

A.1 Proposal Title

MT. ETNA SUPERSITE VOLCANO

A.2 Supersite Point-of-Contact (PoC)

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A.3 Core Supersite Team and organization

The core Supersite team is the **Istituto Nazionale di Geofisica e Vulcanologia (INGV)**, which is the largest Italian research institution in Earth Sciences with headquarter in Rome and offices in many cities all over Italy (Milano, Pisa, Bologna, Napoli, Palermo and Catania) with about 1.000 personnel units. INGV main mission is monitoring and study of geophysical phenomena in both solid and fluid components of the Earth. INGV runs surveillance networks, laboratories and observatories and collects, studies and disseminates data in the field of seismology, volcanology, geodesy, geochemistry and marine sciences. It is the reference scientific institution for the Italian government in the field of geo-hazard. INGV works in close coordination with civil protection authorities at national (DPC, Dipartimento della Protezione Civile) and local level. INGV manages 24hours/7days nationwide seismic surveillance service and early warning based on monitoring infrastructures. The INGV seismic and volcanic surveillance networks and the laboratories fit into the European Plate Observing System (EPOS), one of the research infrastructures listed in the roadmap of ESFRI, also included in the Italian research infrastructures roadmap. INGV has a relevant experience in coordinating research activities both in national and international projects. INGV participated both as coordinator and partner in several past and ongoing projects funded by international bodies such as EU (e.g. EXPLORIS, ITN NEMOH, SHARE, MIAVITA, SAFER, NERIES, NERA). INGV now leads the Preparatory Phase projects of two ESFRI research infrastructures of the environmental sector, namely EPOS and EMSO (EMSO, European Multidisciplinary Seafloor Observatory).

Future activities for the next three years for the Mt. Etna Supersite will be modulated by the MED-SUV (MEDiterranean SUPersite Volcanoes) project, funded within the Environment program of the 7th Framework Programme of the European Commission (Theme ENV.2012.6.4-2 “Long-term monitoring experiment in geologically active regions of Europe prone to natural hazards: the Supersite concept”), in which INGV is the project Coordinator.

The INGV core supersite team includes researchers which have experience working with a wide range of ground and space-based monitoring techniques, data analysis and research into volcanic process.

Following the list of the researchers involved on the team with their role and expertise.

- **Giuseppe Puglisi** is a Director of Research and Leader of the “Ground Deformation” unit of the INGV Section of Catania, Osservatorio Etneo. His research activity has concerned investigation in the dynamics of the volcanic and surrounding areas by geodetic techniques, mainly GPS and SAR interferometry. He also deals with researches working on ground deformation data inversion mainly using numerical optimisation techniques. He is the coordinator of the EC-FP7 Project entitled Mediterranean Supersite Volcanoes (MED-SUV).
- **Francesco Guglielmino** is a researcher at the INGV Section of Catania, Osservatorio Etneo. Since 2001, he has been developing research activity on deformation studies to achieve better knowledge of dynamic processes in tectonic and volcanic areas. He works on: acquisition, processing and analysis of InSAR data to monitor large-scale and small-scale ground deformations; modelling of ground deformation in volcanic and tectonic areas; inversion of intrusive processes and magma storage at depth. He also deals with development of new techniques to integrate geodetic data with information derived for EO InSAR processing.
- **Salvatore Stramondo** Laurea degree (M.S.) in electronic engineering in 1996, Ph.D. in Geoinformation in 2007) joined the INGV in 1997 where he is currently Senior Researcher. Since 2004 he is Adjunct Professor at the University of Calabria, Italy. He was Invited Researcher at the CNR-IRECE (Naples, Italy), IPGP (Paris, France), JPL (Pasadena, CA), IIT (Bombay, India). He is author of 70 international papers, several contributions to National and International conferences and some book chapters. He is actually the PI of APHoRISM - Advanced Procedures for volcanic and Seismic Monitoring and MIUR “*Progetto Premiale INGV Studio multidisciplinare della fase di preparazione di un terremoto*”; WP Leader and task leader in National (MIUR PRIN 2009; Abruzzi Project; PON Calabria) and International (FP7 MarSite; FP7 SAFER) projects, and chair of the Satellite Information Data WG8 of EPOS European Project. Since 2009 he is Editor of Remote Sensing journal and Associate Editor of IEEE GRS Letters and International Journal of Applied Earth Observation and Geoinformation. He is Senior Member of IEEE.
- **Sven Borgstrom** , PhD geologist from the University of Naples “Federico II”, Italy (Degree in 1983, PhD in 1990), now Technical Researcher at INGV-OV. His field of research interest is the SAR Interferometry, on which, since 2002, he has been working also jointly with other Italian and international institutions (IREA-CNR, TUDelft, ESA, DLR) on SAR data processing, interpretation and integration with classical geodetic data for ground deformation studies in active volcanic areas. Borgstrom was leader of Work Packages/Tasks in national and international projects (e.g. MINERVA ESA-DUP, GLOBVOLCANO ESA-DUE). Author of more than 60 papers in national, international and peer-reviewed journals.
- **Maria Fabrizia Buongiorno** is researcher Manager at INGV. At INGV, she is the leader of the Remote Sensing Unit at CNT and coordinator of INGV Remote Sensing Activities. She is an expert in the remote sensing field. In 2005-2007 she coordinated the Earthquake and Volcanoes application platform in the European Community Project FP6 EURORISK-PREVIEW, in 2009-2011 European Community Project FP7 SAFER, European Community Project FP7-MIA-VITA. At national level, she coordinated the Italian Pilot project ASI-SRV funded by Italian Space Agency.

Other INGV researchers involved in the Supersite activities are:

- **V. Siniscalchi, P. De Martino, C. Del Gaudio, C. Ricco, G. Berrino, G. Macedonio, G. Chiodini, F. Bianco, L. D'Auria, F. Giudicepietro, R. Peluso, S., M. Musacchio, M. Silvestri, C. Bignami.**

The list includes researchers not only from the “Osservatorio Etneo” Catania section, with strong expertise in SAR and optical data processing, geodetical (e.g. GPS, optical levelling, tilt, etc.), seismological and geochemical methodologies, data integration and interpretation, modelling.

A.4 Other Supersite Research Teams

The supersite Point of Contact will coordinate interaction with other research teams, and in particular with the participants of the consortium of the European Commission funded by MED-SUV (MEDiterranean SUPersite Volcanoes) project. The project addresses a call in the Environment program of the 7th Framework Programme of the European Commission (“ENV.2012.6.4-2: Long-term monitoring experiment in geologically active regions of Europe prone to natural hazards: the Supersite concepts”). The consortium is formed by 20 leading academic and research institutions and 4 SMEs from 10 countries, which will implement a long-term monitoring experiment aimed at fitting the rationale of the “Supersite” initiative to a large geographical key region prone to hazards including Mt. Etna.

Following the institutions involved in MED-SUV project and the names of the most relevant persons involved in the project activities.

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 MED-SUV project. CNR-IREA incorporates a Microwave Remote Sensing Group that is active since 1987. Their main research interest is Differential SAR interferometry (DInSAR), with two main goals: (a) development of tools to detect and monitor Earth surface deformations and (b) demonstration of applicability of the proposed techniques in real scenarios. CNR-IREA has a high level expertise in scientific SAR and DInSAR algorithm development and large experience in scientific software development. IREA has also implemented its DInSAR processing chain into the G-POD and GENESI-DEC framework of ESA, allowing to process automatically satellite data. It has also been involved in a number of National and International Project in the SAR related field, as coordinator or participant. CNR-IIA attends the project with the Earth and Space Science Informatics Laboratory (ESSI-Lab) whose main research topics are relevant to the application of information science and technologies to manage, harmonize, and share Earth & Space Science resources and develop Spatial Information Infrastructures. The research interests of the group are inherent the study of atmospheric pollution in urban and industrial areas, the development of global and regional atmospheric modelling and the treatment of geospatial information. These activities are also pursued as member of the OGC (Open Geospatial Consortium), IEEE ICEO, GEO SIF, as well as an affiliated organization to the US UCAR (University Corporation for Atmospheric Research).

Key personnel involved: Dr. **A. Pepe**, Research Scientist with CNR-IREA, in the DInSAR field. Dr. **M. Manzo**, Research Scientist with CNR-IREA, DInSAR data processing and applications for the monitoring of surface displacements. Dr. **G. Solaro** and Dr. **P. Tizzani**, CNR-IREA Research Scientists, processing SAR data acquired by the C- and X- band sensors, and integration of geophysical numerical modelling of volcanic sources. **S. Nativi**, Research Scientist with CNR-IIA, coordinator of the Earth and Space Science Informatics Laboratory of CNR-IIA, member of the GEOSS Infrastructure Implementation Board (IIB), co-chair of the GEO Science & Technology Committee, and coordinator of the CNR Inter-departmental project GIIDA. Dr. **P. Mazzetti**, researcher at CNR-IIA, design and development of infrastructures and services for geo-spatial data sharing in the context of national, European (FP7) and global initiatives, member of the 2011 GEOSS Evaluation Team. Dr. **L. Bigagli**, researcher at CNR, ICT applications for geographic information management, addressing the gap between the scientific community and the society/decision makers.

