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MED-SUV 1th Year Meeting

Nicolosi (Catania) 7 | 9 July 2014

23

Istituto Nazionale di
Geofisica e Vulcanologia

Segreteria di Redazione

Francesca Di Stefano
Tel. +39 06 51860068
Fax +39 06 36915617
Rossella Celi
Tel. +39 095 7165851

redazionecen@ingv.it

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Editors: Giuseppe Puglisi, Letizia Spampinato, Danilo Reitano, Salvatore Mangiagli.

23

Istituto Nazionale di Geofisica e Vulcanologia

MEDiterranean SUpersite Volcanoes MED-SUV

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Letizia Spampinato	Researcher, Leader of Organizing Committee and Project Management Team.
Alfio Amantia	Technician, Member of the Organizing Committee, Logistics
Stefano Branca	Senior Researcher, Member of the Organizing Committee, Field Trip
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Rossella Celi	Technologist, Member of the Organizing Committee, Editorial Coordinator
Salvatore Consoli	Technician, Member of the Organizing Committee, Field Trip
Salvatore Mangiagli	Technologist, Member of the Organizing Committee, Web Master and pre-editing on line
Danilo Reitano	Technologist, Member of the Organizing Committee, Web Master
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Rosanna Velardita	Researcher, Member of the Organizing Committee, Front Desk

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Simona Di Salvo, Antonella Catalano, Luca Pirré La Terra (Servizio Civile Nazionale)

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Con la collaborazione di

Comune di Nicolosi

Parco dell'Etna

PARCO DELL'ETNA

Revisione e normazione ortoeditoriale

Francesca Di Stefano — Centro Editoriale Nazionale INGV
Rossella Celi — Centro Editoriale Nazionale INGV

Immagine di frontespizio

La lava dell'eruzione del 1669 circonda Catania. Affresco di Giacinto Platania (testimone oculare dell'evento), conservato nella cattedrale di Catania.

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ISSN 2039-6651
Anno **2014**_Numero **23**

Indice

WP6 | Posters

Romolo Romano: the man and the scientist

On the 15 May, 2014, Dr. Romolo Romano passed away after a long illness. He will be remembered not only for his scientific and knowledge-dissemination services, but above all for his invaluable work in drafting the geological map of Mt. Etna. For over thirty years this map has been the bible for those studying Mt Etna. More than the volcanologist, however, his colleagues will miss someone who left a deep, human imprint with his mild but firm character. He was methodical, could build on intuition, and had great vision.

Romolo knew every nook and cranny of Mt. Etna. He could remember eruption dates, and taught students too numerous to be counted about the mysteries of the "Montagna". He loved to explain and reveal its innermost secrets. He was highly active in the early years of his academic career. After graduating in Earth Sciences he was among the first to be part of the International Institute of Volcanology of the National Research Council directed by the Swiss volcanologist Prof. A. Rittmann. In 1994, in recognition of his expertise, Romolo was named by president Nello Musumeci Councilor of the Territory and Environment of the Province of Catania.

Romolo wrote many international scientific publications, and after 1969 devoted himself entirely to the study of Mt. Etna. He drew strength from old volcanology traditions, but at the same time had vision, implemented new techniques and adapted them to his studies. He was among the first to understand the potential of, and apply, aerial platforms to volcanology. He pioneered the use of helicopters for photographic surveys and observing eruptions. In 1981, he had the rare opportunity to photograph, from a helicopter, the start of an eruptive event with the opening of fissures. This was one of the very first attempts to apply a methodology now widely used to study and monitor volcanoes.

Romolo made a major contribution to the remote sensing of volcanic degassing. He pressed to study gas emissions from Mt. Etna summit craters, in particular the flux of sulphur dioxide, by the first use of a spectroscopic method, i.e. Correlation SPECtrometer (COSPEC).

Nevertheless his greatest contribution is certainly the magnificent geological map of Mt. Etna. To this he linked morpho-tectonic studies and the publications of authors with expertise ranging from seismology to petrography. From Romolo’s enormous work, it is possible to appreciate his scrupulous attention to detail, massive achievement, and unstinting attention to the ultimate scientific rigor permitted by the scientific methods of his time (up to the end of the 1970s). In all his work, the humble personality of this great scientist shone through. He bestowed on the world of volcanology a contribution that is considered remarkable even to this day.

Romolo’s scientific honesty is an example to scientists, as are his scrupulous and meticulous records of volcanic phenomena. These qualities make his work a standard to which all similar work can be compared. He was the acknowledged authority on Mt. Etna for the Smithsonian Institution bulletin.

Romolo’s colleagues will remember him for his simplicity and modesty, his scientific precision, and the open-mindedness that made him world famous. His advice in different fields, his intuition, and his ability to interpret and answer the questions of the scientific community will be greatly missed.

Farewell, dear Romolo. Thank you for what you left us, in particular your example of deep humanity that taught us to be men before we are scientists.

Preface

The MED-SUV project is a response to the European Community call "ENV.2012.6.4-2 - Long-term monitoring experiments in geologically active regions of Europe prone to natural hazards: the Supersite concept - FP7-ENV-2012-two-stage – of 20 July 2011.

Among the requests, the call stated that the accepted projects had to contribute to the Geohazards Supersites and Natural Laboratories (GSNL) initiative. The GSNL is an ambitious initiative, which is based on the "Frascati declaration" stated at the conclusion of the "3rd International Geohazards Workshop" of GEO held in ESA-ESRIN in November 2007. The declaration recommended "*…to stimulate an international and intergovernmental effort to monitor and study selected reference sites by establishing open access to relevant datasets according to GEO principles to foster the collaboration between all various partners and end-users…*". After a first period based on a volunteer approach, during which seven initial Supersites were identified, including Mt. Etna and Campi Flegrei/Vesuvius, the Supersites initiative was developed in the framework of the GEO-GEOSS Work Plan.

The MED-SUV project aims to apply the Supersite concept to Mt. Etna and Campi Flegreii/Vesuvius, recently recognized as Permanent Supersites by the Scientific Advisory Committee of GSNL and the Supersites Coordination Team of the Committee on Earth Observing Satellites. These two active volcanic areas represent end-members of volcanic systems, Mt. Etna being an open-conduit volcano and Vesuvius and Campi Flegreii closed-conduit systems. Given their differences, and that the two volcanic areas lie in densely populated areas, these two Supersite volcanoes pose diverse volcanic hazards at local, regional, and continental scales.

In order to improve understanding of the volcanic processes of Mt. Etna and Campi Flegrei/Vesuvius, and thus improve hazard assessment, the MED-SUV project will use the large sets of data available for both sites. Integration of both ground and EO data, collected over long time periods, will enable the volcanology community to answer key questions relating to prediction of the occurrence, location, duration, and magnitude of eruptive events. Additional achievements will include (1) optimization of the link between observations and end-users during eruptive events, and (2) evaluation of the project outcomes to assess whether they provide enforceable prototypes for the next generation of fully integrated volcano-monitoring-and research systems, and whether they are applicable to other volcanic areas.

Last but not least, a crucial mandate emerging from the Supersites rationale is the need to guarantee the sharing of data and scientific products for the promotion of unselfish scientific collaboration. The MED-SUV consortium comprises 24 partners from 9 countries, including two from outside Europe (the USA and Canada). The consortium includes both scientific and industrial partners as well as public agencies with long experience covering all volcanic risk management practice from making observations to public communication.

To accomplish the objectives, the MED-SUV Project is structured in six Work Packages for research and technology implementation (WP2-7), and two Work Packages devoted to project management (WP1) and information dissemination (WP8). WP2 and WP3 implement the next generation of observing systems. Their activity embraces the development of new systems (WP2) and full exploitation of existing ones (WP3). This includes the design and development of an e-infrastructure for sharing data and products. WP4 and WP5 focus on characterization and modelling of volcanic processes at the two Supersites. Hazard assessment and fostering relationships between scientists and end users are the aims of WP6. WP7 will test the main outcomes of the other WPs, and implement a pilot phase at the two supersites and in two selected test cases– Piton de la Fournaise and the Azores.

The MED-SUV project started in June 2013. One year later, the kick-off meeting was held in Naples. We now convene again to present and discuss our ongoing activities and first outcomes, to revisit our future plans, and to strengthen the cooperation between participants. The 1st Year Meeting is hosted in Nicolosi village, a popular place in the European volcanology community because of its history as the base for many teams working at Mt. Etna. It is considered to be the "door" to Mt. Etna. Nicolosi was the birthplace of the brothers Carlo and Mario Gemmellaro, who were born in the 18th century. They began the modern volcanology studies of Mt. Etna that we continue, in the MED-SUV project, at the present day.

Project Leader
Giuseppe Puglisi

ISSN 2039-6651
Anno 2014_Numero 23

WP1

Posters

Principles of MED-SUV Data Policy

Agata Sangianantoni[1], Giuseppe Puglisi[2], Letizia Spampinato[2]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy*

MED-SUV proposes the development and implementation of a digital infrastructure for data access and for volcanic risk management aimed at applying the rationale of Supersites GEO initiative to Campi Flegrei/Vesuvius and Mt. Etna. In MED-SUV there is a multitude of different partners with varying scientific, technical, legal and economic backgrounds and interests, and therefore data and data products produced will be wide-ranging. Such a variety needs the setting of principles and legal arrangements to be implemented in order to ensure that data will be properly and ethically managed and in turn can be used and accessed from both MED-SUV and the external volcanology community. MED-SUV does include public and private and industrial partners and, as a consequence, particular care has to be taken so as to harmonise different rules regarding use of data/information and identify any potential legal issues related to Intellectual Property.

Management of European Research Projects: the Case of MED-SUV

Letizia Spampinato[1], Giuseppe Puglisi[1], Agata Sangianantoni[2], Sofia Mariano[3], Gianluca Carà[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Roma 1, Roma, Italy*

Management of research projects is quite challenging and effort consuming especially while dealing with several partners and stakeholders, and more than one final goal. Indeed the success of a project lies on the clarity of the final goals, the a priori evaluation of the resources available for goal achievements, and on how well the management team coordinates and promotes project activities and collaboration within the consortium. Since the final achievements commonly include different aspects such as products and their performance, and attainment of scheduled results and costs, project management foresees a broad range of activities and skills needed to meet the requirements of a given project. In the case of MED-SUV, the Management Team daily faces a variety of project aspects such as:

- setting up of the goals;
- application of the strategic plans;
- optimization of the resources;
- application of quality standards on products;
- evaluation and overcoming of scientific, financial and technical issues;
- communication management within the consortium as well as with EC and external stakeholders;
- coordination of the consortium governance bodies;
- managing of legal and financial issues;
- outreach dissemination and event organization.

To fulfil all duties, MED-SUV management team was conceived and structured according to two main tasks i.e. Management and strategic and legal issues, whose results fall into six deliverables. Management activities are carried out by the coordinator and four experts, each having a peculiar role in the team. Aside the overall decisional and supervision role played by the coordinator, the rest of the team includes an EC project manager, a lawyer, a researcher, and an administrative collaborator. A robust team for management is crucial for success of any research project and we strongly believe that the combination of different skills might be the key requirement for project coordinator and consortium support.

ISSN 2039-6651
Anno **2014**_Numero **23**

WP2

Talks

New Monitoring and Observing Systems: WP2 Status Overview

Christian Minet

DLR - Deutsches Zentrum für Luft- und Raumfahrt, Köln, Germany

This short presentation will focus on the administrative aspects of the WP2 "New Monitoring and Observing Systems" and will show the overall status of the work package 12 months after the projects Kick-Off. The deliverables, the according responsibilities and the status of each deliverable will be presented. A similar overview will be provided for the WP's Milestone contributions. General information on major meetings and staff changes will finishes the presentation.

WP2 – Task 1 New satellite-based monitoring systems

Christian Minet[1], Marcello De Michele[2]

[1]DLR - Deutsches Zentrum für Luft- und Raumfahrt, Köln, Germany
[2]BRGM - Bureau de Recherches Géologiques et Minières, Orléans, France

The two tasks WP2 are quite different in their goals and methods, so there is a difference in the presentable results after one year. All the Sub-Tasks of the Task "New ground based monitoring systems" already have prototypes running and have conducted first field tests. Therefore these subtasks get the opportunity to have dedicated presentations at the Annual Meeting of the MED-SUV Consortium. The Sub-Task using space-based sensors are still in the progress of software development and data acquisition. During the meeting, DLR and BRGM will present the latest developments in the software systems and ideas and plans on how to continue the implementation of the software.

A New Data Logger for Volcano Monitoring

Massimo Orazi, Rosario Peluso, Marcello Martini, Antonio Caputo, Flora Giudicepietro

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy

Over the past decades, the progress in scientific and technological capacity has led to a remarkable improvement of geophysical monitoring systems. The growth of the scientific community, an increased sensitivity of decision-makers to the problem of natural hazards, and the increased awareness of public opinion, require more and better answers on issues of safety and risk.
The evolution of the scientific and social approach to the problem of geophysical hazards, led to a radical change in the monitoring systems. The systems for volcano monitoring have evolved to dense meshed networks with several dozens of geophysical sensors and multiparametric digital recorders. These networks are typically located in areas not easily reached by power supply, requiring the use of solar panels.
In this context, it was necessary to create a digital acquisition system, named GILDA (Geophysical Instrument for Low-Power Data Acquisition), with high performance and low power consumption. This allows the user to easily implement networks based on solar panels while its modular structure makes it flexible to fit any requirement, including multichannel acquisition (e.g. seismic arrays). Furthermore, its low production costs allow an increase in the number of stations in the networks. An acquisition system, based on the GILDA data logger, has been successfully implemented, and it is currently in use, for monitoring Vesuvius, Campi Flegrei, Ischia and Stromboli where it is used to acquire the data of different types of sensors (seismometers, accelerometers, infrasonic sensors, OBS, electrometers etc.).
Currently we are upgrading this instrument as part of the project MED-SUV with the main objectives to further reduce power consumption and to create a stand-alone version able to locally store data. This acquisition mode may be especially useful to record data in sites where the realization of a data transmission system is prohibitive or during geophysical experiments and measurement campaigns.

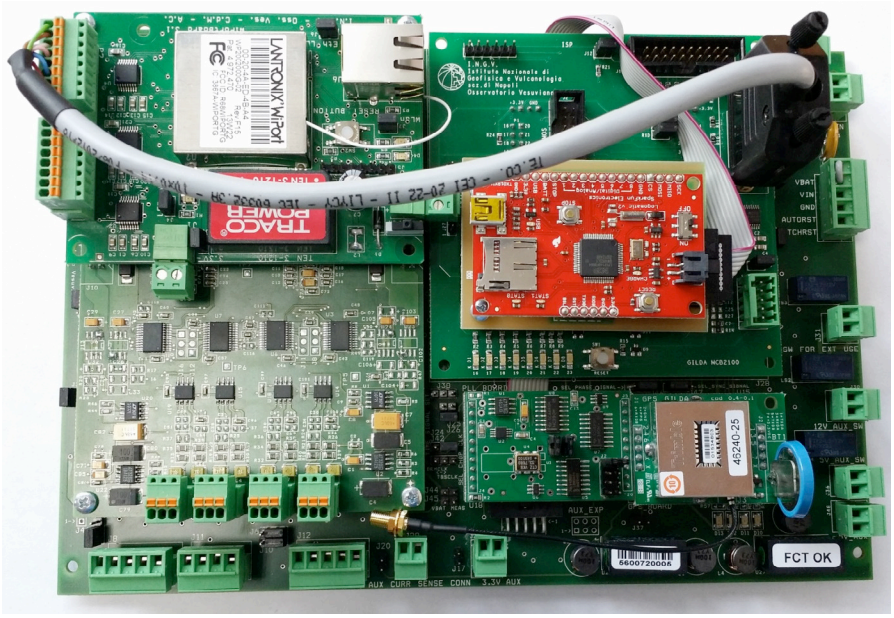

Figure 1. An example of a GILDA system: it is possible to detect the WiFi module, the main ADC and, in red, the board to write data to an uSD card.

FBG strain Sensor Development and Test

Nicolò Beverini[1], Massimo Calamai[1], Daniele Carbone[2], Francesco Francesconi[3], Salvatore Gambino[2], Renzo Grassi[3], Alfio Alex Messina[4], Enrico Maccioni[1], Mauro Morganti[5], Fiodor Sorrentino[3]

[1]*Dipartimento di Fisica, Università di Pisa, Pisa, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy*
[3]*Marwan Technology Srl, Pisa, Italy*
[4]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Roma 2, Roma, Italy*
[5]*Istituto Nazionale di Fisica Nucleare, Pisa, Italy*

Stress and strain changes at volcanic areas are recognized among the best indicators of changes in the activity of the system, and its possible evolution towards critical stages. Depending on their time evolution, stress and strain changes have been the focus of either geodetic (static changes) or seismological (dynamical changes) studies. In volcano geodesy, encouraging results have been obtained though borehole strain-meters. However, they are not easy to install and involve high costs. Therefore, the near future of strain observations at volcanoes depends on the development of broad-band sensors which are low-cost and easy to install, even in the form of dense arrays. Advancements in opto-electronics have allowed the development of low-cost sensors, reliable, rugged and compact, which are particularly suitable for on-field application. In the framework of WP 2 (New monitoring and Observing systems) of the MED-SUV project, the sub-task 2.2 involves the development of strain sensors based on the fiber Bragg grating (FBG) technology. In comparison with previous implementation of the FBG technology to study rock deformations, the system that is being developed within MED-SUV is expected to offer a significantly higher resolution and accuracy in static measurements. Moreover, a careful study will be carried out in order to obtain a smooth dynamic response up to 100 Hz, thus allowing the observation of seismic waves. Finally, strategies to implement a tri-axial configuration will be studied. The performances of the proposed systems will be tailored to suit the requirements of volcano monitoring, with special attention to the trade-off between resolution and cost. Here we present an overview of FBG technology applied to strain measurement, the main objectives of our sub-task in the framework of MED-SUV and some preliminary data from a test installation on Etna.

Assessing and Improving the Measuring Capability of the Etna_NETVIS Camera Network for Lava Flow Rapid Mapping

Maria Marsella[1,2], Peppe Junior Valentino D'Aranno[1], Carla Nardinocchi[1,2], Silvia Scifoni[1,2], Marianna Scutti[1,2], Alberico Sonnessa[1,2], Emilio Biale[3], Francesco Ciancitto[3], Mauro Coltelli[3], Emilio Pecora[3], Michele Prestifilippo[3], Cristina Proietti[3]

[1]*DICEA, Sapienza - Università di Roma, Roma, Italy*
[2]*Survey Lab srl Spin Off of Sapienza - Università di Roma, Roma, Italy*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy*

This work is aimed at improving the performance of the ground NEtwork of Thermal and VIsible cameras located on Mt. Etna volcano (Etna_NETVIS) by optimizing its observational capability on lava flows evolution and by developing dedicated tools for systematically measuring quantitative parameters of known accuracy. The first goal will be achieved through the analysis of the geometrical configuration and its improvement by means of the establishment of additional observation sites to be equipped with mobile stations, depending on the area of interest. This will increment the spatial coverage and improve the observation of the most active areas for surface sin-eruptive processes. For the second objective we will implement new processing tools to permit a reliable quantitative use of the data collected by the surveillance sensors of NETVIS, extending their capability in monitor the lava flow thermal and spatial evolution and by providing georeferenced data for rapid mapping scope. The tool will be used to automatically pre-process multitemporal datasets and will be tested on both simulated and real scenarios.

