Research Networking Programmes

Science Meeting – Scientific Report

Scientific report (one single document in WORD or PDF file) should be submitted online <u>within two months of the event</u>. It should not exceed seven A4 pages.

***<u>Proposal Title</u>*:** **European Volcano Observatories Workshop – EVOW**

<u>Application Reference N°</u>: 4751

1) Summary (up to one page)

Volcano observatories worldwide are the institutions responsible for the monitoring of active volcanoes and the assessment of volcanic hazards to advise civil protection agencies.

This task was primarily of local interest, related to the geographic area under the influence of the volcanoe(s). Such perspective has changed over time because the increase of economic activity around volcanoes has shown that even a mild explosive volcanic eruption may have a severe impact, which enlarge greatly the role of volcanic observatories.

The constant growing of basic knowledge on the behaviour of volcanic systems and the rapid proliferation of technology available for volcano surveillance imposes a hard task on observatories to keep up to date with predicting models and technological development. These factors determined the present perspective that an effective cooperation between observatories can greatly enhance the response capability of each observatory and reinforces the need for cooperation among them.

The EVOW was intended to be a step to strengthen the collaboration among the European volcano observatories promoting the discussion on:

- National and regional policies for volcanic monitoring and surveillance
- Strengths and weaknesses of each volcano observatory
- Strategies to stimulate the cooperation among volcano observatories

2) Description of the scientific content of and discussions at the event (up to four pages)

Volcano observatories, Civil Protection and Local authorities – state of the art
The **first session** was dedicated to review the national and regional organisation and policies regarding Volcano Observatories (VO), civil protection agencies and political authorities. Each institution was invited to present a short talk to illustrate the state of the art on several issues concerning VO:

- Which is the legal framework that supports the links between volcano observatories and authorities?
- Which is the autonomy level of volcano observatories?
- Which are the funding mechanisms for volcano observatories?
- Which are the European policies and initiatives to promote the cooperation among volcano observatories?

The outcome of this session allowed a clear view of the distinct realities in each observatory and the distinct legal framework determining the relations between volcano observatories and civil authorities. Key observations were highlighted in this session and are of paramount importance to set the background for a future understanding between VOs:

- In Europe, volcano observations are conducted by different types of institutions;
- Not all countries have institutions formally commissioned to perform volcano observations;
- Very different legal frameworks bound European VOs on each country;
- The demanded response from VOs is quite different on each country;
- European VOs have very different organisational structures;
- VOs are receptive to strengthen the cooperation among them;

Those are the foundations for a future understanding between VOs because any agreement must accommodate all the identified differences between countries and between VOs.

Volcano observatories, Civil Protection and Local authorities – Brain storming
The **second session** was a brain storming session dedicated to analyse the weaknesses and strengths of the existing formal framework governing the monitoring and surveillance activities as well as the relations between volcano observatories and civil authorities. Main issues addressed were:

- What are the main strengths of the legal framework governing the monitoring and surveillance activities, in each country, on routine and under crisis situation?
- What are the constrains imposed on volcano observatories by the present legal framework, in each country, on routine and under crisis situation?
- How effective can informal cooperation be?
- Were the formal links between volcano observatories and civil authorities effective during recent crisis?

A survey was also conducted to assess each VO position regarding their administrative status and autonomy, statutory and legal obligations towards civil authorities, legal contact persons, geographic target, data policy, staff composition and budget.

A core issue was raised in the course of the debate regarding the statute of the different types of institutions conducting volcano observations in Europe. Depending on their legal mandate and on the respective demanded response, 3 different types of institutions were proposed:

- **Volcano Observatories** - public or private entities, that either individually, associated or in a consortium, have a legal mandate at a national (NVO) or regional (RVO) level to conduct the volcanological monitoring and surveillance of one or more volcano(es), including the maintenance of an alert and/or warning system on the status of the volcano(es) in a 24/7 basis.
- **Volcano watching institutions** - public or private entities, that either individually, associated or in a consortium, have a legal mandate at a national or regional level to conduct volcanological monitoring of one or more volcano(es) and advise civil protection authorities on a non-permanent basis, by request or on their own initiative.
- **Volcano laboratory institutions** - public or private entities, that either individually, associated or in a consortium, conduct volcanological observations on one or more volcano(es), providing useful information to better understand its(their) behaviour and/or status of activity

Cooperation among observatories – State of the art

The **third session** was dedicated to assess which are the capabilities of each observatory and the needs to improve its response capability. Each institution was invited to present a short talk to illustrate the state of the art on several issues concerning VO:

- What facilities, technics and knowhow each observatory can provide?
- What are the areas that need reinforcement in each observatory?
- Are the observatories wiling to organize groups to develop/improve areas of networking?
- How to grow from bilateral cooperation to networking?
- In which circumstances an observatory can be called to support another?