AMRA S.c.a r.l. is an entirely public, no-profit company, established in 2005 as a result of an EU funded project. The leading partner of AMRA is the University of Naples “Federico II”, the other partners being four public Universities, CNR, INGV and the “Anton Dohrn” Zoological Station. AMRA operates in the fields of natural and anthropogenic risk assessment and mitigation, with early warning methods for natural hazards and quantitative probabilistic multi-risk assessment as its core activities. AMRA, the owner of the ISNET EEW network installed in Irpinia, works in close partnership

with the National Department of Civil Protection. AMRA, currently involved in several FP7 Projects, is now coordinating the REAKT (Towards real-time earthquake risk reduction) and the CLUVA (Climate change and Urban Vulnerability in Africa) projects. Among the others, it is partner of the following projects: SYNER-G (Systemic Seismic Vulnerability and Risk Analysis for Buildings, Lifeline Networks and Infrastructures Safety Gain); SAFELAND (Living with Landslide Risk in Europe); GEISER (Geothermal Engineering Integrating Mitigation of Induced Seismicity in Reservoirs); MATRIX (New Multi-Hazard and Multi-Risk Assessment Methods for Europe); NERA (Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation).

Key personnel involved: Prof. **R. Moretti**, Department of Civil Engineering of the Second University of Naples and associate researcher at INGV-OV.

The Italian **Civil Protection Department** (Dipartimento della Protezione Civile, DPC) of the Presidency of the Council of Ministers (<http://www.protezionecivile.it>) is the focal point of the Civil Protection National System, which includes Research Institutes, Private Companies, Volunteers and all Italian operative Forces. The main activities are: (a) forecasting, in order to analyse causes of disaster events, to identify risks and detect risky areas; (b) prevention, to reduce disaster damages; (c) assistance, to ensure elementary aid to the population and (d) management and overcoming of the emergency situations. DPC is involved in many National and International activities related to the evaluation and mitigation of natural risks and crises management (i.e. volcanic, earthquake, landslide).

Key personnel involved: Dr. **V. Bosi**, DPC team Leader.

DLR is the German Aerospace Center. Its extensive research and development work in Aeronautics, Space, Transportation and Energy is integrated into national and international cooperative ventures. The **Earth Observation Centre (EOC)** at DLR consists of the German Remote Sensing Data Centre (DFD) and the **Remote Sensing Technology Institute (IMF)** and it is the centre of competence for earth observation in Germany. The IMF is focused mainly on developing sensor-specific algorithms and methodologies, whereas DFD concentrates on developing user-oriented products and services. IMF scientists have been involved in SAR data processing since the early days of SEASAT, the first SAR satellite launched by NASA in 1978. They have had and continue to play leading roles in all civil German SAR missions (SIR-C/X-SAR in 1994, SRTM in 2000, TerraSAR-X in 2007 and TanDEM-X in 2010) and they accompanied ESA in all European SAR missions. The SAR Signal Processing Department (IMF-SV) at IMF is involved in MED-SUV project. They carry out research on data from spaceborne and airborne SAR instruments, developing algorithms and software for the focusing and interferometric processing of SAR signals. They develop and operate generic, interferometric and D-InSAR processors for purposes such as deriving digital elevation models and determining the rates of ground deformation.

Key personnel involved: Dr. **M. Eineder**, Head of the SAR Signal Processing Department at IMF and Dr. C. Minet expert in SAR processing for ground deformation monitoring.

Ludwig-Maximilians-University (LMU) is one of only three universities that achieved elite status in the first round of the German Excellence Initiative. The volcanology group has 6 permanent staff members, 2 junior professors, 5 PostDocs and 9 PhD students. It 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. LMU involvement in EU-projects consists in the ITN participation (FP6: 12 RTNs, 5 as coordinator; FP7: 9 ITNs, 2 as coordinator). The volcanology group was involved in EXPLODE, MULTIMO and Volcano Dynamics and is part of the ongoing networks MeMoVolc, NEMOH (both FP7 ITNs) and VUELCO (FP7 Cooperation).

Key personnel involved: Prof. **D. Dingwell**, Chair of Mineralogy and Petrology, Research Professor of Experimental Volcanology, and Director of Earth and Environment Department. Dr. **U. Kueppers**, geologist specialised in experimental volcanology.

GFZ was founded in 1992 as the national research institution for geosciences in Germany and is *ab initio* member of the Helmholtz Association of National Research Centres. With currently more than 1.100 staff, GFZ combines all solid earth science fields including geodesy, geology, geophysics, mineralogy, palaeontology and geochemistry in a multidisciplinary scientific and technical environment. Research is accomplished using a broad spectrum of methods, such as in-situ monitoring and observations, satellite geodesy and remote sensing, deep geophysical sounding, scientific drilling and the experimental and numerical modelling of geo-processes. In order to provide its activities around the globe and in space, GFZ maintains massive scientific infrastructure and platforms, including observatories, a modular Earth science infrastructure, the home base of the International Continental Scientific Drilling Programme (ICDP) with the Operational Support Group, the novel drilling InnovaRig and the Centre for GeoInformation Technology CEGIT, to mention the most relevant for MED-SUV project.

In 2012 a BubbleLab will start its activity, allowing the simulation of earthquake waves and their effect on various types of fluid reservoirs. GFZ has a relevant experience in coordinating and participating into international projects, e.g. TRIDEC, Collaborative, Complex and Critical Decision-Support in Evolving Crises (FP7); GEISER, Geothermal Energy Integrating Mitigation of Induced Seismicity in Reservoirs (FP7); CO2CARE, CO2 Site Closure Assessment Research (FP7); GITEWS German Indonesian Tsunami Early Warning System Project; SAFER, Seismic Early Warning for Europe (FP6); SHARE, Seismic hazard harmonization in Europe (FP7); MATRIX, New Multi-Hazard and Multi-Risk Assessment Methods for Europe (FP7); REAKT, Strategies and Tools for Real Earthquake Risk Reduction (FP7).

Key personnel involved: Dr. **H. Woith**, earthquake hydrogeology and monitoring of thermal waters. Dr. T.R. Walter, Head of the Research Group "VolcanoTectonics". Dr. **E. Rivalta**, physical modelling of magma-filled dikes and hydrofractures, general physical modelling of volcanic processes.

The **University of Durham**, in the United Kingdom, was founded in 1832. It has over 15.000 undergraduate and postgraduate students (3.500 postgraduates and 1.900 international students from over 120 countries) and employs over 3.000 staff. Its academic teaching and research programmes are delivered through departments organised within three faculties: Arts and Humanities, Science, and Social Sciences and Health. Durham University is one of the UK's leading research universities and has been successfully involved, both as partner and coordinator, in a large number of Framework Programme projects and networks.

The University is engaged in several aspects of activity such as high-quality teaching and learning, advanced research and partnership with business, regional and community partnerships and initiatives. The University's strategy is directed at creating the future through internationally recognised research, scholarship and learning within a distinctive collegiate environment.

Key personnel involved: Dr. **G.R. Foulger**, seismic tomography.

University of Bristol (UNIBRIS). With about 16.000 full-time students and more than 5.000 staff, the University organises its academic activities in 34 departments and 15 research centres arranged in six faculties. League tables generally place Bristol within the top ten universities in the United Kingdom and within the top 30 in the world. The School of Earth Sciences was ranked in the top 5 UK Earth and Environmental Sciences for research by the HEFCE in 2008. The school includes five research groups covering the spread 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. All group members are associated with the Cabot Institute, a world-class multidisciplinary

institute for research on all aspects of global environmental change, from basic science and social science to technological and policy solutions. It brings together some of Bristol's most outstanding research - in natural hazards and risk, Bayesian statistics, uncertainty and decision-making, climate modelling, poverty, global insecurities and governance, and systems engineering.

Key personnel involved: Dr. **J. Gottsmann** currently holds a Royal Society University Research Fellowship, senior lecturer at the School of Earth Sciences.

Centre national de la recherche scientifique (CNRS) [IPGP, ISTO, ISTERRE, ENS]

IPGP (Institut de Physique du Globe de Paris) will be leader of the French consortium in MED-SUV project. IPGP is a mixed research Unit (UMR7154) of CNRS and Paris Diderot University. It hosts 330 permanent researchers, engineers and technicians, 65 on contracts, and 90 doctorate students. Scientists are grouped in 13 research teams working in various fields of Earth and Planetary Sciences. Three of those teams have strong international expertise in geophysics, field and physical volcanology, gas geochemistry and remote sensing, magma petrology and geochemistry, and numerical/ analogue modelling of geological fluid dynamics. IPGP is the Institute responsible for monitoring French active volcanoes and shares the management of Montserrat Volcano Observatory. Key personnel involved: Dr. **P. Allard**, Director of research in French CNRS, attached to IPGP. Dr. **F. Beauducel**, geophysicist (equivalent Professor) at the IPGP, Volcanol. And Seismol. Observatories Department.

ISTO (Institut des Sciences de la Terre d'Orléans) is a mixed research Unit (UMR7327) of CNRS, Orléans University and BRGM. It hosts 70 permanent researchers, engineers and technicians, 35 doctorate students and 15 postdoc. Scientists are grouped in 4 research teams working in various fields of Earth and Planetary Sciences. One of those teams is involved in volcanology studies, with strong international expertise in experimental petrology aimed at defining pre-eruptive conditions, volatile solubilities, physical properties of magmas.

