 7, 8a, 11, 12) and 60 m (bands 1, 9, 10). The authors utilized the Multispectral Imager (MSI) on-board Sentinel-2 satellite and the high-resolution topographic data derived from tri-stereo Pléiades-1 satellite imagery. Lava-flow maps produced adopting this approach, compared with ground-based measurements and actual lava flows of Mount Etna emplaced on December 2018, provides excellent results in terms of accuracy, precision, and sensitivity (figure 7).

The ability of the SEVIRI sensor, on board the MSG geostationary satellite, to follow the evolution of th Decembere 2018 volcanic activity from the source to the atmosphere in near real time is presented by Corradini et al., (2020).. The estimations are realized in the whole period, with a time frequency from 5 to 15 min. The hot spot analysis indicates the onset of the eruption on 24 December at 11:15. The TADR estimation on 24 December shows an abrupt increase with peak of 8.3 m3 /s and a subsequent exponential decrease, indicating the occurrence of a lava flow from the eruptive fracture toward Valle del Bove. (Figure 8). The distal monitoring indicates that the volcanic cloud flowed generally toward the south/south-east and that ash and SO2 are totally collocated.

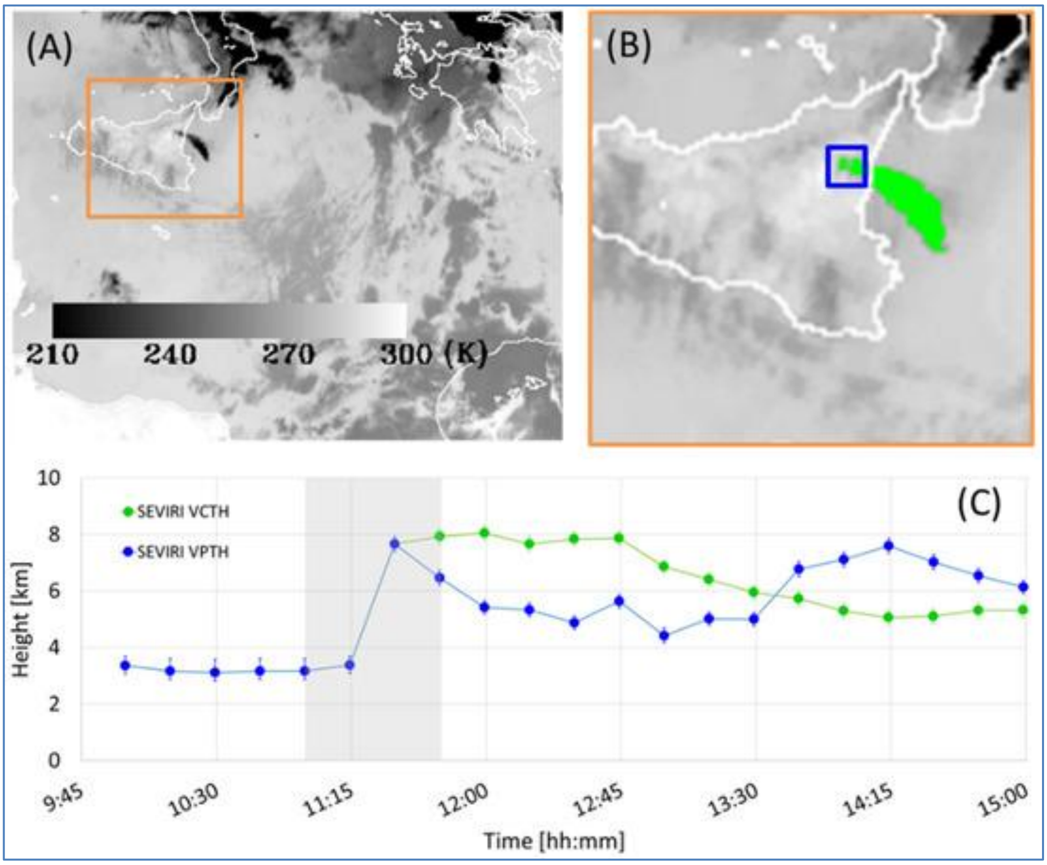


Figure 8. Brightness temperature at 10.8 µm considering the SEVIRI image collected on 24 December 2018 at 12:00. (B) Image of Sicily with the blue square area and the green area used for the Volcanic Plume Top Height (VPTH) and Volcanic Cloud Top Height (VCTH) computation, respectively. (C) Plot of VPTH (blue points-line) and VCTH (green points-line) time series obtained from SEVIRI data collected every 15 min on 24 December 2018. The green and blue vertical bars represent the VCTH and VPTH SEVIRI retrieval uncertainties, respectively. [From Corradini et al., (2020)]

