Final Report Summary - MED-SUV (MEDiterranean SUpersite Volcanoes)

Executive Summary:
The Mediterranean Supersite Volcanoes (MED-SUV) project improved the capacity of the volcanological community to assess the volcanic hazards at Campi Flegrei/Vesuvius and Mt. Etna, two of the largest European volcanoes. This was achieved by optimising and integrating existing and new monitoring systems, by a breakthrough in understanding volcanic processes and by increasing the effectiveness of the coordination between the scientific and end-user communities.

Overall, more than 3 million people are exposed to potential volcanic hazards in these two areas; furthermore, as they are located in the centre of the Mediterranean Sea, the effect of a large volcanic crisis in one of these volcanoes may impact an even wider region, whose geo-political, economic and environmental relevance is utmost in Europe. This project fully exploited the unique multidisciplinary long-term in-situ monitoring data sets available for these volcanoes and integrated them with Earth Observation.
Data. The project’s consortium carried out researches, accomplished technological developments, and implemented algorithms that led to significant progress in distinguishing pre-, syn- and post-eruptive phases. The wide range of styles and intensities of volcanic phenomena observed on these volcanoes, archetypes of ‘closed conduit’ and ‘open conduit’ volcanoes, together with the long-term multidisciplinary data sets, gave an exceptional opportunity to improve the understanding of a very wide spectrum of geo-hazards, as well as implement and test a large variety of innovative models of ground deformation and motion. The project had important impacts on the European industrial sector, arising from a partnership of the scientific community and SMEs to implement new observation/monitoring sensors/systems. Specific experiments and studies have been carried out to improve our understanding of a volcano’s internal structure and volcanic processes, as well as to recognise signals related to impending unrest or eruption. Hazard quantitative assessment benefitted from the outcomes of these studies and from their integration with cutting edge monitoring approaches, thus leading to a step-change in hazard awareness and preparedness and leveraging the close relationship between scientists, SMEs, and end-users.

Project Context and Objectives:
Active volcanoes have over time deeply influenced the lifestyle of people living on them or nearby, impacting human health as well as the economy and ecosystem of the territory. The need to monitor the behaviour of active volcanoes in order to evaluate the hazards associated with their activity, especially in densely populated areas, has led to implementing in-situ volcano monitoring systems, as well as the increasing interest of Earth Observation (EO) communities. The ability to gather, analyse, model and interpret geophysical, geochemical and volcanology information is vital to correctly recognise premonitory signs of volcanic unrest in sufficient time to enable adequate responses and, when the eruptive activity is ongoing, to properly track its evolution.

Some of the most active volcanic areas in Europe – Mt. Etna and Campi Flegrei/Vesuvius – are located in southern Italy (Figure 1). About 3 million people, living on or around these volcanoes, are potentially at risk to the wide spectrum of volcanic phenomena, ranging from lava flows to volcanic ash or pyroclastic flows, as well as to associated hazards (e.g. those related to the seismic activity or the failures of parts of the volcanic flanks). Indeed, these areas are characterised by different kinds of volcanic systems, which can produce diverse types of eruptive activities, and thus different volcanic hazards.

From a volcanology point of view, the Mt. Etna and Campi Flegrei/Vesuvius areas can be seen as archetypes of volcanic systems given that the former is an open-conduit system while the latter two closed-conduit systems, and thus they are effectively natural laboratories to carry out intense research activities. The different features of the Mt. Etna and Campi Flegrei/Vesuvius systems mainly relate to the geodynamic context of the central Mediterranean, which is characterised by active tectonics associated with the diachronic convergence of the boundary between the Eurasian and African plates (Figure 2). The local tectonic setting of the Campanian and Sicilian regions produces highly different magmas feeding Mt. Etna, Campi Flegrei and Vesuvius. This generates different eruptive behaviours controlled by “open” or “closed” conduit conditions, and the two sites together encompass almost the entire spectrum of threatening, and sometimes disruptive/destructive volcanic phenomena.

The almost continuous volcanic activity of Mt. Etna produces lava flows, pyroclasts, earthquakes and landslides, which threaten villages or cities located on its flanks. Recent volcanic history provides clear examples of the dramatic social and economic impact of the lava flows in case of vent opening at lower elevations, as during the 1381 and 1669 eruptions when the lava flows destroyed large areas of the
southern flank, today occupied by the metropolitan area of Catania (about 0.5 million people). Often Etna’s ash clouds threaten large surrounding regions and disrupt aviation activities and airport operations, as happened several times during recent decades, causing a cumulative economic loss of about 10-20 M€ since 2001 or risks to life such as the aviation incident in 2000.

Campi Flegrei and Vesuvius are highly explosive volcanoes. In both cases a new eruption is expected to produce 10-30 km-high volcanic columns, ash cloud dispersal over substantial portions of Europe and beyond (depending on wind directions), and devastating pyroclastic flows. Urbanization in the Neapolitan area is very heavy: about 1.5 million people are considered to live under the menace of pyroclastic flows from the two volcanoes. All this makes the Neapolitan region the highest volcanic risk area in the world. As a matter of fact, a volcanic eruption here has the potential to cause a crisis of European proportions. Besides catastrophic phenomena related to an eruption at these volcanoes, unrest dynamics are by themselves capable of producing substantial hazards. About 40 thousand people were evacuated in 1983 from the town of Pozzuoli, in the Campi Flegrei caldera, as a consequence of serious damage to buildings due to seismic swarms and intense ground deformation. Phreatic explosions are very likely and may have dramatic consequences in such a heavily populated area.

Both sites have cutting-edge in-situ multidisciplinary monitoring systems and long-term data archives of the in-situ data (apart from the oldest description of a volcanic eruption made by Pliny the Younger, concerning to the 79 AD Vesuvius eruption, earliest volcanologic data date a few centuries back, while modern monitoring geophysical networks managed by INGV have been continuously implemented since the 80s). Space Agencies have run backup missions for both sites for a long time (since the 90s), so that the current EO data base, for both Synthetic Aperture Radar (SAR) and optical data, is probably the largest in the world for active volcanoes as it includes EO time series starting from 1984 (LANDSAT) and 1992 (ERS). All current EO missions include among their qualified objectives the collection of data on these volcanic areas.

Both sites have great impact on the international scientific initiatives fostering volcanologic researches (e.g. IAVCEI included Mt. Etna and Vesuvius in the Decade Volcanoes Project; International Continental scientific Drilling Program (ICDP) approved a project to study the inner structure of the Campi Flegrei).

Considering (1) the extensive surveillance and monitoring activity carried out at Mt. Etna, Campi Flegrei and Vesuvius, (2) the hazards posed by the three volcanoes, and (3) the huge amount and variety of data (in-situ and Earth Observation-EO) collected while tracking their volcanic activity, in summer 2014, Mt. Etna, Campi Flegrei, and Vesuvius were made by the Group of Earth Observation - Geohazard Supersite and Natural Laboratories (GEO-GSNL) initiative and the Committee on Earth Observation Satellites (CEOS) as Permanent Volcano Supersites.

Thus the overall goal of MED-SUV is to apply the rationale of the Geohazard Supersites and Natural Laboratories GEO-GEOSS initiative to Campi Flegrei/Vesuvius and Mt. Etna in order to better assess the volcanic hazards posed by these volcanoes. To this end, the MED-SUV community is improving the understanding of volcano system dynamics and processes by integrating and sharing in-situ and EO data sets and implementing new instrumentation and monitoring systems.

Indeed, taking account of the valuable resources and information available for Mt. Etna, Campi Flegrei, and Vesuvius volcano, the MED-SUV project aims at exploiting the huge and unique record of
geophysical, geochemical and volcanological data on the three Supersite volcanoes and to design and
carry out experiments to fill gaps in the knowledge of their structure or the processes driving their activity.
The project aims to:
* gain new insights into the inner structure of these volcanoes,
* evaluate the suitability of the current EO and in-situ observations to track the dynamics of the volcano
supply system and/or the eruptive phenomena,
* make access to observations easy
* define the effects of magma ascent on the stress/strain field (and vice versa),
* assess the capability of the Earth science community to forecast eruptions in terms of both location and
time,
* optimize the functioning of the chain from observations to end-users during an eruptive event, and
* make the project outcomes “exportable” to other European volcanic areas and elsewhere.

The project’s main goal can be divided into five specific objectives:

Ob. 1: development of next generation geo-hazard monitoring/observing systems.

This objective has been achieved by integrating three parallel groups of activities aimed at: Ob.1.1.)
developing new instruments/observation methods; Ob.1.2.) achieving the integration of EO and in-situ
data; Ob.1.3.) implementing a digital infrastructure to guarantee the interoperability and sharing of the data
sets. The achievement of this objective involved SMEs, which optimized their efforts by making the most of
the wealth of volcanic and geophysical phenomena existing in the Italian Supersites.