Key personnel involved: Dr. **B. Scaillet**, Director of research at French CNRS, unravelling of magmatic and volcanic processes. Dr. **M. Pichavant**, Director of research at French CNRS, experimental petrology.

ISTerre (Institut des Sciences de la Terre) is a laboratory dedicated to Earth and Environmental Sciences. It was created in 2010 by merging LGIT and LGCA. It belongs to the CNRS (National Centre for Scientific Research), the University "Joseph Fourier" in Grenoble (UJF), the Université de Savoie in Chambéry (UdS), to IRD and LCPC. It hosts about 250 people, including 92 academics, 50 technical and administration staffs, 19 postdocs and 90 Ph.D. students. The annual budget is 4.9 M€ (without salaries for permanent staff and academics). 55% of this budget comes from contracts, and 16% from the CNRS. 10% of the budget is dedicated to observation activities. ISTerre hosts 9 research groups covering the major fields in following disciplines: Seismic cycle and transitory movements, Geochemistry 4D, Geodynamo, Volcanoes geophysics, Faults mechanics, Mineralogy and environments, Waves and structures, Tectonics reliefs and basins, and Seismic Risks. The laboratory has produced 836 articles in international journals between 2005 and 2009 (162 per year on average), including 24 in journals with Impact Factor > 5. As a member of the OSUG (Observatoire des Sciences de l'Université de Grenoble), ISTerre is responsible for a number of national facilities for permanent (OMIV, RAP, RENAG, RENASS, RLBP) and mobile (SISMOB) observations in geophysics and data centers (FOSFORE, RAP). It is involved in research infrastructures for European seismology (NERIES, RESIF which is part of EPOS). ISTerre scientists have close connections with beamlines at synchrotron and neutron facilities in Grenoble (ESRF and ILL), Paris (SOLEIL) and abroad.

Key personnel involved: Dr. **V. Pinel**, researcher at IRD, is specialized in mechanical modelling of magmatic systems (magma storage and transport through the crust and volcanic edifice behaviour) and expert of deformation studies using SAR data. Prof. **J. Vandemeulebrouck**, associate professor at Université de Savoie, is an expert on the physics and imagery of hydrothermal systems.

Ecole Normale Supérieure (ENS). The Laboratoire de Géologie (<http://www.geologie.ens.fr>) is specialized in the study of the Earth deformation at all ranges of timescale, from second (seismology) to million years (mantle rheology). One of its research axes is Earth dynamics and earthquakes. The laboratory has worked and is working on the several large earthquakes that occurred in the last decades and in particular the three giant earthquakes of Sumatra (2004), Chile (2010) and Japan (2011), with particular focus on ground deformations observed with GPS and SAR interferometry. The laboratory is involved in field GPS monitoring with campaign and permanent GPS in Chile, Indonesia, Greece, Bulgaria, Guatemala. It has a leading position in two observatories, the Laboratoire International Associé "Montessus de Ballore" (<https://www.lia-mb.net/>) in Chile and the Corinth Rift Laboratory (<http://crlab.eu>) in Greece. It is also one of the leading institutions in the GPSCOPE project (<http://gpscope.fr> and <https://gpscope.dt.insu.cnrs.fr>) which is a national initiative gathering various CNRS laboratories involved in Geophysical GPS. ENS participates in various national and international R&D projects, in collaboration with several research institutions, in particular in the countries where ENS installed sensors in the field. The Ecole Normale Supérieure has participated and currently participates into several EU projects relevant to the hazard theme (EU projects CORSEIS, AEGIS, ASSEM, 3HAZ, SISCOR, REAKT for Greece, ANR projects for Chile and Indonesia). Key personnel involved: Dr. **P. Briole**, senior CNRS researcher, is expert in geodesy and remote sensing applied to volcanoes and seismic zones.

Bureau de Recherches Géologiques et Minières (BRGM). 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 division (RIS), which will be 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 has coordinated or contributed to many EC research projects in risk and vulnerability evaluation fields, including MIAVITA on volcanic risk management and many others like RISK-BASE, LESSLOSS, ORCHESTRA (FP6); ENSURE, SHARE, SAFELAND, PERPETUATE, SYNER-G, MATRIX, ENVISION, REAKT, EuroGEOSS (FP7).

Key personnel involved: Dr. **M. De Michele**, researcher in remote sensing. Dr. **A. Vagner**, Specialist in Systems and Automation Engineering, she is currently involved as Project manager of FP7 MIAVITA and works on technical activities related to vulnerability assessment (ENSURE, SYNER-G).

European Space Agency (ESA). ESRIN, the ESA EO centre located in Italy, is responsible for collecting, storing and distributing EO satellite data. Major EO activities today are related to the exploitation of the ERS and ENVISAT missions. ESA actively supports projects aimed at optimising the accessibility and use of these data. Examples of relevant ESA-funded EO Programmes are the Data User (DUP/DUE), the Marked Development and the GMES (Global Monitoring for Environment and Security) Service Element Programme. Through these programmes and via the participation to EC-funded projects, ESA gained excellent contacts with the EU Earth science and EO user community. ESA is also active in promotion of relevant technology (Grid, digital libraries, portals, web-services) for various space-related applications, including Earth science & EO.

Key personnel involved: Dr. **R. Cossu**, working in ESA since 2005, has been working in several projects dealing with different aspects of EO applications and related innovation technologies.

Agencia Estatal Consejo Superior de Investigaciones Científicas (CSIC). The Agencia Estatal Consejo Superior de Investigaciones Científicas (CSIC) is the largest public multidisciplinary research organisation in Spain. CSIC collaborates with national and international universities, public RTD organisations, SMEs companies and other institutions of scientific/technological nature. It has a staff of more than 13.500 employees, among these about 3.500 are permanent researchers and more than 4.000 are pre- and post-doctoral researchers. The CSIC has 135 institutes/centres distributed throughout Spain, including 51 Joint Research Units with universities or other research institutions. CSIC has also a delegation in Brussels. It has considerable experience in both participating and managing RTD projects and training of research personnel. Under the 6th Framework Programme CSIC has signed 404 actions (37 coordinated by CSIC). CSIC has been the 5th organisation in Europe in project execution and funding in the 6th FP. Under the 7th FP CSIC has signed as of today more than 459 projects (including 51 coordinated by CSIC as well as 22 ERC). The **Institute of Geosciences (IGEO)** is the largest Earth Sciences Institute in Spain. The MED-SUV participant team has a great experience in geodetic research, applying ground and space-based geodetic techniques to the monitoring of volcanic hazards, data integration (GPS, InSAR, optical, etc.) to obtain 3D displacement field, as well as theoretical modelling (direct and inverse problem), being able to carry out simultaneous interpretation of terrestrial and space data of deformation and gravity changes. This team has taken part in a wide range of national and international projects, including several EU and ESA projects in which the members have been actively involved.

Key personnel involved: Dr. **J. Fernández**, Research Scientist, expert in Geodesy applied to natural and anthropogenic hazards, including ground and space base techniques.

University of Granada (UGR). The UGR research group is composed by professors and researchers from the Andalusian Institute of Geophysics. This group has broad experience in analysis of seismic signals in different volcanoes like Etna, Stromboli, Vesuvius, Campi Flegrei, Teide, Azores, Colima, Popocatepelt, Arenal, Telica, San Cristóbal, Copahue, Kilauea and Deception Island. Among different 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. The group has participated in several European and National research projects, and it has managed, in the last 10 years, a few millions of Euros. In the last 5 years the group has published more than 35 high quality scientific papers, presented more than 60 communications in international meetings, presented more than 10 doctoral thesis and other scientific products. The group is the responsible of the use and management of a broad portable seismic network, focused on the study of volcano seismicity. The net is composed by 10 modules of 12 channels seismic array and 15 broad band seismometers. Some of the seismic arrays are, at the present, deployed in active volcanoes as Colima, Copahue or Deception island. Many of the results of the group are directly applied to the early warning alert of different volcanoes, and some of the members of the group are permanent advisors of different Civil Protection organizations of Spain, Italy, Mexico and Argentina. The group has a large experience in active seismic experiments on volcanoes, being responsible of two of them, one developed in the Antarctica (Deception Island) and the second one in Tenerife Island (Canary Island, Spain).

Key personnel involved: Dr. **J. Ibañez**, Director of Instituto Andaluz de Geofísica, Campus de Cartuja s/n, Universidad de Granada.

CVARG (Centre for Volcanology and Geological Risk Assessment) is a multidisciplinary research unit of the **Universidade dos Açores (UAç)** belonging to the portuguese national research system. The CVARG activities are developed in the Earth Sciences branch and are mainly directed to prevention and forecast of natural disasters. It develops its main activities in the volcanology domain and associated phenomena, including among others volcanic activity, earthquakes, ground deformation, landslides and tsunamis. In the research component, CVARG integrates various national and international networks and consortia and its research team has a considerable experience in

international UE funded projects from the FP5, FP6 and FP7, namely, RETINA, FORESIGHT, EXPLORIS, VOLUME, ESONET, EMSO and EPOS among others. In a more operational component CVARG gives a strong emphasis to multi-parametric monitoring of geological hazards in the Azores region running in association with CIVISA (Centre for Information and Seismovolcanic Surveillance of the Azores) seismic, geodetic, geochemical and meteorological networks for seismovolcanic, landslide and environmental surveillance. It makes part of the Volcano Observatory and provides scientific advice to the Azorean Civil defence.