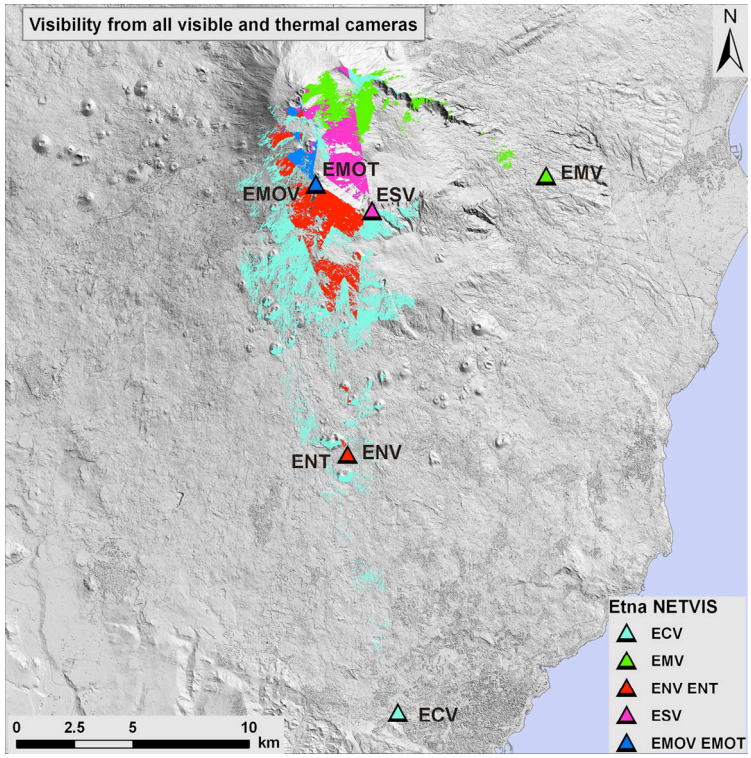

Figure 1. Visibility analysis, performed on Etna DEM, from the five sites composing Etna_NETVIS (ECV, EMV, ESV Visible sensor installed at Cuad, Milo and Schiena dell'Asino; ENV, ENT, EMOV and EMOT Visible and Thermal sensors installed at Nicolosi and Montagnola).

Thanks to data collected and archive by the NETVIS INGV team, the implementation and testing of the procedure in different operational conditions will be carried out. Additionally, Etna_NETVIS data can be used to downscale the information derived from satellite data and/or to integrate the satellite datasets in case of incomplete coverage or missing acquisitions (both due to low revisiting time or bad geometrical conditions). Therefore an additional goal is that of comparing/integrating quantitative data derived from visible and radar satellite sensors with the maps obtained using Etna_NETVIS. Preliminary results on the procedure and algorithm adopted for geometric and radiometric sensor calibration, definition of optimized configurations through simulation and for extracting updated mapping data from multi-temporal dataset will be presented.

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WP3

Talks

The Use of Long-Term Earth Observation (EO) Data Products within the MED-SUV Project: the Task 3.1 on EO Data Processing Fine Tuning

Antonio Pepe[1], Susi Pepe[1], Sven Borgstrom[2], Giuseppe Solaro[1], Francesco Guglielmino[3], Malvina Silvestri[4]

[1]*Istituto per il Rilevamento Elettromagnetico dell'Ambiente - Consiglio Nazionale delle Ricerche, Napoli, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy*
[4]*Istituto Nazionale di Geofisica e Vulcanologia, Centro Nazionale Terremoti, Roma, Italy*

Earth Observation (EO) data products are nowadays the result of several remote sensing data processing chains. However, their mutual exploitation in a synergic and efficient way in a multi-disciplinary context still represents a key aspect to be investigated. Within Task 3.1 of the MED-SUV project, the exploitation and fine tuning of the EO data processing steps are the key issues to be addressed. The aim is to generate EO products for both supersites, and help in the implementation of specific interfaces to transfer them to subsequent integration and interoperability environments. In particular, the Task 3.1 of the project is devoted to the analysis of EO data collected both at the microwave (X-band) and optical frequencies, and it is organized in three subtasks. Sub-Task 3.1.1 performs an analysis of the on-going deformations at the X band frequencies (3cm wavelength) through the application of the DInSAR technique known as Small Baseline Subset (SBAS). It is a powerful tool allowing the deformation monitoring via the production of displacement time-series as well as mean deformation maps. Sub-Task 3.1.2 is aimed at the systematic data processing of optical EO data acquired by direct broadcast through owned multi-mission antennas. The real time acquired multi-mission images are processed to produce an automatic estimation of at sensor brightness temperature on both supersite volcanoes. These products can be used to support volcanic risk monitoring offering a prompt response for hazard mitigation. Sub-task 3.1.3 results in the production of single interferograms to complement the activities conducted within Sub-Task 3.1.1. During the project first stages C- and X-band data acquired on Campi Flegrei by ENVISAT and TerraSAR-X sensors are analyzed. On Mt. Etna supersite, the activities are focused on the improvement and standardization of use of the Two-pass DInSAR interferometry, which is adequate when a limited number of SAR scenes are available.

In Situ Data Processing: a Step Towards the Data Integration and Interoperability Environment

Fawzi Doumaz

Istituto Nazionale di Geofisica e Vulcanologia, Centro Nazionale Terremoti, Roma, Italy

After collecting information about data and products coming from the INSITU acquired data, we will present the first results about the adopted organization and metadata implementation in order to get them ready for next step data integration and interoperability. Many data type are well known in volcanological communities hence, they have already been subject of organization and present yet a well-documented Metadata profiles, storage technics and file standards such as Geodetic Data, seismic data, EO data, etc. INSPIRE for metadata, IRIS for handling Seismological data, UNAVCO for geodetic data and networks, WOVODAT for many volcanoes-related data, are all advised and mandatory standards the will help MED-SUV to be projected in an up-to-date working and production environments. We will discuss how data coming from other groups (Tasks) may be integrated by the system in order to create innovative products for volcanic risk management. In coordination with the 3.4 task we will drive all the data in a data management system that will provide a large visibility and many interfaces to search, find and get data through the net. These web-oriented operations will be covered by modern and certified technics and protocols such as open-search data harvesting, OGC protocols for geographic data, NetCDF.

MED-SUV Project: First Results and Ongoing Activities of WP 3 Task 3.3 Data Integration

José Fernández[1], Michael Burton[2], Francesco Guglielmino[3], Maria Marsella[4], Simona Scollo[3], Claudia Spinetti[5], Kristin F. Tiampo[6]

[1]*Instituto de Geociencias, Consejo Superior de Investigaciones Científicas, Madrid, Spain*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Pisa, Italy*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy*

EO and terrestrial data integration, or fusion, is a basic tool to obtain the maximum information from EO data as well as to help the extension and broad use of those data. The integration/fusion will concern different aspects of the volcano monitoring: the ground deformation (Sub-Task 3.3.1) (by integrating InSAR and other geodetic deformation data); the effects of water content in the atmosphere on SAR signal (Sub-Task 3.3.2) (by combining EO data, GPS and atmospheric modelling), the thermal data (Sub-Task 3.3.4) and the gas emissions (Sub-Task 3.3.3) (by integrating EO optical and geochemical/geophysical in-situ measurements), the lava flow evolution maps (Sub-Task 3.3.4) and the study of volcanic plume (Sub-Task 3.3.5). Concerning the atmospheric water vapour content the interaction on data integration are also within the subtask, as modeling output are for ground deformation and auxiliary data coming from gas emission and volcanic plume will be possible used. The new developed software and integrated data sets will be implemented in the Multidisciplinary Interoperability Infrastructure (Task 3.4). We present the status of development, results obtained during the first year of the project, and objectives for the next ones.

The MED-SUV Multidisciplinary Interoperability Infrastructure

Stefano Nativi[1], Paolo Mazzetti[1], Fabrizio Papeschi[1], Roberto Cossu[2],
Pierre Philippe Mathieu[2], Danilo Reitano[3]

[1]*Consiglio Nazionale delle Ricerche - Istituto sull'Inquinamento Atmosferico - Firenze, Italy*
[2]*European Space Research Institute - European Space Agency, Frascati, Italy*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy*

The MED-SUV European project (http://med-suv.eu/) aims to provide datasets and services to support the lifecycle of the volcanic risk management in southern Italy. To this aim it needs achieving the integration of existing components, such as monitoring systems and data bases, novel sensors for the measurements of volcanic parameters, and tools for data analysis and process modelling. Moreover MED-SUV is a direct contribution to the Global Earth Observation System of Systems (GEOSS) as one the volcano Supersite recognized by the Group on Earth Observation (GEO). To achieve its goals, MED-SUV needs to set up an advanced e-infrastructure allowing: (a) heterogeneous data and processing systems to provide and share their resources, and (b) supersite Users to run their workflows and generate significant products. In the first year of activity a general survey on relevant in-situ and satellite data products have been conducted. It resulted in a gap analysis identifying actions needed to improve interoperability, e.g. collection of metadata, adoption of metadata and data models and encodings, setup of local publishing services, etc. Then the general architecture has been designed. It leverages concepts and solutions adopted by the GEOSS Common Infrastructure (GCI). The architecture requirements and system technologies builds on the experience done by relevant European projects in the framework of GEOSS and ESFRI (e.g. EuroGEOSS, GENESI, GEOWOW). The MED-SUV e-infrastructure adopts a three-tier architecture distinguishing among:

- local and distributed Data/Information Providers;
- the MED-SUV Brokering framework for harmonization and interoperability;
- the MED-SUV e-collaboration environment for the generation and publication of advanced products.

MED-SUV e-infrastructure development considers interoperability with the other two FP7 supersite projects: MARSITE and FUTUREVOLC, as well as EPOS.As a first step towards the implementation, MED-SUV set up a repository, filling it with a subset of in-situ data, and connecting it with a discovery and access broker. This pilot serves as an experimentation tool, and it will be extended towards the full implementation during the next years of project.

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WP3

Posters

A New Web-GIS for SAR Remote Sensing Data Management, Distribution and Sharing

Marco Aliotta[1], Carmelo Cassisi[1], Chiara Cocorullo[2], Francesco Guglielmino[1], Placido Montalto[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy*
[2]*DeltaG srl, Arezzo, Italy*

The huge quantity of SAR data, coming from remote sensing, requires particular managing and sharing methods to make it available to the community. The web based Geographical Information Systems (GIS) technology provides a convenient way to SAR data management, distribution and sharing. In the framework of WP3 - Data Sharing, Integration and Interoperability, of MED-SUV European Project (MEDiterranean Supersite Volcanoes), the Osservatorio Etneo (OE) WEB-GIS service will be accessible to interface systems that will be developed as part of the WP3.In particular, the WEB-GIS design architecture is structured in the following steps:

- Ingestion of raw data;
- Pre-processing and extraction of metadata;
- Semi-automatic processing;
- Storage and transfer of data to the WEB for distribution and/or consultation.

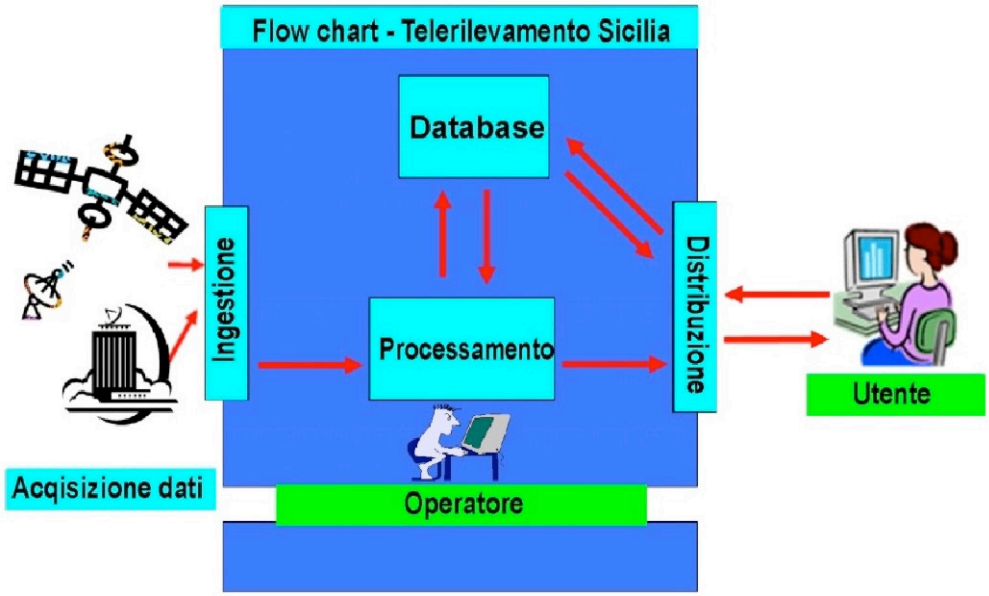

Figure 1. WEB-GIS prototype flow chart.

The OE WEB-GIS acts as an interface for spatial data (i.e. earthquakes, lava flows) or any other georeferenced information. The OE WEB-GIS design architecture was implemented in order to take in account both geocoded SAR displacement maps in Line Of Sight (LOS) than the displacement time series provided by ADInSAR techniques (i.e. SBAS, PS).The work started with the population of the OE database. For the preliminary test, we used the results obtained processing ERS and ENVISAT data referring to Mt.

Etna area and covering the 1992-2010 time spanning. This work takes advantage of the WEB-GIS developed in the framework of the Task D7- Enhancement of the remote sensing laboratory - of the project APQ Sicilia, funded by the Sicilian regional government, and the results will populate the collaborative area of the MED-SUV project in future. Actually, it is possible to query the OE WEB-GIS by temporal range acquisition, by satellite (ERS or ENVISAT), and by acquisition geometry (ascending or descending).The OE WEB-GIS includes map based navigation search interface, full resolution imagery shown overlaid the map and downloading data online.

Seismological Data at Mt. Etna

Salvatore Alparone, Marcello D'Agostino, Giuseppe Di Grazia,
Ferruccio Ferrari, Salvatore Spampinato

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy

Data of local seismicity recorded in the Etna area during the time span 2005-2011 have been selected for sharing. Basically they are of three types. First, raw continuous signals from permanent digital stations, equipped with three-component broad band sensors 40s period, for the most part. The sample rate of the signals is 100 Hz. Taking into account criteria such as: signal quality, availability of at least 3 year of data for each station, and sufficient azimuthal coverage of the Etnean volcanic area, we obtained a network of about twenty stations. We also provide an earthquake catalogue, obtained from off-line analysis of the digital seismograms daily performed by expert personnel at Osservatorio Etneo (INGV). The data are in ASCII format, and concern parametric information (latitude, longitude, depth, magnitude, etc.) about the hypocenter of ca 800 earthquakes, which occurred in the area of Mount Etna between 2005 and 2011. This catalogue reports shocks with magnitude greater than or equal to 2.0 and error threshold not greater than fixed values (e.g., horizontal and vertical hypocentral errors less than or equal to 2.0 km, RMS travel-time residual less than or equal to 0.35s, etc.).The third type of data is the RMS amplitude value of the continuous background seismic signal. These values are calculated by an automatic tool which processes the on-line signal from remote seismic stations. The amplitude data are calculated both in the whole unfiltered continuous signal, and in frequency bands 1 Hz wide, between 0.5 and 15 Hz. The format of data is ASCII. For treatment and characterization of each type of data, appropriate metadata, concerning station position, instrumental and processing specifications and any other useful information, have been considered.

Detect Etna Volcanic Plumes Through the Analysis of the GPS Signal to Noise Ratio Data

Massimo Aranzulla, Flavio Cannavò, Giuseppe Puglisi, Simona Scollo

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy

Mt. Etna, in Italy, is one of the most active volcanoes in the world. In the last years explosive activity formed volcanic plumes that rose kilometers above the vent and volcanic plume detection was carried out by using different approaches such as satellites and ground-based remote sensing systems. Recently, the capability of GPS to retrieve volcanic plumes has been investigated and some tests have demonstrated that GPS may give useful information [Aranzulla et al. 2012; Larson et al. 2013]. The high density (42 permanent stations located on the flank of the volcano) of the permanent and continuous GPS network of the Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, has allowed to investigate the ability of GPS to detect volcanic plumes at Etna through the analysis of the Signal to Noise Ratio (SNR) data. The SNR data provide no information about the distance between the satellite transmitting the signal and receiver, and thus make no direct contribution to positioning solutions. However, the SNR data are important because they can directly measure signal attenuation or blockages. We develop and test the method on the volcanic plume produced during the 23 November 2013 episode. The SNR data are recorded in the binary data (RAW) by the GPS receiver. The RAW data have been converted to Rinex files that contain the SNR, azimuth and elevation data for each satellite and antenna pair. After modelling the SNR (elevation) by using the SNR data of the three days before the eruption, we compare the SNR data with those during the episode. Results show that, during the eruption, the SNR data have a drop caused by the presence of dense ash-laden plumes.

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Volcanic SO_2 Flux Comparison by Satellite and Ground-Based Measurements During the Mt. Etna 2011-2013 Lava Fountain Episodes

Stefano Corradini[1], Giuseppe Salerno[2], Michael Burton[3], Luca Merucci[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia,, Centro Nazionale Terremoti, Roma, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Pisa, Italy*

Between 2011 and 2013 Mt. Etna has exhibited a vigorous eruptive activity consisting of powerful and short-time lava fountaining episodes. Here, volcanic SO_2 emission rate retrieved by the satellite MODIS-TIR images and the ground-based FLAME-UV measurements are compared. MODIS (Moderate Resolution Imaging Spectroradiometer) is a multispectral imaging radiometer aboard the NASA Terra and Aqua polar satellites (http://modis.gsfc.nasa.gov/). SO_2 flux time series by the satellite platform are computed, retrieving SO_2 column amounts in the channels 29 (centered around 8.6 μm) and channels 31 and 32 (centered at 11 and 12 μm) for the correction of uncertainty in the SO_2 estimations due to ash and ice. Records of SO_2 flux are then resembled using the SO_2 amount maps and atmospheric profiles. FLAME (Flux Automatic Measurement on Etna) is a network of an ultraviolet ground-based scanning spectrometer installed on the flank of Mt. Etna. SO_2 flux is retrieved applying the DOAS technique but using a modeled background spectrum, and mass flux rate is then computed in real-time at INGV observatory based in Catania. Uncertainty in the retrieved SO_2 columns amounts and flux estimates in eruptive volcanic plume in both the TIR and UV spectral ranges, arise from the presence of ash and ice particle. Preliminary results indicates that differences in SO_2 flux retrieval in the TIR and UV raise with the increase of the ash mass content in the volcanic cloud. Whereas, a best match between the satellite and ground based retrievals is obtained when, instead of ash, ice is the preeminent species.

Prototype of a GSAC Server for the Mt. Etna GPS Data Sharing

Massimo Rossi, Giuseppe Puglisi

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy

The section of Catania - Osservatorio Etneo National Institute of Volcanology (INGV-OE) operates a network of 80 GPS stations, 35 of with are on Mt. Etna. Furthermore, about 80 benchmarks, installed on this volcano, are surveyed at least yearly. At present the data and metadata are stored in files and databases developed ad-hoc for the permanent CGPS network of INGV-OE, while the data from surveys are recorded on file systems. Programs to process the data from CGPS and display the results are specifically developed around the databases. To facilitate the dissemination of raw data collected by the CGPS stations within and outside INGV-OE the GSAC software, developed by UNAVCO, was implemented. GSAC software suite includes a Web-based interactive client (GSAC Wizard) to locate data, a command-line client to locate and download data, and a retailer. That service uses a macro language to pass commands to a server using the http url. The command-line client uses the service to communicate with the retailer clients. It is also possible to implement a federated system to track the data on other implementations GSAC. For the first implementation we preferred to write specific programs that populate and updated a standard GSAC database, from the proprietary databases used by INGV-OE. Future improvement of the GSAC database will take into account the management of the data collected during the surveys. A current limitation of GSAC concerns the inability to check the credentials of users connecting to the system, preventing the application of the MED-SUV data policy guidelines. Thus, next steps of this activity will be devoted to overcome this limitation for the use of GSAC in compliance with the MED-SUV data policy.