5.3. Interaction between volcanic activity and atmosphere

Beside the studies on the dynamic of the volcano structure, Mt. Etna Supersite stimulated researches on the effect and impact of the volcanic activity (volcanic ash and degassing) on the atmosphere. These studies were supported by the H2020 ENVRIPlus project, aimed at improving and coordinating the access to European Environmental Research Infrastructures. In this case, new in-situ data were considered, in view of its integration in the Supersite in-situ datasets (see Section 3). Thanks to these studies, new knowledge on the internal dynamic of the volcano shallow plumbing system was obtained. The projects carried out in the framework of ENVRIPlus were three: RAVE@Etna (PI, P.J. Gauthier); GEOCUBE+@Etna (PI, P. Briole) and VAMOS-MS (PI, J. Diaz).

RAVE@Etna (*Radon Analyses in Volcanic Emissions from Etna volcano: a tool to shed light on magmatic processes and environmental issues*). This project has a threefold objective:

i) Benefit from innovative 222Rn measurements in the diluted plume of Etna to implement existing degassing models (Terray et al., 2018) and derive sharper constraints on shallow magma dynamics and degassing processes. A long-term time-series of these parameters related to the style and intensity of degassing/eruptive activity will contribute to better volcanic hazard assessment.

ii) Use unprecedented 222Rn measurements to quantify for the first time Etna's degassing budgets in terms of radionuclides injected into the atmosphere, and estimate radiation levels at the summit craters and at distances from the active vents, with implications for radiation safety and related health issues.

iii) Collect and analyze biological samples to study
   a. whether microbial (and other micro- organisms) life may exist under extreme conditions in a volcanic and radioactive environment and how it evolves to get adapted to it;
   b. how more evolved species (honeybees) react to this specific stress and may act as a dissemination factor of radioactivity through beehive products, with implications for life origin and evolution. Results are yet to be presented in a final report to be submitted.

GEOCUBE+@Etna (*Design of a light multi-parameters station based of the GEOCUBE+ architecture*). This project had an objective to consolidate the results acquired during the previous projects as well as the GNSS aspects of the Géocube. It coupled experiments with aerosols sensors in order to assess in the field, the issues to be solved to implement in the future Géocube+. To assess the capability of recording information on gas and aerosols with appropriate add-on sensors. The projected outcome is to develop an array of light and rugged multi-parameter stations organized around the original concept of Géocube.

VAMOS-UAV (*Volcanic Airborne Gas Monitoring using the miniGAS and miniature Mass Spectrometer UAV based Systems*). The projects objectives were to characterize the gas emission of Mt. Etna Volcano using the recently developed UAV ready miniature multiple Gas System (miniGAS) and miniature Mass Spectrometer System (mMS) targeted for in-situ volcanic gas emission analysis during ground and airborne campaigns. The mMS have been used to support earth science missions for both atmospheric and volcanic studies providing a robust and broad spectrum of in situ gas sampling with trace gas analysis capability (1 to 150 amu), combined with temperature, humidity, pressure, position, and particle characterization data for ash-driven volcanic plumes. The system has been tested in Costa Rica and Italy but Mt Etna represent a new and challenging target to characterize the gas emissions with in situ mass spectrometry, measure the different gas ratios among the different gases detected to assess the condition of the volcano and compare to other techniques used by the INGV, to better understand the geochemistry of the volcano. The deployment of the miniGAS and mMS systems at Mt. Etna will serve as a demonstration of the capabilities of the instrument under normal operating condition of a volcanic research center for solid earth and atmospheric studies. The deployment was a success and demonstrated the capabilities of the miniGAS instruments (PRO, NTX, Lite versions) for airborne in situ gas measurements using UAVs in complement with other techniques such as the thermal and optical cameras deployed by ONGV Rome and Napoli. The deployment provided a unique collection of Mt Etna's degassing concentrations to compare with both ground measurements stations and remote sensing instruments. It also provided a list of lessons learned to develop better and more robust systems for permanent monitoring of volcanic activity using drones and portable instruments. As an important note, this was the first time a miniature mass spectrometer to be flown in a small UAV at a volcano with the elevation of Mt Etna, which constitute a milestone in the Chemistry, Physics, Engineering and Volcanology fields but the instrument still requires more development in both the UAV platform and instrument fronts. The team will produce at least 2 scientific papers form this deployment and several conference presentations and they hope to continue this area of work at Mt Etna in 2019 and other locations.