The outcome of this discussion was a synthesis of the present capabilities and needs of each European volcano observatory. The session emphasised that:

- The capabilities of European VOs are quite heterogeneous;
- An effort should be made towards the harmonization of standards among VOs,
- Several portable equipment owned by VOs can be shared under appropriate conditions;
- VOs are receptive to sharing facilities with other VOs under appropriate conditions;
- There is room for efficiency gain with the resources presently available at the VOs ;
- Cooperation should be a common practice under routine situation to potentiate its maximum efficiency under crisis situations;
- Effective cooperation requires building mutual trust between teams;

Importation of scientific expertise into the observatories – State of the art

The **fourth session** was dedicated to keynote talks aiming to overview scientific and technological issues related with the observatory duties and assess the requirements to import those expertise. Main focus was given to:

- Which are the newest developments on scientific and technological issues that can be applied to improve the observatories performance?
- What are the requirements to implement those expertise in the observatories?
- What are the limitations of those scientific and technological expertise?
- How to integrate the new expertise with the installed capability in the observatories?

A wide array of expertise was tapped on this session (see program of the meeting) and several examples illustrated the useful cooperation between scientific and research institutions with VOs. The outcome of this session highlighted that there are valuable resources outside institutions formally commissioned to perform volcano observations. Presently there are already strong cooperation relations between some research institutions and VOs. The development of this type of relations, under appropriate conditions, would be advantageous for all participating institutions.

Strategies to stimulate the cooperation between the observatories - Brainstorming

The **fifth session** was dedicated to promote the cooperation/integration of teams, techniques and know-how among observatories and discuss tangible procedures to implement cooperation. Key issues addressed included:

- What communication channels can be used between observatories?
- What tangible networking activities can be undertaken to improve the capability of each observatory?
- What funding resources can be used to implement networking?

As a result of the discussions it was possible to conclude that VOs are willing to strengthen cooperation to mutual benefit.

Several possible strategies were recognised to enhance cooperation between VOs:

- EPOS infrastructure
- European task force
- Problem oriented project (action limited to a specific timeframe, designed to address a particular problem)
- Laboratory volcanoes/facilities (open VO infrastructure to other partners to perform experiments)
- Bilateral cooperation (long-lasting cooperation between 2 VOs)
- Sporadic cooperation (ephemeral cooperation between partners in the scope of a particular problem)
- Observatory networking (establishment of easy contacts between VOs with the commitment to interact or meet periodically to plan/coordinate joint actions)

Presently there are no formal cooperation agreements between VOs, however informal cooperation is already a common practice between some VOs.

The debate on the various strategies to enhance the cooperation showed that different VOs have different preferred cooperation models.
Not excluding any other arrangements for cooperation, the establishment of networking formal relations between VOs is a consensual procedure to strengthen the cooperation.

Networking can be characterised as:

- Low-cost activity (considering one meeting or one exercise per year);
- Highly cost-effective method (considering no new infrastructures but rather an efficiency gain with the resources presently available at the VOs);
- Light and flexible enough to tackle different problems as they emerge;
- Promote sustained contacts between VOs;

Funding resources to implement Observatory Networking were discussed and two different approaches were considered:

1) No dedicated funding is addressed to VOs cooperation actions;
   a) Any action is dependent on resources available from the VOs budget;
   b) Any action is funded by eventual projects designed to address that action;

2) A dedicated fund is addressed to support VOs cooperation actions;
   a) Annual collection of a fee from the VOs to support a predetermined work plan (e.g. a periodic meeting or an exercise or, if needed, a real action to support an observatory under crisis);
   b) Budget from an external source to support a group of formally associated VOs;

It was consensual that for an effective cooperation and to allow regular collaborations between VOs a dedicated fund is required. Discussions during the workshop pointed to a model based on an annual fee from the VOs as a feasible solution.

3) Assessment of the results and impact of the event on the future directions of the field (up to two pages)

The workshop allowed designing a roadmap to strengthen and formalise the cooperation among VOs. Such plan encompass 3 pillars:

1) **VOs state of the art** - A thorough knowledge of the technical capabilities and legal framework governing each VO (based on the talks presented on the workshop, the online questionnaire, the SWOT analyses from VOs and the questionnaire on resources). This comprise :
    a. a clear understanding of the legal procedures required to establish a formal cooperation agreement among VOs;
    b. an overview of the standards and practices currently approved on each VO;
    c. a comprehensive view of the areas that need further improvement on each VO and the teams that can potentially contribute to that improvement.

