

## GSNL - Geohazard Supersites and Natural Laboratories

Biennial report for Candidate/Permanent Supersite - July 2016

### *Etna Supersite*

<b>Status</b>	<i>Candidate Supersite</i>
<b>Proposal documents</b>	<a href="http://www.earthobservations.org/documents/gsnl/proposals/MtEtnaVolcano_proposal.pdf">http://www.earthobservations.org/documents/gsnl/proposals/MtEtnaVolcano_proposal.pdf</a>
<b>Acceptance letter(s)</b>	<a href="http://medsuv_portal.ct.ingv.it/documents">http://medsuv_portal.ct.ingv.it/documents</a>
<b>Previous reviews</b>	<i>No previous report</i>
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### Science team issues

The current organization and scientific objectives of the science team mainly reflects those implemented and pursued in the EC-FP7 Mediterranean Supersite Volcanoes (MED-SUV) project, which just ended (31 May 2016). The existence of this project guaranteed the cooperation among the partners as well as the feed-back of the scientific outcomes to the PoC. Thus the main issue concerns the capacity to maintain the same level of cooperation and scientific benefit in the future, and possibly to enlarge the number of users, in absence of a formal frame. To face with this issue, we intend to use the e-infrastructure implemented in the frame of MED-SUV project, which allows the access to EO and in-situ data (see below).

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### In situ data

The in situ monitoring networks of Mt. Etna are summarized below.

Seismic	Permanent:	37 stations	Mobile:	12 stations
Accelerometric	Permanent:	6 stations		
Infrasonic	Permanent:	11 stations		
GPS	Permanent:	38 stations	Periodic surveys:	80 benchmarks
Leveling			Periodic surveys:	38 benchmarks
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 data accessible through the MED-SUV portal ([http://medsuv\\_portal.ct.ingv.it/](http://medsuv_portal.ct.ingv.it/)).

Type of data	Data provider	How to access	Type of access
<b>Seismic waveform</b>	INGV	Link to Network Italian Seismic Network Web Service through MED-SUV Portal Search	Limited to registered users
<b>Seismic events</b>	INGV	Link to Network Italian Seismic Network Web Service through MED-SUV Portal Search	Limited to registered users
<b>GPS data</b>	INGV	MED-SUV GSAC server	Limited to registered users
<b>GPS coordinates / displacement vectors</b>	INGV	MED-SUV File Manager	Limited to registered users
<b>Hydrophone / OBS waveform</b>	INGV	MED-SUV File Manager	Limited to registered users
<b>Thermal cameras</b>	INGV	MED-SUV File Manager	Limited to registered users
<b>Tilt</b>	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, contains the data sets defined by the project consortium agreement. In particular it contains the seismic (raw and products), GPS (raw and products), video and tilt data from 2005 to 2011. It is planned to adopt appropriate initiatives (both from the technical and infrastructural point of view) to extend the in-situ data sets to recent years and include a wider dataset. In some case (e.g., seismic data) a few-months old data are already available for some stations. To this aim, a specific deliverable was

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implemented at the end of the project, which draw the strategic initiatives in which to frame this upgrade, by identifying suitable partners, technical elements, and legal tools.

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### Satellite data

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

### Satellite data issues

Although satellite data provision by Space Agencies represents an added value to the Supersites initiative, some issues arose - from the PoC (Point of Contact) point of view - in the first biennial period, which will be shortly summarized here:

1. The availability of the ESA space-borne data (ERS1/2, ENVISAT and Sentinel) through the respective web-sites for any registered user, although represents a great improvement compared to the past, with free-of-charge data for everyone, does not allow to trace scientists downloading the data, resulting in two drawbacks: a) scientists are not aware of the Supersites initiative, as they could be potentially interested in collaborating with the Supersites teams, to get better results of their work and on the whole and b) the Supersites PoCs are not aware of the activities carried out by colleagues outside the Supersites teams, whose work not only could contribute to a better knowledge of the area of interest, but this could be also an additional contribution to be reported to CEOS.

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A suggestion could be to point out on the web-sites disseminating satellite data, the Supersites initiative and such an opportunity for collaboration for interested scientists, with links to the GEO-GSNL portal to get in touch with PoCs.

2. Also for TSX data, available through the DLR Supersites web-page, there is no means to trace users downloading data, although the service is very fast in uploading data on the web-page after the order of the PoC.
3. Ordering RS-2 data seems to be neither fast nor user-friendly: the task is accomplished through the APT dedicated tool, which is quite complex and slow when searching through the archives. Moreover, it only works on Windows operating system, but not on Mac or Linux, the latter widely used by the InSAR scientific community. A web-based ordering solution would represent a great improvement.
4. ALOS 2 L-band SAR data have not been used to generate products for Mt. Etna Supersite. In many other volcanic areas with moderate to strong vegetation cover the ALOS 2 data have provided very good results, reducing the temporal decorrelation effects with respect to the X- and C-band data. We expect that the joint integration of the multiband imagery dataset will greatly improve the ground deformation mapping over the area, strongly benefiting the Supersite research results. A quota of about 100 ALOS 2 images per year would be sufficient for this purpose.
5. A great improvement in the Supersites initiative and related studies would be the opportunity to get from Space Agencies not only the *routine* satellite data (usually StripMap) but also high or very high resolution data, like the Enhanced Spotlight mode for CSK and the Staring Spotlight mode for TSX, to carry out detailed studies (and monitoring) over some “critical” areas as in the case, for instance, of the area of the Summit Craters on Mt. Etna. Again, a comparison of such in situ with space-borne data, would be an added value for the Supersites initiative on the whole, pointing out the possibility to get very valuable results on a local or very local scale from satellite data, in spite of the preconception that such data are addressed to the use on large/wide areas.

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### Research results

During the last two years significant steps forward have been performed to implement enhanced operational systems, develop applications and give answers to various research questions raised during the Supersite proposal. In overall these progresses accomplished the overarching objective of implementing the GEO-GEOSS work plan.