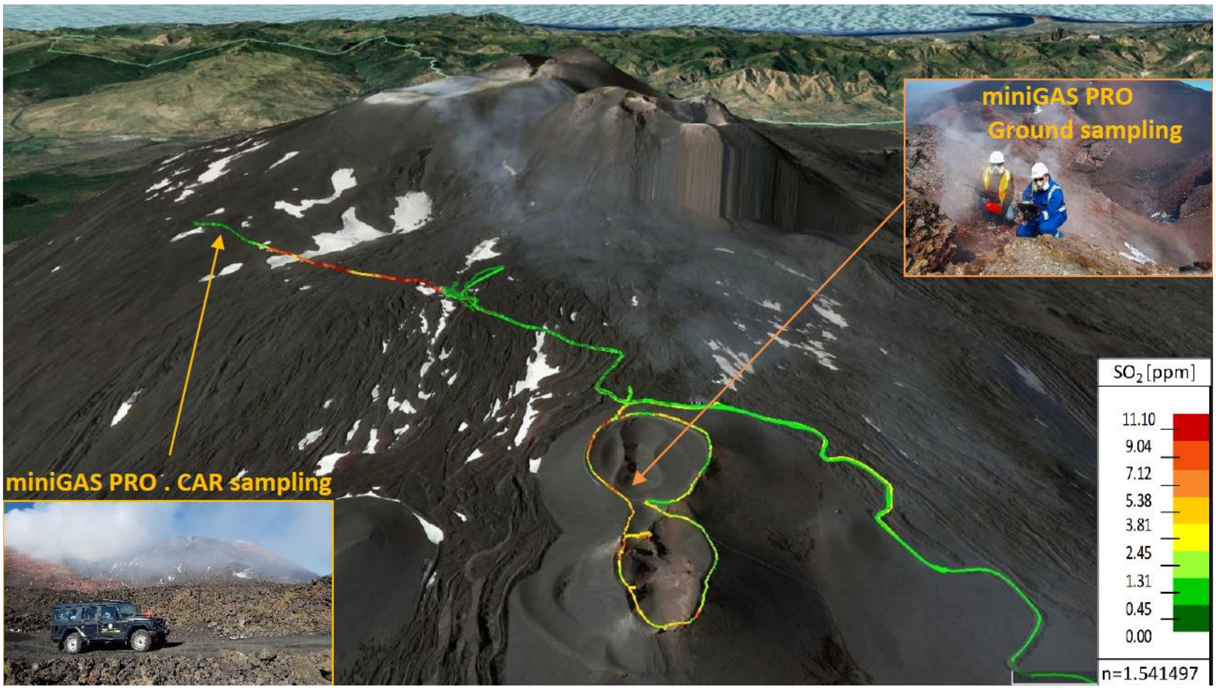


Figure 9. MiniGAS PRO on INGV off-road veicle ride along the path crossing the summit area of Mt Etna and had-held walk to characterize SO2/H2S concentration.