Joint Use of Long Water Pipe Tiltmeters and Sea Level Gauges for Monitoring Ground Deformation at Campi Flegrei Caldera

Roberto Scarpa[1,2], Paolo Capuano[1,2], Umberto Tammaro[3], and Roger Bilham[4]

[1]*Dipartimento di Fisica, Università di Salerno, Fisciano, Italy*
[2]*AMRA S.c.a.r.l Analisi e Monitoraggio del Rischio Ambientale, Napoli, Italy*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy.*
[4]*CIRES Cooperative Institute for Research in Environmental Science, University of Colorado Boulder, Boulder, USA*

Campi Flegrei caldera periodically experiences significant unrest episodes, which include ground deformations, the so-called bradyseism. Following the last eruption (Monte Nuovo, 1538) a general subsidence has been interrupted by episodes of uplift, the most recent of which occurred in 1970-72 and 1982-84. Since 1950 the caldera is showing signs of unrest with ground uplift, seismicity, and composition variation of fumarole fluids. In particular, subsidence has been replaced by intermittent episodes of inflation with short time duration and various maximum amplitudes. They occurred in 1989, 1994, 2000, 2005-06, 2008-09 and 2011-2014 with duration of few months and maximum amplitude ranging between 3 and 18 cm, approximately. In the last years an array of water-pipe tiltmeters with lengths between 28 m and 278 m in tunnels on the flanks of the region of maximum inflation has been installed to avoid problems common to the traditional tiltmeters. The tiltmeters record inflation episodes upon which are superimposed local load tides and the effects of the seiches in the Bay of Naples and in the Tyrrhenian Sea. We use data recorded by three tide gauges in the Bay of Pozzuoli (Pozzuoli, Miseno, Nisida) to compare water pipe data with sea level to extract astronomical tidal components (diurnal and semidiurnal) and seiches periods (particularly between 20 minutes and 56 minutes) that could constitute local loading frequencies recorded clearly by tide gauges and tiltmeters. We perform an analysis of the amplitude stability of seiches amplitudes. After the removal of the tides and seiches component we compare tilt residual and sea level trend for the same periods of time. The comparison between these two kinds of data enables a more sensitive definition of the low level uplift with an accuracy of 1% for nanoradiant tilts in the period range 10 minutes to 10 hours with a long term tilt stability of approximately 0.1 microradiant/yr.

Observations and Simulations During the 12 August 2011 Etna Lava Fountain Event

Simona Scollo[1], Antonella Boselli[2,3], Mauro Coltelli[1], Giuseppe Leto[4], Gianluca Pisani[3,5], Michele Prestifilippo[1], Nicola Spinelli[3,5], Xuan Wang[3,6], Ricardo Zanmar Sanchez[4]

[1]*Istituto Nazionale di Geofisica e Vulcanologia Sezione di Catania - Osservatorio Etneo, Catania, Italy*
[2]*Consiglio Nazionale delle Ricerche - IMAA, Potenza, Italy*
[3]*Consiglio Nazionale Interuniversitario per le Scienze fisiche della Materia, Roma, Italy*
[4]*INAF Osservatorio Astrofisico di Catania, Catania, Italy*
[5]*Dipartimento di Fisica, Università di Napoli Federico II, Napoli, Italy*
[6]*Consiglio Nazionale delle Ricerche - SPIN, Napoli, Italy*

Between 2011 and 2013, Etna produced 46 lava fountains from a new volcanic vent named the New South Crater. Volcanic ash was dispersed in atmosphere and contaminated the air space of the international airport of Catania causing troubles to air traffic operations and sometimes forced the airport closure during the activity. Data from the video-surveillance system of Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo and from the Lidar instrument may give useful support to monitor and forecast Etna volcanic plumes. The video-surveillance system is able to retrieve the variation of the column height with time and the Lidar is able to investigate different volcanic plume layers and help to differentiate ash-dominated from sulphate and water dominated plumes. Furthermore, the analysis of backscattering and depolarization signals allows tevaluating, with a certain degree of uncertainty, the ash mass concentration. We show data retrieved by the VAMP system installed at the astrophysical observatory of the Istituto Nazionale di Astrofisica in Catania on 12 August 2011 when a lava fountain event formed. During this episode, an eruption column rose up to several kilometers above sea level and the volcanic plume was dispersed toward the South-East direction. From video-surveillance system we are able to estimate the variation of the column height (peak value of 9 km above sea level) with time. From those values, we derive the time varying discharge rate and then run a volcanic ash dispersal model to evaluate the ash concentration in atmosphere. These values are hence compared with Lidar data. The comparison highlights the importance to take into account the time variability of Etna eruptions and that the integration of data from monitoring activities and simulations is an essential step to improve the volcanic ash forecasting during volcanic crisis.

GPS Time Series at Campi Flegrei Caldera (2000-2013)

Prospero De Martino, Umberto Tammaro, Francesco Obrizzo

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli, Osservatorio Vesuviano, Naples, Italy

The Campi Flegrei caldera is an active volcanic system associated to a high volcanic risk, and represents a well known and peculiar example of ground deformations (bradyseism), characterized by intense uplift periods, followed by subsidence phases with some episodic superimposed mini-uplifts. Ground deformation is an important volcanic precursor, and, its continuous monitoring, is one of the main tool for short time forecast of eruptive activity. We provide an overview of the continuous GPS monitoring of the Campi Flegrei caldera from January 2000 to July 2013, including network operations, data recording and processing, and data products. In this period the GPS time series allowed continuous and accurate tracking of ground deformation of the area. Seven main uplift episodes were detected, and during each uplift period, the recurrent horizontal displacement pattern, radial from the "caldera center", suggests no significant change in deformation source geometry and location occurs. The complete archive of GPS time series at Campi Flegrei area is available in De Martino et al., [2014], Supplementary files. These data can be usefull for the scientific community in improving the research on Campi Flegrei caldera dynamic and hazard assessment.

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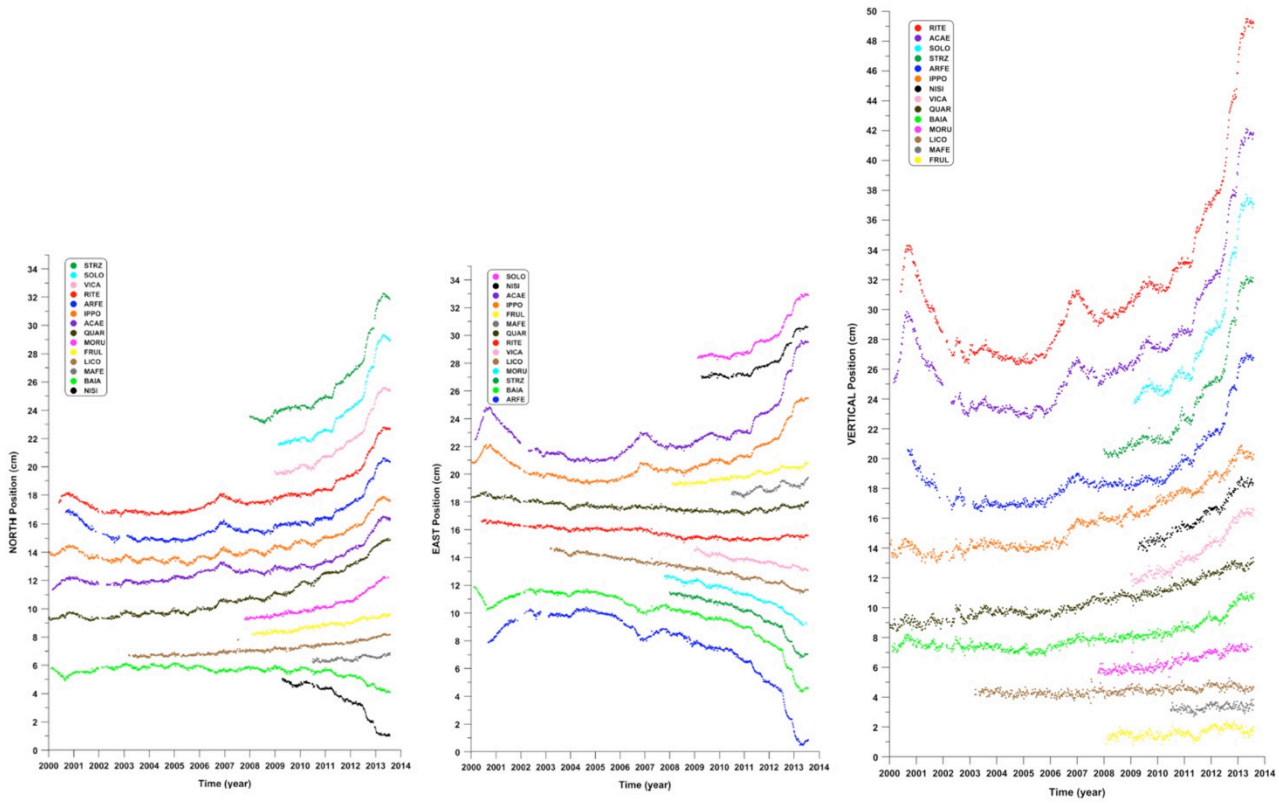

Figure 1. GPS time series for Campi Flegrei stations [De Martino et al., 2014].

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WP4

Talks

Dynamic of Campi Flegrei Hydrothermal System from Geochemical and Geophysical Signals

Giovanni Chiodini[1], Jean Vandemeulebrouck[2], Stefano Caliro[1], Luca D'Auria[1], Prospero De Martino[1], Annarita Mangiacapra[1], Zaccaria Petrillo[1]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy
[2]Université de Savoie, Savoie, France

A ten-year accelerating process of ground deformation is affecting the Campi Flegrei caldera. The deformation pattern is here explained with the overlapping of two processes:

- short time pulses caused by injection of magmatic fluids into the hydrothermal system;
- a long time process of heating of the rocks.

The short pulses are highlighted by comparing the residuals of ground deformation, fitted with an accelerating curve, with the fumarolic CO_2/CH_4 and He/CH_4 ratios, which are good geochemical indicators of the arrival of magmatic gases. The two independent data sets show the same sequence of five peaks with a delay of ~200 days of the geochemical signal with respect to the geodetic one. The heating of the hydrothermal system, which parallels the long period accelerating curve, is inferred by temperature-pressure gas-geo indicators. Referring to a recent interpretation, which relates the variation of fumarolic inert gas species to open system magma degassing, we infer that the heating is caused by enrichment in water of the magmatic fluids and by an increment in their flux. Heating of the rocks caused by magmatic fluids can be a central factor in triggering unrest at calderas.

Laboratory Experiments and Continuous Water Level Monitoring at Geothermal Springs and Wells in the Campi Flegrei Area to understand Pressure Transients in Fluid Reservoirs

Heiko Woith[1], Annarita Mangiacapra[2], Giovanni Chiodini[2], Marco Pilz[1], Thomas Walter[1]

[1]*GFZ German Research Centre for Geosciences, Potsdam, Germany*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli, Osservatorio Vesuviano, Napoli, Italy*

The hydrothermal system beneath Campi Flegrei is strongly affected by sub-surface processes. Temporal variations occur at the geothermal "plume" below Solfatara (Bruno et al. 2007), associated with formation of new fumaroles and the spatial pattern of exhalation vents. In September 2013 four sites were equipped with sensors in the Fangaia mudpool inside Solfatara, and within the geothermal area of Agnano, which is located roughly 3 km to the East of the crater. Autonomous devices are being used to record the water level and water temperature at 5 minute intervals. Records reveal significant changes of the hydrothermal system in September 2013 at the Agnano main spring. In the night from 23 to 24 September both the water level and the water temperature dropped significantly, confirmed by visual inspection of the spa operators. The pool of the main spring almost emptied and the flow rate was significantly reduced, implying a profound change in the system. Test measurements have been carried out during the during the active vibroseis experiments related to radon, soil and fumarole temperature, and high-frequency (400 Hz) water level measurements in Fangaia. Gas bubbles are likely to play a major role with respect to spatio-temporal variations in shallow fluid systems below Solfatara. Thus, additional to the field measurements we investigate potential bubble-related mechanisms capable to increase fluid pressure. The BubbleLab at GFZ has been setup. We are able to simulate earthquake ground motions with a shaking table, track the size and velocity of rising bubbles via a camera system, and quantify transients with a set of pressure sensors (up to 400 Hz). We designed an experimental setup to simulate dynamic triggering effects with and without particles under varying frequency and amplitude conditions. Results suggest that a trigger external to the actual vents, either sub-surface or remote (e.g. earthquake) might be capable of triggering the hydrothermal system.

RICEN : Repeated Induced Earthquakes and Noise. Seismic Campaigns at Solfatara

Gaetano Festa[1,2], Aldo Zollo[1], Marcello Serra[1], Grazia De Landro[1], Francesca Bianco[3], Pier Paolo Bruno[3], Vincenzo Di Fiore[4], Stefano Maraio[5], Imperia Nazzaro[6], Marco Pilz[7], Philippe Roux[8], Jean Vandemeulebrouck[9], Heiko Woith[7]

[1]*Università di Napoli Federico II, Napoli, Italy*
[2]*AMRA S.c.a r.l. Analisi e Monitoraggio del Rischio Ambientale, Napoli, Italy*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy*
[4]*CNR - Consiglio Nazionale delle Ricerche, IAMC - Istituto per l'Ambiente Marino e Costiero, Italy*
[5]*Università di Bologna, Dipartimento di Scienze Biologiche, Bologna, Italy*
[6]*Università del Sannio, Benevento, Italy*
[7]*GFZ German Research Centre for Geosciences, Potsdam, Germany*
[8]*Université Joseph Fourier, Grenoble, France*
[9]*Université de Savoie, Institut des Sciences de la Terre, Savoie, France*

RICEN is a series of experiments whose goal is to study the changes in the properties of the medium at small scales through repeated observations over time. The acronym RICEN stays for Repeated InduCed Earthquakes and Noise and is mostly oriented to the use of seismic waves (both in passive and active mode) as a diagnostic tool. RICEN aims at studying the structural changes of a volcanic structure, through the recognition of changes in seismic records acquired at a large number of sensors. Records are either ambient noise or the signals produced by the MiniVib shots. The investigation area is the Solfatara, a volcano in the Campi Flegrei caldera, characterized by an intense hydrothermal shallow activity, which results in fumarolic emission and a gas release of approximately 1,500 tons per day. The hydrothermal activity is mostly due to the interaction between the atmospheric agents and the deep convection which produces a seasonal change in the structural properties of the area. The structural properties of the subsoil can change for different reasons, such as a perturbation of the stress field in the preparatory phase of earthquakes, the migration of fluids, mainly in volcanic areas, or the fracturing induced by injection in geothermal exploration. If there was no change in the properties of the subsoil, the same source of seismic waves, activated at different times, would reproduce the same signal to an observation site. Changes in the structure, instead, generate differences in the signal, in the arrival times of seismic phases or in the coda, where the effect of the variation of scatterers is more evident due to diffracted waves. If this change is consistently recognized at several receivers it becomes possible to locate the anomaly. The critical aspect of this analysis is the need to reproduce the same seismic source with time, or to use the cross- correlation of the ambient noise, which is less sensitive to the position of the sources. During the first year of the project, we performed two campaigns at Solfatara (RICEN PILOT and RICEN FIRST). For the seismic part, ambient noise was acquired for a week by about 25 to 50 GFZ –wise stations, equipped with 4.5Hz, three components geophones, and 7 intermediate period-velocimeters from INGV sparsely distributed inside the area. Such recording is aimed to characterize the dispersion curve of the surface waves and to obtain the Green's functions through cross-correlation analysis. The active experiment was performed in the central area of the Solfatara, where 108 shots were acquired by 240 stations located on a regular grid of 115 x 90 m2 area in front of the Fangaia and by an additional array located within the Fangaia, having a spiral configuration, to test the potential of the beam forming technique in the location of the sources (the positions of the shots) and possibly scatterers hidden in the medium.

Fluid Circulation at Somma-Vesuvius Volcanic Complex Inferred by Electrical Resistivity Tomography, self-potential, Temperature and Soil Degassing

Anthony Finizola[1], Tullio Ricci[2], Matthieu Poret[1], Eric Delcher[1], Aline Peltier[3], Raphaël Antoine[4], Julien Bernard[5], Guillaume Boudoire[6], Elodie Brothelande[5], Giovanni Fanizza[7], Yannick Fargier[4], Lydie Gailler[5], Erwan Gueguen[8], Rachel Gusset[1], Alfredo Matera[7], Cécile Mezon[1], Sabatino Piscitelli[8], Angélie Portal[5], Enzo Rizzo[8], Matteo Rossi[9], Giuseppe Calamita[8], Eliana Bellucci Sessa[10], Rosella Nave[10]

[1]*Université de La Réunion, Institut de Physique du Globe de Paris, CNRS, La Réunion, France*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Roma 1, Roma, Italy*
[3]*Institut de Physique du Globe de Paris, CNRS, La Réunion, France*
[4]*Centre d'Études Techniques de l'Équipement, Laboratoire Régional de Rouen, France*
[5]*Université Blaise Pascal Clermont-Ferrand II – Laboratoire Magmas et Volcans, Clermont-Ferrand, France*
[6]*Centre de Recherches Pétrographiques et Géochimiques, Nancy, France*
[7]*Università di Bari, Dipartimento di Scienze della Terra e Geoambientali, Italy*
[8]*Consiglio Nazionale delle Ricerche - IMAA, Istituto di Metodologie per l'Analisi Ambientale, Potenza, Italy*
[9]*Università di Padova, Dipartimento di Geoscienze, Padova, Italy*
[10]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy*

Vesuvius is perhaps the volcano with the highest risk in the world threatening the 800.000 residents living on its slopes. In March 2014 an extensive field work was carried out in the framework of the EC FP7 MEDiterranean SUpersite Volcanoes Project. The aim of this survey was to identify the hydrothermal system and its fluid circulation dynamics as well as the structural boundaries associated to this volcanic complex. A high resolution deep Electrical Resistivity Tomography, 64 electrodes, 40m spacing, was performed along a NW-SE profile, 7km long, coupled with self-potential, temperature (30cm depth), and soil degassing (CO_2) with a step of 20m. ERT measurements were performed with a Wenner configuration and reached 500m depth (see Figure 1). Inside Somma caldera, the resistivity cross-section of Vesuvius cone displays a conductive body (20-100ohm.m) located beneath the present-day summit crater and interpreted as its hydrothermal system. This latter is also revealed by the characteristic "W" shape of self-potential signal showing with its minima a hydrothermal system of about 1,7km in diameter (Figure 1). The top of the hydrothermal system is at about 200-250m below the surface, except along four areas characterized by vertical rising of hydrothermal fluids up to the surface. These areas have been evidenced by temperature anomalies (increase of 6-13°C, Figure 1). The largest structure allowing this preferential fluid flow is the 1906's crater rim, while the two others temperature peaks are located close to the present-day fumarolic area. In the lower part of Vesuvius cone, outside of the hydrothermal system, it is possible to detect on both side of the edifice, a sub-vertical body of about 800-1000 ohm.m isolated by higher resistivity values (2500-3000 ohm.m). The more conductive body can be associated with a break in slope in the topography and also to higher CO_2 concentration (Figure 1). This structural boundary seems to fit with the 1631's crater rim.