#### A. MED-SUV e-Infrastructure

Before going into details of the various scientific achievements, we consider a noteworthy outcome the implementation of the e-Infrastructure in the framework of the EC-FP7 MED-SUV project, for two reasons. The first one is mainly technical; the implementation of the e-Infrastructure fosters the community to deal with two main technical drawbacks well-known at the beginning of the project and thoroughly connected each-other: the standardization of the in-situ data sets and the interoperability among data bases (both EO and in-situ). The second reason is typically strategic; the implementation of the MED-SUV e-Infrastructure is a key element for the implementation of the European Plate Observing System (EPOS) platform (EPOS is one of the GEO Participating Organizations), in which MED-SUV is considered as a pilot for the provision of the volcano observations.

MED-SUV e-Infrastructure adopted a distributed architecture managed through a brokering approach; it is built by four main elements: the data nodes, the data broker, the Authorization components, the WEB APIs and the Portal. The distributed data nodes provide both EO and in-situ data; they are located in the ESA, (for ERS 1-2, ENVISAT, Sentinel 1-2 data) and DLR (for TSX data) portals, IRIS node (for seismic data) and INGV data centers (for ASI-CSK data, and GPS, Hydrophone / OBS waveform, Thermal cameras and Tilt data). The data broker is able to connect different data systems exposing a single common and standard interface; its main components are (a) the discovery broker, (b) the access broker, (c) the semantic enhancement module. The Authorization components implements the MED-SUV data policy assessed at the beginning of the project (Deliverable 1.2), which adopts the open access paradigm, by identifying the users as Registered and Authorized. Currently Registered users are all those MED-SUV partners that asked to have an account to the e-Infrastructure, which today number is 58. Authorized users are allowed to access to in-situ data sub-sets, referring to experiments carried out during the projects by specific teams. The WEB-APIs functionalities allow developing client applications for facilitating integration with overarching systems. The Portal ([http://medsuv\\_portal.ct.ingv.it/](http://medsuv_portal.ct.ingv.it/)) is the user's access to the e-Infrastructure.

#### B. MED-SUV scientific achievements

The EC-FP7 project provided significant answers to the main research questions.

##### a. Data integration

The integration of EO and in-situ data sets was of the main topics of the project's activities. The integration was pursued according to three different approaches and aims.

##### i. Data Merging or Fusion

Different data sets measuring a particular volcanic phenomenon or physical characteristic were "merged" or "fuse together" in order to find another new set of data relevant to the same phenomenon or characteristic. This is the case, for instance of the ground deformation measured by

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InSAR and GPS techniques. MED-SUV implemented two different approaches to achieve this objective. Polcari et al. (2015) realized a fusion by using a Bayesian statistical approach searching for the optimal estimation of the three deformation components. INGV and T2 implemented an updated version of the SISTEM method (Guglielmino et al. 2011) to obtain a data set containing a continuous – through the area – 3D information of the ground deformation. SISTEM has been implemented in the ESA Geohazards Exploitation Platform (GEP; <https://geohazards-tep.eo.esa.int/#!>). Another example of data fusion concerns the merging of high resolution optical (WorldView II and Pleiades) and radar (COSMO-SkyMed and TerraSar-X) satellite data, and the maps obtained from the ground based visible and thermal images collected by the surveillance INGV-EO network (Etna\_NETVIS).

### ii. Integration through validation

In-situ data are used to “validate” the EO data sets or vice versa. For instance, this is the case of the SO<sub>2</sub> retrieval in the atmosphere. The project created a semi-automated procedure for the SO<sub>2</sub> fluxes calculation at Mt. Etna volcanic vent position by using satellite images showing SO<sub>2</sub> clouds released during Etna activity and validated by using the Mt. Etna in-situ monitoring network.

### iii. Integration through models

EO and in-situ data have been integrated through models. For instance, this is the case of the integration of MODIS data, the results of GPS analysis and atmospheric models to obtain a 3D tomography of the distribution of the water vapor contents in the troposphere. The final goal of this activity is to eliminate the atmospheric effects from the InSAR products.

## b. Volcanic Unrests

The availability of EO data allowed to investigate and monitor some unrest episodes occurred during the deployment of the activity of MED-SUV.

The oldest studied event was the lava fountain episode occurred on 25-26 October 2013. SBAS time series has been obtained by using 146 ascending SAR images acquired by the Cosmo-SkyMed constellation sensors from 12 July 2009 to 10 January 2015. SBAS time series was modeled together with GPS displacement vectors, by using a FEM approach. This study identified an inflation/deflation dynamics, accompanying the lava fountain episode, as frequently observed on this volcano, which source was inferred in a shallow magmatic reservoir which inflated since July 2013, fed the volcanic activity at the summit craters during 25 – 26 October, and deflated due to magma drainage related to this volcanic activity (Greco et al., GRL, 2016) (Figure 1).

On 11 February 2014 a sudden and unusual hot avalanche originated from the northeastern flank of the New South-East Crater (NSEC), which covers in a few minutes about 2-3 Km in the Valle del Bove. The analysis of amplitude of TerraSAR-X data relevant to the 12 December pass allows defining the shape and extension of the main scarp a few hours after the event, i.e. before the lava flows emplaced during the following days partially covered the area. This analysis, was fruitfully exploited in the reports for Civil Protections Department.