2) **Letter of intent –** A document outlining a set of general principles accepted by all VOs. This letter is not intended as a legal bounding instrument but would be the backbone to regulate the relations between VOs and provide the framework to a future understanding. (a draft of these general principles is currently being discussed, revised and improved by VOs)

3) **Memorandum of Understanding** - The construction of a formal agreement between VOs that translates the general principles referred in 2 (this task is the last stage of this roadmap and its accomplishment will require further work)

The present form of the general principles to regulate the relations between VOs is a document addressing 4 areas:

1) Objectives of formal cooperation between VOs
    a) Improve the efficiency of each VO;
    b) Increase the response capability of each VO under crisis via the support from other VOs;
    c) Promote the standardization of techniques and procedures among VOs;

2) General guidelines for relations between VOs in routine situation
    a) Any cooperation formula must accommodate the diversity of legal frameworks that govern European VOs in each country;
    b) Formal cooperation may be established between any number of VOs;
    c) A formal cooperation model should allow the participation of both Volcano Observatories and Volcano Watching Institutions;
    d) Any cooperation model between VOs must not be an unaccounted burden on the budget of each VO;
    e) Effective cooperation between VOs requires mutual trust;
    f) Effective cooperation between VOs requires regular collaboration;

3) General guidelines for relations between VOs in crisis situations
    a) Under crisis, each observatory is responsible for coordinating all visiting teams from other VOs;
    b) Each VO is exclusively responsible for communication with the public and civil authorities regarding crisis on their volcanoes;

c) In the scope of VOs cooperation, each VO is the exclusive accountable institution for any legal liability regarding their volcanoes (under crisis, visiting VOs provide support to the host VO but cannot be held accountable for the response provided to the civil authorities);

4) Consensual initiatives to build trust and strengthen the cooperation among VOs
   a) Exchange visits of VO personnel to promote training and standardization of datasets across VOs;
   b) A program of joint exercises of response to simulated volcanic crises;

The outcome of the workshop is a clear path to strengthen the cooperation among VOs and the momentum to achieve this goal. The foundations to the establishment of a Memorandum of Understanding between the European Volcano Observatories were laid and the work leading to that objective is on progress.

Future steps to accomplish this objective should include:

1. Further debate to finalise de discussion on funding to support cooperation actions (this is a crucial issue because it will determine the cooperation method and the shape of the future Memorandum of Understanding);
2. Designing the terms of a Memorandum of Understanding between European VOs;
3. Decide on an annual work plan t be developed by the adhering VOs.

4) Annexes 4a), 4b) and 4c): Programme of the meeting, full list of speakers and participants and submitted abstracts

Annex 4a: Programme of the meeting

Workshop plan

13th of October

Arrival at Ponta Delgada.
Meeting point at CVARG (Azores University)
Transfer to Furnas (Hotel Terra Nostra Garden)
21:00 to 24:00 - registration and Icebreaker Cocktail

14th of October - 1st meeting day

9:00 - Welcome of participants

9:30 - Volcano observatories, Civil Protection and Local authorities – state of the art

Session dedicated to review the national and regional organisation and policies regarding volcano observatories, civil protection agencies and political authorities.

09:30	Centro de Informação e Vigilância Sismovulcânica dos Açores	Teresa Ferreira
09:45	Icelandic Meteorological Office	Kristín Vogfjörð
10:00	Instituto Geográfico Nacional	Carmen Lopez Moreno
10:15	Institute for the Study and Monitoring of the Santorini Volcano	Georges Vougioukalakis
10:30	Coffee break	
11:00	Osservatorio Vesuviano	Marcelo Martini
11:15	Osservatorio Etneo	Eugenio Privitera
11:30	IPGP - Volcanological and seismological Observatories – Paris Center	Patrick Allard
11:45	Observatoire de Physique du Globe de Clermont-Ferrand	Philippe Labazuy

12:30h - Lunch break

14:00h – 17:30 Volcano observatories, Civil Protection and Local authorities – Brain storming

Brain storming session dedicated to analyse the weaknesses and strengths of the existing formal framework governing the monitoring and surveillance activities as well as the relations between volcano observatories and civil authorities.

16:00h – 16:30 Coffee break

20:00h – Dinner at the hotel

15st of October - 2nd meeting day

9:30h - Cooperation among observatories – State of the art

Session dedicated to assess which are the capabilities of each observatory and the needs to improve its response capability.

09:00	Centro de Informação e Vigilância Sismovulcânica dos Açores	Teresa Ferreira
09:15	Icelandic Meteorological Office	Kristín Vogfjörð
09:30	Instituto Geográfico Nacional	Carmen Lopez Moreno
09:45	Institute for the Study and Monitoring of the Santorini Volcano	Georges Vougioukalakis
10:00	Osservatorio Vesuviano	Marcelo Martini
10:30	Coffee break	
11:00	INGV - Osservatorio Etneo of Catania: capabilities and cooperation during past volcanic crises (the case of the 2002-3 Stromboli eruption) and in the future European observatories networking	Mauro Coltelli
11:15	IPGP - Observatoires volcanologiques et sismologiques	Patrick Allard
11:30	Observatoire de Physique du Globe de Clermont-Ferrand	Philippe Labazuy
11:45	EPOS Project	Giuseppe Puglisi
12:00	WG2	Giuseppe Puglisi