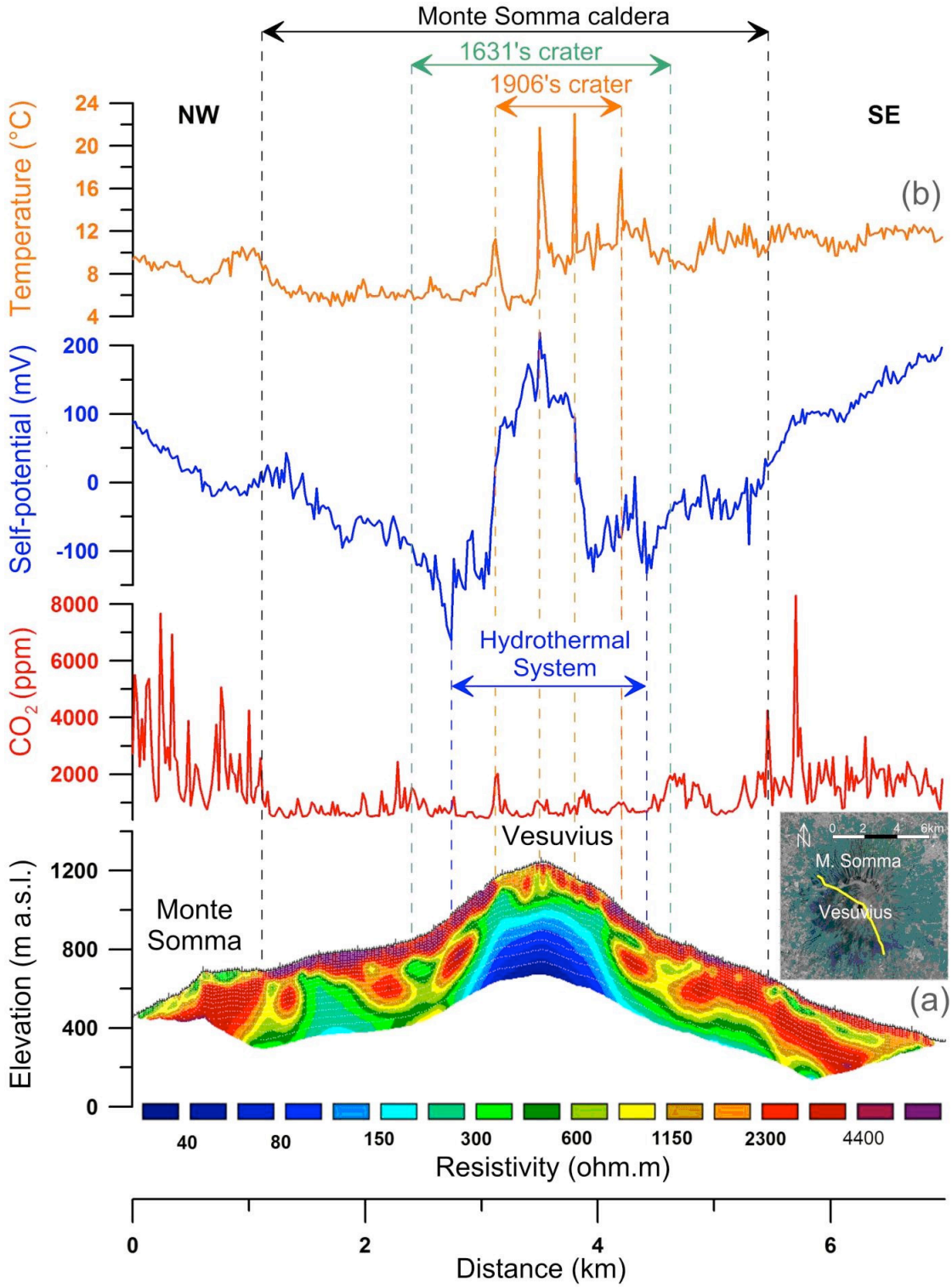

Figure 1. (a) Location of the geoelectrical profile, 7 km long, crossing Somma-Vesuvius volcanic complex; (b) Electrical Resistivity Tomography, Self-Potential, Temperature at 30 cm depth, and Soil degassing (CO_2) along the NW-SE profile shown in (a).

Relations between Electrical Resistivity, Carbon Dioxide Flux and Self-Potential in the Shallow Hydrothermal System of Solfatara (Phlegrean Fields)

Jean Vandemeulebrouck[1], Sventlana Byrdina[1], Giovanni Chiodini[2], Carlo Cardelini[3], Aurelie Legaz[1], Christian Cammerlinck[4]

[1]*Université de Savoie, Institut des Sciences de la Terre, Savoie, France*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli, Osservatorio Vesuviano, Napoli, Italy*
[3]*Dipartimento di scienze della Terra, Università di Perugia, Perugia, Italy*
[4]*Sisyphe, Université Pierre et Marie Curie, Paris 6, France*

We present the results of an electric resistivity tomography (ERT) survey, combined with mappings of diffuse carbon dioxide flux, ground temperature and self-potential (SP) at Solfatara, Phlegrean Fields, Italy. This ensemble of methods aims to image the hydrothermal system of Solfatara, understand the geometry of the fluid circulation, and precise the extension of the hydrothermal plume. Solfatara appears as a globally conductive structure, with resistivity in the range 1-100 Ohm-m. Comparison between spatial variations of resistivity and gas flux rate indicates that resistivity changes at depth are related to gas ratio content and the fluid temperature. Broad negative anomaly of self-potential in the inner part of Solfatara with a minimum in the area of the Bocca Grande suggests a significant downward flow of condensing liquid water. We also perform a 3-D resistivity model of Fangaia hydrothermal plume using 23 high-resolution ERT profiles. Assuming the shallow resistivity variations are mainly due to saturation variations, we propose a 2D axis-symmetric numerical model coupling Richards' equation for fluid flow in conditions of partial saturation with the resistivity calculation as function of saturation only. The numerical model allows the estimation of the permeability of the shallow layers below Fangaia as 5 10-13 m2, which belongs to the upper part of the range of permeability given by laboratory studies for pyroclastic rock samples [Vanorio et al, 2002].

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Advances on Modelling Subsurfaces Dynamics at Restless Volcanoes

Joachim Gottsmann, Karen Strehlow, A. Cocco, B. Hemmings,
Fiona Whitaker, Henry Odbert, Alison Rust, A. Jasim

University of Bristol, City of Bristol, UK

The link between geophysical unrest signals and causative subsurface processes is still poorly understood. However, understanding this link is vital for hazard assessment and risk mitigation at restless volcanoes. The focus of research by our group has thus far been i) on interactions between magmatic and aquifer systems and ii) on the influence of time-dependent rheology in a mechanically and thermally heterogeneous crust on surface strains. The presentation summarises advances made on both aspects. The presence of water can affect the style of volcanic activity, and while the resulting phreatomagmatic eruptions are probably the most popular subject to study in this field, our work in MEDSUV so far focused on how magmatic activity influences the local hydrology and which geophysical signals may result from this interaction. We have followed both literature based-research as well as the development of finite element models to simulate stress interactions between magmatic and aquifer systems. The literature research has yielded a data inventory for magma water interactions to highlight changes in the hydrological response by mechanical and thermal stressing of an underlying magma reservoir and the resultant geophysical signals. Initial parametric studies using a first suite of generic numerical models yield insights into the subsurface stress and strain evolution in two typical volcanic landforms (calderas and stratovolcanoes) from the interaction between magmatic and aqueous reservoirs solving for the combined poro-elastic response of the aquifer due to a pressure change in a magma reservoir. Initial results show a complex parameter space with first order influence on the amplitude and wavelength of hydraulic head changes on the shape of the magmatic reservoir, hydraulic parameters of the aquifer and the reservoir pressure change. We find that ring faults in collapse calderas are important and efficient pathways for the transport of magmatic and meteoric fluids and play a major role in shallow fluid circulation. Furthermore the combined thermo-mechanical effects of a deep-crustal hot zone and hot encasing rocks around a mid-crustal magma reservoir appear to fundamentally alter the time-dependent sub-surface stress and strain partitioning upon reservoir priming. These effects substantially influence surface strains recorded by volcano geodetic monitoring with major implications on the assessment of causative processes behind (pre-eruptive?) unrest.

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WP4

Posters

Automatic Procedure for Quasi-Real Time Seismic Data Processing at Campi Flegrei Caldera (Italy)

Paolo Capuano[1,2], Enza De Lauro[2], Salvatore De Martino[3], Mariarosaria Falanga[3]

[1]Dipartimento di Fisica, Università di Salerno, Fisciano, Italy
[2]AMRA S.c.a r.l. Analisi e Monitoraggio del Rischio Ambientale, Napoli, Italy
[3]Dipartimento di Ingegneria dell'Informazione, Ingegneria Elettrica e Matematica Applicata, Universita di Salerno, Fisciano, Italy

The accuracy of automatic procedures for detecting seismic events and locating their sources is influenced by several factors such as errors in picking seismic phases often buried in the high-level ambient noise, network geometry and modelling errors. Recently a robust automatic procedure has been implemented for detecting onset picking and identifying signal phases in continuous seismic signal with an application at the seismicity recorded at Campi Flegrei Caldera (Italy) during the 2006 ground uplift. An Independent Component Analysis based approach for the Blind Source Separation of convolutive mixtures (CICA) has been adopted to obtain a clear separation of low-energy Long Period events (LPs) from the high-level ambient noise allowing compiling a complete seismic catalogue and better quantify the seismic energy release. In this work, we apply CICA at the seismic signal continuously recorded during the entire 2006 at Campi Flegrei focusing the attention on the remarkable LP swarm occurred in October 2006 for about 1 week and climaxed on days 26, 27 and 28. First, we have performed tests on synthetic data in order to improve the reliability and the accuracy of the procedure. The performance test using very noisy synthetic data shows that the method works even in case of very poor quality data characterized by very low signal to noise ratio (SNR). Second, we compare CICA results with a number of efficient algorithms for ICA employing second order statistics and higher order statistics. In particular we show as also in the case of very low energy LP activity occurred before and after the climax, CICA approach allows obtaining better results clearly discriminating LPs and noise. The extracted waveforms with improved SNR via CICA coupled with automatic phase picking allowed to compile a more complete seismic catalogue and to better quantify the seismic energy release including the presence of LP events from the beginning of October until November 10.

Geophysical Signatures of Magma Chamber Processes at Campi Flegrei

Chiara Paola Montagna, Antonella Longo, Paolo Papale

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Pisa, Italy

Understanding quiescent volcanoes necessarily involves being able to decipher the signals originating from the variety of processes going on at depth, that cannot be observed directly. Signals typically recorded at the surface include geochemical, such as gas fluxes and fumaroles compositions, and geophysical, such as seismicity and gravity anomaly, measurements. In order to better clarify the links between deep dynamics and its surface manifestations, we propose a forward modeling approach that relates magmatic processes to geophysical signals recorded by monitoring networks (Figure 1). Magma dynamics is described by the equations of fluid flow, taking into account space-time dependency of the relevant physical variables. They are solved numerically using a specifically built code, GALES. Results from numerical simulations include stress and density space-time evolution in the whole domain. Stress variations at the magma-rock boundary are used as sources for the propagation of elastic waves in the solid medium at all wavelengths. Quasi-static ground deformation as well as higher-frequency seismic signals are obtained by Green's functions integration. Density changes are used to obtain synthetic gravity anomaly data. Preliminary results for simulations related to magma chamber replenishment at Campi Flegrei show that characteristic convective patterns are related to pressure and density variations on periods of tens to hundreds of seconds (ultra-long-period signals). Consequently, full-band ground deformation spectra peak around the same frequency band. Synthetic signals will be compared with monitoring records from seismometers and tiltmeters, the latter being specifically suited for detection of very long period signals; as well as gravity anomaly surveys. Results from magma dynamics simulations can also provide hints as to the expected gas fluxes related to different deep processes.

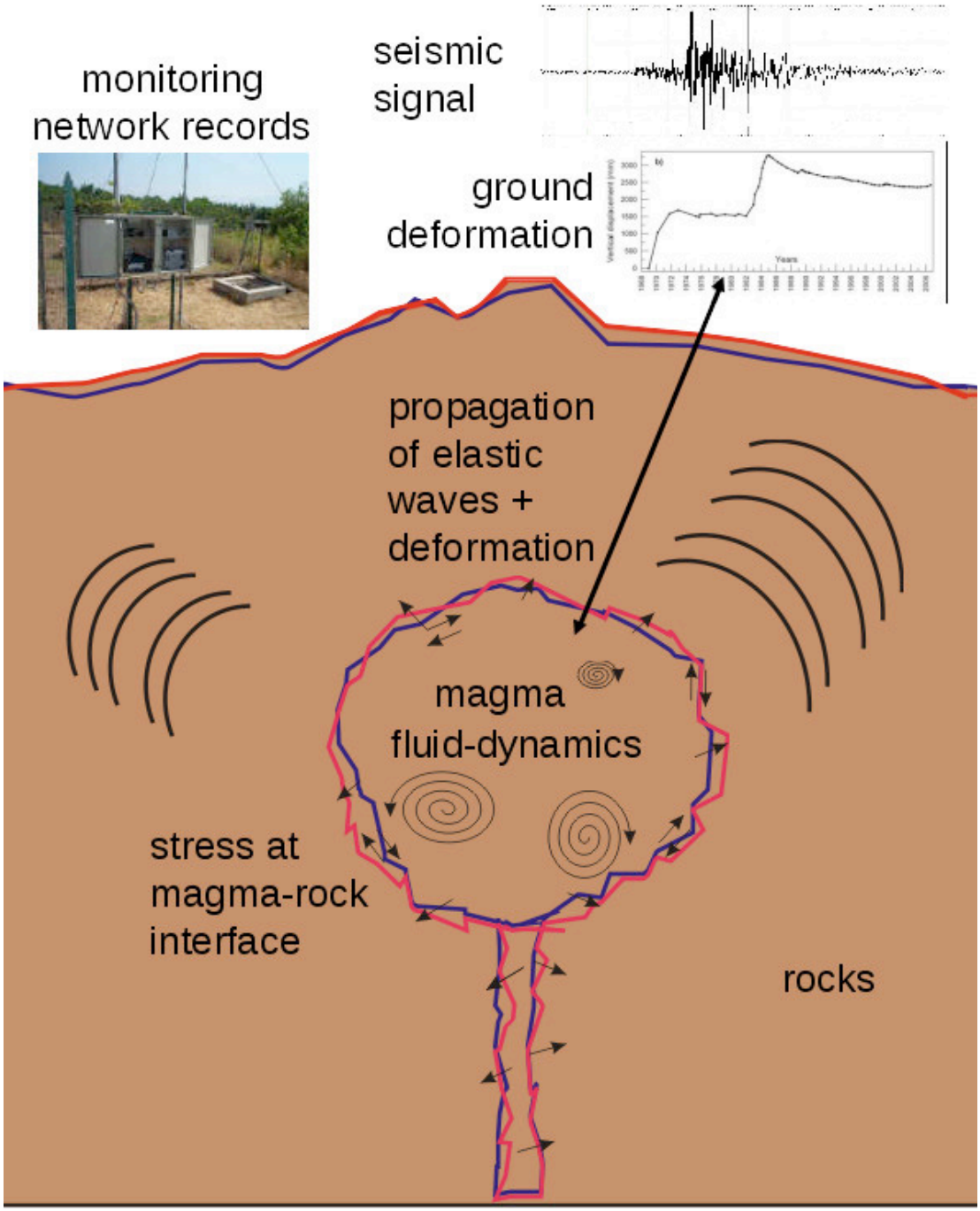

Figure 1. Link between deep magmatic processes and recorded ground deformation signals.

Mingling Dynamics in Magma Chambers at Campi Flegrei

Chiara Paola Montagna, Paolo Papale, Antonella Longo

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Pisa, Italy

Arrival of magma from depth into shallow reservoirs has been documented as one of the most important processes leading to eruption at Campi Flegrei (e.g. Agnano-Monte Spina, Averno 2). Primitive magma intruding and rising to the surface interacts with the already emplaced, more evolved, degassed magmas residing at shallower depths, leaving chemical signatures in the erupted products. We performed two-dimensional numerical simulations of the arrival of gas-rich shoshonite from depth into relatively small (order of 1 cubic km), shallow reservoirs. We solve the fluid dynamics for the two interacting magmas and describe the space-time evolution of the physical properties of the mixture, including composition, density, viscosity and gas content. Convection and mingling develop quickly into the shallow chamber and feeding dyke, leading on longer time scales to density stratification with the lighter, gas-richer magma, mixed with different proportions of the resident phonolitic magma, rising to the top of the chamber due to buoyancy. Over time scales of hours, the magmas in the reservoir appear to have mingled throughout, and convective patterns become harder to identify. The simulations have been performed changing the geometry of the shallow reservoir, and the gas contents of the initial end-member magmas. Both parameters play an important role in determining the efficiency of the mixing processes. Results in terms of space-time evolution of composition in the shallower regions of the domain are shown in Figure 1. Horizontally elongated magma chambers favor mixing, while vertically elongated, dike-like reservoirs inhibit efficient convection. Higher density contrasts between the two magmas cause faster ascent velocities and increase mixing efficiency as well. Petrological evidence suggests for Campi Flegrei residence and mixing times of few days, from the arrival of fresh magmas to eruption, supporting our findings.

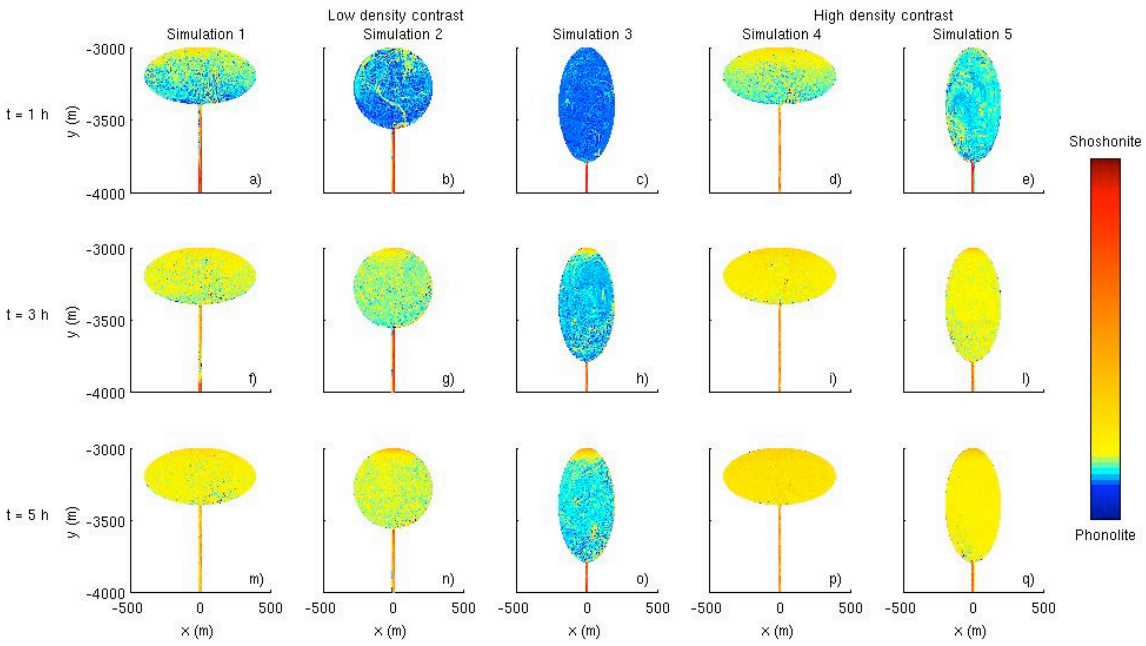

Figure 1. Evolution of composition in space and time for the different simulated scenarios.

A Perturbative Approach for the Modelling of Short-Term Fluid-Driven Ground Deformation Episodes on Volcanoes: the Case of Campi Flegrei Caldera (Italy)

Zaccaria Petrillo, Luca D'Auria, Annarita Mangiacapra, Giovanni Chiodini, Stefano Caliro

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy

We developed a numerical time-dependent inverse method, which allow retrieving the flow rate of fluids injection in hydrothermal systems by using the observed ground deformation. We demonstrate that, under general assumptions, a perturbative approximation, around a steady state, of a thermo-fluid dynamics system, allows the use of a simple linear approach based on numerical Green's function. The thermo-fluid dynamics modelling has been performed in a 3D permeability and porosity model and has been used for computing both the steady state and the Green's function. We model ground deformation by computing the elastic response to the injection of pressurized hot volcanic fluids (CO_2/H_2O mixture) at depth, taking into account both the poroelastic and the thermoelastic strains. The method has been applied to an area of particular geophysical interest: the Campi Flegrei caldera. The first step consisted in determining the shape and the positions of the fluid injection source. The forward modelling has shown that using a NW-SE elongated source with a length of about 2 km, placed at about 2600 m of depth and in the middle of the caldera, we can reproduce the actual spatial ground deformation pattern observed at Campi Flegrei. The method has been tested on a synthetic dataset, showing the capability of retrieving the flow rate pattern over temporal intervals up to about 25 years. We have applied the method to a single ground deformation episode at Campi Flegrei caldera, which showed a clear correlation with episode of degassing and, subsequently, we extended the method to the interval 1987-2013, during which the volcano has shown, repeated episodes of unrest, evidenced by both geophysical and geochemical data. Applying the inverse method we found a good agreement between the measured and the estimated temporal deformation pattern. Results indicate a tight correlation between short-term ground uplift episodes and fluid injection rates in the last 25 years at Campi Flegrei.