Key personnel involved: Dr. **T. Ferreira**, Assistant Professor, Head of the board of directors of the CIVISA (Centre for Information and Seismovolcanic Surveillance of the Azores).

University of Malta (UoM). The University of Malta has about 10.000 students. The Atmospheric research unit of the Physics department (Faculty of Science) includes 5 full time employees. The Research Unit has instruments based in Giordan Lighthouse on Gozo for monitoring trace gases and climate change in the Mediterranean. Both Shipping and Volcanic emissions are detectable and work is underway to install further equipment specific for Volcanic emissions. Noteworthy is the participation of the UoM in the VAMOS-SEGURO project.

Key personnel involved: Dr. **R. Ellul**, Project leader with 30 years experience in trace gas monitoring.

University of Western Ontario (Western). The University of Western Ontario (Western) is one of the top 10 leading research universities in Canada, with annual research funding in excess of \$225 million.

Key personnel involved: Dr. **K. Tiampo** is a Professor in Earth Sciences at Western and has extensive experience in the modelling and inversion of geodetic data.

United States Geological Survey – Hawaiian Volcano Observatory (USGS-HVO). The Hawaiian Volcano Observatory (HVO) was established on the rim of Kilauea caldera in Hawaii in 1912. The Observatories mission is to monitor the activity of Hawaiian volcanoes as a means of assessing and forecasting volcano and earthquake hazards, as well as to gain insights into volcanic and earthquake processes that will help to better understand such hazardous phenomena.

Key personnel involved: Dr. **M. Poland**, expert in deformation monitoring, particularly radar interferometry, inferring magma plumbing system geometry, and monitoring flank instability.

Università degli Studi di Milano (UMIL). The University of Milan, established in 1924, is a public teaching and research-intensive university, the only Italian among the 21 prestigious members of LERU (League of European Research Universities) and an internationally high-ranked university. With a teaching staff of about 2.200 tenured professors and with almost 60.000 students, the University of Milan offers a number of study programmes which can be grouped into three macro-disciplinary areas: Humanities, Social Sciences and Law; Medicine and Healthcare; Natural Sciences. Research activities are conducted in 31 Departments, among which the **Dipartimento di Scienze della Terra "A. Desio" (Department of Earth Science "A. Desio")** and 29 Inter-departmental Research Centres. With its wide spectrum of basic and applied research activities, covering scientific disciplines such as stratigraphy, paleontology, structural geology, geomorphology, mineralogy, petrography, geophysics and engineering geology, the Department of Earth Science has been involved in numerous national and international research projects, often as a coordinator. In particular the Engineering Geology research group focuses its interest on three topics: i) Management of landslide hazard and risk mitigation (also applied to volcanic environment, at different scale, slope landslides or volcano flank collapses); ii) geotechnical and geomechanical studies applied to civil-engineering; iii) advanced techniques for groundwater management. The group has gained proven experience in the use of modern statistical techniques for spatial analysis of geological data and the application of numerical modelling to simulate hazard scenarios. The geotechnical, geomechanical and hydrogeological

characterization of materials and geological media involved in the phenomena, is a strategic requirement for all the thematic studies. The Engineering Geology Laboratory for Testing Material of the Department has supported 40 years of research, through the characterization of soils, rocks and discontinuities, applied to the assessment of slope stability, civil engineering works, and to the exploitation of water resources.

Key personnel involved: Dr. **T. Apuani**, Geologist. Associate Professor in Engineering Geology; responsible of the Engineering Geology Laboratory for Testing Material of the Department of Earth Science.

Université Blaise Pascal - Laboratoire Magmas et Volcans (UBP-LMV). The Laboratoire Magmas et Volcans (LMV) is a joint research unit of the Blaise Pascal University (UBP), the Centre National de la Recherche Scientifique (CNRS) and the Institute of Research and Development (IRD). It is also one of the laboratories of the Observatoire de Physique du Globe at Clermont-Ferrand (OPGC) and one of the Auvergne Regional Centres of Excellence. The LMV coordinates the Laboratory of Excellence CLERVOLC funded by the French government and aimed at bringing a global and multidisciplinary response to volcanism and volcanic risk issues. It hosts over a hundred people, including 62 permanent researchers and 21 PhD students grouped in 3 teams: Volcanology, Geochemistry and Petrology. 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-art methods and techniques. To achieve this goal, it has developed a large range of analytical and experimental equipments and methods for observation and modelling. The LMV has strong international expertise in remote sensing, geophysics, field and physical volcanology, gas geochemistry and magma petrology and geochemistry, and numerical/analogue modelling of deformation.

Key personnel involved: Dr. **F. Donnadieu**, expert in radar remote sensing of volcanic plumes. He is in charge of the OPGC Doppler radar monitoring Etna (INGV-UBP-CNRS research agreement) and of the VOLDORAD service at OPGC.

Other research teams, potentially interested in Mt. Etna volcano Supersite (mainly in the field of SAR Interferometry)

- **University of Miami, USA** (Reference Person: **Falk Amelung**). The University of Miami Geodesy and Seismology Laboratory (UMGSL) is an active research group consisting of 3 faculty members and 10-15 students and postdocs addressing diverse topics in volcanology, tectonics and climate change. UMGSL wants to develop a dynamic predictive block-motion model for Mount Etna's eastern flank consistent with the volcano structure, geodetic and seismic observations of flank motion and laboratory constraints about the frictional properties of faults at depth. UMGSL receives funding from the U.S. National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA). UMGSL depends on excellent in-situ and space data collected by the monitoring and space agencies a to develop winning research proposals.
- **JPL/Caltech, USA** (Reference Persons: **Paul Lundgren**, Eric Fielding). The Jet Propulsion Laboratory (JPL), California Institute of Technology (Caltech), is managed by Caltech for the U.S. National Aeronautics and Space Administration (NASA). It is the lead NASA institution for the robotic exploration of the solar system and a leading institution for a large number of Earth satellites related to climate change and other geoscience objectives. JPL was the original developer of synthetic aperture radar (SAR) interferometry (InSAR) during the 1980's and continues to develop and apply InSAR techniques to scientific problems using both international SAR satellite data and the JPL/NASA developed airborne InSAR, the UAVSAR project.

- **University of Rome 3, Italy** (Reference Person: **Valerio Acocella**). The Department of Science at the University of Roma Tre, Italy, is actively involved in the study of the deformation of volcanic areas, at the regional and local scale, and in any setting, including divergent, convergent, transform plate boundaries and hot spots. In addition to the field analysis, we use analogue and numerical models and InSAR analysis. Using these tools, the researchers of the Department have been studying also the recent evolution of Mt. Etna and, subordinately, the Campi Flegrei Caldera. At Mt. Etna, they have investigated the volcanic activity of the last decades in relation to the instability of the eastern flank of the volcano. At Campi Flegrei Caldera, after defining the fracture pattern, they are now studying the recent surface deformation within the caldera, also providing a comparison with that observed during the unrest of other calderas in the world in the last 25 years.
- **University of Leeds, UK** (Reference person: Andrew Hooper and Tim Wright). The University of Leeds is one of the largest universities in the UK with an income of € 5000m, over 30,000 students and 8,000 staff. The School of Earth and Environment was ranked second in the UK for research power in the 2008 Research Assessment Exercise. The Institute of Geophysics and Tectonics within the school is the largest grouping of geophysicists in the UK and a centre of excellence for geodynamcs and tectonics. Researchers in the institute have been active in the field of radar interferometry (InSAR) since 1997 and have been at the forefront of developing the use of InSAR for measuring tectonic and volcanic deformation. The group has developed dedicated InSAR software packages, which have been made available to the scientific community, and today hundreds of users from all over the world use these softwares. Leeds led the international Afar Rift Consortium and is leading the work package on magma migration in the European FUTUREVOLC project.

A.5 Supersite description and justification

The following subsections provide an overview of the main objectives and characteristics of the Supersite.

A 5.1 How Mt. Etna Supersite support the objectives of the Geohazard Supersites

Mt. Etna supersite presents many characteristics that make it prone to be a Geohazard Supersite. The volcano consists of an open-vent system characterised by continuous degassing from the volcano summit craters and frequent eruptive summit and flank eruptions. Eruptions can be of different kinds passing from violent short-lasting explosive events to long-lasting lava output, thus producing different kinds of impacts on the surrounding environment, and especially on the large number of people living around the volcano foot. Over time, the frequency and variety of Mt. Etna's eruptive activity have made the volcano one of the most well-studied and monitored worldwide. At Mt. Etna volcanic activity produces a wide spectrum of signals, spanning from seismic and geodetic to geochemical and radiometric signals, which are tracked in continuous and in real-and quasi-real time by the automatic multi-disciplinary monitoring systems deployed by INGV. The huge amount of ground-based collected data sets enforces the vision of Mt. Etna supersite as a Geohazard Supersite where applying the overarching criteria of the Geohazard supersite initiative of enriching the knowledge on geohazards, and promoting the co-operation between space and in situ data providers and data cross-domain sharing. In particular the Mt. Etna volcano supersite offers the chance to:

- achieve new scientific results based on the use of available unprecedented data sets;
- develop and transfer timely scientific knowledge on volcanic crises;
- develop sustainable long-term Earth observation strategies following eruption.
- establish user requirements for the Global Earth Observation System of Systems (GEOSS)

The interest of the international volcanological community on Mt. Etna, as well as the growing role as laboratory for hazard assessment during the 20th century, is testified by the inclusion of Mt. Etna in the list of “Decades Volcanoes” identified by the IAVCEI commission during the International Decade for the Natural Disaster Reduction of the UN, and by the great amount of scientific publications (e.g., more than 70 per year, on average, on Mt. Etna over the last ten years).