5.4. Publications

Peer reviewed journal articles

Corradini, S; Guerrieri, L ; Stelitano, D, Salerno, G; Scollo, S; Merucci, L; Prestifilippo, M; Musacchio, M; Silvestri, M; Lombardo, V; Caltabiano, T (2020). Near Real-Time Monitoring of the Christmas 2018 Etna Eruption Using SEVIRI and Products Validation. Remote Sens. 2020, 12(8), 1336; https://doi.org/10.3390/rs12081336

Corradino C., Ganci G., Cappello A., Bilotta G., Hérault A., Del Negro C. (2019). Mapping Recent Lava Flows at Mount Etna Using Multispectral Sentinel-2 Images and Machine Learning Techniques. Remote Sens. 2019, 11(16), 1916; https://doi.org/10.3390/rs11161916.

Bonforte, A.; Guglielmino, F.; Puglisi, G. Large dyke intrusion and small eruption: The December 24, 2018 Mt. Etna eruption imaged by Sentinel-1 data. Terra Nova 2019, 31, 405–412.

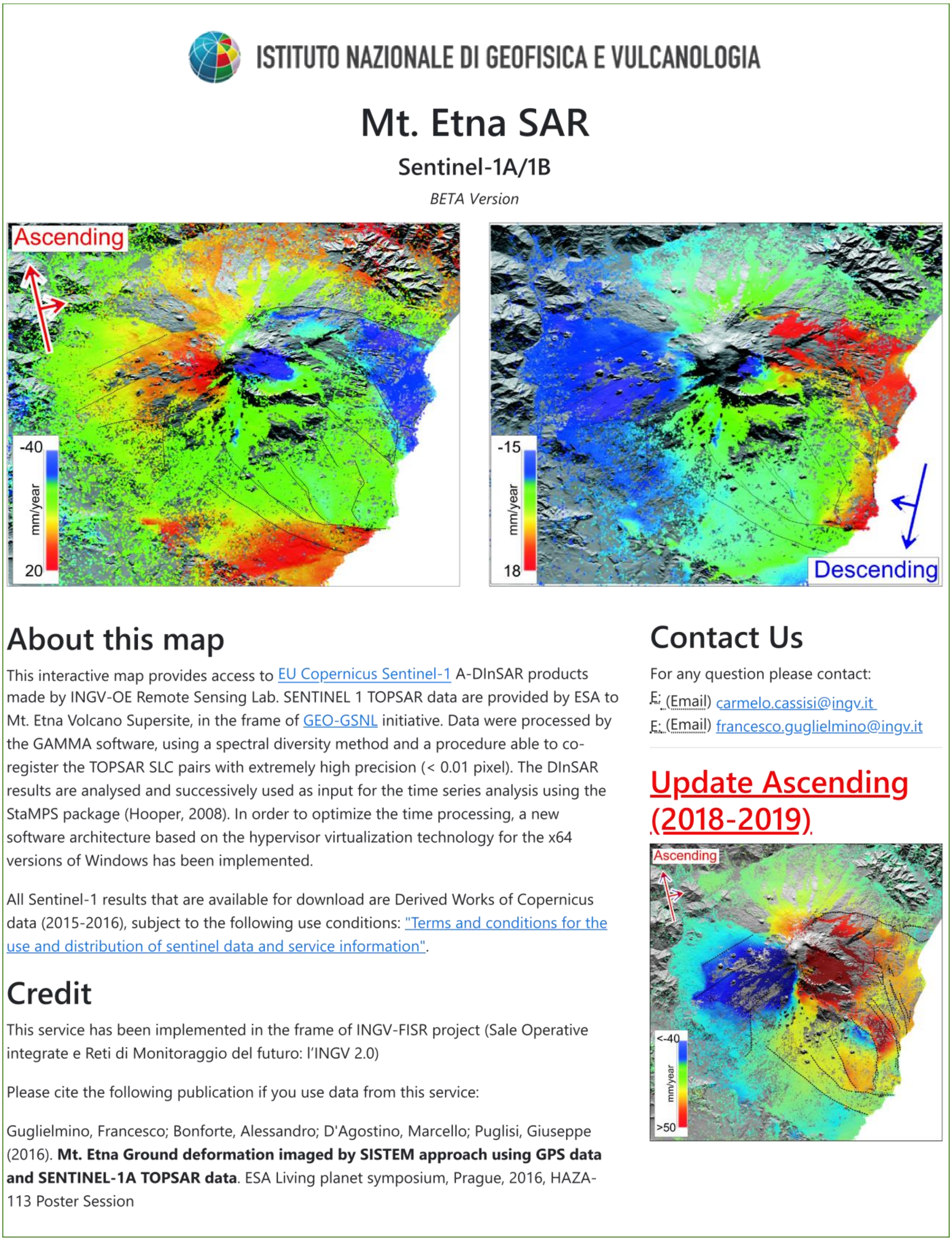
De Novellis V. , Atzori S., De Luca C., Manzo M., Valerio E., Bonano M., Cardaci C., Castaldo R., Di Bucci D., Manunta M., Onorato G., Pepe S., Solaro G., Tizzani P., Zinno I., Neri M., Lanari R., Casu F. DInSAR Analysis and Analytical Modeling of Mount Etna Displacements: The December 2018 Volcano-Tectonic Crisis.First published: 13 May 2019 Https://doi.org/10.1029/2019GL082467Citations: 7