Dense Microarray Measurements for Ambient Noise Tomography at Solfatara (Italy)

Marco Pilz[1], Stefano Parolai[1], Gaetano Festa[2], Heiko Woith[1]

[1]*GFZ German Research Centre for Geosciences, Potsdam, Germany*
[2]*Università degli Studi di Napoli Federico II, Napoli, Italy*

Imaging shallow subsurface structures and monitoring related temporal variations are two of the main tasks for modern seismology. Although many observations have reported temporal velocity changes e.g. in volcanic areas and on landslides, new methods based on passive sources like ambient seismic noise can provide accurate information on the velocity structure and on velocity changes. The success of these passive applications is explained by the fact that these methods are based on surface waves which are always present in the ambient seismic noise wave field because they are excited preferentially by superficial sources. These waves can easily be extracted because they dominate the Green´s function between receivers located at the surface. For imaging the shallow velocity structure of the Solfatara crater, one the forty volcanoes in the Campi Flegrei area characterized by an intense hydrothermal shallow activity due to the interaction of deep convection and meteoric water, we have installed a dense network of wireless seismological sensing units covering the whole surface area in the framework of the European project MED-SUV. On four consecutive days continuous recordings of the ambient seismic noise using different microarray configurations were performed. Based on a weighted inversion procedure for the passive imaging using ambient noise cross-correlations we will present a preliminary velocity model of the structure beneath Solfatara.

Detection of ULP Deformation Signals at Campi Flegrei

Roberto Scarpa[1,2], Antonella Amoruso[1], Roger Bilham[3], Paolo Capuano[1,2], Luca Crescentini[1], Bellina Di Lieto[1], Antonio Errico[2], Alan Linde[4], Selwyn Sacks[4]

[1]*Dipartimento di Fisica, University of Salerno, Italy*
[2]*AMRA S.c.a r.l. Analisi e Monitoraggio del Rischio Ambientale, Napoli, Italy*
[3]*CIRES Cooperative Institute for Research in Environmental Science, University of Colorado Boulder, Boulder, USA*
[4]*Department of Terrestrial Magnetism, Carnegie Institution, USA*

Since spring 2004 a research project has been developed in Italy to install borehole Sacks-Evertson strainmeters (dilatometers) aimed to improve monitoring systems of the Italian volcanoes. 6 borehole dilatometers have been installed around Campi Flegrei and Vesuvius during 2004-2005 (Scarpa et al., 2007). This small network has been implemented by two arrays of long-baseline water tube tiltmeters installed in underground tunnels since 2008. Relevant strainmeter and tiltmeter data have been collected and analyzed at the instruments installed at Campi Flegrei during the recent unrest episodes. Renewed activity started since 2004-2005, characterized by a quite low rate of vertical vertical displacement, amounting initially to a few cm/year. A long term strain episode occurred during summer 2006, in correspondence to an increase of CO_2 emission and displacements measured also by tiltmeters and GPS transducers. This strain episode preceded the seismic activity by few months, as also observed during the 1982 most significant unrest. Other aseismic slip episodes have been recorded in 2009, in correspondence of the renewal of gas emission activity at Solfatara, in 2010, one day before a seismic swarm, and in September 2012, few days before the most significant seismic swarm occurred after the 1982-1984 uplift. The time scale of these phenomena is ranging from some hours to several days, putting further constraints on the origin of ground uplifts at Campi Flegrei. Their location is compatible with the source inferred from long term deformation signals, at about 4 km depth beneath Pozzuoli.

2D and 3D Resistivity Models of the Solfatara-Pisciarelli Area by AudioMT Data

Agata Siniscalchi[1,2], Michela Carlucci[2,1], Luca D'Auria[3], Zaccaria Petrillo[3], Gerardo Romano[1]

[1]*Università di Bari, Scienze della Terra e Geoambientali, Bari, Italy*
[2]*AMRA S.c.a r.l. Analisi e Monitoraggio del Rischio Ambientale, Napoli, Italy*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy*

Magnetotelluric is one of the most powerful tools to investigate the geothermal systems; it concerns structure, fluids and temperature of the volcanic area under study due to its high sensitivity to conductors in depth. In the framework of the MED-SUV project an AMT survey was performed: it consists of 32 soundings. A Stratagem EH4 system was used. In order to record data in the frequency range 0.1 Hz-100 kHz two distinct set of sensors were adopted. Furthermore a controlled source in the frequency range from 1000 Hz to 64000 Hz was used during the acquisition if data quality was low in such frequency range to improve signal-to-noise ratio. The source is an unpolarized transmitter consisting of two horizontal magnetic dipoles. The distance of the antennas from the sounding's point was estimated taking into account for the average resistivity of the medium in such a way that the plane wave hypothesis is hold, but close enough to realize a good signal/noise ratio. Quality data is really good and allowed the recovering of an interesting resistivity characterisation of the area. A 2D inversion modelling was performed along a profile that span Solfatara-Pisciarelli area perpendicularly to the main alignment of the electrical shallow structures that results about N30°W- S60°E, as outlined by the tensor analysis at least in the middle (10Hz -20kHz) of the whole frequency range. Its most interesting feature (see Figure 1) is the image of a conductive horizon above the two distinct fumarole areas that should be attributed to the confined aquifer that appears structurally linked for the two areas. A 3D forward modelling that includes sea effects confirms this feature and gives us insight about a further conductive horizon exists not shallower than 1 km. To constrain the effective depth and the horizontal extent of such horizon a wider area need to be sensed with further soundings.

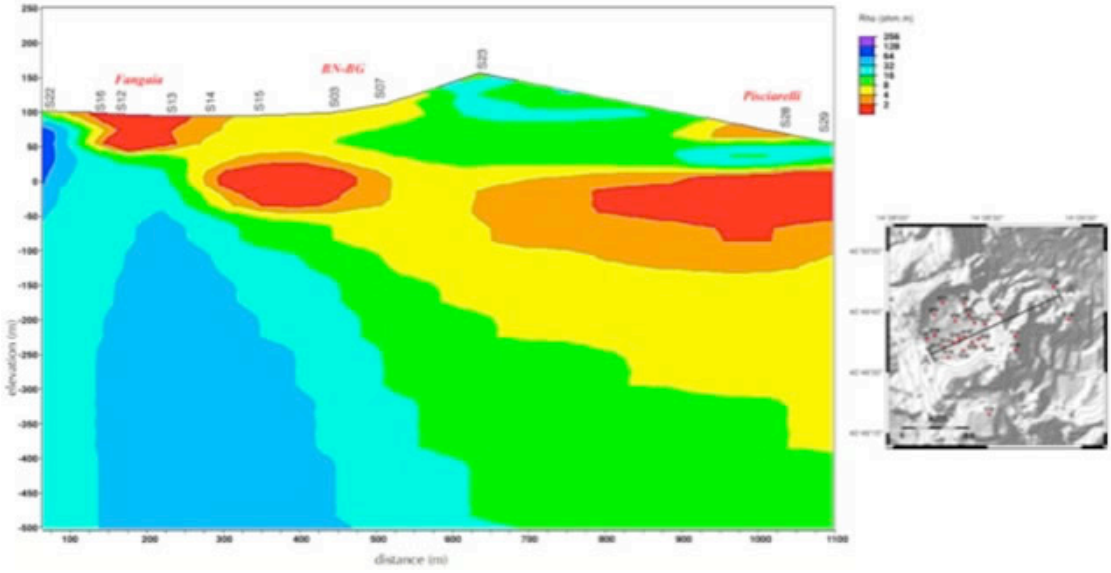

Figure 1. 2D inverse resistivity model obtained along the profile AA' (left). Map of soundings and profile locations (right).

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WP5

Talks

MED-SUV Project: First results and Ongoing Activities of WP 5 – Task 5.1 Characterization of the Threatening Phenomena from Space and Ground

Susanna Falsaperla[1], Tiziana Apuani[2], Mauro Coltelli[1], Franck Donnadieu[3], Horst Langer[1], Eugenio Privitera[1], Giuseppe Puglisi[1]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy
[2]Dipartimento di Scienze della Terra "A. Desio", Università degli Studi di Milano, Italy
[3]Université Blaise Pascal - Observatoire de Physique du Globe de Clermont-Ferrand, Clermont-Ferrand, France

Explosive events, lava-fountains and effusions frequently characterize eruptive activity at Etna. Consequently, the town of Catania and many local municipalities are potentially exposed to ash fallout and lava flows. Besides volcanic hazard, earthquakes and landslides affect this volcanic region as well. The Task 5.1 of the European project "MED-SUV" (Grant Agreement n°. 308665) deals with the observation of these threatening phenomena from space and ground and their characterization and understanding. The Task encompasses six subtasks, which focus on and analyze the aforementioned hazards in terms of their characteristics, duration and spatial dimension:

- Test cases for significant eruptive events have been defined by the subtask 5.1.1. The time span from 2005 to 2011 was chosen for its wealth of eruptive episodes and their well-documented evolution;
- The mapping of eruptive products from satellite data will allow us the improvement of the interpretation and modeling of the mechanisms of cone-forming and lava flow emplacement. This topic is developed in the subtask 5.1.2;
- Multidisciplinary experiments are planned in the subtask 5.1.3, and will be carried out at the North-East Crater in July 2014;
- Another important deliverable is given by tools of data mining proposed by the subtask 5.1.4. These tools will be available for the analysis of parameters of whatever nature (e.g., geochemical, geophysical), providing they are processed in numerical format;
- The subtask 5.1.5 provides a characterization of the volcanic plume and eruptive products, with an integrated analysis of atmospheric, satellite and ground-based measurements, which play an important role in ash-cloud dispersal models;
- The sub 5.1.6 focuses on landslide susceptibility analysis and zoning.

The goal will be to highlight the regional distribution of potentially unstable slopes based on a detailed study of the factors responsible for landslides.

TOMO-ETNA MED-SUV.ISES an Active Seismic and Passive Seismic Experiment at Mt. Etna Volcano. An Integrated Marine and On-land Geophysical Survey

Jesus Ibáñez[1,5], Domenico Patané[2,5], Francisco Carrión[1,5], Luciano Zuccarello[2], Janire Prudencio[1,5], Ornella Cocina[2], Alejandro Díaz-Moreno[1,5], Mauro Coltelli[2], Lucia Urbano[1,5], Luciano Scarfì[2], Francesca Bianco[6], Araceli García-Yeguas[4,5], Birger Lhür[3], Danilo Cavallaro[2], Marco Carlino[2]

[1]*University of Granada, Granada, Spain*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy*
[3]*GFZ German Research Centre for Geosciences, Potsdam, Germany*
[4]*University of Cadiz, Cadiz, Spain*
[5]*Instituto Andaluz de Geofisica, Granada, Spain*
[6]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy*

An active seismic experiment to study the internal structure of Etna Volcano is going to carry out on Sicily and Aeolian islands. The main objective of the experiment, beginning in June 2014, is to perform a high-resolution seismic tomography, in velocity and attenuation, in Southern Italy, by using active and passive seismic data, in an area encompassing outstanding volcanoes as Mt. Etna, and Aeolian volcanoes. The achievement of this objective is based on the integration and sharing of the in-situ marine and land experiments and observations and on the implementation of new instruments and monitoring systems.

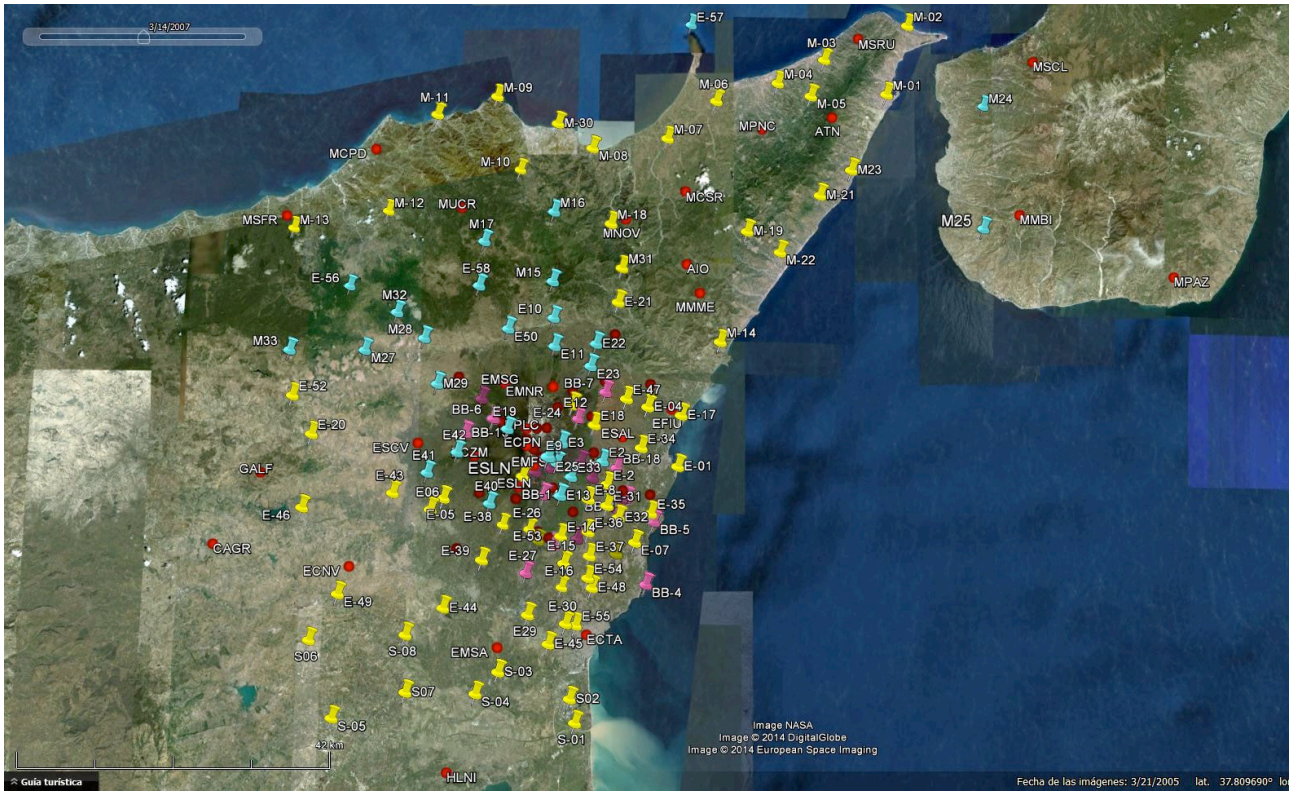

Figure 1. Potential distribution of the onland seismic stations.

For the purpose, onshore and offshore seismic stations and passive and active seismic data generated both in marine and terrestrial environment will be used. Additionally, other geophysical data, mainly magnetic and gravimetric data will be considered to obtain a joint Upper Mantle-Crust structure that could permit to make progress in the understanding of the dynamic of the region. This multinational experiment involves institutions from Spain, Italy, Germany, Ireland, Russia, USA and Mexico. During the experiment air gun shots performed by the Spanish Oceanographic vessel "Sarmiento de Gamboa CSIC-UTM" will be recorder on a dense local seismic network consisting of 100 on land non-permanent stations (80 short period and 20 BB stations), 70 on land permanent stations and 25 OBSs. The shooting process is divided in two legs in the first one using a power of 5200 c.i. more than 6600 signals will be generated. In the second leg a streamer of 240 seismometrer, 3 km long, will be used to additionally record reflection seismicity, and more than 44.000 signals will be generated. Contemporaneously other marine geophysical measures will be performed using a marine Gravimeter LaCoste&Romberg Air-Sea Gravity System II and a Marine Magnetometer SeaSPY using the Italian vessel "Galatea". The experiments will provide a unique data set in terms of data quantity.

MED-SUV Project: First Results and Ongoing Activities of WP 5 - Task 5.4. Models and Software

José Fernández[1], Pierre Briole[2], Marco Aloisi[3], Eleonora Rivalta[4], Alessandro Bonforte[3], Flavio Cannavò[3]

[1]*Instituto de Geociencias, Consejo Superior de Investigaciones Científicas, Madrid, Spain.*
[2]*Centre National de la Recherche Scientifique, Ecole Normale Supérieure, Paris, France*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy*

This Task is devoted to sharing data formats, computer and modelling tools (from the algorithms to the computer codes). The new developed codes, methodologies, and results will be implemented in the multidisciplinary interoperable infrastructure of the project (see WP3, task 3.4). They will also share characteristics with those developed in the WP4. Agreement will be needed in various computational questions: the variables of the overall problem, the format of the input/output data and parameters, the way to handle the uncertainties, the computer code (or codes) that will be used (which can be written in different programming language, e.g. C, Fortran, Python), the visualization tools, the interconnection with existing computer codes (commercial or developed in the partner laboratories) We present the status of development, results obtained during the first year of the project, and objectives for the next ones.

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WP5

Posters

The Mt. Etna Data Mining Software

Marco Aliotta, Andrea Cannata, Carmelo Cassisi, Marcello D'Agostino, Giuseppe Di Grazia, Ferruccio Ferrari, Horst Langer, Alfio Messina, Placido Montalto, Danilo Reitano, Salvatore Spampinato

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy

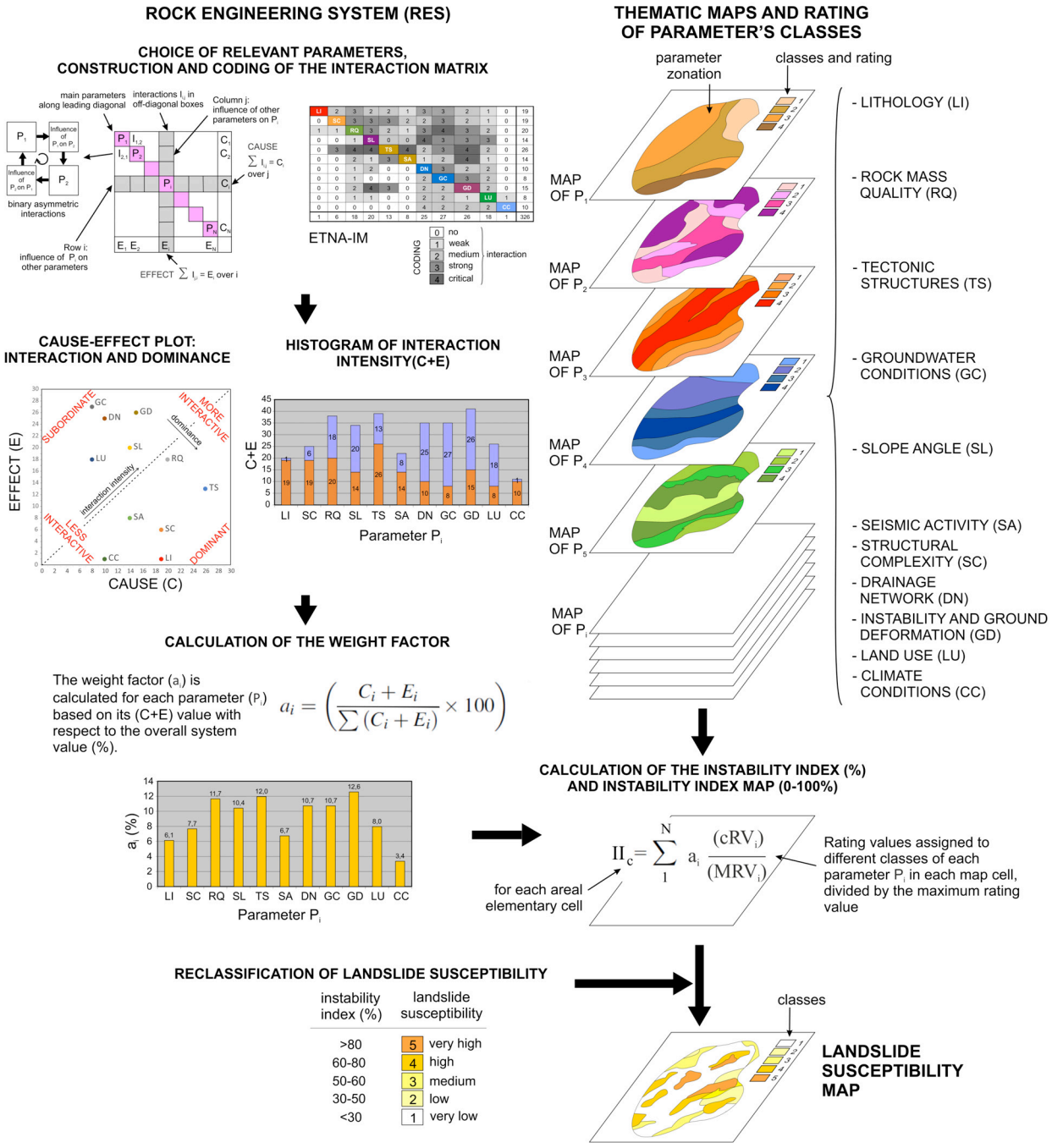
Mt. Etna is permanently active requiring a continuous data acquisition a multidisciplinary monitoring system where huge data masses accumulate and pose severe difficulties of interpretation. Therefore the INGV staff has developed a number of software tools for data mining, aiming at identifying structures in the data which can be related to the volcanic activity and furnish criteria for the definition of alert systems. We tackle the problem by applying methods of clustering and classification. We identify data groups by defining a measure of similarity or distance. Data groups may assume various shapes, once forming convex clouds once complex concave bodies. The tool "KKAanalysis" is a basket of clustering methods and forms the backbone of the tremor-based automatic alarm system of INGV-OE. It exploits both SOM and Fuzzy Clustering. Besides seismic data the concept has been applied to petrochemic data as well as in a combined analysis of gas-emission data and seismic data. The software "DBSCAN" focuses on density-based clustering that allows discovering clusters with arbitrary shape. Here, clusters are defined as dense regions of objects in the data space separated by regions of low density. In DBSCAN a cluster grows guaranteeing that the density within a group of objects exceeds some threshold. In the context of volcano monitoring the method is particularly promising in the recognition of ash particles as they have a rather irregular shape. The "MOTIF" software allows identifying typical wave forms in time series. It overcomes shortages of methods like cross-correlation, which entail a high computational effort. MOTIF on the other hand can recognize non-similarity of two patterns on a small number of data points without going through the whole length of the data vectors. The development includes modules for feature extraction and post-processing verifying the validity of the results obtained by the classifiers.