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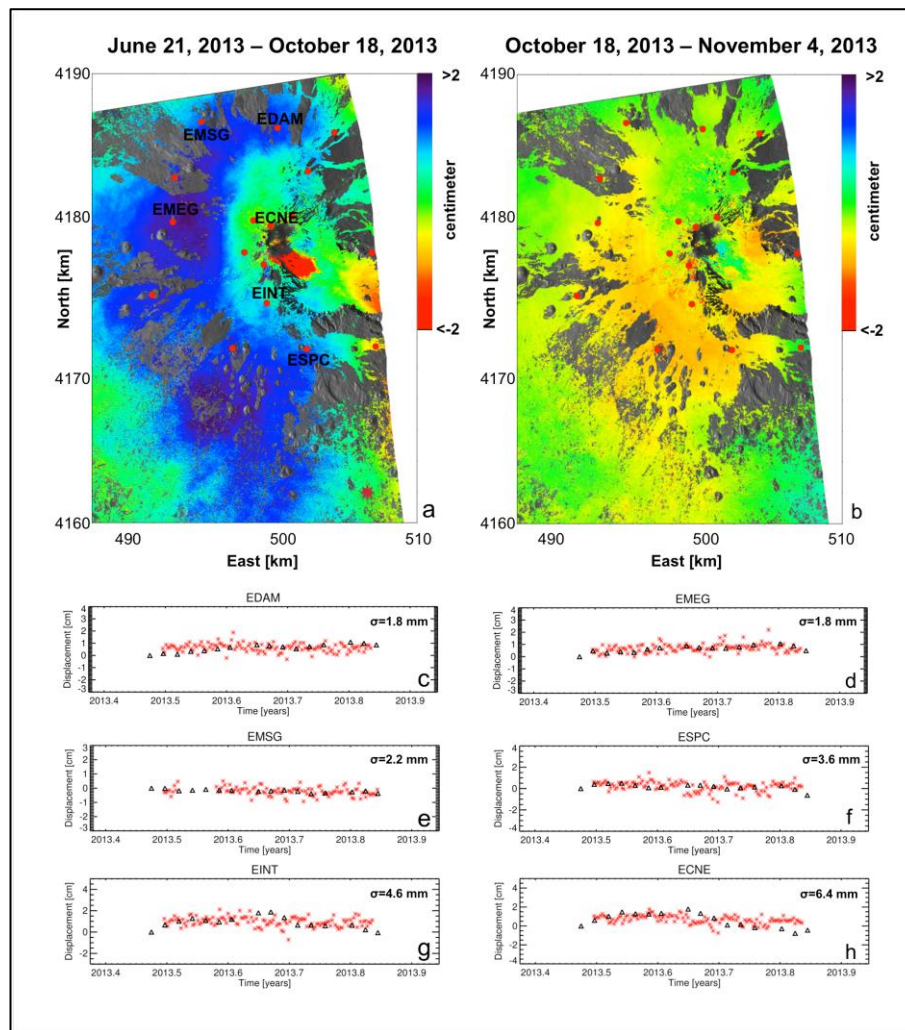


Figure 1: SBAS DInSAR Time-Series Results. (a) cumulative LOS displacement from June 21, 2013 to October 19, 2013. (b) Relative LOS displacement from October 19, 2013 to November 14, 2013. (c-h) Comparison between GPS and LOS-projected time-series (Greco et al., 2016)

The most well studied unrest episode was on 28 December 2014, when the summit eruption interrupted a quiet period lasted about four months (Bonforte and Guglielmino, 2015). This event was accompanied by strong ground displacements recorded by the GPS network on the summit of the volcano. GPS surveys carried out a few days after the eruption, and DInSAR Sentinel-1A ascending interferogram confirmed and detailed the ground deformation field affecting the area surrounding the summit, showing decimetric displacement around the craters and on the westernmost part of the Valle del Bove. The inversion of GPS data infers a very shallow sub-vertical dyke intruding just beneath the New South-East Crater (NSEC). The dyke geometry suggests that the intrusion started from the uppermost part of the feeding conduit of the NSEC. The interferogram shows an eastward/downward ground deformation pattern on the western wall of the Valle del Bove that suggests an additional ground deformation source acting on that area of the volcano (Figure 2). The shape of the residual fringes suggests a gravity-driven motion of the thick post-2011 lava flow field. By combining the GPS and InSAR based information, it was possible to infer on a series of threatening events never investigated earlier: the very shallow and rapid dyke intrusion and the presence of a recent thick lava flow field emplaced on a steep slope produced a local failure of

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the western wall of the Valle del Bove, involving an area much wider than the one previously affected by the failure and hot avalanche on 11 February 2014. Such feature could represent a new element of concern, being a potential source of hazardous phenomena.

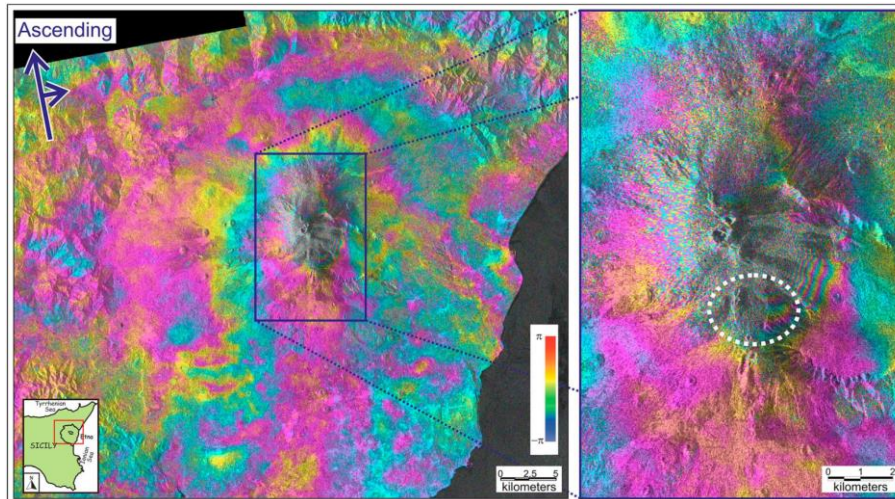


Figure 2: 7 December 2014 to 12 January 2015 Sentinel-1A ascending interferogram (Bonforte and Guglielmino, 2015).