Ob.1.1: New instruments/observation methods. The project fostered new monitoring methods and
instrumentations, privileging the systematic acquisition of parameters (e.g. the 3D strain) or production of
new deliverables (e.g. routine deformation maps), as well as the improvement of the accuracy of the
measurements.

Ob.1.2. Data integration. The integration of EO and in-situ data is one of the key strategic objectives;
MED-SUV contributed by exploiting multiple EO data sets and in-situ monitoring systems and adopting
different approaches ranging from the cross-validation of the EO and in-situ data to the “merging” of the
two data sets to obtain a new information.

Ob. 1.3. Digital infrastructure. This objective addressed technical and management issues. The
implemented infrastructure aims to simplify the access of the users to different Italian Supersite data
sources through a unique hub and to guarantee its compliance with the GEO/GEOSS principles.

Ob. 2: characterization of volcanic processes by cutting-edge data analysis/modelling

This objective aimed to improve the knowledge on the volcanic subsurface or surface processes during
the pre-, syn- and post eruptive phases of the target volcanoes, by fully exploiting the complete
(integrated) data set and by performing new specific experiments. This objective has been achieved by:
Ob. 2.1.) identifying the spatial and/or temporal parameters relevant to internal process among the huge
available data; Ob 2.2.) modelling the subsurface processes; Ob. 2.3.) characterizing the surface volcanic
processes, especially during eruptive phases.

Ob. 2.1. Identification of relevant parameters. The huge amount of in-situ and EO data sets, available on
the cluster of Supersites, fuelled researches based on the use of data mining techniques on multi-
parametric data sets to detect and validate any signals related to possible unrests or changes in volcanic activity (e.g. anomalies in the time series of deformation measurements, seismic signals, thermal surveys, gas emissions, etc.).

Ob. 2.2. Modelling of the subsurface processes. This intrinsically complex objective has been addressed through multidisciplinary approaches aimed at: i) defining unclear, weak or approximate parameters and/or boundary conditions and/or structural setting to improve the implementation of the models, ii) modelling of parameters (e.g. ground deformation) sensitive to or – better – specific of the magma dynamics and its interaction with hydrothermal systems/faults/landslides. Field and laboratory experiments and direct or inverse models (either analytic or numerical) have been widely used. The ultimate goal of this objective is the understanding of the complex equilibrium between the structural framework (stress field) and the forces controlling magma ascent in the volcano plumbing system, in order to improve the capability to detect or forecast the onset of an eruption as well as its evolution or waning phases.

Ob. 2.3. Characterization of the surface processes. This specific objective sought to improve exploiting the integrated data sets for the evaluation of parameters characterizing the surface volcanological processes, such as the spatial and temporal distribution of the volcanic products, the evaluation of the magma and gas emission rate, the atmospheric dispersal of the eruptive plume, etc., which are crucial for hazard assessment.

Ob. 3: definition of strategies for volcano hazard evaluation and development of guidelines to define the role of scientists and that of decision makers

The project followed two specific action lines to fulfil this objective: Ob. 3.1.) a quantitative multi-hazard assessment, based on the results of the monitoring, data analysis and modelling activities, and Ob. 3.2.) improved communication among scientists, decision-makers and end-users through shared protocols and awareness actions.

Ob. 3.1. Quantitative multi-hazard assessment. The main goal was to further implement the current practice on short- and long-term volcanic hazard assessment for the Italian Supersite volcanoes, by exploiting the continuous streaming of multiparameter monitoring data, the databases already available in the INGV Observatories, and the cutting-edge monitoring systems already existing on the target volcanoes.

Ob. 3.2. Transfer of outcomes to the decision-makers and relationships with end-users. This objective is aimed at reinforcing the relationship and cooperation between the scientific and risk-management communities and clarifying the respective roles. This problem has been tackled by cooperating with the decision makers (e.g. the national and regional Departments of Civil Protection).

Ob. 4: Testing and validating the project outcomes [Pilot Phase]

The wide spectrum of the volcanic phenomena associated with the Italian Supersites gave the opportunity to test the applicability of the project products (e.g. new monitoring systems and methods). This objective has been achieved by carrying out a Pilot Phase out on the Supersites, as well as on other volcanic systems with similar behaviours controlled by “open” or “closed” conduit conditions. (e.g. Piton de la Fournaise and Azores).

Ob. 5: Dissemination
This objective was aimed at broadcasting the outcomes of the project to the scientific community and the general public. This view of the dissemination activities also contribute to achieving the general objective (knowledge of the volcanic risk) by addressing communities not necessary living close to acti

Project Results:
The objectives were achieved by defining a proper workplan and assembling a qualified Consortium. Thus, in the following, before describing the main results of the project, a short description of the workplan and the Consortium are given. Tables listing the work packages leaders, the project planning, the structure and leaders of the RTD Tasks, the project beneficiaries, the components of the Advisory Board and the description of the Deliverables as well as some relevant figures showing the main results of the project, are attached as complementary materials.

WORKPLAN

MED-SUV objectives were pursued by organizing the work into eight Work Packages (Figure 4 and Table 1), as follows:

WP 1: Project Management. This was in charge of the overall management of the project, including the legal and strategic issues.

WP 2: New Monitoring and Observing Systems. This focused on developing new instruments/monitoring systems devoted to measuring new parameters, increasing measurement accuracy and precision, incrementing the spatial/temporal data sampling and reducing costs of collecting the information.

WP 3: Data Sharing, Integration and Interoperability. This aimed at fine-tuning the processing chains of the existing monitoring systems, both EO and in-situ, integrating the EO and in-situ data to obtain a “new truly integrated data set”, and implementing a new digital infrastructure that allows data interoperability and sharing.

WP 4: Closed-conduit volcanoes laboratory. This included field activities, lab-scale experiments and processing and modelling issues in order to determine the internal structure of the supersite volcanoes Campi Flegrei and Somma-Vesuvius and reveal the way they behave.

WP 5: Etna volcano laboratory. This was devoted to improving the knowledge of the structure and processes occurring at Mt. Etna.

WP 6: Volcanic hazard assessment, disaster preparedness and mitigation. The purpose of this WP was to show how improving the monitoring system in the Italian Supersite volcanoes may contribute to a better hazard assessment and help bridge the gap between science and the mitigation and preparedness of volcanic disasters.

WP 7: Pilot Phase - Validation and transfer of project outcome. This oversaw the validation and testing of project outcomes on Mt. Etna, Campi Flegrei and Vesuvius and the applicability of the WP2, WP3, WP4 and WP5 project outcomes to other European volcanoes and Observatories.

WP 8: Dissemination and Outreach. This WP aimed at ensuring scientific visibility beyond the project area, promoting effective and widespread application of results, linking MED-SUV to other data sharing initiatives and providing a continuing resource for end-users of supersites beyond MED-SUV.

The Ob. 1 was achieved in the WPs 2 and 3, while the Ob. 2 in WPs 4 and 5. WP6 and WP7 fulfil the Objectives 3 and 4 respectively. The Ob. 5 was achieved in WP8 (Figure 4). The schedule of the project followed the Gantt chart reported in Table 2.
Overall, the work can be grouped in coordination, scientific/technological development, and dissemination activities, as follows:

Coordination (WP1) focused on the management of the Consortium and coordination of the project’s activities in the framework of the relevant international initiatives. The main actions concerning the Consortium management dealt with the (i) assessment and application of the guidelines of the data policy on the project’s activities - and specifically on the e-Infrastructure data management, (ii) relationship with the Advisory Board, (iii) checking the activities compliance with the EC Grant Agreement and the Consortium Agreement (including the financial and legal issues), and (iv) designing the strategic vision for the project’s follow-up. Coordination also aimed at finding synergies and shared strategies with EC and international initiatives, such as the geohazard activities of GEO-GEOSS, EPOS (the Preparatory Phase, up to October 2014, and the Implementation Phase, from October 2015), and the other two FP7 Supersite projects - MARsite and FUTUREVOLC - to build the future research infrastructures for Earth Science in Europe.

Scientific/Technological development focused on improving the volcanic system and process knowledge of Mt. Etna, Campi Flegrei and Vesuvius. The activities provided a) new methods/instruments for monitoring the volcanic activity and exploiting/integrating long-term EO and in-situ data sets, b) appropriate tools for sharing data and products, c) laboratories and field experiments to collect data and test methods/instruments, and d) new numerical and conceptual models to improve the understanding of volcanic systems and processes, and the hazard assessment at the Italian Supersites. The activities were carried out in the framework of Tasks and Sub-Tasks of the Work Packages 2 to 7 (Table 3). Cross activities involving different Tasks, Sub-Tasks or WPs were promoted, as for instance those concerning the e-infrastructure, the pilot phase and the use of new knowledge as input for improving the hazard assessment tools. Knowledge and experience exchanges with other volcanic areas was strongly encouraged, not only regarding the Piton de la Fournaise and the Azores (as planned in DoW) but also for the Eyjafjallajökull and Kilauea volcanoes.