The Rock Engineering System (RES) Applied to Landslide Susceptibility Zonation of the Northeastern Flank of Etna: Methodological Approach and First Outcomes

Tiziana Apuani, Claudia Corazzato

Dipartimento di Scienze della Terra "A. Desio", Università degli Studi di Milano, Italy

Ground deformations in the northeastern flank of Etna are well known. Despite only a few landslides have been documented, these have significantly involved and damaged lifelines and buildings. These events are mainly related to the activity of the volcano-tectonic structures and associated seismicity, as in the case of the 2002 reactivation of the Presa landslide during an increased activity of the Pernicana fault system. To contribute to risk management, the susceptibility map of the northeastern flank of Etna in the Pernicana area is under development. Different methods are proposed in the literature to obtain the regional distribution of potentially unstable slopes, depending on the problem scale, the slope dynamic evolution in the geological context, and the availability of data. Among semi-quantitative approaches, the present research combines the Rock Engineering System (RES) methodology with parameter zonation mapping in a GIS environment (Fig.1). The RES method represents a structured approach to manage a high number of interacting factors involved in the instability problem. A numerically coded site-specific interaction matrix (IM) analyzes the cause-effect relationship in these factors, and calculates the degree of interactivity of each parameter, normalized by the overall interactivity of the system (weight factor). Thematic maps are then prepared for each parameter, and instability-related numerical ratings are assigned to classes. Then an instability index map is produced, where each areal elementary cell is assigned the sum of the products of each weight factor to the normalized parameter rating. This map is then classified in landslide susceptibility classes, enabling to discriminate areas prone to instability. No previous application of the RES nor its combination with the parameter zonation have ever been used in active volcanic environments up to now. The methodological approach and first outcomes for the NE flank of Etna are presented.



$$a_i = \left(\frac{C_i + E_i}{\sum (C_i + E_i)} \times 100 \right)$$

$$II_c = \sum_{1}^{N} a_i \frac{(cRV_i)}{(MRV_i)}$$

Figure 1. Flow chart for landslide susceptibility zonation.

Etna Volcanic SO_2 Plume Dispersion over the Maltese Islands

Francelle Azzopardi[1], Giuseppe Salerno[2], Simona Scollo[2],
Tommaso Caltabiano[2], Raymond Ellul[1]

[1]*Physics Department, University of Malta, Msida, Malta*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy*

In Malta, at the Global Atmosphere Watch station at the Giordan Lighthouse on the island of Gozo, continuous SO_2 concentrations are measured by the University of Malta. Anomalous SO_2 peaks are noted during North Easterly winds. Insights into these high levels of SO_2 were explored by evaluating the potential effect of Etna volcanic SO_2 plume on the Maltese Islands. Investigation was carried out by examining relationships between SO_2 concentrations gathered by the University of Malta and volcanic SO_2 column amounts measured at Etna volcano by the ultraviolet scanning network FLAME during eruptive phases occurring between the 2011 and 2013. Case studies were examined by evaluating the strength of association between the two data sets using IBM SPSS Statistics. Significant Pearson correlations were found between the two signals in 72% of the case studies. The time lag between the two geochemical records was retrieved to investigate the effects of wind speed and direction on the SO_2 plume. These results show for the first time the impact of Etna volcanic SO_2 plume on the island of Malta and its possible effects on the environment and global climate.

Seismic Anisotropy at Mt. Etna: Massive Measurements Strategy and Background State

Francesca Bianco[1], Lucia Zaccarelli[2], Edoardo del Pezzo[1], Domenico Patanè[3]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna, Bologna, Italy*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy*

The anisotropic features of investigated rock volumes are generally evidenced by shear wave splitting measurements. Shear-wave splitting (SWS) is analogous to optical birefringence: when a shear wave enters into an anisotropic volume, it splits in two shear waves (named qS1 and qS2) that travel with different velocities and with polarizations that are orthogonal one to each other.
In order to attempt the anisotropic structure of Mt. Etna, we performed a thorough revision of our Matlab SPY code that allows the measurements of the shear wave splitting parameters working in a semi-automatic way. The algorithm, that requires in input the event waveforms, their hypocentre locations, and P and S arrival times, defines the leading polarization direction, Φ (in degrees from the North) and the delay Td between qS1 and qS2 onsets (see Figure panel a). This revision was necessary, as well as the development of several new shells, macros and Matlab utilities, in order to easily managing the huge amount of useful data for reconstructing the anisotropic structure of Mt. Etna.

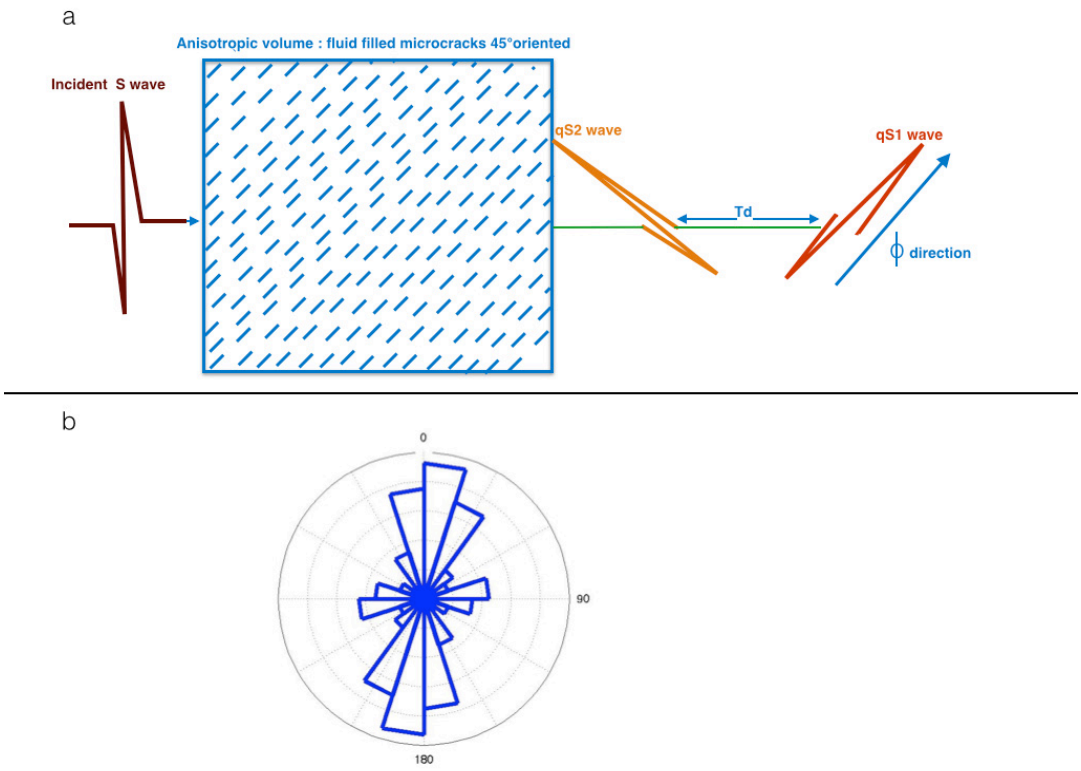


Figure 1. a) Sketch of the shear wave splitting phenomenon. Note that Φ is parallel to the symmetry axis of the anisotropic volume (45 deg); b) Average background direction of for Mt. Etna anisotropy.

The analysis of the seismic background data has been performed applying the revised code to a selected seismic dataset for a first attempt in defining the anisotropic background for data available from 1988 - to-2006. The analysed data constrain a leading polarization direction, and hence, the main direction of the anisotropic volume, approximately NS oriented (see Figure panel b), roughly for all the sector of M. Etna, except for:

- the Pernicana fault, where the main direction is fault oriented;
- for the West sector, where only few available data passed the selection, furnishing results that are not significant from a statistical point of view.

The depth extent of this volume seems to affect, on average, the first 8 km of the upper crust. The percentage of anisotropy ranges from 1.5 to 3%. The obtained results depict a reliable background anisotropic volume at Mt. Etna.

Geophysical Multidisciplinary Investigation of the Structure of the Unstable Sector of Mt. Etna Volcano

Alessandro Bonforte[1], Ornella Cocina[1], Agata Siniscalchi[2], Graziella Barberi[1], Francesco Guglielmino[1], Gerardo Romano[2], Simona Sicali[3], Simona Tripaldi[2]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy*
[2]*Università degli Studi di Bari, Dipartimento di Scienze della Terra eGeoambientali, Bari, Italy*
[3]*Università degli Studi di Catania, Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Catania, Italy*

Mount Etna is characterized by a complex regional tectonics with a N-S compression related to the Africa - Europe convergence that interacts with a WNW-ESE extension associated to the Malta Escarpment. A general eastward motion is present in the eastern flank. Although the existence of these phenomena is overt, the geometry of the sliding sector is still debated. The non-uniqueness of the geophysical inverse models and the different limitations in resolution and sensitivity of each technique spurred us to undertake a joint interpretation of the independent datasets in order to better constrain the results. Seismic data come from the network run by the Istituto Nazionale di Geofisica e Vulcanologia (INGV) - Osservatorio Etneo, Sezione di Catania. The relocated seismicity defines two main seismogenic volumes in the NE sector of the volcano: the first cluster is related to the known Pernicana Fault system, while the second one is located southwards, beneath the northern wall of the Valle del Bove. The resistivity models come from a MT survey carried out on the eastern flank of the volcano and consisting of thirty broad-band soundings along N-S and NW-SE oriented profiles. The resistivity modeling of MT profiles reveal three major layers in a resistive-conductive-resistive sequence. A low resistivity volume is clearly identified on the NE flank of the volcano, between The Pernicana fault and the northern wall of the Valle del Bove. Ground deformation studies (GPS and InSAR) revealed the segmentation of the unstable flank and define the NE sector as the most mobile one; this sector is perfectly bounded by the two seismic clusters and corresponds to the low resistivity volume. The sliding surface modeled by ground deformation data inversions well matches in depth with a resistivity transition and with two seismogenic layers.

Insights into the Deep Plumbing System of Mt. Etna from the Petrology of Sub-Aphyric Primitive Magmas

Rosa Anna Corsaro[1], Nicole Metrich[2]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy*
[2]*Institut de Physique du Globe de Paris - Geologie des Systemes Volcaniques, Paris, France*

To determine the pre-eruptive magma condition (magma composition, pressure and temperature), we focused on the petrologic study of Mt. Etna sub-aphyric primitive magmas which are erupted during rare and highly explosive flank eruptions. These eruptions were previously known as eccentric (Rittmann 1965) and more recently have been renamed DDF, i.e. deep dyke-fed eruptions (Corsaro et al., 2009). They occurred both in historical (1763, 1974, 2001 and 2002-2003) and pre-historical times (from 15ky to 3540y with the eruptions of Mt. Spagnolo, Mt. Frumento delle Concazze, Mt. Maletto and FS Mg-rich tephra). It is widely accepted that DDF eruptions are driven by the rapid ascent of deeply-rooted intrusions which bypass the shallow plumbing system of the volcano. Accordingly, the composition of DDF magmas is poorly modified by pre-eruptive magmatic processes (i.e. fractional crystallization, mixing etc.) and consequently their study allows tinvestigating the deep plumbing system (> 10 km b.s.l.) of the volcano. To this aim we integrated the literature with new data concerning the petrochemistry and the composition of melt inclusions in olivine of the pre-historic DDF eruptions. Our data evidence significant compositional changes of DDF magmas erupted from about 15 ky to the present. In particular a substantial differentiation has been observed between the most recent DDF magmas (1974, 2001 and 2002-03 eruptions) and the older ones. On the basis of preliminary data, this variability is consistent with long-term magmatic processes involving different melting degrees of the source region and variable contributions of slab-derived components. Furthermore, the short-term compositional variability which, for example, has been documented for the products of Mt. Frumento delle Concazze eruption, is referable to more local processes, such as fractional crystallization occurring in the deep storage region of the plumbing system.

First Results of Long-Range Seismic Noise Correlation on Etna Top Stations

Mickael Delatre[1], Francesca Bianco[2]

[1]*Bureau de Recherches Géologiques et Minières (BRGM), Orléans, France*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy*

Long range correlation of background seismic noise is now one of the tools available to seismologists to retrieve shear wave speed structure below the surface. It allows to take full advantage of the continuous data gathered by seismological networks, and was successfully used previously on the Piton de la Fournaise volcano. Using this method on Mt. Etna represents a new challenge, as at this volcano numerous daily tremor and LP events that can contaminate the noise correlations if not done carefully, occur. Using the horizontal transverse component of 1 day dataset on the two stations EBCN and ECPN located at the top of the volcano (in the vicinity of the usual tremor and LP event sources), we devised a new temporal whitening method: using the analytical signal analysis, we remove the data portions with an energy greater than a threshold computed on "quiet" parts of the signal. We showed that this method is quite efficient in removing LP and tremor events. Using the cleaned signals, the total correlation on only one day of data shows the appearance of Love waves along with some tremor correlation remnants. Inversion of Love waves in the small frequency range obtained allows us to get a first attempt in reconstructing the structure for the first 200 meters below the surface. Based on this experience, we are quite confident that larger datasets, including more stations and more duration, will allows us to retrieve a better image of the velocity structure at greater depths, which can also be a contribution to the TOMO-ETNA experiment helping to constrain the global 3D model.

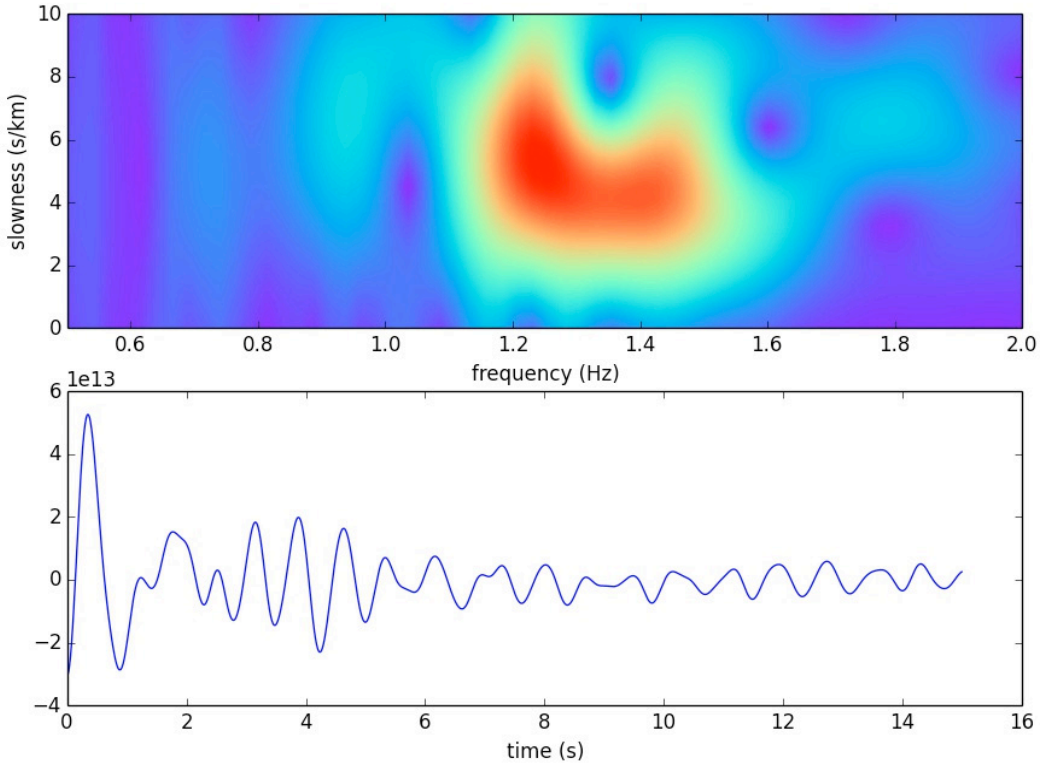


Figure 1. Cross-correlation of 1 day noise, E component, on EBCN and ECPN stations

Failed Eruptions: Examples Revealed by a Multidisciplinary Study at Mt. Etna in Spring 2007

Susanna Falsaperla, Boris Behncke, Horst Langer, Marco Neri,
Giuseppe Giovanni Salerno, Salvatore Giammanco, Emilio Pecora, Emilio Biale

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy

Continuous monitoring at Mt. Etna volcano usually unveils remarkable changes in geophysical and geochemical parameters before the onset of volcanic activity. However, signals of apparent impending volcanic unrest are sometimes recorded without being followed by any eruption. Based on data acquired by the permanent monitoring networks run by INGV, we present cases of "failed eruptions" at Mt Etna from February to April 2007. In the time span analyzed, there were recurrent seismic unrest episodes in the form of enhancements of the volcanic tremor amplitude, which did not culminate in eruptive activity. To explain the origin of these variations, we propose a multidisciplinary study, in which we analyze plume SO_2 flux, in-soil radon and ambient parameters (pressure and temperature), thermal and volcanic tremor data. A pattern classification method based on Kohonen maps and fuzzy clustering sheds further light on changes in volcanic tremor, radon and ambient parameters. Overall, we conclude that the variations observed were the results of episodes of gas pulses and/or rock fracturing. The fluid pressure build up allowed upraise of magma batches that generally failed to reach the surface. Actually, only two "real eruptions" (with short-lived lava fountains on March 29 and April 10-11) occurred during the studied period. In summary, the application of unsupervised classification techniques to volcanic tremor, radon data and ambient parameters represent a promising tool for the surveillance of active volcanoes.

Ongoing Development of Pattern Classification Techniques Applied to Volcanic Tremor Data at Mt. Etna

Horst Langer, Susanna Falsaperla, Salvatore Spampinato, Alfio Messina

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy

Timely identification of changes in the state of volcanoes and onset of potentially dangerous eruptive phenomena requires efficacious surveillance methods. In the case of an active volcano like Mt Etna, the continuous background seismic signal called volcanic tremor is of paramount importance. The huge amount of continuously acquired digital data entails the necessity of data reduction and parameter extraction. For this purpose, techniques of automatic analysis of volcanic tremor were applied by INGV for the real time monitoring of this signal. We checked the possibility to identify regimes of volcanic activity based on pattern classification of volcanic tremor. A specific software named "KKAnalysis" was developed. It combines various unsupervised classification methods (Kohonen Maps and fuzzy cluster analysis) and forms the backbone of an automatic alert system at INGV-OE. Besides its near real time application, it can be operated off-line, allowing an efficient a-posteriori processing of data and tuning of the alarm criteria to match specific needs of sensitivity and robustness. An ongoing development of this tool will allow us to include a large number of seismic stations in a multistation-alarm system. The new system will be more robust in case of failure of single sensors, and will achieve a better coverage of the various eruptive craters. In an off-line test, we exploited a dataset covering eight years of seismic records, and analysed the performance of the new system in terms of "trigger timing" and spatial distribution of the stations. Intriguing results were obtained throughout periods of renewal of volcanic activity at Bocca Nuova-Voragine and North East Crater, and in the absence of paroxysmal phenomena at South East Crater and New South East Crater.