A progressive upswing of the volcanic activity was observed at the end of November 2015, anticipating a few days the paroxysmal events occurred on 2-8 December 2015. Sentinel-1 data were used to monitor the evolution of the ground deformation at both the Summit Craters and along the Pernicana-Provenzana fault system (PFS). This analysis was used in the daily updated of the Civil Protection systems and summarized in some presentations (REFERENCES). From December 2, 2015, volcanic activity suddenly occurred on Mt. Etna with very violent fire fountaining at central crater, known also as “Voragine”. This activity continued with other intense episodes at the same crater during the three following days and involving also, in turn, all the other three summit craters. This sudden eruption produced a rapid deflation of the volcano and was followed, from December 8, by a seismic swarm, with almost eighty earthquakes during this day, located on the uppermost segment of the PFS. This seismicity was characterized by shallow foci (from few hundred meters until 1.5 km below the sea level) and a M3.6 main-shock. In order to investigate and measure the dynamics controlling and accompanying the PFS activation, a dataset composed of C-Band Sentinel-1A data has been used for SAR Interferometry (InSAR) analysis. Some interferograms have been generated from ascending and descending orbits in order to analyze both short- and long-term deformation. The availability of GPS data allowed comparing and integrating them with InSAR for ground truth and modeling aims. The surface kinematics and modeling obtained by InSAR and GPS data and integration have been compared to the distribution of the seismicity and related focal mechanisms in order to define the fault geometry and motion. The fault plain solutions obtained show kinematic already known in the PFS sector, in fact are present both left strike-slip and reverse movements. Moreover, essential constraints have been achieved about the PFS dynamic and its relationship with the intense volcanic activity occurred. In particular, the observed compressive dynamic is consistent with a rapid deflation of the volcano.

EO data were very useful for monitoring the resumption of the volcanic activity at the Summit Craters in May 2016. The thermal monitoring has been carried out by using ASTER and Landsat 8

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Thermal Infrared Sensor (TIRS), which nominally collect data on the entire Earth every 16 days, improved with the use of Meteosat Second Generation (MSG), which cover Mt. Etna with 96 images (288 images in 'Rapid Scan' mode Service) per day. This high frequency of MSG has offered the possibility to quickly detect the 18<sup>th</sup> May 2016 eruption. The analysis of Sentinel-1 data shown an inflation preceding the paroxysmal event of 18<sup>th</sup> May, which accelerated near the summit craters, during the last days preceding the event. The analysis of the Pleiades data allows to produce a preliminary DEM, which is the first digital information of this area, which dramatically changed the shape of this area after several decades.

### c. Knowledge on volcanic processes

The long-term in-situ data sets available for Mt. Etna were exploited to infer some key characteristics of the volcanic processes.

The flank dynamics of Mt. Etna is the focus of the comparative analysis with Kilauea (Island of Hawaii, USA) and Piton de la Fournaise (La Reunion Island, France). This research, born in the frame of MED-SUV and started in the last months of the project, is based on the long-term ground deformation monitoring data sets, both from SAR images and geodetic networks, available for these three volcanoes, two of which are Supersites. It aims to investigate the relation between basement setting and volcanic activity and stability at the three volcanoes. They host frequent eruptive activity (effusive and explosive) and share common features indicating lateral spreading and collapse, yet they are characterized by different morphologies, dimensions, and tectonic frameworks. Magma supply and plate velocity also differ in the three settings, as to the sizes of the edifices and the extents of their rift zones. These volcanoes, due to their similarities and differences, coupled with their long-time and high-level monitoring networks, represent the best natural laboratories for investigating the manifestations and mechanisms of spreading and collapse, the feedback process between spreading and eruptive activity (especially along rift zones), and the role of the regional geodynamics.

A part from the studies based on the use of the EO data, the MED-SUV project offers the opportunity to carry out new experiments and analyze the long-term multidisciplinary in-situ dataset based on the monitoring system; large part of these data and products are, or will be, accessible in the e-Infrastructure. The characteristics of the source of the magma and the dynamics of the magma in the plumbing system were inferred by studying the chemistry of the rocks and fluids emitted by Mt. Etna through the time. Several researches were focused on the definition of the structure of this volcano by carrying out field or laboratory experiments (e.g. TOMO-ETNA), field surveys, or by using geophysical data set (e.g. seismic, gravity, etc.). The dynamics of the explosive and effusive products were studied by integrating field works, laboratory experiments, monitoring data and modelling approaches.

### d. Tools for improving volcanic hazard assessment

The results of the real-time analysis of the GPS data were used as input of a new algorithm to rapidly invert the shape and position of the ground deformation sources; this innovative approach was tested on the test-case of the 2008 flank eruption (Cannavò et al., 2015).

MED-SUV project was also the test-bed for innovative approaches for a probabilistic assessment of the volcanic hazard that aim to use the multidisciplinary monitoring data base; however, so far EO data are not included in this approach, although GPS and other ground deformation monitoring data are already considered.

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### C. ESA SEOM InSARap achievements

S1-A data over Mt. Etna were processed in the framework of a recent project funded by ESA (Sentinel-1 - INSAR Performance Study with TOPS data, [http://seom.esa.int/page\\_project006.php](http://seom.esa.int/page_project006.php)) in the context of the ESA-SEOM (Scientific Exploitation of Operational Missions) activities. Apart from some interferograms of the December 2014 eruption, a mean velocity map of Mt. Etna in the time-span October 2014-October 2015 was produced with the PSI (Persistent Scatterers Interferometry) technique, pointing out a clear deformation signal in the summit craters area.

### Publications

#### Peer reviewed journal articles

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Pardini, F., Spanu, A., de' Michieli Vitturi, M., Salvetti, M.V., Neri, A. (2015) Grain size distribution uncertainty quantification in volcanic ash dispersal and deposition from weak plumes, *J. Geophys. Res.*, Vol. 121, USA.

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Wiesmaier, S., Heap, M.J., Branca, S., Gilg, H.A., Kueppers, U., Hess, K.U., Lavallée, Y., Dingwell, D.B. (2015) Variability in composition and physical properties of the sedimentary basement of Mt. Etna, Italy, *J. Volcanol. Geotherm. Res.*, Vol. 302, USA.