On Mt. Etna, GPS and seismic networks in combination with globally observing low resolution SAR sensors (Sentinel-1, Alos) will provide the need background monitoring. Local and temporary in-situ networks in combination with high resolution SAR sensors (TerraSAR-X, Cosmo-Skymed, Radarsat-2) provide monitoring for specific sites and crises.

A.5.2 What geological process characterizes the site?

Mt. Etna is one of the most active volcanoes on Earth and, in the past few decades, has erupted virtually every year. The etnean volcanism results from the interaction between magma ascent in the rather complex plumbing feeding system and the local tectonic regime controlled by the volcano edifice’s eastern flank instability, whose driving conditions (e.g., structural setting, tectonic forces) and cause-effect relationships are not yet completely understood. At the surface, the combination of the two factors produces eruptions that might consist of either strongly explosive (e.g., 2002; 2011) and produce volcanic ash plumes likely to disrupt air traffic for hours to weeks (e.g., 5 January 2012), including powerful summit paroxysms in the 2012-2013 time span or lava flows capable of invading the populated sectors, that can threaten human property and vital infrastructures.

A.5.3 How can the geohazard be characterized?

The first step in the characterisation of every kind of hazard is its identification. In the case of volcanic hazards, mainly associated with eruptive events, the phase of identification is linked to recognition of anomalies in the volcano common state, and thus in volcano parameters. At Mt. Etna, the availability of extended geophysical, as well as geochemical and volcanological data sets, has allowed both identification of baselines of the volcano behaviour and first-order assessment on the main characteristics of the incoming eruptive event/geohazard. The onset of an eruption, evolution and waning phase are controlled by the complex equilibrium between the structural framework (stress field) and the forces controlling magma ascent in the volcano plumbing system at different depth. Changes in this equilibrium produce geophysical, geochemical, and thermal anomalous signals that can be modelled to characterise and interpret the subsurface processes triggering the eruptive event. When eruption start, the quantitative evaluation of physical parameters (e.g., volume changes, duration/magnitude of eruptions, variations in gas emission rate and heat budgets, etc.) provides valuable insights for assessment of the evolution of the eruptive scenarios and the associated hazards. Indeed, the reliability of models largely depends on the degree of knowledge of the structural setting, the physical and chemical properties of both the magma and the surrounding medium, and any other “boundary” condition. Therefore, multidisciplinary approaches aimed at: i) defining unclear, weak or approximate parameters and/or boundary conditions and/or structural settings 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 tectonic setting, are needed. Throughout the last decades, space-based techniques, in the form of thermal and optical imaging and radar interferometry, have become increasingly used to enhance the volcano monitoring systems. Although both the spatial and temporal resolution of satellite-based observations has often been insufficient to fit the needs of civil protection, especially in the case of rapidly evolving volcanic phenomena, and the elevated costs, satellite-recorded data are fundamental for monitoring the above-mentioned threats. In fact, despite the higher resolution offered by the ground-based monitoring techniques with respect to satellite observations, these latter provide synoptic views of the areas affected by the volcanic phenomenon/hazard and information on poorly accessible areas not covered by monitoring networking.

A.5.4 What research questions, application developments or operational system enhancements will be pursued at this site?

The availability of a huge number of EO data coupled with in-situ data providing from the existing networks, will promote the use of different kinds of geophysical data and their integration in cutting-edge models, will achieve a step-change in our understanding of Mt. Etna dynamics.

This will:

- i) increase the capability to interpret the clues of a volcanic unrest, in particular InSAR data just before and during eruption (during dike propagation) led to new insights on where exactly the erupted magma comes from and what forces bring the magma to the surface, while optical data will allow the detection of thermal anomalies likely associated with resumption of eruptive activity at the Summit Craters or opening of eruptive vents / fissures at the flanks of the volcano.
- ii) deepen the knowledge of volcanic processes by, deformation produced by either deep magma storage or flank dynamics that produce deformations detected by SAR interferometry, SO₂ flux measurements, mapping of volcanic plume dispersion, lava flow fields emplacements, etc.
- iii) lead to more accurate evaluations of the effects of an impending eruption and, in general, better assess the hazard of a specific volcanic area over both the short- and long-term, such as identifications of areas of high strain accumulation, evaluation of effusion rate and lava volumes for initialising modelling of lava flow field emplacements, forecasting of volcanic ash dispersions and fall-out, etc.

A.5.5 What data and observation systems and models are available for this site? Who operates them? Can these data/systems/models be accessed readily by the research team? and local support to the Supersite proposal.

During recent decades, Mt. Etna has become one of the most intensely monitored volcanoes of the world, allowing significant progress in eruption forecasting. The Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo - Sezione di Catania (INGV-OE) is devoted to monitoring of the volcanic and seismic activity in Sicily. The (INGV-OE) manages a very complex system of instrumental networks made of 280 multi-parametric stations. The monitoring activity includes: geochemical and geophysical monitoring (seismicity, gravity, magnetic and ground deformation), thermal and video surveillance, together with geological analysis (geological and structural surveys, mapping of lava and tephra dispersal).

The permanent geochemical network is composed by 9 UV-scanners for SO₂ flux and 3 in-soil Radon detectors. The continuous monitoring of gases and groundwater is integrated by measurements of diffuse soil CO₂ degassing, performed monthly. Since mid-2000, periodic surveys based on a Fast Fourier Transform Infrared spectroscopy (FTIR) has allowed to recognize variations of SO₂/HCl and SO₂/HF ratios in the volcanic plume which provide new insights into the dynamics of ascent and degassing of discrete magma bodies.

Seismic signals (velocimetric, accelerometric and infrasound) are collected by a permanent seismic network composed of 49 permanent seismic stations, 12 accelerometric stations and 13 infrasonic stations. In the past decade an accurate analysis of the seismic signals allowed seismic velocity and attenuation tomographies of the volcano; this results improved the knowledge of the inner and deep structure the volcano, constraining the models of hits feeding system.

The gravimetric network is made of 3 permanent stations and 71 other stations measured periodically, and located at 500-3100 m above sea level. The magnetic network consists of 5 continuous stations located on the volcano edifice at elevations ranging from 2500 to 3000 m above

sea level, coupled with an external reference station installed about 50 km west of Etna on the Nebrodi Mountains.

Ground deformation studies (up to year 2000) have been carried out only using periodic GPS survey (about 80 stations), leveling surveys and periodical distance measurements (EDM network), coupled with the clinometric network (10 tiltmeters), located to medium-summit area (higher than 1000 meters above sea level). From 2000 onwards this ground deformation monitoring was complemented by 32 permanent GPS stations and by differential SAR interferometry analysis. These ground deformation studies allowed to image the long and short term dynamics of the volcano, and to better define its structural framework and feeding system. Recently a new approach (SISTEM) was developed, integrating geodetic and DInSAR data which provide the complete gradient displacement tensor and the 3-D component of the deformation within the entire investigated area. The SISTEM integration method is hence promising for future studies aimed at improving the knowledge on particular aspects of the dynamic of this volcano (e.g. the plumbing system, the flank dynamics, etc.). Ground motion models developed for these areas not only integrated ground-based and satellite-based observations, but are also constrained by a profound knowledge of the volcanic structures including the underground magmatic and geothermal systems and their dynamics.

Video surveillance of Mt. Etna is exploited by 5 visible and 2 thermal cameras, located at different distances (3 – 27 km) from the summit of the volcano, in order to monitor both large eruptive plumes and high-resolution details of the summit craters.

All this heterogeneous information is currently processed and interpreted with the aim to recognise the subsurface magma dynamics and precursory events that may announce forthcoming eruptions. The complete list of Mt. Etna monitoring networks is reported in Section A.12.

A.5.5.a Mission of the organization providing the in-situ data

The mission of the INGV is to observe, monitor and understand the geophysical phenomena in both the fluid and solid components of our planet. In this framework, INGV is in charge of the surveillance of the seismicity and volcanic activity of the entire Italian national territory through state-of-the-art observations systems (e.g. instrumental networks covering the national territory or concentrated around the active volcanoes, laboratories, etc.). As far as this application to CEOS is concerned, INGV is the provider of the in-situ data collected on Mt. Etna and Campi Flegrei/Vesuvius Supersites.

A.5.5.b Relationship to decision makers

The INGV belongs to the Italian Civil Protection system. Its relationship with the National Department of the Civil Protection is organized in the context of a decennial Framework Program, which outlines the guidelines for implementing and maintaining the monitoring system, sharing of the information between INGV and DPC, defining of the procedures for the alerts in case of volcanic or seismic events and as well as any issue related to the organization of the surveillance system in Italy. INGV organizes and maintains the complex volcano and seismic monitoring system in Italy through periodic agreements (annual, triennial, etc.) with the DPC, regional and local authorities.