Dissemination activities (WP8) consisted in participation at international and local scientific conferences and initiatives, publication of scientific articles in peer-reviewed international journals, interviews contributing to journal articles, videos and TV programs, use of social networks for project promotion, and distribution of project material during scientific events (e.g. GEO weeks or EGFU General Assemblies). Moreover, some educational activities were carried out by making leaflets and organizing dissemination activities aimed at explaining to young people in schools what volcanoes are and what kinds of hazards they might pose.

THE CONSORTIUM

The MED-SUV consortium brought together research, academic and public institutions and industrial partners having the needed experiences and expertise for the achievement of the project objectives. The Consortium included twenty-five partners. Following the withdrawal of two partners, at the end of the project, 31 May 2016, the Consortium comprised twenty-three partners: twenty-one are European and two come from US and Canada (Figure 5 and Table 4). Together, these scientific and industrial partners as well as public agencies with proven experience formed a partnership able to cover the entire volcanic risk
management cycle, from observations to public communication. In addition to the remarkable human resources that make up the consortium, the partners also brought critical infrastructure into play, with world class monitoring networks, laboratories, computer facilities, etc.

The Istituto Nazionale di Geofisica e Vulcanologia (INGV), which coordinated the project, is a high-level European scientific institution of Earth Science; it is made up of 9 branches distributed throughout Italy. Eight INGV branches participated in the project activities: Catania – Osservatorio Etneo, Naples – Osservatorio Vesuviano, Palermo, Pisa, Bologna, and the three branches located in Rome, the National Centre of Earthquakes, the Seismology and Tectonophysics and the Geomagnetism, Aeronomy and Environmental Geophysics. In the Osservatorio Etneo and Osservatorio Vesuviano are based the Points of Contact of the Mt. Etna and Campi Flegrei / Vesuvio Supersites respectively. Besides implementing and managing the geophysical, geochemical and volcanological monitoring networks (e.g. seismic, geodetic, geochemical, magnetic, video, satellite data, etc.), the skills of INGV include geological and structural surveys, the modelling of volcanic phenomena (e.g. lava and pyroclastic flows, volcanic plumes, ground deformation and the dynamics of internal magmatic sources, etc.) and the experimental characterization of rocks in chemical or physical laboratories. By law, INGV is responsible for the monitoring and surveillance activities of volcanic areas in Italy and works closely with the National Civil protection authorities, within specific official agreements, on issues including the hazard assessment in Italy and management of seismic and volcanic crises. During the last decade, INGV has been deeply involved in the scientific surveillance of the eruptions occurring at Mt. Etna and Stromboli volcano, as well as in the monitoring of recent bradyseism events in Campi Flegrei. In MED-SUV, INGV leads the WP1 (Management) as well as two more RTD WPs (3 and 6). Furthermore, it worked together with the participants in the consortium on all WPs - and almost in all Tasks - of the project, making the most of the long cooperation with many of them.

Two more Italian Research Institutions participated in MED-SUV: CNR and AMRA.

The Consiglio Nazionale delle Ricerche (CNR) is the main public research entity in Italy, which is organized in more than 100 “Institutes” grouped in 11 Departments. The Institute for Electromagnetic Sensing of the Environment (CNR-IREA) and the Institute of Atmospheric Pollution Research (CNR-IIA) are involved in the project. CNR-IREA incorporates a Microwave Remote Sensing Group that has been active since 1987. CNR-IREA has high-level expertise in scientific SAR and DInSAR algorithm development and wide experience in scientific software development. CNR-IIA participates in the project with the Earth and Space Science Informatics Laboratory (ESSI-Lab) whose main research topics are relevant to applying information science and technologies to manage, harmonize, and share Earth & Space Science resources and develop Spatial Information Infrastructures. CNR groups have been involved within WP3 and WP4 to provide Earth deformation maps and develop the MED-SUV e-Infrastructure for sharing the data and products relevant to the two Supersites.

The Analisi e Monitoraggio del Rischio Ambientale (AMRA) is an entirely public, non-profit Company. It was formed in 2005. The leading partner of AMRA is the University of Naples “Federico II”, the other partners being four public Universities and Italian research institutions. AMRA operates in the fields of natural and anthropogenic risk assessment and mitigation in close partnership with the National Department of Civil Protection. AMRA was deeply involved in WP4, in the study of the Campi Flegrei by implementing a new algorithm to analyse geophysical data, by carrying out seismic surveys (RICEN) to define the geometry of the inner structures. With INGV they will also investigate the internal dynamics of magmatic sources and its measurable effects on the surrounding rocks and surface of the Campi Flegrei (e.g. seismicity, gravity variations, deformations etc.) by implementing appropriate numerical models. It
also contributed to assess the hazard in Campi Flegrei, in WP6. The Centre National de la Recherche Scientifique (CNRS) is a Joint Research Centre that groups a team of French Universities and scientific institutions having wide-ranging skills that are also wholly complementary with the INGV. Apart from CNRS researchers and laboratories directly involved in the project activities, the other Universities and Research Institutions embedded in the CNRS participation are the “Instut de Physique du Globe de Paris” (IPGP), the “Ecole Normale Superieure” (ENS), the “Insitut de Sciences de la Terre d’Orleans” (ISTO), the “Institut de recherche pour le développement” (IRD) and the “Université de Savoie” (UdS) in Chambery. CNRS leads the activities on WP5 and WP7, due to its valued experiences on studying Mt. Etna’s volcanic processes and monitoring of both European and non-European (from the geographic point of view) volcanic areas. In MED-SUV, this team was also involved in integrating observation systems in WP3 (ENS), carrying out geophysical and geochemical experiments and modelling in WP4 and WP5 (IPGP, ISTO, IRD, UdS, ENS) and supporting test and validation activities in WP7 (IPGP - Volcano Observatories at Piton de la Fournaise).

The Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum (GFZ) was founded in 1992 as the national research institution for geosciences in Germany. GFZ combines all solid earth science fields including geodesy, geology, geophysics, mineralogy, palaeontology and geochemistry, in a multidisciplinary scientific and technical environment. In order to furnish its operations around the globe and in space, GFZ maintains massive scientific infrastructure and platforms, including the BubbleLab to simulate the earthquake waves and their effect on various types of fluid reservoirs, which was used in MED-SUV. Indeed, GFZ carried out laboratory experiments, calibrated by field measurements, to define the physical and chemical characteristics of the processes that relate the dynamics of the fluids with stress field changes in Campi Flegrei (WP4). It also modelled the ground deformations acquired by the monitoring systems on Mt. Etna to study the process of the interaction between magmatic and structural systems (WP5.)

The Agencia Estatal Consejo Superior de Investigaciones Científicas (CSIC) is the largest public multidisciplinary research organisation in Spain. The CSIC has 135 institutes or centres distributed throughout Spain, including 51 Joint Research Units with universities or other research institutions. The Institute de Geosciences (IGEO), in Madrid, was involved in MED-SUV. It has great experience in geodetic research, applying ground and space-based geodetic techniques to the monitoring of volcanic and seismic areas, as well as theoretical modelling (direct and inverse problem), being able to do simultaneous interpretation of terrestrial and space data of deformation and gravity changes. IGEO led the task of WP3 in charge of integrating EO and in-situ geodetic data for assessing continuous 3D ground deformations map. It applied its experience on the use of EO and in-situ data for investigating internal structures of active volcanoes and modelling ground deformations on Campi Flegrei/ Vesuvius and on Mt. Etna (WP4 and WP5).