### Conference presentations/proceedings

2nd IUGG-WMO workshop on Ash dispersal forecast and civil aviation; The contributions of the EU-funded MEDiterranean SUPersite Volcanoes (MED-SUV) project to the assessment of volcanic ash hazard( 2013) Geneva, Switzerland. Type of activity: Workshop

A Roadmap for Earth Science in Europe: The next generation of Geophysical Research Infrastructures: Session 2: Global Cooperation and Synergies. MED-SUV supersite project.( 2013) Erice, Italy. Type of activity: Workshop

AGU Fall Meeting; SO<sub>2</sub> emissions from paroxysmal eruptions at Etna volcano in 2011-12( 2013) San Francisco, USA. Type of activity: Conference/congress

AGU Fall Meeting; Analysis of Volcanic Plume Detection on Mount Etna through GPS ( 2013) San Francisco, USA. Type of activity: Poster

AGU Fall Meeting; Session : NH13B. Geohazard Supersites and Natural Laboratories Posters ( 2013) San Francisco, USA. Type of activity: Conference/congress

AGU Fall Meeting; The Mediterranean Supersite Volcanoes (MED-SUV) Project: an overview ( 2013) San Francisco, USA. Type of activity: Poster

Conferenza Nazionale delle Infrastrutture di Ricerca per le Scienze della Terra Solida( 2013) Rome, Italy. Type of activity: Conference/congress

Dingue Conference; Two-component mantle below Mt Etna (Italy): insights from noble gases and geochemistry of primitive volcanics and comparisons with nearby Hylean mantle( 2013) Florence, Italy. Type of activity: Poster

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- Goldschmidt Conference 2013. Session 11g. Mt. Etna from Source to Surface. Mount Etna: storyboard of an exceptional basaltic volcano. (keynote talk)( 2013) Florence, Italy. Type of activity: Conference/congress
- Goldschmidt Conference; A two-component mantle below Mt Etna volcano: Evidences from noble gas and trace element geochemistry of primitive products( 2013) Florence, Italy. Type of activity: Conference/Congress
- Goldschmidt Conference; Magma dynamics at Mount Etna (Italy) inferred from geochemistry of gas emissions( 2013) Florence, Italy. Type of activity: Conference/Congress
- Goldschmidt Conference; Mt. Etna from Source to Surface: Deciphering How a Complex Basaltic Magma Storage and Transport System Works. The summit activity at Mt. Etna from 1995 to 2001: A multidisciplinary approach to investigate the long-term processes of the magmatic plumbing system( 2013) Florence, Italy. Type of activity: Conference/congress
- Goldschmidt Conference; Paroxysmal degassing at Mt. Etna in 2011-12( 2013) Florence, Italy. Type of activity: Conference/congress
- Goldschmidt Conference; Sulfur and Chlorine isotopes in volcanic products at Mt. Etna, Italy( 2013) Florence, Italy. Type of activity: Conference/Congress
- Goldschmidt Conference 2013; The summit activity at Mt. Etna from 1995 to 2001: a multidisciplinary approach to investigate the long-term processes of the magmatic plumbing system( 2013) Florence, Italy. Type of activity: Presentation
- IAVCEI ; Shallow dike injection at Mt. Etna in May 2008 imaged by dense GPS and DInSAR data: interaction between magma and flank dynamics( 2013) Kagoshima, Japan. Type of activity: Presentation
- IAVCEI; The Pernicana and Trecastagni faults: the most active structures dissecting Mt. Etna volcano (Sicily) studied by multidisciplinary ground deformation measurements( 2013) Kagoshima, Japan. Type of activity: Poster
- AGU Fall Meeting; Joint Inversion of 1995 -2001 Ground Deformation Data and Gravity Changes Observed at Mt. Etna: New Insight Into the Shallow Plumbing System ( 2014) San Francisco, USA. Type of activity: Presentation
- 1st Convegno di Struttura Vulcani INGV; Contributions from an integrated analysis of geochemical and geophysical parameters to the study of failed eruptions at Mt. Etna( 2014) Rome, Italy. Type of activity: Poster
- 2nd Conferenza A. Rittmann; Forecasting eruptive activity at Mt. Etna (Sicily): the May 2008 - July 2009 case study( 2014) Nicolosi, Italy. Type of activity: Poster
- 2nd Conferenza A. Rittmann; Probability hazard map for future vent opening at Etna volcano (Sicily, Italy)( 2014) Nicolosi, Italy. Type of activity: Poster
- 2nd Conferenza A. Rittmann; Short term impending eruptive activity at Mt Etna revealed from a multistation system based on volcanic tremor analysis( 2014) Nicolosi, Italy. Type of activity: Presentation
- 2nd Conferenza A. Rittmann; TOMO-ETNA: an active seismic experiment at Etna volcano( 2014) Nicolosi, Catania, Italy. Type of activity: Conference/congress
- 2nd Rittmann Conference; Proposal for a conceptual model behind possible scenarios for Mt. Etna( 2014) Catania, Italy. Type of activity: Presentation
- 33<sup>rd</sup> Convegno NGTS; TOMO-ETNA: an active seismic experiment at Etna volcano( 2014) Bologna, Italy. Type of activity: Conference/congress
- AGU Fall Meeting; Real-Time Measurements of CO<sub>2</sub> and  $\delta^{13}C$  in Volcanic Gases Emitted in Atmosphere from Mt. Etna (Italy) ( 2014) San Francisco, USA. Type of activity: Poster
- Contribution and attendance to EPOS-Supersites booth within the EC Stand at the GEO-X summit( 2014) Geneva, Switzerland. Type of activity: Exhibitions
- EGU Genera Assembly; Improvement of ash plume monitoring, modeling and hazard assessment in the MED-SUV project( 2014) Vienna, Austria. Type of activity: Presentation
- EGU Genera Assembly; Improving the monitoring of Etna's volcanic Activity using a new scanning Lidar( 2014) Vienna, Austria. Type of activity: Presentation

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EGU Genera Assembly; Relationships between lava and tephra volumes erupted during the 26 October 2013 lava fountaining episode from the New Southeast Crater of Etna( 2014) Vienna, Austria. Type of activity: Poster

EGU General Assembly; Assessing and improving the measuring capability of the Etna\_NETVIS camera network for lava flow rapid mapping( 2014) Vienna, Austria. Type of activity: Poster

EGU General Assembly; Joint inversion of ground deformation and gravity changes using free geometry bodies( 2014) Vienna, Austria. Type of activity: Presentation