A.5.5.c Data policy and vision for data access

INGV data policy is inspired to GEO and EC directives for the data sharing and dissemination (INSPIRE, etc.). Furthermore, thanks to the wide spectrum of the kinds both of the available data and participants (data providers and data users), the MED-SUV project - as whole - is the ideal forum to find worldwide enforceable data policies aimed at promoting retrieval and systematic access to the EO and the in-situ data for Supersites. This Task deals with the definition of such a data policy, by implementing specific deliverables (at months 6 and 36 of the project) which test and propose a specific data policy. Currently, data sets are shared through INGV web portals. However, during the

MED-SUV project, a specific e-infrastructure will be designed and implemented to allow data interoperability and sharing. To this aim this e-infrastructure will consider concepts and solutions introduced and adopted by the GEOSS Common Infrastructure (GCI), as well as the standards recognized by the GEO Standard and Interoperability Forum (SIF-INSPIRE) and GMES. The activities of GEOWOW project will be taken into account through the partners involved in the MED-SUV project. For data archiving and sharing, the supersite digital infrastructure will also consider the experience and best practices developed by previous relevant projects (e.g., DIVO, ASI-SRV, PREVIEWS). The e-infrastructure will be developed using a Service-oriented approach. In this context, added value processing services for exploiting the information contained in low level ESA satellite data will be implemented. The added value products will include integrated parameters and maps obtained merging satellite and in situ data.

Data and data products will be classified according to the level of processing, starting from raw data, i.e. data that keep unchanged the original format of the sensors (e.g. seismic waveform, raw GPS data, etc.) or the original information (e.g., rock samples), to quality controlled data, to data products coming from automated or nearly automated procedures, to data products coming from scientific investigations. Furthermore, according to their availability on the data storage, data from permanent stations can be classified as “real-time” or “near real-time”, depending on the delay needed to upload the acquired data on the data storage and make them sharable.

As general rule, the access to the data and data products can be open, restricted or embargoed. Open data and data products are freely available to any users; they will be available under appropriate licences, which regulate observation intellectual properties and copyrights. Restricted data and data products are available to registered authorized users after signing an agreement for accepting the INGV data policy; they are available according to an appropriate license, that regulate observation IP and copyrights. Embargoed data and data products are available only after a specific time (embargo period) has passed since collection/generation. During the embargo period they will be only available to specific authorized users (usually, only to components of the national Civil Defence system). Once the embargoed period has passed they may become open or restricted.

A.6 Current or future use of requested data

Integration between space and ground-based collected data is not new at volcanology; however previous studies have regarded only limited time windows, mainly due to the lack of continuous sets of ground-based collected observations. In this view, the requested data provide an unique opportunity for improving the capabilities of the EO systems for monitoring active volcanoes increasing the amount and quality of information available on Mt. Etna. Here, in fact, the large number of ground data collected by INGV coupled with the request EO data will represent a great contribution for development of new observation methods and will give the opportunity to scientists to implement, test and apply many algorithms and methods for processing EO data. In particular, the integration between ground-based networks and InSAR data will be an added value for Mt. Etna volcano monitoring, as InSAR is able to extract the information on wide areas, not available from classical networks due to their poor space coverage. On the other hand, ground-based networks (e.g. GPS and tilt networks, etc.), routinely used for surveillance, will provide *continuous* information not detectable from space-borne SAR sensors. Moreover, the requested data will allow the systematic acquisition of parameters up to now measured only occasionally (e.g., the 3D strain) or production of new deliverables (e.g., routine deformation maps), as well as improvement of the accuracy of the measurements.

As far as the requested optical data are concerned, the multi-mission satellite images will be automatically processed to mainly produce (1) time series of brightness temperature for thermal anomaly detection, (2) time series of SO₂ flux to be integrated, in the case of Mt. Etna, to the flux

derived from the INGV-OE ultraviolet scanning network, (3) lava flow mapping, (4) to observe volcanic plume dispersion and quantify mass eruption rates and volcanic ash grain-size distribution at the source.

Integration between EO and in situ data acquired at Mt. Etna and in other active volcanic areas, will enable scientists to gain high quality multidisciplinary observations of the volcanic phenomena and, thus improved modelling of the processes responsible for the features observed at the surface. This last will provide better assessment of the hazards posed by volcanic activity as well as helpful insights for volcano risk mitigation.

A.7 Schedule

The requested data will be used in the framework of the MED-SUV project. Hence the milestones for setting up Mt. Etna Supersite, as an *infrastructure* available for the interested Scientific Community, will be suggested by the timetable of the three year-lasting MED-SUV project (1 June 2013-31 May 2016).

A.8 Detailed geographic region of interest

Mt. Etna is located on the eastern sector of Sicily (Italy). The regional geodynamics of the area is characterized by the oblique convergence of the African plate towards the Eurasian plate. Mt. Etna stands within the deforming zone at the plate boundaries, with the Apenninic-Maghrebian chain to the north and the Hyblean Foreland to the south (Fig 1). The volcano has grown on the continental lithosphere at the junction of two major structural lineaments, at the regional scale, which separates the continental lithosphere of the eastern Sicily from the oceanic lithosphere of the Ionian basin: the NE-SW striking Messina fault system and the NNW-SSE-oriented Malta Escarpment to the Hyblean Foreland (Monaco et al., 1997).

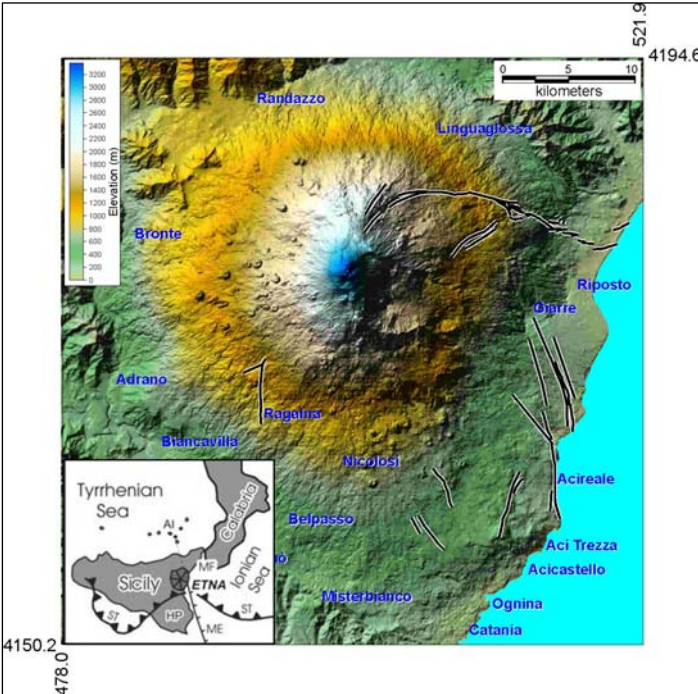


Figure 1: Sketch map showing the location of Mt. Etna, the volcano elevation above the sea level and the main volcanological and structural features of the volcano edifice. In the inset, the main geodynamic structures, are reported.

Over time Mt. Etna's volcanic activity has been fed by either the summit craters (in the last 40 years there have been 4 distinct summit craters, and recently since 2010, a further crater has developed) or by numerous flank vents. The continuous activity at the summit craters ranges from passive degassing to episodic explosions, whose regime has varied from Strombolian activity to fire fountaining. Flank eruptions mainly result from intrusion of dikes that have commonly allowed drainage of volumes of magma from the volcano central conduits. These eruptions are mainly effusive, and have produced initially explosive activity and emplacement of moderate to very large lava flow fields. During some eruptions, fed by rising of magmas that had bypassed the central conduit, the activity was quite vigorous resulting in continuous Strombolian explosions and fire fountains, and lava output that produced large cinder cones in correspondence to the eruptions vents, as occurred during the eruptions of 2001 and 2002-03.

A.9 Data requirements

Considering the geographic location of Mt. Etna, the satellite acquisitions requested fall within 37.3° - 38° N, and 14.5° - 15.5° E.

RADAR data

In order to quantitatively compare satellite-derived data with ground-based geodetic networks (e.g. optical levelling), the availability of Synthetic Aperture Radar (SAR) data from different sensors exploiting different bands of the electromagnetic spectrum (typically X, C and L-band for space-borne sensors) and from different tracks (ascending and descending) is critical. These characteristics will allow, in fact, evaluation of diverse phenomena at different scales and reconstruction of ascending and descending datasets covering larger time spans, as well as, splitting of data into vertical and easting components of ground motion, when the information on common pixels from both viewing geometries is available.

Available data:

TerraSAR – X (130 acquisition per year suggested)

TerraSAR –X acquisitions from 4 different swaths (both ascending and descending mode) covering the Mt. Etna area, are needed; in particular all available data (StripMap mode, single polarization, Slant range product - SSC) from:

- Descending Beam 17 / Strip 5
- Ascending Beam 55 / Strip 6
- Descending Beam 108 / Strip 13
- Ascending Beam 131 / Strip 14

TerraSAR –X is flexible to collect with a 11 day repeat time about 33 acquisitions using each of the different swaths per year, thus leading to a total of 130 requested acquisition per year. The TerraSAR-X data, with the 11 days repeat cycle, will allow the formation of time series of deformation, considering also the opportunity to use the large dataset available (from 2008). Currently, at Mt. Etna TerraSAR-X acquisition is tasked in the framework of the project GEO0999, since 2010.