CIVISA (Centre for Information and Seismovolcanic Surveillance of the Azores) is a non-profit private research organization founded in 2008 by the Azores University and the Azores Government. The CIVISA aim is to assure the geological hazards monitoring and assessment in the Azores, to provide the technical and scientific support to the Azorean Regional Civil Protection and to the local civil protection authorities. The CIVISA activities are mainly directed to the prevention and forecast of natural disasters, catastrophes and calamities, by integrating the geophysical, geodetic, geochemical, environmental and meteorological monitoring techniques for seismovolcanic, landslide and environmental surveillance. From July 2014, CIVISA replaced the Azores University as MED-SUV partner. CIVISA helped define the strategies for volcanic disaster preparedness and mitigation hazard in WP6 and gave fundamental support to the
transfer of the project’s outcomes to-from the Azores (WP7).
The MED-SUV partnership has seen eight Academic institutions involved in the activities. The Ludwig-Maximilians-Universität München (LMU) led WP4. The volcanology group of LMU has a strong background in field and experimental volcanology. Instrumentation includes shock tubes for decompression experiments, rock characterisation and grain-size analysis, rheology, thermal analysis, geochemistry, petrology, high-speed filming, high-performance computer facilities. In the project, LMU investigated the physical conditions controlling the shift regime from permeable flow to steam explosions in the hydrothermal systems of the Campi Flegrei, by carrying out cutting-edge laboratory experiments (WP4), and the physical-chemical characteristics of the basement rocks of Mt. Etna (WP5).
Two British Universities participated in MED-SUV. Bristol University (UNIBRIS) is one of the top ten universities in the United Kingdom and within the top 30 in the world. The School of Earth Sciences encompasses five research groups covering the entire range of Earth Sciences topics. The Volcanology group is a global leader in the area of field and laboratory investigations of active and young volcanoes, theory development and modelling. In WP4 UNIBRIS applied its proven expertise in identifying the anomalies in the geophysical and geochemical signals related to the dynamics of the shallow hydrothermal system of Campi Flegrei by using other volcanoes as analogues (Montserrat).
The University of Durham (UDUR) was founded in 1832 and is engaged in several aspects of activity such as high-quality teaching and learning, advanced research and partnership with business, and regional and community partnerships and initiatives. In the project UDUR provided seismic analysis to build a tomographic model of Mt. Etna (WP5).
The University of Granada (UGR) group comprised members of the Andalusian Institute of Geophysics, which has wide experience in active seismic experiments in volcanoes, being responsible for two of them, one developed in Antarctica (Deception Island) and the other in Tenerife Island (Canary Island, Spain). Among various research lines, array analysis, seismic tomography, volcanic signal source location and analysis or automatic signal recognition are the most productive from the scientific point of view. UGR coordinated the TOMO-ETNA seismic experiment (WP5), which involved MED-SVU partners (e.g. INGV, GFZ, CNRS) and others institutions (e.g. UCL, Ireland, Berkley University, USA, IPGG-SB, Russia). The University of Malta (UoM) contributed with the Atmospheric research unit of the Physics department in the Faculty of Science. This Unit has instruments based at Giordan Lighthouse on Gozo. These instruments serve to monitor trace gases and climate change in the Mediterranean. Both shipping and volcanic emissions are detectable and work is underway to install further equipment specific to volcanic emissions. They participated in WP5, by studying and modelling Mt. Etna volcanic plume.
The Milan University (UMIL), Dipartimento di Scienze della Terra “A. Desio” (Department of Earth Science "A. Desio"), contributed to WP5 by defining landslide susceptibility on Mt. Etna and applying geotechnical models to explore the instability factors, identify the critical conditions necessary to generate slope instability, as well as the geometry of the failure surfaces, volumes involved and kinematics, under different instability factors induced by volcanic dynamic.
The Laboratoire Magmas et Volcans (LMV) is a joint research unit of the Blaise Pascal University (UBP), Centre National de la Recherche Scientifique (CNRS) and Institute of Research and Development (IRD). The main scientific focus is the study of all magmatic and volcanic processes, from melting in the Earth's mantle to the eruption of magma at the surface, by combining state-of-the art methods and techniques. The UBP-LMV contributed to the Mt. Etna plume monitoring and modelling by exploiting the multi-disciplinary monitoring system managed in cooperation with INGV on Mt. Etna in WP3 and WP5.
The Italian Department of Civil Protection (DPC) is responsible for national civil protection and includes research institutes, private companies, volunteers and all Italian armed forces. The main activities are: forecasting, in order to analyse the causes of disasters, to identify risks and detect risky areas; prevention, to reduce disaster damages; assistance, to ensure elementary aid to the population; management and overcoming of emergencies. DPC was involved in the WP6 activities, contributing to the definition of the strategies for volcanic disaster preparedness and mitigation.

The Bureau de Recherches Géologiques et Minières (BRGM) is a French public institution providing R&D and expertise for public policies, decision making and citizen information in different fields of the Earth Sciences. Activities at BRGM cover areas such as observation, mapping and databases, development and modelling for surface and subsurface processes, natural risks evaluation, management and mitigation and the protection of the environment. BRGM also provides support for EU policies in partnership with other geological surveys (EuroGeoSurveys). The Risks (RIS) division, which has been involved in the MED-SUV project, features teams of renowned international experience in the fields of geotechnical, earthquake, landslide, coastal and structural engineering, emergency management with activities related to geophysical monitoring, numerical modelling, natural hazards evaluation, vulnerability assessment and risk mitigation. BRGM led the WP8 and was responsible for implementing the MED-SUV web portal and other dissemination activities. Furthermore, it developed innovative techniques to identify the effects of volcanic plumes in EO data (WP2) and implement probabilistic approaches for hazard assessment (WP6).

Two main European Space Agencies participated in MED-SUV: the European Space Agency, ESA, and the Deutschen Zentrums für Luft- und Raumfahrt, DLR. They play an active role in international initiatives aimed at building systems for an improved use of the EO and in-situ data. Together with some scientific institutions (CNR) and industrial partners (Terradue; T2, see below), these brought the experiences of the Earth Observation community in the project. DLR, which has an indubitable expertise in the implementation and exploitation of EO systems, led WP2 and implemented a new system that automates all the monitoring process on the selected volcanoes based on the Terra-SAR-X satellite, from data ordering to the productions of interferograms (WP2). ESA participated in the implementation of the e-infrastructure (WP3), and in particular focusing on the link with the Geohazard Exploitation Platform (GEP); during the second reporting period, ESA contributed only in-kind to the project.

The industrial partners, Survey Lab, T2 and Marwan Technology achieved the twofold objective of designing and implementing new monitoring instruments / systems and facilitated the transfer of the technological know-how developed in the project toward the European industrial sector.

SurveyLab s.r.l is a spinoff of “Università di Roma ‘La Sapienza’”, funded in 2008 by researchers of the Geomatic section of the Department of Civil and Environmental Engineering. It focuses on the development of geomatic monitoring systems by means of advanced surveying and mapping technologies. It develops applications in many fields of civil and environmental engineering including infrastructure control and monitoring. It was deeply involved in WP2 and WP3 activities by implementing new methods to use the visual and thermal images provided by the INGV monitoring systems operating on Mt. Etna (NETVIS) and by integrating these results with Earth Observation data respectively.

Marwan Technology (MATEC) is a Spin-off of Pisa University, mainly dealing with laser sensors for industry and research. In WP2, it designed and built an innovative instrument for measuring the strain in 3 dimensions, by using the Fiber Bragg Grid. In cooperation with INGV, the new sensor was installed on Mt. Etna for an operational test.

Terradue UK Ltd (T2) is the UK subsidiary of Terradue Srl, an SME operating mainly in the geospatial and space sectors, whose offices are in Rome. Terradue Srl owns the complete set of T2 shares. Terradue’s
core business is Grid/Cloud based distributed computing (infrastructure and platform) and distributed data
discovery and access, from global environmental analysis using massive amounts of EO data, to regional
land change detection with complex 3rd party algorithms. In WP3, T2 contributed to building the e-
Infrastructure. Furthermore, as it replaced the withdrawn partner DeltaG, T2 completed the
implementation of the algorithm to integrate EO and GPS data for measuring 3D displacements (SISTEM)
and made it operational in GEP.

A qualified partnership from American countries (University of Western Ontario, Western, and the United
States Geological Survey, USGS) brought into MED-SUV the experiences acquired in studying the
dynamics of other Supersites volcanic areas (e.g. Hawaii) by using EO and in-situ geodetic data. These
participants complemented the expertise of CSIC and INGV in studying volcano dynamics by using EO
and in-situ geodetic data in WP3, 4, 5 and 7.

Finally, it would be remiss here if we did not acknowledge the precious contribution of the external
Advisory Board (Table 5). They helped steer the activities in the most effective direction and contributed to
improving the consistency of the results and foregrounds with the objectives of the EC-FP7 Work
Programme and the work plans of the main international initiatives within which MED-SUV was operating
(e.g. GEO-GSNL, EPOS, etc.).

MAIN RESULTS

An overview of the main achievements of the project are reported here according to the thematic order
above (i.e. Coordination, Scientific/Technological development, and Dissemination activities). Details of all
the activities and results can be found throughout the Deliverables of the projects (listed in Table 6) and
the two Periodic Reports issued at Month 18 and 36 respectively.