EGU General Assembly; Real-time measurements of chemical and isotope composition of atmospheric and volcanic CO<sub>2</sub> at Mt. Etna (Italy)( 2014) Vienna, Austria. Type of activity: Conference/Congress

EGU General Assembly; Combining observations and model simulations to reduce the hazard of Etna volcanic ash plumes ( 2014) Vienna, Austria. Type of activity: Poster

EGU General Assembly; Eruption column height: a comparison between ground and satellite( 2014) Vienna, Austria. Type of activity: Poster

EGU General Assembly; GPS Signal Feature Analysis to Detect Volcanic Plume on Mount Etna( 2014) Vienna, Austria. Type of activity: Poster

EGU General Assembly; New insight into the relationships between stress, strain and mass change at Mt. Etna during the period between the 1993-94 and 2001 eruptions ( 2014) Vienna, Austria. Type of activity: Presentation

EGU General Assembly; Probability hazard map for future vent opening at Etna volcano (Sicily, Italy)( 2014) Vienna, Austria. Type of activity: Poster

EGU General Assembly; Probability hazard map for future vent opening at Etna volcano (Sicily, Italy). Vents Pattern Analysis at Etna volcano (Sicily, Italy).( 2014) Vienna, Austria. Type of activity: Poster

EGU General Assembly; Redistribution of static stress, induced by the 2002-2003 Etna eruption, triggers seismic activity: a viscoelastic numerical model( 2014) Vienna, Austria. Type of activity: Poster

EGU General Assembly; TOMO-ETNA MED-SUV.ISES an active seismic and passive seismic experiment at Mt. Etna volcano. An integrated marine and onland geophysical survey( 2014) Vienna, Austria. Type of activity: Poster

EGU General Assembly; Towards a multidisciplinary e-infrastructure for the Mediterranean Supersite Volcanoes (MED-SUV) project( 2014) Vienna, Austria. Type of activity: Presentation

EGU General Assembly; Vents Pattern Analysis at Etna volcano (Sicily, Italy) ( 2014) Vienna, Austria. Type of activity: Poster

EGU General Assembly; Vents Pattern Analysis at Etna volcano (Sicily, Italy) ( 2014) Vienna, Austria. Type of activity: Poster

EGU General Assembly;The summit activity at Mt. Etna from 1995 to 2001: a multidisciplinary approach to investigate the long-term processes in the plumbing system( 2014) Vienna, Austria. Type of activity: Poster

GEO European Project Workshop, 8; The MEDiterranean SUPersite Volcanoes (MED-SUV) project( 2014) Athens, Greece. Type of activity: Presentation

VOLAND2014; Natural disasters and emergency strategies: an overview on major Etna flank eruptions( 2014) Santorini, Greece. Type of activity: Presentation

26th IUGG General Assembly; Application of a multistation alert method for short-term forecasting of eruptions at Etna, Italy( 2015) Prague, Czech Rep.. Type of activity: Presentation

26th IUGG General Assembly; PlumeMoM: A moments-based computational plume model with ash aggregation( 2015) Prague, Czech Rep.. Type of activity: Presentation

26th IUGG General Assembly; The Mt. Etna Volcanic Plumes Detection by GPS ( 2015) Prague, Czech Rep.. Type of activity: Presentation

26th IUGG; Detection of volcano unrest from multiparameter pattern classification( 2015) Prague, Czech Rep.. Type of activity: Poster

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- 26th IUGG; DInSAR deformation analysis of flank collapsing volcanoes: examples from Etna, Piton de La Fournaise and Fogo( 2015) Prague, Czech Rep.. Type of activity: Poster
- 26th IUGG; Long-term versus short-term deformation processes at Mt. Etna volcano( 2015) Prague, Czech Rep.. Type of activity: Poster
- 26th IUGG; Pattern classification: A promising tool for the characterization of volcanic products at Mt. Etna( 2015) Prague, Czech Rep.. Type of activity: Poster
- AGU Fall Meeting; Multiparametric Experiment at Mt. Etna: Investigation on Both Degassing and Eruptive Dynamics( 2015) San Francisco, USA. Type of activity: Poster
- AGU Fall Meeting; Spreading And Collapse Of Big Basaltic Volcanoes( 2015) San Francisco, USA. Type of activity: Poster
- EGU General Assembly; Automatized near-real-time short-term Probabilistic Volcanic Hazard Assessment of tephra dispersion before and during eruptions: BET\_VHst for Mt. Etna( 2015) Vienna, Austria. Type of activity: Presentation
- EGU General Assembly; Data Mining in the Context of Monitoring Mt Etna, Italy( 2015) Vienna, Austria. Type of activity: Poster
- EGU General Assembly; Development and testing of an automated High-resolution InSAR volcano-monitoring system in the MED-SUV project( 2015) Vienna, Austria. Type of activity: Poster
- EGU General Assembly; Joint inversion of displacement and gravity changes at Mt. Etna volcano during the 1995-2000 period: results and conclusions( 2015) Vienna, Austria. Type of activity: Presentation
- EGU General Assembly; Reconstruction of SO<sub>2</sub> emission height time-series and plume age using a combination of satellite imagery, volcanic tremor and back trajectory modelling at Mt. Etna( 2015) Vienna, Austria. Type of activity: Poster
- EGU General Assembly; The Rock Engineering System (RES) applied to landslide susceptibility zonation of the northeastern flank of Etna: methodological approach and results( 2015) Vienna, Austria. Type of activity: Poster
- EGU General Assembly;The magma storage capacity of Etna plumbing system: updated estimate from lava compositional changes in the last four decades( 2015) Vienna, Austria. Type of activity: Presentation
- ESA FRINGE workshop; The Italian Supersites volcanoes: a long-term monitoring experiment in active volcanic areas prone to natural hazards( 2015) Frascati, Italy. Type of activity: Presentation
- ESA FRINGE workshop; The wet refractivity tomography for improving the DInSAR deformation measurements on Mount Etna( 2015) Frascati, Italy. Type of activity: Poster
- ESA FRINGE workshop;Modelling of ground deformation at Mt Etna observed with the MSBAS InSAR during 2009-2013( 2015) Frascati, Italy. Type of activity: Presentation
- ESA Workshop FRINGE; The wet refractivity tomography for improving the DInSAR deformation measurements on mount Etna ( 2015) Frascati, Italy. Type of activity: Poster
- FisMAT; Advanced GPS products for Volcanos Monitoring applied at Mount Etna( 2015) Palermo, Italy. Type of activity: Presentation
- FisMAT; Automatized near-real-time short-term Probabilistic Volcanic Hazard Assessment of tephra dispersion before and during eruptions: BET\_VHst for Mt. Etna( 2015) Palermo, Italy. Type of activity: Presentation
- GEO European Project Workshop, 9; MEDiterranean SUPersite Volcanoes (MED-SUV) project: goals, achievements and perspectives ( 2015) Copenhagen, Denmark. Type of activity: Presentation
- Goldschmidt Conference; A two-component mantle below Mt Etna volcano: Evidences from noble gas and trace element geochemistry of primitive products( 2015) Prague, Czech Rep.. Type of activity: Poster
- 15th Plinius Conference on Mediterranean Risks EGU Topical Conference Series; Recent advancements in monitoring, observations and analysis of extreme events( 2016) Giardini Naxos, Italy. Type of activity: Poster
- EGU General Assembly; 2D dynamical magma propagation modeling: application to the 2001 Mount Etna eruption( 2016) Vienna, Austria. Type of activity: Poster