12:30h - Lunch break

14:00h - Importation of scientific expertise into the observatories – State of the art

Session of keynote talks dedicated to overview scientific and technological issues related with the observatories duties and assess the requirements to import those expertise.

keynote talks

14:00	Geochemical monitoring of volcanic fluids in observatories: updated overview	Patrick Allard
14:30	Rocks and minerals as predictive tool for volcanic eruptions – implementation of scientific expertise into the observatories	Valentin Troll
15:00	Characterization of the eruption source term and associated uncertainties	Costanza Bonadona
15:30	Remote sensing of eruptive plumes and integration of scientific expertise into volcano observatories	Franck Donnadieu
16:00	Coffee Break	
16:30	Seismic monitoring and volcanic unrest – implementation of scientific expertise into the observatories	Kristin Vogfjörð
17:00	Volcano Acoustic: state of the art and perspectives	Maurizio Ripepe
17:30	Crustal deformation and magma movements – implementation of scientific expertise into the observatories	Freysteinn Sigmundsson

20:00h – Dinner at the hotel

<u>16th of March - 3nd meeting day</u>

9:00h - Strategies to stimulate the cooperation between the observatories - Brainstorming

Session dedicated to promote the cooperation/integration of teams, techniques and know-how and discuss tangible procedures to implement cooperation.

10:30h – 11:00 Coffee break

13:00h - Final Lunch at Furnas Lake

Transfer to Ponta Delgada
Check-in in The Lince Hotel

Visit to the CIVISA Azores volcano observatory

Annex 4b: Full list of speakers and participants

Name	Country	Affiliation	
Marcello Martini	Italy	Osservatorio Vesuviano	Observatory
Eugenio Privitera	Italy	Osservatorio Etneo	Observatory
Giuseppe Puglisi	Italy	Osservatorio Etneo EPOS Project	
Mauro Coltelli	Italy	Osservatorio Etneo	Observatory
Kristín Vogfjörð	Iceland	Icelandic Meteorological Office	Observatory
José Pacheco	Portugal	Centro de Vulcanologia e Avaliação de Riscos Geológico	Observatory
Gabriela Queiroz	Portugal	Centro de Vulcanologia e Avaliação de Riscos Geológico	Observatory
Teresa Ferreira	Portugal	Centro de Vulcanologia e Avaliação de Riscos Geológico	Observatory
João Gaspar	Portugal	Centro de Vulcanologia e Avaliação de Riscos Geológico	Observatory
Carmen Lopez Moreno	Spain	Instituto Geográfico Nacional	Observatory
Georges Vougioukalakis	Greece	Institute for the Study and Monitoring of the Santorini Volcano	Observatory
Patrick Allard	France	IPGP- Volcano Observatories	Observatory
Maurizio Ripepe	Italy	University of Florence	Stromboli monitoring
Costanza Bonadonna	Switzerland	Université de Genève	University
Valentin Troll	Sweden	Uppsala University	University
Freysteinn Sigmundsson	Iceland	University of Iceland	University
Franck Donnadieu	France	Université Blaise Pascal	University
Philippe Labazuy	France	Observatoire de Physique du Globe de Clermont-Ferrand	Observatory

EVOW meeting
Cooperation among observatories – State of the art

Institute for the Study and Monitoring of the Santorini Volcano
I.S.M.O.SA.V.

presented by G.E. Vougioukalakis
Coordinator of the ISMOSAV Scientific Committee

Santorini Volcano has been in a state of unrest during 2011-2012.

Since January 2011, several (up to ~50 per day) small earthquakes (M<3.5) have been recorded beneath the Santorini caldera. The events were located beneath the Kameni Islands on a NE-SW-striking plane 6 km long, 5 km deep and inclined at 80° to the north. They are interpreted as volcanotectonic in nature, with fault plane solutions that are normal with strike-slip components. The increased seismicity has been accompanied by inflation of the caldera floor, as revealed by GPS and InSAR data. The northern part of Nea Kameni has risen several cm (up to ~15-20 cm of radial extension and vertical uplift). Mogi modelling indicates a pressure source situated at 4-5 km depth , about 2 km north of Nea Kameni. This depth corresponds approximately to that of the magma reservoirs of previous Kameni eruptions (5–7.5 km; from petrological data), suggesting that the inflation source is intruding magma. The source volume increase over 14 months is estimated to be about 14 million m^3. Seismic activity is highest at periods of increased uplift rate, showing a causal relationship between the deformation and seismicity.