Guglielmino, F., G. Nunnari, G. Puglisi, and A. Spata (2011), Simultaneous and integrated strain tensor estimation from geodetic and satellite deformation measurements to obtain three-dimensional displacement maps, IEEE Trans. Geosci. Remote Sens., 49, 1815–1826, doi:10.1109/ TGRS.2010.2103078

5.5. Research products

A part from the papers and presentations listed above, it has been recently implemented a INGV-OE Remote Sensing Lab service to visualise the interferogram products obtained from the Sentinel-1A/1B data acquired at Mt. Etna (Figure 10). The displayed products consist in the ascending and descending mean LOS (line-of-sight) velocity maps, and in the time-series of the displacements (positive toward the sensors) and comparison between time series that can be get by clicking the individual maps (Figure 11). This open access service has been implemented in the frame of INGV-FISR project (Sale Operative integrate e Reti di Monitoraggio del futuro: l'INGV 2.0). The link to the service is going to be embedded in within the MED-SUV portal.

Type of product	Product provider	How to access	Type of access
Ground Deformation Time series	*Francesco Gugliemino (INGV)*	http://tsd.ct.ingv.it/tsdws/sar	*public*



ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

Mt. Etna SAR

Sentinel-1A/1B

BETA Version

About this map

This interactive map provides access to EU Copernicus Sentinel-1 A-DInSAR products made by INGV-OE Remote Sensing Lab. SENTINEL 1 TOPSAR data are provided by ESA to Mt. Etna Volcano Supersite, in the frame of GEO-GSNL initiative. Data were processed by the GAMMA software, using a spectral diversity method and a procedure able to co-register the TOPSAR SLC pairs with extremely high precision (< 0.01 pixel). The DInSAR results are analysed and successively used as input for the time series analysis using the StaMPS package (Hooper, 2008). In order to optimize the time processing, a new software architecture based on the hypervisor virtualization technology for the x64 versions of Windows has been implemented.

All Sentinel-1 results that are available for download are Derived Works of Copernicus data (2015-2016), subject to the following use conditions: "Terms and conditions for the use and distribution of sentinel data and service information".

Credit

This service has been implemented in the frame of INGV-FISR project (Sale Operative integrate e Reti di Monitoraggio del futuro: l'INGV 2.0)

Please cite the following publication if you use data from this service:

Guglielmino, Francesco; Bonforte, Alessandro; D'Agostino, Marcello; Puglisi, Giuseppe (2016). **Mt. Etna Ground deformation imaged by SISTEM approach using GPS data and SENTINEL-1A TOPSAR data**. ESA Living planet symposium, Prague, 2016, HAZA-113 Poster Session

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Update Ascending (2018-2019)