Multiparametric Experiment at the North-East Crater (Mt. Etna): Motivation, Planning and Time Schedule

Eugenio Privitera[1], Daniele Andronico[1], Talfan Barnie[7], Alessandro Bonforte[1], Michael Burton[8], Tommaso Caltabiano[1], Andrea Cannata[1], Daniele Carbone[1], Francesco Ciancitto[1], Antonio Chiarugi[8], Danilo Contrafatto[1], Stefano Corradini[2], Francesco D'Amato[8], Elisabetta Del Bello[2], Franck Donnadieu[7], Ferruccio Ferrari[1] Juan José Pena Fernández[6], Filippo Greco[1], Andrew Harris[7], Ulrich Küppers[5], Alessandro La Spina[1], Philippe Labazuy[7], Marcello Liotta[3], Luigi Lodato[1], Antonio Paonita[4], Roberto Maugeri[1], Luca Merucci[2], Sevèrine Moune[7], Filippo Muré[1], Raphael Paris[7], Arianna Pesci[8], Manuel Queisser[8], Salvatore Rapisarda[1], Tullio Ricci[2], Giuseppe Salerno[1], Piergiorgio Scarlato[2], Mariangela Sciotto[1], Simona Scollo[1], Luciano Scuderi[1], Joern Sesterhenn[6], Letizia Spampinato[1], Laura Spina[5], Jacopo Taddeucci[2], Luciano Zuccarello[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Centro Nazionale Terremoti, Roma, Italy*
[3]*Seconda Università di Napoli, Caserta, Italy*
[4]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Palermo, Italy*
[5]*Ludwig-Maximilians Universitat, Munich, Germany*
[6]*Technische Universität, Berlin, Germany*
[7]*Université Blaise Pascal - Clermont-Ferrand II, France*
[8]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Pisa, Italy*

In the framework of the MED-SUV FP7 project, a multiparametric experiment for degassing dynamics definition is planned (sub-task 5.1.3 of MED-SUV project). This experiment will involve about 35 researchers/technicians of different institutions from Italy, Germany and France: INGV, Seconda Università di Napoli, Ludwig-Maximilians Universitat, Technische Universität Berlin, Université Blaise Pascal - Clermont-Ferrand II. It will be performed at the North-East Crater (NEC; one of the five summit craters of Mt. Etna) for several reasons: i) NEC is one of the main contributor of Mt. Etna degassing; ii) NEC has almost continuously generated infrasound events (at least from the installation of the permanent infrasound network in 2006); iii) NEC has recently emitted ash both during the paroxysmal episodes at the New South-East Crater and during the inter-episode periods.

In order to investigate the degassing dynamics of NEC in details, we plan to apply a multiparametric approach by making use of different kinds of instruments: seismometers, microphones, radiometers, mini-UV scanner, FTIR spectrometer, SO_2 cameras, high-speed video cameras, gravimeters, active alkaline traps, GNSS stations. Such instruments will be set-up on both the crater rim and the flanks of the cone of NEC for the period 15-18 July 2014. The information acquired by these instruments will be integrated with the data recorded by the Etna permanent multiparametric network, run by INGV. The gas measurements, which will be performed from ground instruments, will be compared with gas estimations obtained by the ASTER satellite on 17 July. The integration of all these data will allow to quantitatively track the degassing process from the gas bubble rising in the NEC conduit to the gas release in the atmosphere. Moreover, during 9-12 July by both laser-scanner and photogrammetry we plan to obtain the detailed reconstruction of the inner part of the crater.

Figure 1. Picture showing the inner part of the North-East Crater.

Mt. Etna Test Cases for MED-SUV Project

Giuseppe Puglisi[1], Letizia Spampinato[1], Susanna Falsaperla[1], Pierre Briole[2], Patrick Allard[3], José Fernández[4]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy*
[2]*Ecole Normale Superieure, CNRS, Paris, France*
[3]*Institut de Physique du Globe de Paris, CNRS, Paris, France*
[4]*CSIC-UCM, Instituto de Geociencias, Madrid, Spain*

In the framework of MED-SUV, WP5 is in charge of studying Mt. Etna's volcanic activity. We defined periods and phenomena of the volcano activity to be used by the WP5 partners as Test Cases in the time window 2005-2011 i.e. that of the data available in the MED-SUV database. Overall, characterisation of eruptive activity and/or periods of quiescence will improve our knowledge on the geophysical and geochemical processes taking place inside Mt. Etna's volcanic system. These processes to be characterized include:

- magma formation and evolution,
- conditions of storage and transfer of magma in reservoirs at different levels within the crust;
- physical and chemical interaction of magma with surrounding rocks and fracture/fault systems and their effects at the surface;
- opening of eruptive vents/fissures as well as eruptive processes (including the formation and evolution of lava fields, volcanic plumes, pyroclastic fallout, etc.).

The joint effort around the Test Cases will help the WP5 team addressing key questions such as:

- what has determined changes of Mt. Etna eruptive style (mainly effusive vs. short-lasting, frequent paroxysmal events) in the last decades?
- how is the shallow plumbing system (~1-4 km from the summit) structured? What are the processes occurring in this portion of the volcano feeding system and the key parameters controlling these processes? How does magma behave at shallow depths?
- what is the suitability of cross-correlated parameters/models for shedding light on the relationship between shallow (<5-6 km) earthquakes of the eastern flank of Mt. Etna and volcanic activity (if any)?

For such questions, analysing carefully the periods of "quiescence" that precede eruptions is not less important than analyzing the eruptions themselves.

TYPE	LOCATION	DATES	MAIN FEATURES
Flank	Eastern flank	7 Sep 2004 - 8 Mar 2005	Eruptive fissure opening, lava effusion
Summit	South-East crater	14 Jul 2006 - 24 Jul 2006 31 Aug 2006 - 15 Dec 2006	Eruptive fissure opening, explosive activity, lava effusion, cinder cone
Summit	South-East crater	29 Mar 2007 - 10 May 2008	Explosive activity, lava effusion
Flank	Eastern flank	13 May 2008 - 7 Jul 2009	Dike injection, eruptive fissure opening, explosive activity, lava effusion
Flank	Eastern flank	12 Jan 2011 - 15 Nov 2011	Explosive activity, lava effusion, cinder cone

Table 1. List of the Mt. Etna eruptions included in the period considered in the MED-SUV project.

SO_2 Flux at Mount Etna between 2005 and the 2011: Results and Perspectives

Giuseppe Salerno[1], Michael Burton[2], Tommaso Caltabiano[1], Vincenza Longo[1], Filippo Murè[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Pisa, Italy*

Mount Etna, is one of the most active volcanoes in the world, and is also regarded as one of the strongest volcanic sources of sulphur dioxide (SO_2) emissions to the atmosphere, accounting for ~15% of the global flux of volcanic S into the Earth's atmosphere (e.g., Andres and Kasgnoc, 1998). Regular SO_2 flux observations from both summit and flanks have been performed at Mount Etna since 1987 using COSPEC and since late 2004 by the FLAME scanning spectrometer network. In the period between 2005 and 2011 Etna has displayed an intense eruptive activity, which spanned from soundless lava flows to vigorous lava fountains. We present here bulk SO_2 flux observations carried out in this time window. Over the seven years noteworthy changes in gas flux have been observed strongly correlated with the eruptive activity at both short and long-time scale. SO_2 flux has varied between 200 and 21,000 Mg/day (standard deviation of 1900 Mg/day), suggesting stages of progressive degassing of magma batches and increasing trends reflecting the ascent of volatile-rich magma within the volcano shallow feeding system. Waxing-waning steps were recognised throughout the seven year and were indicative of cycling of volatile rich magma supply for the depth to the shallow part of the feeder conduit. Considering the original content in sulphur of Etna's magma, the balance between the erupted magma and the SO_2-degassed magma budget, which sustained the observed bulk plume emission, has been explored. Short- and long-time scale estimates of degassed magma enabled us discriminating between steady-state magma degassing-erupted transfer processes and unbalances due to excess degassing.

The Borehole Experiment: Investigation of Cortical Structures Through 3D Array Techniques

Luciano Zuccarello[1], Mario La Rocca[2], Ferruccio Ferrari[1], Danilo Contrafatto[1], Salvatore Rapisarda[1], Stefano Branca[1], Paola Cusano[2], Danilo Galluzzo[2], Alfio Messina[1], M. Paratore[1], Simona Petrosino[2]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy*

Over the last few years it is growing the need to monitor the volcanic activity with modern technology in order to mitigate volcanic hazard through the detection of any possible precursor phenomena. The use of high performance seismic stations, such as borehole instruments, may increase the signal to noise ratio (SNR), improving the capability to detect very small signals. Over the past 40 years much attention has been given to the use of seismic arrays to measure the slowness vector of coherent signals. The main advantage of seismic arrays consists in their ability to detect weak or emergent signals, and to allow for an effective noise reduction through multichannel waveform stacking. A reliable prediction of the ray-path back-propagated from the recording site to the source is strongly limited by the poor knowledge of the local shallow velocity structure. Usually in volcanic environments the propagation of seismic signals through the shallow layers is strongly affected by lateral heterogeneity, attenuation, scattering, and interaction with the free surface. Driven by these motivations, on May 2014, in collaboration with the colleagues of Osservatorio Vesuviano (INGV), we deployed a 3D seismic array in the area where the borehole seismic station called Pozzo Pitarrone is installed at a depth of about 130 meters. This will improve our knowledge about:

- the structure of the top layer and its relationship with geology;
- analysis of the signal to noise ratio (SNR) of volcanic signals as a function of frequency;
- study of seismic ray-path deformation caused by the interaction of the seismic waves with the free surface;
- evaluation of the attenuation of the seismic signals correlated with the volcanic activity.

The results of these analyses will improve the general knowledge of wave propagation in the shallow layers and will give a new contribution to the seismic monitoring of Etna volcano.

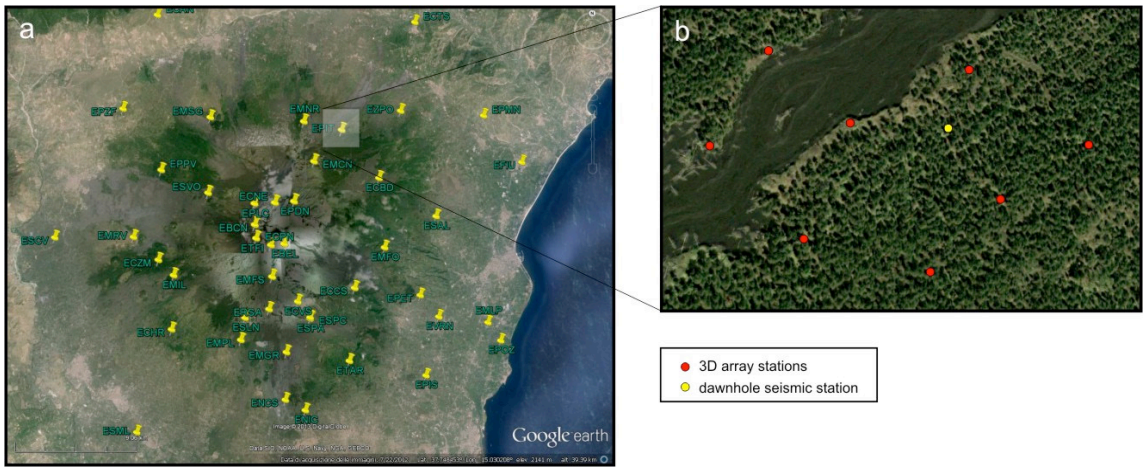


Figure 1. Map of Mt. Etna with location of the seismic permanent network (a), and 3D seismic array in the area of Pozzo Pitarrone (b).

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WP6

Talks

Short-Term Probabilistic Volcanic Hazard Assessment of Tephra Fallout at Campi Flegrei and Vesuvius

Jacopo Selva[1], Antonio Costa[1], Laura Sandri[1], Giovanni Macedonio[2], Warner Marzocchi[3]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna, Bologna, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Roma 1, Roma, Italy*

Probabilistic Volcanic Hazard Assessment (PVHA) represents the most complete scientific contribution for planning rational strategies to mitigate the risk posed by volcanoes at different time scales. During volcanic unrest episodes or eruptions, it is very important to produce short-term (days to weeks) tephra fallout forecast and frequently update it, to account for the rapidly evolving situation. This information is crucial for crisis management, since tephra may heavily affect building stability, public health, transportations and evacuation routes (airports, trains, road traffic) and lifelines (electric power supply). Here, we propose a method for short-term PVHA (named BET_stVH) in which monitoring data are used to routinely update the forecast of eruption occurrence, vent position and eruption size. Then, considering all possible vent positions and eruptive sizes, tephra dispersal models are coupled with frequently updated meteorological forecasts. Finally, these results are merged through a Bayesian procedure, accounting for epistemic uncertainties at all steps (see Figure 1). As case studies, we retrospectively analyze:

- some stages of the unrest that took place in Campi Flegrei in 1982-84;
- the MESIMEX exercise at Vesuvius.

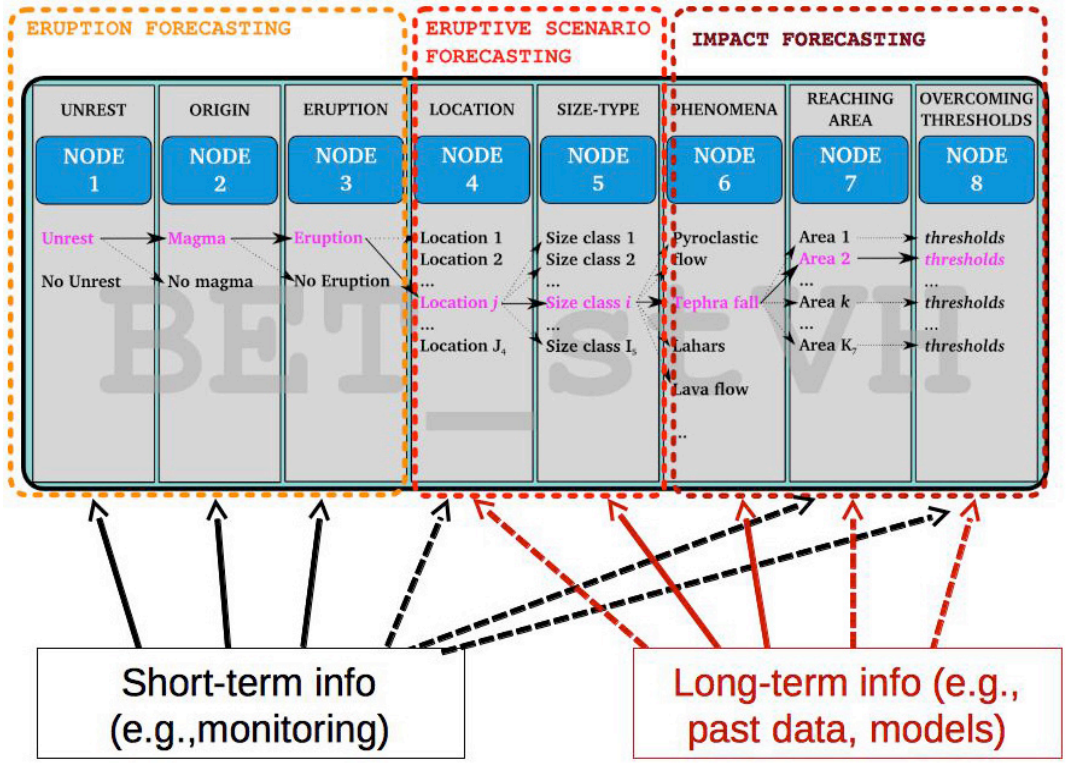

Figure 1. Scheme of the method BET_stVH for short-term PVHA assessment, here applied to tephra fallout. It is highlighted what pieces of information (monitoring data and/or long term info) concur to determine the forecast at the different nodes of the scheme.

In particular, we aim at presenting practical examples of possible tephra fall PVHA on a daily basis, in the surroundings of the volcanoes. Tephra dispersal is simulated using the analytical HAZMAP code. We take advantage here of several novel improvements, allowing to model how the probability of eruption evolves within a given time window, to treat time-variable epistemic uncertainty, and to produce hazard curves and their confidence levels for a complete description of PVHA. The general goal is to show what and how pieces of scientific knowledge can be transferred to decision makers, and specifically how this could have been done during the 1982-84 Campi Flegrei crisis and MESIMEX, if scientists knew what we know today.

Propagation of Source Grain-Size Uncertainty by Using a Lagrangian Volcanic Particle Dispersal Model

Mattia De' Michieli Vitturi[1], Antonio Spanu[2,1],
Federica Pardini[3], Maria Vittoria Salvetti[3], Augusto Neri[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Pisa, Italy*
[2]*Scuola Normale Superiore di Pisa, Pisa, Italy*
[3]*Dipartimento di Ingegneria Civile e Industriale, Università di Pisa, Pisa, Italy*

Lagrangian particle dispersal models are often used for tracking ash particles emitted from volcanic plumes and transported under the action of atmospheric wind fields. In this work, we present preliminary results of an uncertainty quantification analysis applied to volcanic ash dispersal in the atmosphere and focused on the uncertainties associated to the particle source conditions. To this aim the Eulerian fully compressible mesoscale non-hydrostatic model WRF is used to generate the driving wind field. The Lagrangian particle model LPAC is then used to simulate the transport of mass particles under the atmospheric conditions. The particle motion equations are derived by expressing the Lagrangian particle acceleration as the sum of the forces acting along its trajectory, with drag forces calculated as a function of particle diameter, density, shape and Reynolds number. The simulations were aimed to reproduce a weak plume event of Mt. Etna and to quantify the uncertainty in the prediction of particle dispersal due to the uncertainties on the source conditions. The analysis focused on the uncertainty affecting the mean and variance of a Gaussian density function describing the grain-size of the mixture and on particle sphericity. Simulation results and associated uncertainty analysis allowed to quantify the sensitivity of dispersal results to the uncertain variables and to compute the most probable values and the pdf of these variables at various distances from the source, both in air and on the ground.