There have also been changes in the compositions and circulation patterns of fluids within the Kameni edifice. Fluctuations of sea temperature around the Kameni islands since September 2010 are attributed to increased discharge of hot fluids into the sea. The flux of CO_2 emanating from Nea Kameni has increased since measurements in 1995. Increase of H_2 emissions over the same period are suggestive of increased temperature of deep fluids filtered by shallow aquifers.

Chemical and isotopic analyses of fluids discharged from fumaroles and submerged gas discharges register a significant increase of deep-originated gas species, i.e. H_2, HCl, HF and NH_3. Such a temporal evolution of the fumarolic gas composition was preceded by a significant increase of the CO_2/CH_4 ratios since August 2010, i.e. several months prior the seismic crisis. The whole compositional changes can be interpreted as a induced by a deep heat pulse related to the magma transfer to shallower depths. No SO_2 output from Nea Kameni has been detected.

Magma probably intruded at 4-5 km beneath the caldera at a rate of about 10 million m^3 per yr, but there was no evidence (e.g., ascending earthquake focii, ascending deformation sources, long-period earthquakes) that it is rising to the surface.

A gradual reduction of seismicity levels after February-March 2012, led to pre-crisis seismicity levels after May 2012. Similar results are registered by fumarolic gas composition and soil gas flux. Ground deformation measurements indicate no more inflation, but there is also no deflation pattern. These results lead as to the conclusion that the 2011-2012 unrest is in a waning stage.

An " ***International workshop on the Unrest at Santorini Caldera (2011-2012), Santorini (Greece), 27-28 March, 2012***" was of great help to evaluate the state of the volcano and the efficiency of the monitoring networks. The workshop was cosponsored by the Institute for the Study and Monitoring of the Santorini Volcano, the European Science Foundation (MeMoVolc Research Networking Program), EPOS and the Municipality of Thera.

The same period, the Hellenic "Special Scientific Committee for the Monitoring of Santorini Volcano" addressed an invitation for cooperation to 30 highly regarded foreign scientists, most of which have accepted it with great willingness and without expense for our country. This cooperation includes the availability of measurement data and specialized equipment that the country does not dispose of, the transfer of knowhow and the consultation on volcanic risk management.

The above actions and facts illustrate that both the needs and the necessity for cooperation and networking between Observatories is of great importance and needs to be planed and consolidated on a more stable basis, probably on a "constitutional" European level (Observatories network + special task force?) providing also the indispensable to operate finance.

The work reported in this publication was financially supported by the European Science Foundation (ESF), in the framework of the Research Networking Programme MeMoVolc

The role of the INGV – Osservatorio Etneo in the framework of the national and local Civil Protection organization.

Eugenio Privitera

Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo – Sezione di Catania. Piazza Roma, 2, I95123 Catania, Italy.

The Osservatorio Etneo (OE) is the Catania Section of the Istituto Nazionale di Geofisica e Vulcanologia (INGV). INGV is one of the competence center of the National Department of Civil Protection (NDCP) in the seismic and volcanic sectors and participates to the National Alert System.

The role of INGV inside this complex system is stated in the "framework-agreement" that defines the INGV duties and the amount of the funding, so as to assure *i)* 24/7 seismic and volcanic surveillance, *ii)* the maintenance and development of INGV monitoring systems, and *iii)* the advance of selected research projects that have relevant impact in the Civil Defense activities.

Until the end of 2013, OE is part of a special agreement with the Regional Department of Civil Protection (Sicily has an autonomous statute) that funds the infrastructural activities. Such agreement was made under the coordination of the NDCP and the renewal is now under negotiation.

As regard volcanic cloud monitoring, that in the last years has represented a hazard issue for the aviation activities, OE has drawn up an agreement with civil and military aviation authorities, in order to face the problem in the proper way.

In this framework, the talk will focus on the INGV – Osservatorio Etneo autonomy level and funding mechanisms.

The work reported in this publication was financially supported by the European Science Foundation (ESF), in the framework of the Research Networking Programme MeMoVolc

Operational and near real-time monitoring of the April-May 2010 Eyjafjallajökull ash cloud at the Observatoire de Physique du Globe de Clermont-Ferrand, France

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Laboratoire Magmas et Volcans, Université Blaise Pascal
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The Observatoire de Physique du Globe de Clermont-Ferrand (OPGC) is one of the French Universe Sciences Observatories (OSU) of the National Institute for Universe Sciences (INSU) and the National Scientific Research Centre (CNRS). It must lastly be pointed out that as for the others French volcanological observatories, the Observations systems operated by the OPGC are united under the Service National des Observations en Volcanologie (SNOV, National Service of Observations in Volcanology). Within the SNOV, the HotVolc Observation System, one of the OPGC scientific services, is dedicated to the near-real-time monitoring of thermal anomalies related to the eruptive activity of volcanoes. The main goal of HotVolc deals with estimation of quantitative parameters that give stringent constraints on ash plumes dynamics, from the vent to the atmosphere. Data from HOTVOLC give near –real time monitoring of ash plume, and its height, crucial parameter for predictive models and risk assessment.