Figure 10. WEB-Gis home page

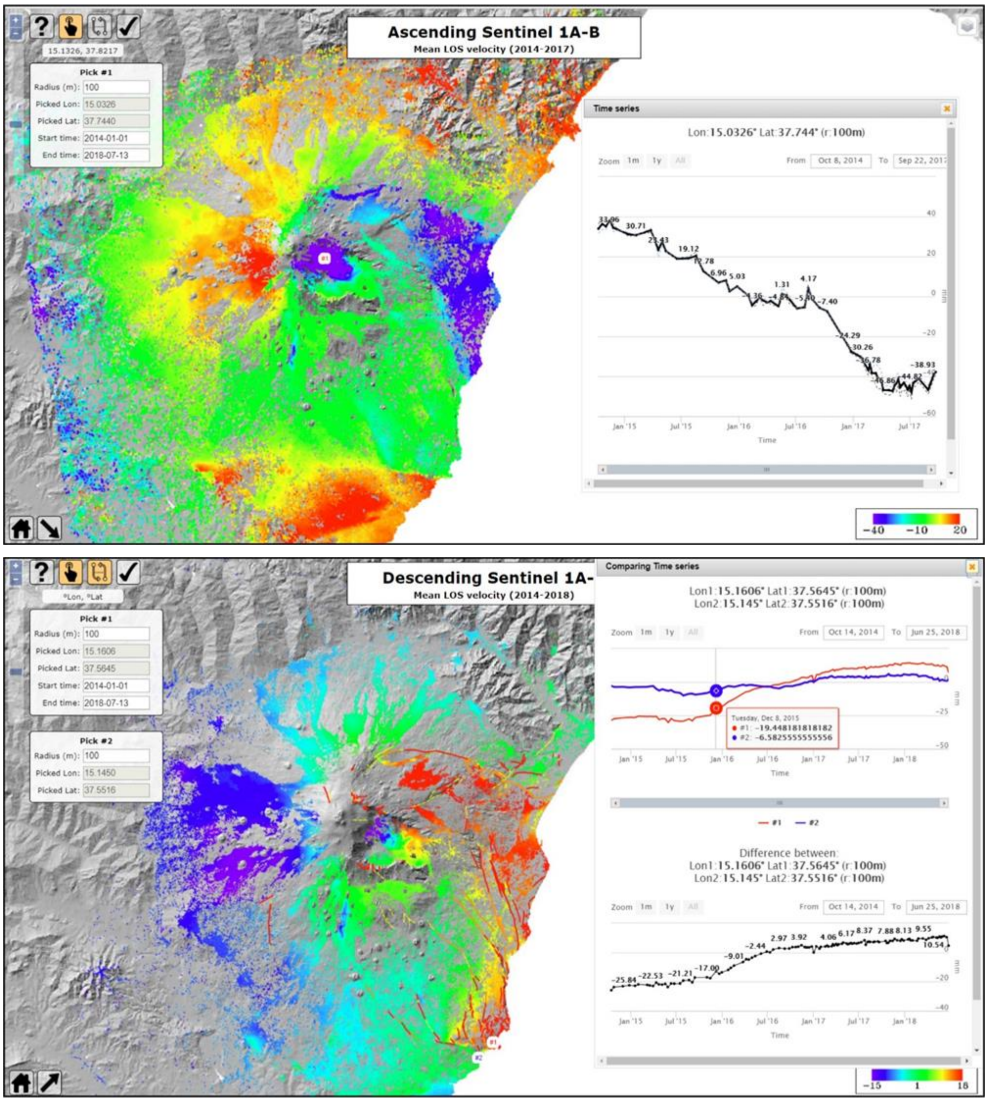

Figure 11. (upper part) Single Time Series Visualization; (lower part) Snapshot of Comparing Time Series tool

6. Dissemination and outreach

In order to increase the effectiveness of the dissemination and outreach activities, Mt. Etna Supersite has promoted the submission of an Italian project funded by the National Civil Service (Servizio Civile Nazionale) started on February 2020 (SCN Project), which supports seven volunteers involved in the activity of the management of the data base (update, implementation, etc.) and in the implementation of specific dissemination and outreach initiatives (e.g. the Supersite Day). Unfortunately, SNC project started just before the outbreak of the COVID-19 pandemic, jeopardising the original workplan that is currently under deep revision.

Besides, dissemination activities were carried out during national and international meetings (e.g during EPOS meetings), as well as in the frame of the EUROVOLC project.