(1) Data Policy. One of the main issues to tackle during the project was the Data Policy. It was mainly a
Coordination task. Whilst the definition of the project data policy guidelines were formulated and achieved
in the first reporting period (D1.2 – Data Policy Guidelines), their implementation in the project’s activities
and the exploitation of this experience in a proposal for the European Supersites were the objects of the
second part of the project (D1.5 - Strategic and legal deliverables). The proposal is based on the GEO
Open Data Principles (http://www.earthobservations.org/dswg.php) and on the EC initiative of promoting
investigations (science and technological innovations) for better understanding of the geologic hazards
posed by four Supersite areas: the Marmara Sea fault zone (Turkey), the Icelandic volcanic zone, and Mt.
Etna, Vesuvious/Campi Flegrei volcanoes (Italy). This result benefitted from the intense cooperation with
MARsite and FUTUREVOLC projects through the period of the projects (e.g. meetings and the EGU
Supersite sessions). Indeed, the data policy guidelines were also used to define terms on the basis of the
foreground exploitation agreement among some of the project’s partners sharing the generation of some
project’s products (D1.5). The document concerns the possible exploitation of the implemented products,
as well as the shared use of the scientific and technological products. The document will be finalised in
agreement with the partners.

(2) MED-SUV e-infrastructure. The MED-SUV e-infrastructure creation (D3.7 - MED-SUV e-infrastructure)
was a unique test bed for a) designing an interoperable infrastructure to manage data sources with very
different protocols, formats, timings, and access rules, b) implementing the design in an operational
c) applying the data policy guidelines agreed with the consortium, and d) envisaging the possible strategies of sustainability after the project in a coherent national and international framework (D1.5). The e-infrastructure was designed in order to be compliant and interoperable with the main relevant international initiatives (e.g. GEO-GEOSS or EPOS) (Figure 6) and is based on the brokering architecture, where specialized components - the brokers - connect existing and new data sources carrying out all the necessary mediation and harmonization (Figure 7). This approach allows to keep existing systems unchanged, and to easily connect with external systems. The e-infrastructure was the result of work involving the entire project consortium in different phases and levels. The data sets of the in-situ monitoring systems, selected to feed the e-infrastructure, were entirely revised, edited or updated in order to define shared requirements for their access (D3.3 – System and Gap Analysis). The sources of the EO data sets were identified and appropriate interfaces or specific data repositories were implemented in order to fulfil the heterogeneous data policies of the Space Agencies; in the case of foreground based on EO data this was managed by the consortium (D3.4 - EO data processing and distribution). All the heterogeneous data sources have been connected to the MED-SUV multidisciplinary interoperability infrastructure, extending the brokers, where needed (Figure 7). The MED-SUV multidisciplinary interoperability infrastructure allows seamlessly discovering and accessing heterogeneous data systems using standard interfaces. A Web Portal including a geospatial portal has been developed and connected to the MED-SUV multidisciplinary interoperability infrastructure allowing users to discover and access data published by the connected data systems (Figure 8).

(3) SAR data processing. MED-SUV offered the opportunity to improve the capability of SAR in detecting and monitoring ground deformation. An automated acquisition and processing system based on TerraSAR-X satellite, named Integrated Wide Area Processor (IWAP), was developed by WP2 (D2.4 - Terra SAR-X system and FBG prototypes) and applied at Mt. Etna and Piton de la Fournaise during the pilot phase (D7.4 - Final pilot phase). This system reduces the load of manual work necessary to perform interferometric stacking and quickly gain first information on evolving geophysical processes at the studied volcanoes; it was implemented for the Italian Supersites, but it is not restricted to them (Figure 9 and 10). The huge amount of SAR images available for both areas allowed the participants to study the long-term deformations at both Mt. Etna and Neapolitan volcanoes by applying time-series analysis. In particular, the well-established Differential Synthetic Aperture Radar (SAR) Interferometry (DInSAR) approach known in literature as Small BAseline Subset (SBAS) was used to process ENVISAT and CSK data for Mt. Etna and Campi Flegrei and Naples areas (Figure 11 and 12). Furthermore, specific volcanic episodes were investigated by using the InSAR approach (D3.4) (Figure 13).

(4) Prototypes and software. NETVIS, FBG strain sensors, GILDA and plume detection by EO data are the new software tools, instruments, and methods designed and implemented in the frame of WP2, and tested in the pilot phase (WP7) at Mt. Etna and Campi Flegrei/Vesuvius. The influence of volcanic plumes on SAR signal propagation was characterized by running tests on TerraSAR-X data acquired during the Eyjafjallajökull eruption in 2010 and Radarsat-2 data of an eruptive episode of Mt. Etna in 2011 (D2.5) (Figure 14). NETVIS tool seeks to optimise and extend the observational capability of the INGV network of thermal and visible cameras installed at Mt. Etna (Etna_NETVIS) with the final goal of using the acquired images for monitoring and quantifying surface syn-eruptive processes. The tool was used for studying the emplacement of some of the recent lava flow fields of this volcano (D2.5 – WP2 Final Report) (Figures 15 and 16), and applied also on Piton de la Fournaise (D7.4). The Fibre Bragg Grating (FBG) sensors...
developed in the framework of MED-SUV have emerged as new cost-effective tools to measure strain due to volcanic activity; both linear and tri-axial models were successfully tested at Mt. Etna (D2.4 D2.5 and D7.4) (Figures 17 and 18). The Geophysical Instrumentation for Low power Data Acquisition (GILDA) digital data recorder was considerably improved and successfully tested with the FBG sensors in operational conditions (D2.5 D7.4) as well as on field experiments on Campi Flegrei and Stromboli (Figures 18 and 19).

(5) Data integration. The integration of EO and in-situ data (D3.6 - Final release of integration procedures and software) was pursued according to three different approaches and aims: a) data validation/calibration, b) data merging and c) models.

a. In order to unite different data sets, in-situ data were used to validate or calibrate EO data sets or vice versa; this approach was adopted for the SO2 retrieval in the atmosphere by using the Ozone Monitoring Instrument (OMI), on NASA’s Aura satellite, as data source, a backward trajectory simulation of the plume and the in-situ SO2 FLAME network to validate/calibrate the results of the retrieval.

b. Different data sets measuring parameters of specific volcanic phenomena were “merged” in order to achieve new/more accurate parameters relevant to the same phenomena. For instance, the ground deformation measured by InSAR and GPS techniques merged by using the SISTEM approach will result in a new product consisting of 3D displacement maps. The SISTEM tool, was also implemented in the ESA Geohazards Exploitation Platform (GEP; D3.8 - 3D integrated deformation maps (Figures 20 and 21). Examples of data merging concerned the integration of high resolution optical and radar satellite data and NETVIS-derived parameters to discriminate between volcanic products of the same event (Figure 22).

c. EO and in-situ data were also integrated through analytical or numerical models of physical phenomena; in this approach the data sets are used as experimental input data in an inversion procedure. This is the case of MODIS data, GPS-derived atmospheric parameters and atmospheric models to obtain 3D tomography of the distribution of the water vapour content in the troposphere (Figure 23). The integration through models approach is widely adopted in inferring ground deformation sources by using data sets (DinSAR, GPS, levelling, tilt, etc.) and simple deformation sources (e.g. the pressurized penny-shape crack, buried within a homogeneous half-space applied in the case of Campi Flegrei); several examples of such approach are reported below (point 7).

(6) Data analysis. The project’s experiments and the in-situ monitoring systems provide long-term and complex multidisciplinary data sets that allow developing new methods or algorithms for geophysical data analysis. The follow up of this work is framed in the knowledge of the dynamic of volcanic processes (see point 7 below) and in view of possible use in alert system improvements (point 8). The difficulty of operating in an environment characterized by high-level ambient noise (either natural or anthropic), as in the case of the Neapolitan volcanoes, fostered the development of cutting-edge analysis techniques (D4.3 - Algorithms development; D4.5 – Test of CICA). Neural networks were used to exploit the seismic and geodetic data to estimate the possible trend of the seismicity level during an unrest of the Campi Flegrei caldera, in the following short-term interval (e.g. a week); this approach was tested on the 1982-1985 bradyseismic crisis and the results were promising to support the Civil Protection operations in the case of possible future crises (D4.3). A time-frequency holographic method was applied to image seismic sources...
in real time; this approach was aimed at studying the feasibility of an automatic system to detect and locate arbitrary seismo-volcanic sources during crises (e.g. intense seismic swarms) (D4.3). An Independent Component Analysis based approach for the Blind Source Separation of convolutive mixtures (CICA) was implemented in the project; it was applied to discriminate Long-period (LP) and volcano-tectonic (VT) events, as well as anthropogenic and meteo-marine noise in the 2006 Campi Flegrei data set (D4.5). Innovative pattern recognition techniques and feature extraction procedures were applied at Mt. Etna geophysical and volcanological multidisciplinary database; for instance, very useful results were obtained for predicting the occurrence of lava fountains by volcanic tremor or detecting ash particles with irregular shape (D5.11 - Characterization of volcanic processes). Moreover, the project offered an opportunity to implement a new method to analyse the deformation data in near-real time; it was successfully tested on the inflation phase preceding the Mt. Etna 13 May 2008 eruption (D5.9 – Prototype of Deformation modelling).