HotVolc has been involved in the 24/7 monitoring survey of the April-May 2010 eruption of Eyjafjallajökull volcano (Iceland) and belonged to the French Volcanology Warning Group within the Governmental Center for Operational Monitoring and Alert (CMVOA : Centre Ministériel de Veille Opérationnelle et d'Alerte), at the request of the MEEDDM (Ministry for ecology, energy, sustainable development and sea). The experience of the 2010 eruption of Eyjafjallajökull, made in a crisis mode, showed how, during a volcanic crisis, such a system can provide information in a timely manner for predictive models and risk assessment.

It has to be stressed that this eruption was the first major volcanic crisis that directly involved the French volcanological community, since the 1976 Soufrière de Guadeloupe (Lesser Antilles) eruption. Thus, the Icelandic crisis was the first operational case study in France since more than thirty years and benefited from recent high-technology ground-based or onboard satellite monitoring sensors. Following this, a scientific coordination has been initiated with the creation of a steering committee of the SNOV, one of whose tasks is to organize the scientific research conducted in the French observatories for improving crisis management and risk reduction.

Acknowledgments:
The work reported in this publication was financially supported by the European Science Foundation (ESF), in the framework of the Research Networking Programme MeMoVolc.

EVOW meeting
Volcano observatories, Civil Protection and Local authorities – state of the art

Institute for the Study and Monitoring of the Santorini Volcano
I.S.M.O.SA.V.

presented by G.E. Vougioukalakis
Coordinator of the ISMOSAV Scientific Committee

The **Institute for the Study and Monitoring of the Santorini Volcano (I.S.M.O.SA.V.)** is a non-profit organization, founded in the summer of 1995, whose primary aim is to continue to maintain the operation of the Volcano Observatory and the monitoring networks, which were established under the research program "*European Laboratory Volcanoes*" funded by the E.U. during 1992-1996.
Its main target is the promotion of volcanological research on the island, more specifically how to achieve the most accurate assessment possible regarding volcanic phenomena, and the increased probability of precise forecasting of future volcanic eruption.
The Institute provides Santorini with an integral monitoring system, which aim is to guarantee the timely prediction of a possible volcanic eruption and undertakes the responsibility of disproving any false statements or rumors regarding a negative state of the volcano.
Amongst the founding members, ISMOSAV includes the majority of Greek scientists who participated in the above mentioned E.U. program, members of the Santorini civil authorities and members of the public interested in the volcanic phenomena on Santorini island group.
ISMOSAV is directed by a Board of Directors (7 persons) elected every 3 years by a General Assembly of the members.
The responsibility of the operational efficiency of the Observatory and the monitoring networks and the continuous evaluation of the state of the volcanic field belongs to the I.S.M.O.S.A.V. **scientific committee** in which participate the senior scientists who coordinate the different monitoring sectors and networks (seismic, deformation, physicochemical).
ISMOSAV employs on a permanent basis, one observer, who is accountable for all the scientific equipment and networks and has the responsibility of a first evaluation of the recorded signals.
ISMOSAV is actively supported by the following Institutions:

- University of Thessaloniki
- University of Patras
- Geodynamic Institute of the National Observatory of Athens
- Institute of Geology and Mineral Exploration

There is a permanent cooperation and support in the monitoring efforts from other Universities and research centers as Florence Un., Rome Un., Georgia Tech. et al.
The necessary funds for the operation of ISMOSAV were secured up until 2004 by the following means:

- Own income (selling guidebooks, member fees etc.)
- Ministry of the Aegean
- Prefecture of the Cyclades

- Thira Municipality
- Oia Community

Since 2005 the necessary funds for the operation of ISMOSAV are provided by the Municipality of Thira through its Municipal Companies "Cultural and Tourist Development of Thira" (until 2010) and "Geothira" (from 2011)

ISMOSAV received notable donations back in 1999 and 2001 (total of 58.000 Euro) from the **Piraeus Bank** Group.

There is no legal framework supporting the links between our Observatory and Civil Protection authorities.

During the 2011-2012 Santorini volcanic unrest, a "*Special Scientific Committee for the Monitoring of Santorini Volcano*" was set up in February 2012 by decision of the Minister for Infrastructure, Transport and Networks, under the responsibility of Earthquake Protection and Planning Organization (EPPO). The chair of the committee is the EPPO president, and it comprises 18 members, with a two years term of office. In this committee all of the members of the ISMOSAV scientific committee participate. The presence of a Civil Protection Secretary delegate has been an important link between scientists and state authorities.