COSMO SkyMed (250 acquisition per year suggested)

The advanced capabilities of the SAR sensors aboard COSMO-SkyMed will allow to achieve high resolution products (<1 metre, to 3 metres) in short repeat time intervals (1 to 4 days). At Mt. Etna, COSMO-SkyMed data are acquired with different modes (i.e. spotlight, stripmap) and with different geometries. The quite short revisiting time of CSK data is essential to detect and image the transient

volcanic activity, which is characterized by high deformation gradients. A background acquisition strategy will be needed in order to update the archives created during the projects ASI-SRV and SAR4VOLCANOES.

Radarsat-2 (30 acquisition per year suggested)

Currently, the Radarsat-2 is the only operating C-band mission. In the last two decades, ground deformation on Mt. Etna has been largely analyzed by C-band SAR data (ERS and ENVISAT), which has allowed the investigation of the dynamics of medium-depth magma reservoirs and of some of the principal structural features of the volcano. Given the peculiar geographic characteristics of Mt. Etna (e.g. prominent topography, proximity to the sea, etc.) and the wide spectrum of ground deformation scale, the data analysis carried out at this volcano has proved that, in order to improve the applications of radar interferometry, understanding of methodological aspects (e.g. possible atmospheric effects on the interferograms, or effects of topography on the deformation models - a feature ubiquitous to volcano surface deformation), is needed. At present, Mt. Etna is covered by 1 ascending and 1 descending Radarsat-2 frames having a 24 day repeat cycle, acquired in S3 beam mode, and corresponding to 30 images per year (each frame 15 images/yr); hence in order to achieve our focus available data from:

- Descending Beam S3 , H/H+V polarization
- Ascending Beam S3, H/H+V polarization,

are required.

OPTICAL satellite data

High spatial resolution data is required to monitor volcanic activity during quiescent period and changes in critical parameters, such as gas compositions emitted in the degassing plumes and fumaroles, surface temperature variation and for detailed thermal analysis during lava flows emissions.

Available data:

ASTER

Advanced Spaceborne Thermal Emission and Reflection (ASTER) is one of the five sensors on-board the Terra platform satellite launched in December 1999 as part of the NASA Earth Observing System (EOS). ASTER consists of three different subsystems operating in the visible and near infrared (VNIR, 3 bands), short wave infrared (SWIR, 6 bands) and thermal infrared (TIR, 5 bands) regions of the electromagnetic spectrum. The ASTER spatial resolution varies from 15 m (VNIR), 30 m (SWIR), to 90 m (TIR). ASTER is an on-demand instrument. This means that data over a location are acquired only following the submission of a request aimed to observe that area. Any data that ASTER has already acquired, are available by searching and ordering them from the Earth Observing System Data Gateway (EDG) or from the Japanese GDS system. Mt. Etna is actually covered by 2 frames every 16 days (1 frame in daytime and the other in nighttime acquisition), corresponding to about 44 images per year (each frame 22 images/yr).

HYPERION

Hyperion is an imaging sensor payload of the Earth Observing (EO-1) platform. Hyperion provides a high resolution hyperspectral imager capable of resolving 220 spectral bands (from 0.4 to 2.5 μm) with a 30-metre resolution. The instrument can image a 7.5 km by 100 km land area per image, provide detailed spectral mapping across all 220 channels with high radiometric accuracy and with a 16-day repeat cycle on Mt. Etna, corresponding to about 22 images per year.

LANDSAT-8

Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) images, launched in February 2013, consists of nine spectral bands with a spatial resolution of 30 metres for Bands 1 to 7 and 9. New band 1 (ultra-blue) is useful for coastal and aerosol studies. New band 9 is useful for cirrus cloud detection. The resolution for Band 8 (panchromatic) is 15 metres. Thermal bands 10 and 11 are useful in providing more accurate surface temperatures and are collected at 100 metres. Approximate scene size is 170 km north-south by 183 km east-west. The Landsat 8 satellite images the entire Earth every 16 days in a 8-day offset from Landsat 7. Data collected by the instruments onboard the satellite are available for download at no charge from GloVis, EarthExplorer, or via the LandsatLook Viewer within 24 hours of reception.

PLEIADES

Pleiades is the optical component of the ORFEO system developed in cooperation with Italy. Pleiades is an optical observation system with a metric resolution designed to offer a high acquisition capability with a revisit lower than 24 hours to satisfy both civilian and military needs. For this aim, the Pleiades system is constituted of a constellation of two optical satellites (visible and near infrared domain) on a Sun-synchronous orbit at 694 km. This number of satellites is essential to guarantee the accessibility and revisit frequency required to operationally answer to defence and civil security missions. The Pleiades system offers daily access to every point on Earth, resolution of 0.7 m in vertical viewing in panchromatic, acquisition of a 120 km x 120 km image mosaic in the same orbit, and field of view of 20 km.

High temporal frequency data

To monitor rapid changes during eruptive phases, it is important to access polar and geostationary satellites with large swaths and high repetition cycles.

MODIS

The Moderate Resolution Imaging Spectrometer (MODIS) is a multispectral instrument with 36 spectral bands in the wavelength range from visible to thermal infrared. MODIS is aboard the NASA Terra and Aqua polar satellites launched in 1999 and 2002 respectively, as part of the Earth Observing System (EOS) mission (Barnes et al., 1998; <http://modis.gsfc.nasa.gov/>). MODIS spatial resolution varies from 250 m (channels 1 and 2), 500 m (channels from 3 to 7) and 1000 m for all the remaining channels. The sensor scans ± 55 across-track about the nadir from the EOS orbit altitude of 705 km, resulting in a 2330 km swath and full global coverage every one to two days. Mt. Etna is actually covered by 2 Terra frames (at 10.30 and at 21.30 UTC) by 2 Aqua frames (at 00.00 and at 12.00 UTC) with daily repeat cycle corresponding to 1460 images per year (each polar satellites 730 images/yr).

AVHRR

The National Oceanic and Atmospheric Administration (NOAA) series of satellites carries the Advanced Very High Resolution Radiometer (AVHRR). The AVHRR sensor provides imagery in the visible, near infrared and thermal infrared wave length bands. The NOAA satellites have a circular, polar, sun-synchronous orbit with an altitude of 850 km and a period of about 100 min. A sun-synchronous orbit means that each satellite overpass a same point always at the same local time. As a matter of fact for the NOAA satellite, this characteristic allows up to 10 overpassing using all the available satellite. The imagery data from a NOAA AVHRR sensor can be recorded and/or directly transmitted to a receiving station at a nominal nadir resolution of 1.1 km. In this case, the across track swath width is about 2400 km. The temporal coverage of Mt. Etna consists in at least four passes per day. The constellation of NOAA allows high repetition rate with daily repeat cycle

corresponding to 1460 images per year. The combination with spatial resolution and spectral capabilities makes this sensor useful and widely used for monitoring volcanic activity.

MSG-SEVIRI

The Meteosat Second Generation (MSG) satellites produce Spinning Enhanced Visible & InfraRed Imager (SEVIRI) image data in the form of both High and Low Rate SEVIRI image data. The spatial coverage of imager includes the whole Europe, Africa and locations at which the elevation to the satellite is equal or greater than 10°. The different channels provide measurements with resolution of 3 km at the sub-satellite point. The 12 SEVIRI channels consist of 8 InfraRed (IR) detector packages (3 detectors each), and 1 High Resolution in the Visible (HRV) channel (9 detectors), 2 Visible and 1 Near-IR (3 detectors each), with a baseline repeat cycle of 15 min (that can be reduced in 5 minutes in 'Rapid Scan' mode Service, RSS). Mt. Etna is actually covered by 96 images (288 images in RSS) per day, corresponding to about 35040 images per year (105120 images in RSS).

SAC-D

SAC-D/Aquarius is a cooperative international mission between CONAE (Comisión Nacional de Actividades Espaciales), Argentina, and NASA, USA. NASA uses the term Aquarius for the mission within its ESSP (Earth System Science Pathfinder) program (where Aquarius happens to be the prime instrument of the mission). Instrument contributions are provided by ASI (Agenzia Spaziale Italiana) of Italy, CNES (Center National d'Etudes Spatiales) of France, and CSA (Canadian Space Agency) of Canada. SAC-D/Aquarius is a multi-sensor mission covering ocean, land, atmosphere and space environments. The payload instruments on the SAC-D/Aquarius mission are different (<https://directory.eoportal.org/web/eoportal/satellite-missions/s/sac-d>). NIRST has 3.8, 10.7 and 11.7 µm bands, swath of 180 km Tilt ±470 km, patial resolutio of 350 m, and a revisit time of 7 days.