(7) Knowledge improvement. Many MED-SUV results significantly helped improve our understanding of the volcanic systems and processes at Mt. Etna, Vesuvius and Campi Flegrei. The advances made in knowledge have enhanced the ability to exploit the EO and in-situ monitoring systems, and eventually the assessment of volcanic hazard in the targeted areas as follows:

a. MED-SUV provided significant new constraints on the structure of the Neapolitan volcanoes. A very large set of gravity data (more than one thousand measurement points) was used to study the structural setting of the Campania Plane, where Campi Flegrei and Vesuvius are located. This study provides new constraints for further multidisciplinary studies of this wide area by clear identification of the main structural element geometry (D4.9 – Final report on the WP4 campaigns) (Figure 24). The shallow structures of Vesuvius were detailed by integrating Electrical Resistivity Tomography (ERT) and results of self-potential, soil degassing and temperature surveys (D4.4 – Mid-term report on the WP4 campaigns; Figure 25). The active degassing areas of Solfatara and Pisciarelli of Campi Flegrei were studied using large data sets recorded during repeated campaigns carried out in the framework of the RICEN experiment and ERT and magneto-telluric surveys. Detailing of the geometry and physical characteristics of the shallow structure of these areas and their evolution through time represents a step-forward as the information obtained is entirely new (e.g. D4.9) (Figures 26 and 27).

b. Campi Flegrei were also used as a test case to investigate the dynamics of hydrothermal system fluids and the associated volcanic hazard. The pressure transients in fluid reservoirs were studied by a combination of laboratory experiments and continuous pressure monitoring in equipped wells (D4.9) (Figure 28). Moreover, the effects of strong distant earthquakes on fluid and magma reservoirs were modelled, and the fumarole action on the physical and chemical characteristics of the surface rocks was also experimentally investigated. It was found that hydrothermal alteration can lead to higher magma fragmentation and increased ejection speeds in the case of “steam-driven” explosions, which can facilitate forming fine particles that are damaging to health (D4.11 - Rock permeability and explosion probability) (Figure 29).

c. The current dynamics of Campi Flegrei, including also the recent unrest phase, was investigated by models and multidisciplinary data sets. Simultaneous joint inversion of SAR and GPS data allowed detecting a magma volume that has periodically deflated and inflated, showing slightly different geometries
throughout the 1993-2013 investigated period (D4.10 - Method for inverting geodetic data) (Figure 30). SBAS CSK time series and GPS displacement vectors were also used to study the 2012-2013 uplift episode. Data were analysed by using the non-linear optimization algorithm and the analytical penny-shape crack model in a homogeneous medium. The results inferred the physical characteristics of magma inside the source and the volume changes, as well as the induced stress changes (D4.6 - Models of magmatic and hydrothermal system) (Figure 31). The same uplift episode was studied by combining the same GPS data sets and GAMMA-IPTA algorithm for producing the CSK time series. These data were modelled by a 3D heterogeneous FE model and a Bayesian inversion approach (Figure 32). Despite the differences in the used models (inversion approaches and resulting sources), the results suggest that the amount of magma involved in 2012-2013 should have been one order of magnitude less than that involved during the 1982-84 unrest episode. Interesting results were obtained by modelling ground deformation by computing the medium elastic response to the injection of pressurized hot volcanic fluids (CO2/H2O mixture) at depth, taking into account both the poroelastic and the thermoelastic strains; a 3D Finite Element model was used. Furthermore, theoretical models and numerical modelling of experimental data investigated the thermo-poroelastic response of the hydrothermal system in a caldera by simulating pore pressure and thermal expansion associated with deep injection of hot fluids (D4.8). Simulation and evaluation of coupled fluid flow and mechanical modelling on the short-term in a mechanically heterogeneous crust were carried out. Given the lack of experimental data on the mechanical response of the shallow crust to eruptive activity at the Campi Flegrei, Soufriere Hills volcano on Montserrat was used as “analogous” of the Neapolitan volcanoes (D4.8 - Fluid flow and rock mechanics model). Further studies to characterise the Campi Flegrei activity were devoted to the dynamics of magmatic reservoirs and their effect on measurable geophysical data (gravity and deformations) by using numerical models and assuming the replenishment of a shallow (3 km) magma chamber from a deeper one (8 km). Results suggest that in such a case, in a few hours the geophysical network should record measurable anomalies (D4.6) (Figure 33).

d. Mt. Etna structural setting was the focus of coordinated activities ranging from geological to geophysical approaches. This huge volcano lies on a complex sedimentary basement along the boundary between Africa and Eurasia plates, which is crossed by significant lithospheric faults (e.g. the Malta-Aeolian alignment). The geologic constraints of the basement were investigated by field surveys and laboratory experiments (D5.6 - Constraints on the structure of Mt Etna) (Figure 34), and by the TOMO-ETNA seismic experiment (data available in MED-SUV Portal), which was carried out off-shore and in-land Mt. Etna, and in the north-eastern corner of Sicily and southern Tyrrhenian Sea (D5.4 – Report on the TOMO-ETNA experiment). The seismic surveys were integrated with other geophysical surveys (magnetic and gravity measurements), thus also involving institutions not belonging to the MED-SUV consortium (D5.4). The preliminary results of the TOMO-ETNA experiment (D5.10 – Global structural model of Mt. Etna) have led to a special issue of Annals of Geophysics (see list of the project’s products) (Figure 35). A specific experiment to obtain 1D detailed velocity model of the shallow crust was carried out by installing a very dense seismic network around a seismic borehole station in NE flank of the volcano. Analysis of the background seismic anisotropy contributed to defining the structural setting and showed that seismic arrival time delay increases before the start of a paroxysmal event (D5.10). The model of gravity data provided by surveys over the last four decades confirms previous seismic tomographies and encourages the integrated use of gravity and TOMO-ETNA results (D5.8). For the first time, Mt. Etna’s shallow plumbing system was investigated in depth by using the same geophysical and geochemical integrated
approach adopted for Vesuvius (D5.7 - Gas budget) (Figure 36). Additionally, a 3D consensus structural model was implemented and shared in the project portal (D5.10).

e. The “open-conduit” characteristics of Mt. Etna offered the opportunity to investigate the volcano plumbing system starting from the characterisation of the magma source to the eruptive dynamics at the surface. Analysis of the chemistry of rocks discharged during the last thousands of years up to the most recent eruptions, allowed inferring the variation of mantle source composition in time; for instance it was possible to assess that the very rapid alkali enrichment of the post-1970s basalts is associated with an increase in volume of erupted magma as well as the modification of seism-tectonic patterns of the volcano (D5.11) (Figure 37). The “open-conduit” characteristics of the volcano have also enabled estimating the volumes of magma supplying the continuous (eruptive/quiescent) degassing by investigating the gas species flux rates and plume chemistry (SO2 and radiogenic elements). Overall, the estimated volume of degassing magma exceeds more than 3.5 times the erupted one, thus suggesting magma recycling and compressibility able to justify such discrepancy (D5.7 and D5.11). Further studies applied on volcanic plumes were aimed at estimating and modelling the content of volcanic ash during explosive eruptions. Radar Doppler based estimation of volcanic mass erupted during lava fountains, integrated with dispersion models were used to quantify the tephra emission of Mt. Etna (D5.11) (Figure 38). The eruption in August 2014 was used as a natural laboratory for organising multi-parametric experiments involving several tens of participants, and testing new techniques for monitoring explosive activity and studying the dynamic of the gas emission and ash aggregation (D5.5 – Fieldwork and multidisciplinary experiments on gas dynamics and ash aggregation) (Figure 39).

f. The dynamics of Mt. Etna was investigated at local and global scales by developing new models and exploiting the large ground deformation data set of the volcano (Figure 13). The interaction between magmatic sources (as intruding dikes) and structural or topographic features were studied by implementing theoretical models calibrated at different volcanic settings (Figure 40), and tested using specific test cases (e.g. the 2001 eruption, Presa landslides; e.g. D5.8 – Stress and Strain transfer) (Figure 41). These studies evidenced the structural/ topographic control on timing, position, and geometry of the magmatic intrusions (Figure 42), as well as the capability of the stress induced by an intrusion to trigger the strain (either seismic or aseismic) along pre-existing faults (e.g. the Pernicana or Santa Venerina faults; D5.10). The global stress/strain behaviour of the volcano, and in particular of the eastern flank dynamics and its relationship with the magmatic sources and tectonic setting, was investigated by analysing a few significant test cases and by comparing Mt. Etna to other two active basaltic volcanoes: Kilauea and Piton de la Fournaise (D5.11) (Figure 43).