The committee objectives are

- Constant monitoring and evaluation of scientific data related to the activity of Santorini volcano.
- Direct opinion and recommendation to the EPPO on the protection measures indicated in each case.
- Recommendation to the EPPO on required measures and actions related to safeguarding the sufficiency and the constant and unobstructed operation of scientific equipment and monitoring instruments, in order for the collection of recordings and data necessary for the monitoring of volcanic activity to be ensured.

The work reported in this publication was financially supported by the European Science Foundation (ESF), in the framework of the Research Networking Programme MeMoVolc

INGV - Osservatorio Etneo of Catania: capabilities and cooperation during past volcanic crises (the case of the 2002-3 Stromboli eruption) and in the future European observatories networking

Mauro Coltelli – INGV Osservatorio Etneo, sezione di Catania, Pizza Roma 2, 95123 Catania, Italy

Osservatorio Etneo, the Catania section of Istituto Nazionale di Geofisica and Vulcanologia (INGV) recovers the name of the first volcano observatory created in 1881 to study the activity of Mt. Etna, the Regio Osservatorio Vulcanologico Etneo, and continues to carry on the volcano monitoring started 130 year ago.
In the last decade after the reorganization of the Italian public research institutions working on earthquake and volcano monitoring, merged into INGV in 2001, the Catania section has enhanced its capabilities in both monitoring and studying the volcanic activity of the Sicilian active volcanoes located in mainland (Etna), Aeolian Islands (Stromboli, Vulcano, Lipari and Panarea) and in the Sicily Channel (Pantelleria and Ferdinadea/Graham bank).
Presently the seismic network covers all Sicily and its minor islands, and is more dense on the most active volcanoes: Etna, Stromboli and Volcano. The geophysical network includes the volcanoes ground deformation (GPS, tiltmeter, other devices), gravimetric and magnetic stations, and the geochemical monitoring of the volcanic plumes. All data are transmitted continuously to the Control Room in Catania where both real-time and off-line processing is performed by scientific and technician personnel that operate 24/7 the surveillance of the pre-eruptive phenomena recorded. The volcano monitoring is completed by a multiband video-surveillance network that together with the instruments for volcanic ash detection, ground (Lidar, Radar, other devices) and satellite (imagery) based, permit to report in quasi real-time the main features of the explosive and effusive activity also for initializing the numerical modelling of these phenomena. In particular due the impact on the air traffic operations of the airports located near the Etna volcano, the numerical simulation of the ash dispersal in atmosphere is forecasted daily for the next 48 hours to be immediately evaluable for air traffic controllers in case of a paroxysmal explosive event.
Since INGV birth, we experienced some volcanic crises at Etna (2001, 2002, 2006, 2008, 2011-13) but only the 2002-3 eruption of Stromboli that produced the unexpected flank collapse of Sciara del Fuoco and caused a tsunami, has been addressed in unison by all the INGV sections in collaboration with some university departments, the Italian military and rescue corps, under the coordination of the national Civil Protection Department. This experience allowed us to maturate the capability of interact during a crisis with both the scientific community and the Civil Protection authorities that ask us for a daily synthesis of the volcanic phenomena monitored from the different components of the scientific community (INGV and universities groups) allowing them to take the most appropriate decisions to prevent and mitigate the damages to the population and to forecast the crisis development. Stromboli crisis practice can be useful for organizing interactions and cross supports among the European volcano observatories in case of future large impact volcanic crises.
The Osservatorio Etneo contribution to the future European observatories networking should be focused on our experience on the volcano monitoring of basaltic explosive and effusive eruptions, furnishing instruments (mobile networks) and computer codes for processing collected data and forecasting eruptive scenarios. An expert task force to support large impact volcanic crises outside Italy is in preparation at INGV including specialists from all groups of the just set up Volcanic Department of INGV and in particular from Osservatorio Etneo and Osservatorio Vesuviano that are the facilities

dedicated to the volcano monitoring in Italy.
Since volcanic crisis have normally a regional impact only particular phenomena, as the widespread ash clouds, could be addressed in a continuous coordinated manner in the EVO framework, to support all observatories in both the techniques to monitoring the explosive eruptions and the capability to detect the ash cloud far from the source in collaboration with the meteorological observatories.

The work reported in this publication was financially supported by the European Science Foundation (ESF), in the framework of the Research Networking Programme MeMoVolc'

Volcano monitoring capabilities of the Remote sensing Pole at the Observatoire de Physique du Globe de Clermont-Ferrand, France

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The Observatoire de Physique du Globe de Clermont-Ferrand (OPGC) presents a unique capability for the tracking of volcanic plumes taking advantages of both volcanology and atmospheric science skills. These competences lie on the mastering of both Lidar and radar techniques particularly, as well as in-situ and airborne gases and aerosols measurements by the Laboratoire de Météorologie Physique (LaMP, OPGC). Besides, the Laboratoire Magmas et Volcans (LMV, OPGC) has a first-rate expertise in eruption dynamics and satellite and ground-based ash cloud monitoring from thermal infrared measurements particularly. The synergy between both laboratories is unique in France, and allows unprecedented broad range measurements on a volcanic ash cloud. Operating capability of this monitoring platform is also the result of technical support and expertise of the OPGC staff.