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- EGU General Assembly; A Blind Test Experiment in Volcano Geodesy: a Benchmark for Inverse Methods of Ground Deformation and Gravity Data ( 2016) Vienna, Austria. Type of activity: Poster
- EGU General Assembly; A prototype of an automated high resolution InSAR volcano-monitoring system in the MED-SUV project( 2016) Vienna, Austria. Type of activity: Poster
- EGU General Assembly; A prototype of an automated high resolution InSAR volcano-monitoring system in the MED-SUV project ( 2016) Vienna, Austria. Type of activity: Presentation
- EGU General Assembly; Chemical heterogeneity of Mt. Etna magmas in the last 15 ky and inferences on their mantle sources ( 2016) Vienna, Austria. Type of activity: Presentation
- EGU General Assembly; Degassing dynamics at Mount Etna inferred from radioactive disequilibria ( $^{210}\text{Pb}$ - $^{210}\text{Bi}$ - $^{210}\text{Po}$ ) in volcanic gases( 2016) Vienna, Austria. Type of activity: Poster
- EGU General Assembly; Doppler radar retrievals from lava fountaining paroxysms generating tephra plumes at Mt. Etna( 2016) Vienna, Austria. Type of activity: Poster
- EGU General Assembly; Eruptive pattern classification on Mount Etna (Sicily) and Piton de la Fournaise (La Réunion) ( 2016) Vienna, Austria. Type of activity: Poster
- EGU General Assembly; Etna\_NETVIS: A dedicated tool for automatically pre-processing high frequency data useful to extract geometrical parameters and track the evolution of the lava field( 2016) Vienna, Austria. Type of activity: Poster
- EGU General Assembly; Etna\_NETVIS: A dedicated tool for automatically pre-processing high frequency data useful to extract geometrical parameters and track the evolution of the lava field ( 2016) Vienna, Austria. Type of activity: Presentation
- EGU General Assembly; Fault activation after vigorous eruption: the December 8, 2015 seismic swarm at Mt. Etna ( 2016) Vienna, Austria. Type of activity: Poster
- EGU General Assembly; Insights into the dynamics of Etna volcano from 20-year time span microgravity and GPS observations( 2016) Vienna, Austria. Type of activity: Poster
- EGU General Assembly; Pattern of geochemical variations within the volcanic system of Mt Etna, Italy, from 1995 to 2013( 2016) Vienna, Austria. Type of activity: Presentation
- EGU General Assembly; Pattern of geochemical variations within the volcanic system of Mt Etna, Italy, from 1995 to 2013( 2016) Vienna, Austria. Type of activity: Presentation
- EGU General Assembly; Real-time estimation of distributed volcanic source for the 3 December 2015 eruption on Mt. Etna( 2016) Vienna, Austria. Type of activity: Poster
- EGU General Assembly; Spreading and collapse of big basaltic volcanoes ( 2016) Vienna, Austria. Type of activity: Poster
- EGU General Assembly; The 3 December 2015 paroxysm of Voragine crater at Etna: insights from Doppler radar measurements( 2016) Vienna, Austria. Type of activity: Poster
- EGU General Assembly; The 3 December 2015 paroxysm of Voragine crater at Etna: insights from Doppler radar measurements( 2016) Vienna, Austria. Type of activity: Presentation
- EGU General Assembly; The summit part of Mount Etna revealed by High Resolution DC Electrical Resistivity Tomography coupled with complementary geophysical and soil gas techniques( 2016) Vienna, Austria. Type of activity: Poster
- EGU General Assembly; Towards a multidisciplinary e-infrastructure for the Mediterranean Supersite Volcanoes (MED-SUV) project ( 2016) Vienna, Austria. Type of activity: Presentation
- EGU General Assembly; Volcanic Plume Elevation Model Derived From Landsat 8: examples on Holuhraun (Iceland) and Mount Etna (Italy)( 2016) Vienna, Austria. Type of activity:
- EGU General Assembly; Volcanic Plume Elevation Model Derived From Landsat 8: examples on Holuhraun (Iceland) and Mount Etna (Italy) ( 2016) Vienna, Austria. Type of activity: Poster
- EGU General Assembly; Volcanic Plume Elevation Model Derived From Landsat 8: examples on Holuhraun (Iceland) and Mount Etna (Italy)( 2016) Vienna, Austria. Type of activity: Poster

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EGU General Assembly; Etna\_NETVIS: A dedicated tool for automatically pre-processing high frequency data useful to extract geometrical parameters and track the evolution of the lava field( 2016) Vienna, Austria. Type of activity: Presentation

EGU General Assembly; The use of EO Optical data for the Italian Supersites volcanoes monitoring( 2016) Vienna, Austria. Type of activity: Poster