NPP

The Suomi National Polar-orbiting Partnership collects and distributes remotely-sensed land, ocean, and atmospheric data to the meteorological and global climate change communities, as the responsibility for these measurements transits from existing Earth-observing missions such as Aqua, Terra and Aura, to NPOESS. It orbits the Earth about 14 times per day and observes nearly the entire terrestrial surface. In order to monitor the planet, Suomi NPP carries diverse payload of scientific instruments. The spacecraft crosses the equator every afternoon at about 1:30 p.m. local time, carrying five key instruments: the Advanced Technology Microwave Sounder (ATMS), the Cross-track Infrared Sounder (CrIS), the Ozone Mapping and Profiler Suite (OMPS), the Visible Infrared Imaging Radiometer Suite (VIIRS), and Clouds and the Earth's Radiant Energy System (CERES). In particular VIIRS, a 22-band radiometer similar to the MODIS instrument, collects visible and infrared views of Earth's dynamic surface processes. VIIRS also measures the atmospheric and oceanic properties, including clouds and sea surface temperature.

FUTURE MISSIONS

The combination and integration of data coming from the different satellites currently in operation have provided the best chance to monitoring and assessing of land surface and motion risks including volcanology applications. Hence, considering the rapid technology advance, we expect to extend the Supersite concept in the future, so as to be able to include new satellite missions; in particular we expect to be able to take advantage from the planned ALOS-2, SENTINEL-1, ASI-PRISMA, and SENTINEL 2 and SENTINEL 3 missions.

ALOS-2 (16 acquisition per year suggested)

The PALSAR (Phase Array type Lband Synthetic Aperture) onboard the Japanese ALOS-2 (Advanced Land Observation Satellite) platform, is an L-band (1.27 GHz, corresponding to the 23.6 cm

wavelength) SAR sensor, with high resolution capabilities (4 X 9 m in Fine Beam Single (FBS) and 4 X 18 m in Fine Beam Dual (FBD) polarization), and 46 day repeat time. Thanks to its carrier frequency and spatial resolution, PALSAR is less affected by loss of complex correlation, due to temporal and spatial baselines, which reflects in more coherent interferograms with respect to X- band and C-band interferograms. The ALOS L-band interferometric data are able to detect large gradients of ground deformation (about 6 cm per pixel), as for instance in the case of dike intrusion or along the ground trace of the fault plane of shallow earthquakes. Therefore, when the mission will come on line, data from ALOS-2 will be essential components for the study of Mt. Etna ground deformations.

SENTINEL-1 (104 acquisition per year suggested)

The Sentinel-1 European Radar Observatory is a polar-orbiting satellite system ensuring the continuity of SAR C-band data for operational, as well as scientific applications. The first Sentinel-1 satellite (Sentinel-1 A) was envisaged to be launched in early 2014 and will be followed by the second satellite (Sentinel-1 B) a few years later. The Sentinel will have a 12-day revisit time (becoming two times better with both satellites A and B), allowing the measurements of deformation over all major volcanic sites including Mt. Etna. The interferometric coherence is expected to be higher compared to previous sensors, as it is expected a more frequent and regular temporal frequency of acquisitions (thus decreasing temporal decorrelation) and tighter orbital control (thus decreasing geometric decorrelation).

ASI-PRISMA

Concerning the optical sensor, in terms of future mission, PRISMA (PRecursores IperSpettrale of the application mission) is an earth observation system with innovative electro-optical instrumentation which combines a hyperspectral sensor with a panchromatic, medium-resolution camera. The advantages of this combination are that in addition to the classical capability of observation based on the recognition of the geometrical characteristics of the scene, there is the one offered by hyperspectral sensors which can determine the chemical-physical composition of objects present on the scene. This offers the scientific community and users many applications in the field of environmental monitoring. The satellite will be a space resolution of 30 m (Hyp) / 2.5-5m (PAN), a swath width: 30-60 km, spectral range: 0.4 - 2.5 μm (Hyp) / 0.4 - 0.7 μm (PAN) and a continuous coverage of spectral ranges with 10 nm bands.

SENTINEL 2 and SENTINEL 3

The European Space Agency (ESA) Sentinel-2 and Sentinel-3 satellite platforms will each host four science instruments, supporting primarily oceanographic and global land applications. Data will be delivered in near real time to support a wide range of operational systems and applications. The design lifetime of the Sentinel-2 and Sentinel-3 platform and their instruments is seven and a half years (with consumables for twelve years of operations). Each Sentinel will move in a sun-synchronous orbit with repeat cycle of 10 day with one satellite and 5 days with 2 satellites for Sentinel-2, and 27 days for Sentinel-3. The first satellite is expected to be launched in 2013/14, probably on a Vega launch vehicle from the European Spaceport in Kourou, French Guyana. The Sentinel missions are designed for the specific needs of the GMES programme.

SAR data archive

Access to the archive of SAR data collected over Mt. Etna would stimulate research on ground deformation, in particular the opportunity to derive extended time series of deformation data, will improve the capability to infer on complex ground deformation sources, so as to attain more reliable interpretations of the geophysical phenomena. For the purpose, we require the archive data of ERS-1, ERS-2, Envisat, JERS, ALOS, RADARSAT, RADARSAT-2, TerraSAR-X and COSMO-SkyMed.

In this framework, we consider the re-use of the data sets already available from the scientific institutions involved in the MED-SUV project (e.g. INGV, CNR-IREA, ect.).

Optical data archive

Also for optical sensors, data collected over Mt. Etna would stimulate research providing time-series data for monitoring significant volcanogenic phenomena, for assessing volcano hazards and risks, and for attaining insights into the volcano dynamics. In this view, we ask for the archive data of ASTER, HYPERION, MERIS, ATSR, AVHRR, MSG, MODIS, LANDSAT.

A.10 Available resources

The research activities that will benefit of the here requested data, will be funded by the FP7 MED-SUV project (6 million Euros) until May 2016, in addition to the resources coming from the individual partners listed above (research grants from other ongoing projects, HW/instrumental and SW resources owned by participant/interested institutions).

A.11 Additional comments

N/A

A.12 Comprehensive list of in situ data

Below the list of the current and historical monitoring networks of Mt. Etna and the map with the location of each of the stations.

Network	Continuous	Campaigns
Accelerometric	12 accelerometric stations	
Cameras	5 visible and 2 thermal cameras	
Tilt	10 tiltmeters	
Geochemical	9 UV-scanners for SO ₂ flux and 3 in-soil Radon detectors	FTIR campaigns, CO ₂ soil prospections
GPS	32 permanent stations	80 benchmark
Gravimetric	3 permanent stations	71 benchmark
Infrasonic	13 infrasonic stations	
Magnetic	5 continuous stations	
Seismic	49 permanent stations	
Levelling		190 benchmarks
EDM		43 benchmarks

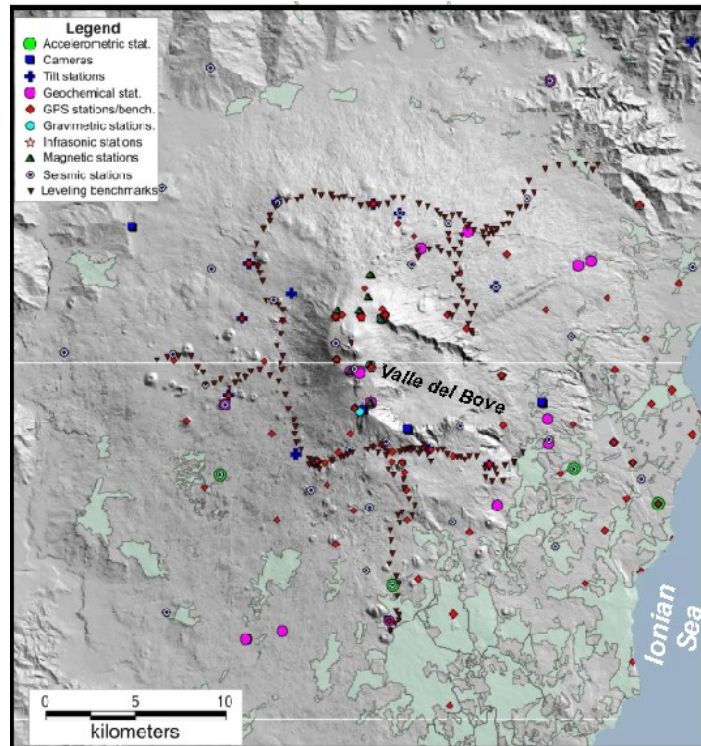


Figure 2. Distribution of the Campi Flegrei and Vesuvius monitoring stations.

Below the list of the data and data products available for Mt. Etna.

		continuous	campaigns	
	Raw data			current availability
SEISMIC AND INFRASOUND DATA AND DATA PRODUCTS	Velocimeter Seismic waveform	x	x	Through DB to accredited users
	Accelerometer Seismic waveform	x	x	Through DB to accredited users
	Infrasound waveform	x	x	Through DB to accredited users
	Data products			
	Earthquake parameters			Open access after the scientific validation
	Volcanic Tremor plot			Open access
	Event seismic array parameters			Through DB to accredited users
	Event infrasound array parameters			Through DB to accredited users
Shake maps			Open access	
	Raw data	continuous	campaigns	current availability
GEODETTIC DATA AND	GPS	x	x	Continuous data Through DB to accredited users, Campaigns on UNAVCO site
	Tilt	x		On demand
	Gravity	x	x	On demand
	Levelling		x	On demand
	EDM/Theodolite		x	On demand
	Data products	continuous	campaigns	current availability
Other geophysical data sets	SO2 flux	x	x	On demand
	Geospatial information (DEM)			On demand
	Geospatial information (digital fault map)			Open access