(8) Hazard assessment. Overall, the project has fostered assessment of the short-term volcanic hazard in the Italian Supersites and the exploitation of the information provided by the monitoring systems (in particular from the permanent networks). Indeed, given the different intrinsic characteristics of Mt. Etna and Campi Flegrei/Vesuvius – open versus closed system – as well as the different societal requirements and background in volcano hazard assessment and management, the work carried out was organized in diverse ways at the two areas. The main breakthroughs in the hazard assessment of Neapolitan volcanoes focused on fine-tuning the Bayesian approach for the probabilistic evaluation of the occurrence of an eruptive event at Campi Flegrei and its effects in the area. This activity benefitted from the follow up of other projects (e.g. VUELCO and Italian DPC initiatives) and from the improvements on the long-term
probability assessment based on new knowledge of the volcanic processes in this area (e.g. new models in the plume and ash dispersion) (Figure 44). A highly relevant project outcome consisted of implementing operational software in the INGV-OV Operative Room (D6.2). The two main threatening phenomena at Mt. Etna are paroxysmal explosive events producing volcanic plumes and lava flows, these last particularly threatening in case of vents opening at low altitudes. MED-SUV project offered the opportunity to develop a preliminary application of the Bayesian approach to probabilistically assess the occurrence of flank eruptions and the effects of volcanic plume fallout (D6.1) (Figure 45). Another significant result of the project was the improvement in communication techniques between scientists and decision makers by evaluating the suitability of scientific outcomes (e.g. hazard maps) to be informative for this goal. Meetings with civil protection officials were organised at Campi Flegrei, Mt. Etna and Azores and ad-hoc questionnaires were formulated and used to collect feedback and suggestions from decision-makers. Also in this case, the activities benefitted from the collaboration with other projects (VUELCO). At Campi Flegrei, the suitability of the new software implemented in the INGV-OV Operative Room was also discussed with the decision-makers (D6.3).

Potential Impact:

As a whole, the results of the MED-SUV project significantly contribute to the achievement of the FP7 Work Programme “Cooperation”, one of whose overarching objectives was “... to promote and facilitate knowledge transfer, assessment, uptake and exploitation of scientific data and results, in particular through demonstration and delivery of innovative tools and services such as ... earth observation systems”.

In detail, MED-SUV has contributed to the EC-FP7 Work Programme “Cooperation” objective as follows:

a) it has increased the European technical know-how for monitoring active and threatening volcanoes. The project developed new monitoring software, instruments, and methods to improve the accuracy, precision and quality of measurements of significant parameters, by acting from data collection to their analysis and processing. The use of new instrumentation or methods and the deployment of new field campaigns as test-beds allowed integrating multi-parametric data sets in cutting-edge models which have led to a better understanding of Mt. Etna and Campi Flegrei/Vesuvius volcanic systems and processes;

b) it developed cutting-edge solutions in volcano monitoring by promoting collaboration between scientific and industrial (SMEs) partners of the consortium. Significant aspects of the conceptually new monitoring system are the design and implementation of prototypes of cutting-edge systems/instruments for measuring new in-situ parameters, reducing the costs, increasing the accuracy of measurements, and integrating EO and in-situ data;

c) it implemented a digital infrastructure for data access and distribution. The digital-infrastructure facilitates access to observations and data (both in-situ and EO), thus providing the most important and effective contribution to the GEO 2015-2026 work-plan. To guarantee the full achievement of this objective, the e-infrastructure is compliant with the GEO/GEOSS interoperability principles and expectations. The digital infrastructure, which will be further developed within a legal framework defined in the strategical project’s deliverable, will set a new milestone for research. It will provide a unique multi-parametric data set of each volcano enabling to accelerate scientific progress and ensure that the maximum value is extracted from both in-situ and EO data. The availability of the whole data set will also
help decision-makers in organising activities relevant to the management of the risks related to volcanic disasters;

d) it has improved the use of scientific observations and related information to probabilistically assess volcanic hazard, to inform policies, decisions and actions associated with disaster prevention, preparedness and mitigation. Indeed, a robust cooperation between scientists, decision-makers and end-users is needed to protect citizens living in or near volcanic areas from volcanic threats. To this end, MED-SUV carried out specific activities to define pilot actions to improve the risk awareness of decision makers involved in data management risk in the Italian Supersites;

e) it has improved communication and coordination between national, regional and global communities in support of disaster risk reduction starting from the analysis of the management of past volcanic crises. The results obtained will be the starting point to implement new actions devoted to volcanic risk preparedness by exploiting scientific, social and economic resources.

Outside the EC-FP7 Work Programme, the impact of the MED-SUV project is here considered over the short, mid, and long-terms.

In the short-term, the project’s impacts are expected at national (Italy), European and global level. In particular, at national level, the project will affect the daily management of the monitoring and surveillance activities of the Italian volcanic areas. The project has given an important incentive to implement operational solutions to guarantee seamless access to the volcanological and geophysical data sets. This is the necessary pre-requisite to contribute, at European level, to the implementation of the European Plate Observing System (EPOS) platform, in which MED-SUV infrastructure is considered a fundamental pilot outcome. In turn, MED-SUV impacts also on the achievements of the objectives of the Disaster Resilience SBA (Social Benefit Area) of the GEO 2016 Work Programme, and specifically on the GI-08 GSNL initiative (Geohazard Supersites and Natural Laboratories), in which EPOS is one of the Participating Organizations. In terms of community building, the project has promoted a thematic task on Volcano Geodesy, which already met to discuss sharing of data, methods and practices during international conferences (EGU and AGU).

In the mid-term, the results of the project have provided the basis to foster new ideas to cover the current gaps in H2020 concerning the lack of initiatives on volcanic hazards. Indeed, volcanic eruptions can have severe environmental and socio-economic impacts and are extremely costly in terms of human life and the economy. In this framework, the continuous acquisition and integration of multi-parametric in-situ and satellite observations, available for the Italian Supersites, can provide breakthroughs in the observation, parameterisation and modelling of natural phenomena impacting the environment.

In the long-term, MED-SUV might contribute to 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. It also provides access to real-time reliable data, encourages the update and dissemination of risk information, such as hazard maps for decision makers, 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 has addressed all these aspects during its implementation period and, thus it might be a good example for discussing best practices in a global framework.
MAIN DISSEMINATION ACTIVITIES

Considering the contribution of MED-SUV to the FP7 Work Programme “Cooperation” and the multi-temporal scale impact of its outcomes, in order to make the project products available and thus, to accomplish the main goals stated in the preliminary dissemination strategy (see the Description of Work), the MED-SUV Consortium was involved in several initiatives coordinated by WP8 “Dissemination and Outreach”. Overall, the general objectives of this strategy were those of disseminating the project outcomes, so as to spread new volcanology knowledge among the scientific community, as well as among decision-maker bodies and public, and to allow the end-user community to access data on the two Italian Supersites through a proper implemented e-infrastructure. Indeed, in order to translate these goals into actions, a proper communication plan strategy was defined by WP8 (D8.4; Communication Plan). In compliance with the “Guide for project participants” EC document, the communication plan provided the procedures to carry out dissemination inside and outside the project consortium clearly detailing and refining the key objectives, the kind of audience, the dissemination methodology, and the concrete actions.

The actions undertaken included drawing the attention of the project end-users in the period following the project start, providing news and updates on the project activities after, promoting the connection of MED-SUV with other EU projects and initiatives, and ensuring the sustainability of the project after its termination. Throughout the three year project, the actions were carried out by the diverse means and tools listed below.

- MED-SUV logo. The creation of the identity of the project benefitted from the design of the logo, outlining an active volcano and reporting the EU flag (Figure 3). The colours, similarly to those used for the GEO colour chart, also recall the ground and the sea, the two elements in common between these two volcanic areas, located close the Tyrrhenian and Ionian seas.

- MED-SUV website. A few months after its start, the project implemented a website (http://www.med-suv.eu/) to spread the main outcomes and activities of the project, and to share the information among the consortium. This last aim was also achieved by creating a private “Collaborative area”, linked to the website, in order to archive the project data and documents, share them among the partners, and to provide each WP the opportunity to have a reserved operative area to manage their data and documents. The website is also linked to the MED-SUV portal (http://medsuv_portal.ct.ingv.it/) for accessing to data and products relevant to the Supersites (Figure 8).

- MED-SUV Facebook page. In January 2014, a Facebook page was started (https://www.facebook.com/medsuv). Facebook increased the visit to the web page and allowed distributing news concerning the project activities and the eruptive state of the project’s volcanoes (in particular of Mt. Etna). It now counts more than two hundred “likes” and has regular visits and comments.