ESA Living Planet Symposium; Development and assessment of an automated high-resolution InSAR volcano monitoring system( 2016) Prague, Czech Rep.. Type of activity: Poster

GEO European Project Workshop, 10; The Mediterranean Supersite Volcanoes (MED-SUV) project: outcomes and follow-up ( 2016) Berlin, Germany. Type of activity: Presentation

Secondo Convegno della Struttura Vulcani; Short-term Probabilistic Volcanic Hazard Assessment: a tool developed in MED-SUV project, applied to Campi Flegrei, Vesuvius and Etna for tephra fallout( 2016) Palermo, Italy. Type of activity: Presentation

SIF 102° Congresso Nazionale di Fisica Italiana; The wet refractivity tomography at Mt. Etna volcano( 2016) Padova, Italy. Type of activity: Presentation

The European contribution to the GEO Supersite initiative ( 2016) Vienna, Austria. Type of activity: Organisation of event (conference, workshop)

### Research products

A part from the papers and presentations listed above, so far there are no formally complete, publically available research products. For this reason, the table below has been intentionally left blank.

However, it is noteworthy that Supersite data have been used to make various of non -publically-available products, as for instance, those used in the surveillance activities managed by Civil Protection authorities, available only for internal uses.

Type of product	Product provider	How to access	Type of access
<i>e.g. ground deformation time series, source model, etc.</i>	<i>Name of scientist(s)</i>	<i>Link to publication, research product repository or description of procedure for access</i>	<i>E.g. public, registered, limited to GSNL scientists, etc.</i>
...	...	...	...
...	...	...	...

### Research product issues

As no products are reported, this subsection is left intentionally blank.

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### Dissemination and outreach

Dissemination activities are related to those carried out in the frame of MED-SUV project. The table available at the web-page "[http://medsuv\\_portal.ct.ingv.it/documents](http://medsuv_portal.ct.ingv.it/documents)" lists all MED-SUV dissemination products, as papers, presentations, meetings, newsletters, factsheets, and any kind of materials.

### Funding

Currently, the participation of Mt. Etna to GNSL is not supported by specific funds. Monitoring systems are supported by INGV funds (mainly provided by Italian national Civil Protection Department throughout specific agreements); however, so far, they do not include the maintenance and/or the upgrade of MED-SUV portal.

Mt. Etna Supersite has benefitted in this biennial period from the financial support of the above said MED-SUV project, funded by the EC since May 2013 for a total amount of ~ 6 M€, which involved 25 partners (research institutions, universities, Space Agencies and SMEs). The project ended in May 2016 therefore, besides institutional funding/in-kind contributions by each participant in the Supersite initiative, other opportunities need to be investigated if mid/long-term activities are foreseen for this Supersite.

MED-SUV proposed a formal agreement among a few partners for the sustainability of the web-page and portal in the next two years, which is still under negotiation. Moreover, EPOS-IP foresees the possibility to contribute to the maintenance of the activities allowing the access to the data and products, in the frame of the project's financial model; this opportunity is currently under evaluation.

INGV participates to the ongoing EVER-EST (European Virtual Environment for Research-Earth Science Themes) EC H2020 project, leaded by ESA, which has planned some funds to implement a Virtual Research Environment designed to meet the needs of Supersites scientists and to provide a variety of services for improving the collaboration in the Supersites.

For the near future, any funding opportunity will be investigated, with the submission of new project proposals to both European and National funding agencies.

### Societal benefits

A part from the scientific communities, the main benefitting 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 National and Regional departments in the disaster risk management activities.

Furthermore, the implementation of the MED-SUV portal positively impacts also on the achievements of the objectives of the Disaster Resilience SBA (Social Benefit Area) of the GEO 2016

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Work Programme, and specifically on the GI-08 GSNL initiative (Geohazard Supersites and Natural Laboratories).

In long-term, MED-SUV might contribute to achieve the objective of the Actions of the Sendai Framework for Disaster Risk Reduction. The Priorities 1 (Understanding Disaster Risks) promotes the collection, analysis, management and use of data and information relevant to the disaster risk as well as the access to real-time reliable data, encourages the update and dissemination to decision makers of risk information, as maps, and the dialogue and cooperation among scientific and technological communities at local and global level to promote common efforts in partnership with academia and private sector. Indeed, MED-SUV addressed all these aspects during its implementation period and thus it might be good example for discussing best practices in a global framework.

### Conclusive remarks and suggestions for improvement

The Supersites initiative fits into a particularly favorable period for the Scientific Community. The opportunity offered by ESA to get free-of-charge satellite data for any registered user, represents a great improvement compared to the past. On the other hand, Supersites further contributed to make immediately available satellite data also from other Space Agencies (e.g. the DLR Supersites website), with the possibility to download in-situ data as well, from the MED-SUV portal, just implemented and further updated in the forthcoming months.

Moreover, the recent development of some cloud services-on-demand for data processing allows to carry out the whole process, from data acquisition to final processing.

This will result in the future in real advantages not only for the Scientific Community but also for “experienced” stakeholders.

As already mentioned, relevant scientific results were achieved by the Science team and future activities are planned as well, anyway a key point for the future of the Supersites activities on the whole, will be the provision of adequate funding resources, especially if mid/long term activities are foreseen.

The next two year period will be challenging after the end of the MED-SUV project, which gave support to Supersites in very different ways. In spite of this, the PoC vision for the future is positive, because the MED-SUV portal will be a relevant element for the building of the EPOS-IP platform and some valued outcomes were also gathered from researchers/activities outside MED-SUV.

Also continuous data provision from Space Agencies will be critical for a successful next two year period: in this regard we ask also, if possible, for high resolution data, whose exploitation - in addition to in-situ data - can result in relevant progresses in the knowledge of the areas of interest.

In the light of what just said, besides considering the strategic importance for INGV to deepen the knowledge of the Italian volcanoes, not only for scientific research purposes but also for civil protection issues, the PoCs of the two Italian Supersite volcanoes jointly ask for the continuation of Mt. Etna and Vesuvius/Campi Flegrei Supersite initiatives, also on behalf of their Science teams.