7. Funding

The analysis of the economic support to the Etna Supersite should be distinguished between the support to the scientific activities and the management.

Except for the scientific results obtained in the frame of ENVRIPlus project, which will end in 2019, all the above scientific products were produced without properly dedicated financial support.
To overcome this difficulty, through the biennial period the management of the Supersite continued the efforts to promote the support to the Supersite in the frame of international or national projects or calls for proposals. This effort partially succeeded in the frame of the EUROVOLC project, in which Mt. Etna was identified as one of the volcanoes for testing new methods and algorithms to analyse the monitoring data. At the time of writing, no scientific products have been published yet; however the cooperation is ongoing and some relevant results are expected.

The management of Mt. Etna Supersite is largely based on the in-kind contribution of the INGV, through the personnel efforts. However, during the biennial reporting period, the Italian EPOS Joint Research Unit (EPOS JRU) included the Etna Supersite as one of the Italian nodes of EPOS. Thanks to this condition, the EPOS JRU 2018-2019 and 2019-2020 work plans foreseen a contribution to maintain and upgrade the data infrastructure of the of the Etna Supersite. A significant update of the storage resources has been achieved on 2018-2019. Unfortunately, some administrative complications and the difficulty to find skilled IT people slow down the hiring of the new personnel for Etna Supersite, who is not yet operational at the date of writing. However, the support of EPOS JRU or the management activity is definitively a positive aspect of the financial analysis of the Supersite.
Apart from that, Etna Supersite benefitted also from the national funds for the improvement of the volcano monitoring tools (INGV-FISR)

8. Societal benefits

The main benefitting no-scientific stakeholders are the national and regional (Sicilian) departments of Civil Protections, which take advantage of the possibility of INGV to use the remote sensing data provided in the framework of the Supersite. Indeed, INGV is an official "Centre of Expertise" (Centro di Competenza) of the national Civil Protection system, which assignment is to scientifically support the National and Regional departments in disaster risk management activities. Such a benefit is proved by several contributions based on satellite data included in the periodic reports to and meetings with the Civil Protections departments provided by INGV.

9. Conclusive remarks and suggestions for improvement

During the 2018-2020 period of activity of the Mt. Etna Supersite, the main scientific achievements referred to the use of the EO data for investigating the dynamic of the volcano associated to the December 2018 eruption. Furthermore, a few relevant transnational access projects funded by ENVRIPlus finished their activity.

Another objective of the Supersite's activity was the consolidation of the data infrastructure in a wider framework that now includes EPOS European infrastructure and the H2020 EUROVOLC project, as well as the enrichment of the in-situ datasets. In particular, the MED-SUV infrastructure was used as starting point for designing the Gateway of the European volcanological community that is going to be implemented in EROVOLC and EPOS framework.
Some issues in the management of the EO data were encountered, largely due to the work necessary to evolve the e-infrastructure in a wider framework. As this upgrade of the e-infrastructure is going to be accomplished, the solution of these issues is expected in short time.

During the biennial period, several management actions have been achieved. In order to optimize the effort and increase the synergy between the different initiatives, on November 2018 the INGV Branch of Catania - Mt. Etna Observatory - appointed a specific Working Group aimed at coordinating the Supersites activity and the participation to EPOS; indeed, Mt. Etna Supersite is one of the Italian EPOS National Nodes. The activity of the Etna Supersite is at the base of other two important initiatives. A Memorandum of Understanding signed with CNR, on November 2019, by INGV and Catania University, which entered as Associated Members in ECOPOTENTIAL. The submission and approval of the National Civil Service project "Promotion of Italian Supersite volcanoes", started on February 2020, aimed at supporting the management of the data bases and implementing outreach and dissemination activities.

Overall, the management of the Supersite is consistent with the strategic guidelines depicted in the previous biannual report, i.e., to strengthen the link with national and international initiatives aimed at implementing the system of the research infrastructures in Europe and worldwide, to expand toward research domains different from that of the study of the volcano internal dynamics and to foster access modalities different from those linked to the virtual access to the data sets.