- MED-SUV video. The video, co-produced by INGV and ESA, was uploaded on the project website, Facebook page as well as on YouTube. It presents the main objectives and activities of the project, as well as the strategic vision of the volcano monitoring based on the integration between in-situ and Earth Observation systems.

- Interviews and contribution to newspapers. During the project, the Coordinator and the partners granted interviews to national and international printed and on-line newspapers, accessible through the project website (http://www.med-suv.eu/spip.php?rubrique33) and to local TV.
- Informational factsheets. Through the project three versions were issued: the first in July 2013, the second in June 2015, and the third in June 2016. The factsheets presented the objectives and work plan of the project, the outcomes of the first reporting period and those of the final one, respectively. They were distributed in conference and meetings.

- Newsletters. Three versions of electronic newsletters were prepared with articles published on the project website. They are downloadable from the project website and were distributed through an email list of more than five hundred addresses and to the Volcano-list forum.

- Leaflets and activities for young people. The aim of the leaflets was to promote the awareness of young students to volcanic hazard. Consistently with the other dissemination initiatives carried out - “school activities” - the leaflets targeted more specifically 7 to 11 year old pupils. As this public may be less impacted by an electronic leaflet to download, we decided to print copies for distribution among pupils and posters to be distributed to schools. In addition to English, Italian, French and Portuguese versions, Spanish and German translations were also made to broaden the potential impact of the project message. These products have been disseminated at the primary schools of the Vesuvio/Campi Flegrei and Etna areas, and they are accessible through the project website (http://www.med-suv.eu/spip.php?rubrique37).

- Science policy briefs. The project produced two Science Policy Briefs in order to tackle the priorities of the 2005-2015 Hyogo Framework for Action - as foreseen in the project description of work – and to also take into account the new priorities of the Sendai Framework for Disaster Risk Reduction 2015-2030, which were issued during the project implementation. The two documents (accessible through the website; http://www.med-suv.eu/spip.php?rubrique39) represent a bridge between what was done in MED-SUV and the future actions that will involve not only the Italian local scenario (the Italian Supersites) but also the European framework in terms of European volcanology community. For this reason and in order to guarantee the maximum diffusion, both briefs will be published on-line and disseminated in all relevant events, as well as provided to all relevant institutions.

- Dissemination materials. In order to increase the visibility of the project, pens, block notes, USB gadgets, and mugs with the logo of the project were produced and distributed to stakeholders in meetings and conferences.

- Workshops and meetings. Apart from the numerous WP’s and task meetings, the whole Consortium met four times during the Kick-off and final meetings in Naples and Rome, respectively (Deliverables D8.1 and D8.9 respectively) and during the first and second year meetings, in Catania and Naples respectively. During the final meeting a proper session devoted to discuss the outcomes of the project with invited stakeholders was held. Indeed, during the three years of the project the MED-SUV participants attended the most important geophysical and volcanological meetings held in Europe and worldwide (e.g. the EGU General Assembly and AGU Fall meetings) with more than 280 contributions (talks, posters, exhibitions, etc.).

- Article publications. The researchers involved in the project published about one hundred papers focused on the MED-SUV outcomes in international peer-reviewed journals and books.

EXPLOITATION OF RESULTS
The strategies of exploitation were discussed and reported in two key deliverables D8.7 “Action plan for the sustainability of the dissemination” and D1.5 “Strategic and legal deliverables”. Whilst D8.7 mainly concerns the exploitation of the dissemination products, D1.5 deals with the use of all scientific and technology foreground by defining, classifying, ruling, and protecting the project products. The deliverable is actually made up of three crucial documents – a proposal of a data policy for the European Supersites, an Exploitation of Foreground document, and the Memorandum of Understanding for the sustainability of the monitoring systems and e-infrastructure. Indeed, the proposal of a data policy shared among the European Supersites will allow the exploitation of the MED-SUV foreground in terms of data and knowledge sharing with the other Supersite projects’ communities for better understanding of the geologic hazards posed by the EU Supersite areas. Such a sharing will be compliant with the GEO Open Data Principles (http://www.earthobservations.org/dswg.php) and the EC initiative of promoting investigations in volcanic hazardous areas. A shared data policy represents a starting point for protecting and ruling the IP of data providers, while exploiting and disseminating the project data and products outside the consortium.

Aside from defining the most suitable strategy for result exploitation, it was essential to clarify what is intended as project results. As a matter of fact, MED-SUV was a rather complex project whose main objectives were reached by a large consortium and by addressing many topics spanning from research and modelling to development and implementation of novel instrumentation, software, and e-infrastructure for data access, re-use and sharing. The project achievements therefore have different ownership (single or joint) and are of different nature. The analysis of the information of surveys carried out by the Management Team among the Consortium partners (D1.5) allowed distinguishing the single and joint ownerships and grouping the project foreground in the following three classes:

1. Scientific products: publications and data sets from experiments (TOMO-Etna, RICEN, Etna North-East Crater multidisciplinary campaign, etc.);
2. Technological products: new instrumentations and methods/algorithms (GILDA, FBG sensors, new satellite-based monitoring system, SISTEM, NETVIS, ...);
3. Services and Outreach: e-infrastructure (access to data and computing facilities; GEP use cases), web page, factsheets, etc.

The three types of products may require adopting different exploitation strategies while considering the kind of ownership. Indeed, the exploitation of the scientific products will be guaranteed by publication in journals according to the journal access policy (open access or copyright) and dissemination in meetings and conferences. The exploitation of data sets resulting from big project experiments that involved several partners, will be archived in the project portal. Given these data sets are ruled by a joint kind of ownership, for their use and exploitation it is necessary to set a proper agreement among the involved partners. The agreement will define the terms of data access needed to protect the data owners while opening their products beyond the project consortium. To this end, the D1.5 include an exploitation agreement template for the scientific products that can help data owners define the scientific results, their ownership and responsibilities and rules for the exploitations. The template will be submitted to the involved partners, before uploading the data sets in the portal.

The main exploitation of the technological products follows the general criteria of the scientific foreground, and given that none of the SMEs expressed the desire to commercialise their products, it might be
envisaged in the framework of the monitoring systems. Of course the technology products result from the collaboration between industrial and scientific partners, and thus also in this case the joint ownership case is applicable. Hence, in order to respect the Intellectual Property of each of the involved partners, the D1.5 has also foreseen a proper exploitation agreement template. The feasibility of the approach proposed in the template was preliminary and successfully tested during the withdrawal process of DeltaG from the Consortium, at the beginning of the second reporting period. The drafted document was used to define the agreement between DeltaG and INGV, which during the first reporting period implemented in joint partnership a software to integrate SAR and GPS measurements of ground deformations.

The third kind of foreground is mainly related to the dissemination actions and essentially consists in the continuation of advertising the outcomes of the MED-SUV consortium beyond the project duration by sustaining the main dissemination tools – i.e. the e-infrastructure and website – as well as publishing and presenting the project scientific results. This objective is outlined in the two above-mentioned deliverables: D8.7 and D5.1. The first deliverable properly addresses the sustainability of dissemination products by maintenance of the website to make the project results available after the end for the project. The second deliverable then defines the objects to be maintained (on the whole, called “monitoring system”) and the legal perimeter within which the “monitoring system” operates, and the three partners involved - INGV, CNR and BRGM - can act. The MoU foresees that the website will maintain its actual form for 1 or 2 extra years. After this period the results will be considered already reused in following projects and the initial products will become obsolete; thus the main content of the website will be integrated in the data platform hosted by INGV and on a project page hosted on the BRGM institutional website: http://www.brgm.eu/scientific-output/projects/liste-projects. The URL (med-suv.eu) can be prepaid for a longer period (about 5 years) and redirected to INGV or EPOS-IP platform in order to ensure continuity for the visitors of the website. In this way, MED-SUV dissemination products will still be accessible and referenced by search engines and will benefit from the dynamism of bigger websites/platforms. The data portal, managed by INGV and CNR, will be upgraded with new data, products and services.

List of Websites:
Public MED-SUV web site: http://www.med-suv.eu/

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Related documents

- final1-med-suv-finalreport-table4-beneficiaries.pdf
- final1-med-suv-finalreport-table1-wp-leaders.pdf
- final1-med-suv-finalreport-table7-managementteam.pdf
- final1-med-suv-finalreport-table6-deliverables.pdf
- final1-med-suv-finalreport-table3-rtd-tasks.pdf
- final1-med-suv-finalreport-table5-ab.pdf
- final1-med-suv-finalreport-figures.pdf
- final1-med-suv-finalreport-table2-gantt.pdf

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