An Up-to-Date Methodology for the Quantitative Assessment of Lava Flow Hazards

Ciro Del Negro, Giuseppe Bilotta, Annalisa Cappello, Gaetana Ganci, Alexis Herault

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy

We have developed a new methodology for the production of hazard maps by lava flow inundation for long and short term at Mt. Etna (Fig. 1). The short term maps are dynamic instruments, which can be semi-automatically modified by considering the signals collected by the monitoring networks, the evolution of the eruptive activity, and the weighted opinion of experts.
The main products of the methodology are:

1. Lava Flow Inundation Hazard Maps;
2. Vent Opening Probability Maps;
3. Scenario Forecasts.

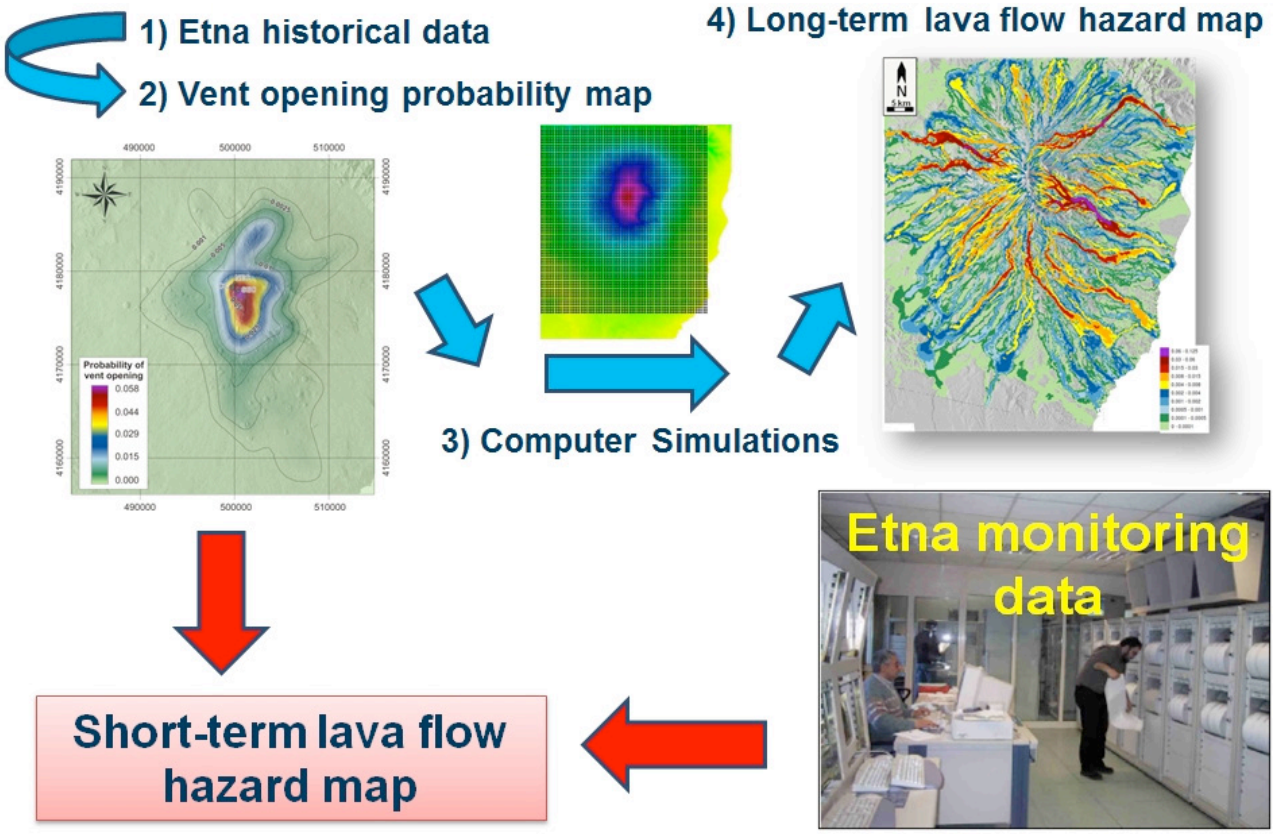

Figure 1. The scheme for the quantitative assessment of lava flow hazards.

The long term lava flow hazard maps are obtained by combining numerical simulations of lava flow paths, spatiotemporal probability of future vent opening, and event probabilities associated with classes of expected eruptions. The simulations of lava flows are based on our knowledge of past Etna eruptions, derived from the integration of historical and geological data and by adopting a high-resolution updated Digital Elevation Model (DEM). Paths of lava flows are computed by MAGFLOW physics-based model. For the construction of short-term lava flow hazard maps, the monitoring networks have a leading role, primarily based on seismological and volcanological data, integrated with strain, geochemical, gravimetric and magnetic data. By integrating information coming from monitoring observations (e.g.: using the BET_EF algorithm), new probability maps for next vent opening can be obtained, allowing the dynamic update of the long-term lava flow hazard map. Moreover, specific scenarios can be extracted at any time from the simulation database, for land use and civil defense planning in the long term, to quantify, in real time, the impact of an imminent eruption, and to assess the efficiency of protective measures.

Capacity Building and Interaction with Decision-Makers

Rosella Nave[1], Laura Sandri[2], Roberto Isaia[1]

[1]INGV Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna, Bologna, Italy

Volcanic Hazard evaluation tools need to be taken in account by decision makers in order then to plan actions able to mitigate the related likely to impact a territory. A crucial issue, in the context of short-term hazard assessment, is to define efficient communication and information sharing between scientists and decision makers. The aim is to establish protocols and practices able to enhance "end user" comprehension and application of scientific information and tools coming from hazard probabilistic assessment. To accomplish this task we started to identify protocols, procedure and best Practise, from evaluation/recommendation outcomes of ongoing projects as Vuelco, NEMOH and the VOBP meeting Communicating Hazard. Furthermore we have selected the Campi Flegrei caldera as the Pilot Area, based both on the peculiar volcanic dynamic, the ongoing volcanic hazard short term evaluation, and the high volcanic risk. End users and decision makers from this area will be involved in the evaluation/validation process of the tools developed in MED-SUV WP6 Task 1 and 2, and in testing procedure and protocols. Moreover in strong cooperation with the VUELCO project, during the simulation exercise at Campi Flegrei held in February 2014 we have tested the feasibility of near-real-time probabilistic volcanic hazard assessment (for tephra fallout), representing the first step for applying Cost-Benefit Analyses in real cases.

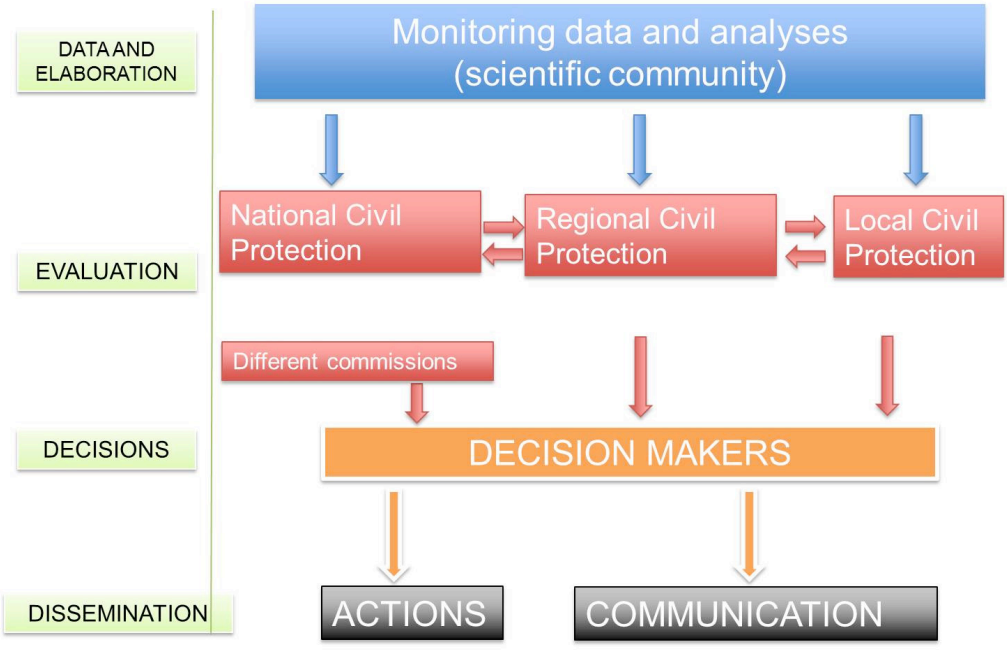

Figure 1. Model of scientific information transmission and sharing that will be tested in WP6 Task 6.3 actions.

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WP6

Posters

Stakeholders Analysis: a Crucial Step for a Successful Volcanic Hazard Assessment, Disaster Preparedness and Mitigation Management Strategy

Alfonso Brancato[1], Giuseppe Puglisi[1], Agata Sangianantoni[2], Letizia Spampinato[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy*

WP6 of MED-SUV aims at showing how the improvement of the monitoring system at the Italian Supersite volcanoes may contribute to better volcanic hazard assessment and to bridge the gap between science, mitigation and preparedness of volcanic disasters. For the purposes, throughout the project scientists and decision makers are working together trying to optimise procedures for improvement their mutual information exchange. To do this effectively and efficiently a management strategy needs to be defined and implemented in order to involve the key players and make them aware of the policy, sector and institutional context within which they are undertaking their work. Stakeholders Analysis is a crucial step to achieve specific objectives related to volcanic hazard assessment, evaluation, and preparedness and mitigation. Indeed management and science are interdependent so WP1 and WP6 need to strength their efforts in setting up a proper joint strategy to identify the different stakeholders, understand their needs, and to investigate their respective roles, resources, and capacities. Stakeholders Analysis, in fact, will enable us getting an overall view of what is needed to implement actions devoted to volcanic hazards by allowing us definition of proper guidelines to clearly define the role of scientists and that of decision makers during a volcanic emergency. Guidelines will state also the kinds of information the scientists should provide to decision makers in term of both short- and long-term hazard assessment. In this prospective, we expect that findings of the analysis will ensure that the resources available in the framework of MED-SUV are appropriately targeted to meet the objectives of the project and its stakeholders. We believe that Stakeholders Analysis, in compliance with EPOS implementation plan, could significantly contribute to the "Information for Societal Benefit" part of the GEO 2012-15 work plan at which MED-SUV has subscribed.

LAV@HAZARD: a Web-GIS Framework for Forecasting Lava Flow Hazards

Ciro Del Negro, Giuseppe Bilotta, Annalisa Cappello, Gaetana Ganci, Alexis Herault

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy

Depending on their intensity and position, volcanic eruptions at Mt. Etna have the potential to cause significant social and economic damage. Here, we combined space-borne remote sensing techniques and numerical simulations in a web-GIS framework (LAV@HAZARD) to evaluate lava flow hazard in real time. By using the HOTSAT satellite thermal monitoring system to estimate time-varying TADR (time averaged discharge rate) and the MAGFLOW physics-based model to simulate lava flow paths, the LAV@HAZARD platform allows timely definition of parameters and maps essential for hazard assessment, including the propagation time of lava flows and the maximum run-out distance.
LAV@HAZARD consists of four modules regarding monitoring and assessment of lava flow hazard at Etna:

- satellite-derived output by HOTSAT (including time-space evolution of hot spots, radiative power, discharge rate, etc.);
- lava flow hazard map visualization;
- a database of MAGFLOW simulations of historic lava flows;
- real-time scenario forecasting by MAGFLOW.

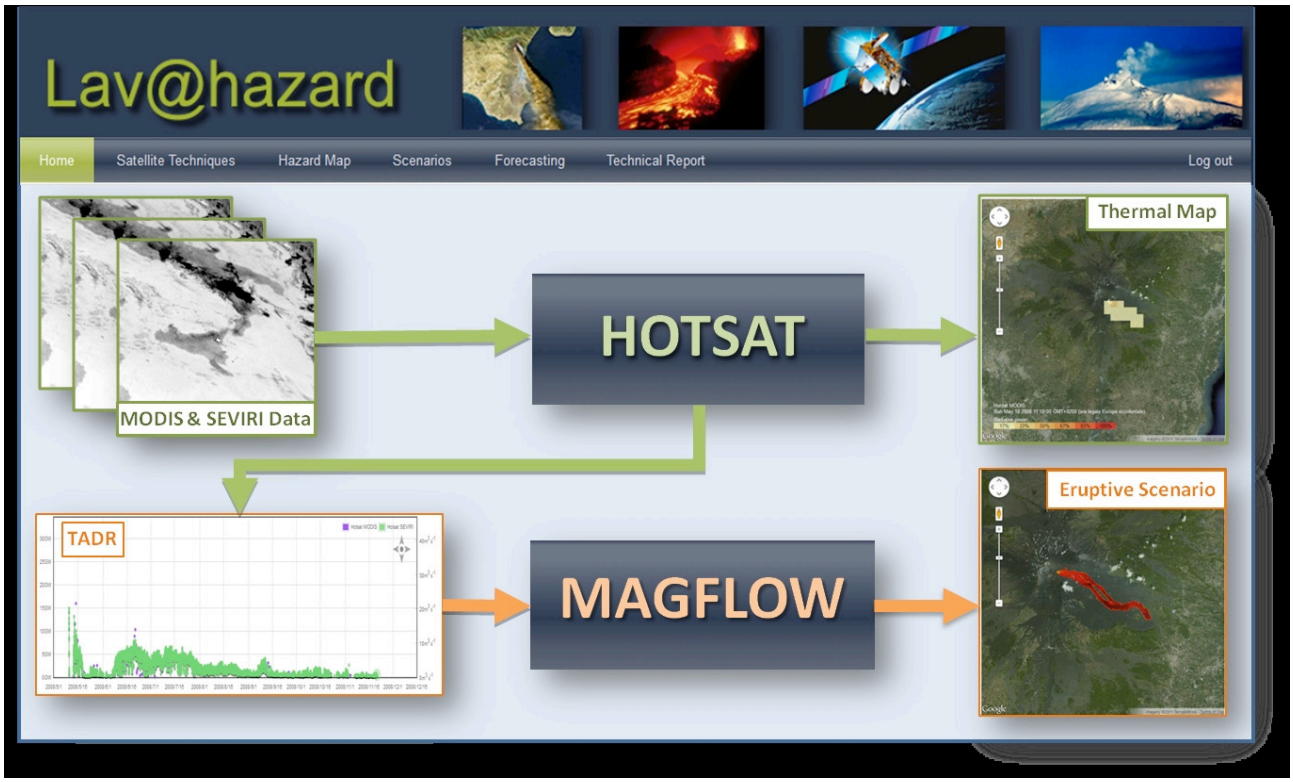

Figure 1. Flow diagram of the Web-GIS platform LAV@HAZARD available at the link http://ctmgweb.ct.ingv.it/joomla (password protected).

As part of the satellite module, MODIS and SEVIRI images are automatically analyzed by HOTSAT, which promptly locates the thermally anomalous pixels. Next, the heat flux from the anomalous pixels is calculated, which is converted to lava discharge rates. Using SEVIRI, these can be calculated, up-date on the LAV@HAZARD database up to four times per hour. The satellite-derived discharge rate estimates are then used in the scenario forecasting module as input parameters to MAGFLOW. Because HOTSAT provides minimum and maximum estimates for TADR, two corresponding (end member) lava flow simulations are produced by MAGFLOW. Every time the satellite obtains a new image of Etna volcano, the TADR is updated, and a new pair of simulations is produced. Automatic updating of lava flow hazard scenarios and the remote control of HOTSAT and MAGFLOW on the web, make LAV@HAZARD a helpful tool to validate and adjust/refine our output in real time.

The Future Eruptions of Mount Etna: Probabilistic Modelling and Lava Flow Hazard Maps

Ciro Del Negro, Annalisa Cappello, Marco Neri, Giuseppe Bilotta, Alexis Herault, Gaetana Ganci

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy

We present an up-to-date methodology for the quantitative assessment of lava flow hazards based on a combination of field data, numerical simulations and probability analyses. In particular, we produce lava flow hazard maps for Mt. Etna by combining numerical simulations of lava flow paths, spatiotemporal probability of future vent opening, and event probabilities associated with classes of expected eruptions. Our purpose is to give a rigorous statistical treatment of the historical records of summit and flank eruptions and to explore a much wider range of eruptive scenarios, than is possible to observe directly in identifying areas at risk. Accounting for a more comprehensive range of possible scenarios, through the combination of field data, numerical modeling and probabilistic analysis, gives a better understanding of effusive eruptions and their effects. However, such a combination is rarely straightforward and requires an accurate evaluation of diverse stages.

For this reason, we developed a methodology based on four different tasks:

- assessment of the spatiotemporal probability of future vent opening;
- estimation of the occurrence probability associated with classes of expected eruptions;
- simulation of a large number of eruptive scenarios with the MAGFLOW model;
- computation of the long-term probability that a lava flow will inundate a certain area.

We applied this four-stage methodology to estimate lava flow hazard at Mt. Etna both for flank eruptions and summit eruptive activity, showing the probability that a certain area will be inundated by future lava flows over a specific time period. The effective use of hazard maps of Etna may help in minimizing the damage from volcanic eruptions through correct land use in a densely urbanized area with a population of almost one million people. Although this study was conducted on Mt Etna, the approach used is designed to be applicable to other volcanic areas.

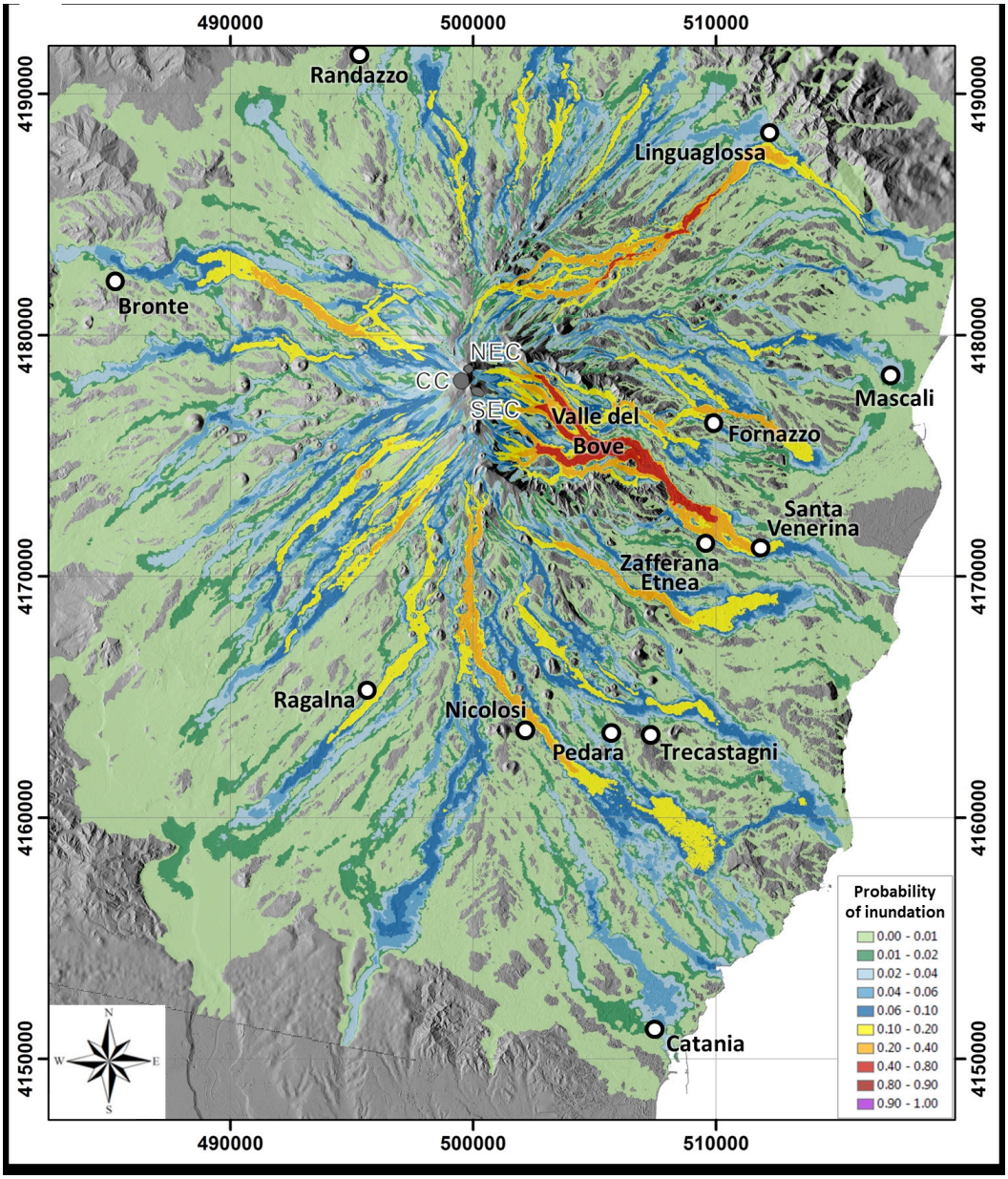

Figure 1. Lava flow hazard map at Mt. Etna based on 28,908 simulations of lava flow paths starting from 4,818 different potential vents. Colors represent different hazard levels indicating a range of probability of lava flow inundation in the next 50 years.

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Progetto grafico e redazionale
Daniela Riposati | Laboratorio Grafica e Immagini | INGV

Via di Vigna Murata, 605
00143 Roma
Tel. +39 06518601 Fax +39 065041181

http://www.ingv.it

Istituto Nazionale di Geofisica e Vulcanologia