In this framework, the remote sensing group of LMV-OPGC completed an unprecedented multiparametric experiment at Stromboli volcano (Eolian islands, Italy) during Sept. 27 – Oct. 7, 2012 to (1) characterize explosive eruption dynamics at the highest possible spatio-temporal resolution, with the aim of quantifying the emitted products and to better understand the processes that control the emission and ascent of volcanic plumes; and (2) test the combined deployment of a complete geophysical instrument package, and evaluate its potential for operational ash plume tracking. The objective was to set up a true pluri-disciplinary approach that properly integrates the full range of textural, geochemical, geophysical and remote sensing approaches currently available to us so as to achieve the tightest possible constraint on all source terms parameters during an explosive eruption. Our approach here incorporated ultraviolet, visible, infrared and radar data, with standard geophysical measurements also being combined along with gas chemistry and textural analysis. Such a system designed to provide data for volcanic plumes needs to deliver quality data in real-time, if it is to be of use in a hazard response, projection and assessment role. Our system is fully operational, and potentially deployable in less than an hour by a trained field crew, with software development underway to allow real-time data processing with a special emphasis on provision of source terms.

At the French level, following the recommendations of the Scientific Committee of the Service National des Observations en Volcanologie (SNOV, National Service of Observations in Volcanology), in 2012, the French volcanological community should be aware of that the National Institute for Universe Sciences (INSU) has concerns in helping management of volcanic crisis. This could be achieved by the creation of a National Committee which will be competent to advise the authorities in case of volcanic crisis. This committee should have a permanent contact with Civil Protection and may further encourage cooperation with and operational supports to the others European volcano observatories.

Acknowledgments:

The work reported in this publication was financially supported by the European Science Foundation (ESF), in the framework of the Research Networking Programme MeMoVolc.

Rocks and minerals as predictive tool for volcanic eruptions; an example from Krakatau volcano

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Crustal contamination of ascending arc magmas is generally thought to be a significant process the lower to mid crustal levels only, where magmas inherit their isotopic character by blending, assimilation and differentiation (e.g. Annen et al. 2006,). Anak Krakatau, like many other volcanoes, erupts shallow-level crustal xenoliths (e.g. Mandeville et al., 1996, Gardner et al. 2012, Troll et al., 2013), indicating a potential role for upper crustal modification and hence late-stage changes of magma rheology and thus the potential eruptive behaviour. To distinguish deep vs. shallow crustal contamination processes at Krakatau and elsewhere is therefore crucial to allow for a useful assessment of pre-eruptive magmatic conditions of active arc-type volcanoes and the associated hazard potential. Here we report on a multi-disciplinary approach to unravel the crustal plumbing system of the persistently active and dominantly explosive Anak Krakatau volcano (Fig. 1; Dahren et al. 2012, Gardner et al. 2013), employing rock-, mineral- and gas-isotope geochemistry and link these results with seismic tomography (Jaxybulatov et al. 2012).

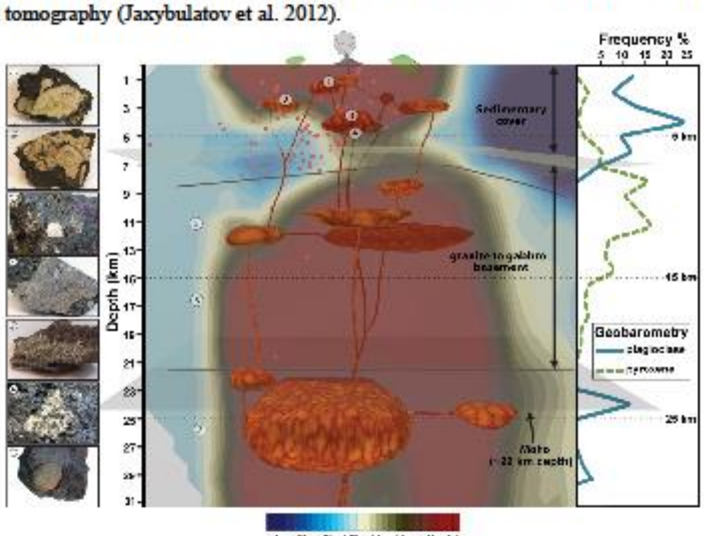

Figure 1. 3D model of Anak Krakatau plumbing system based on seismic tomography (Jaxybulatov et al. 2011), xenolith stratigraphy (Gardner et al. 2013) and plagioclase and pyroxene mineral melt barometry (Dahren et al. 2012).

We show that pyroxene crystals formed at mid- and lower-crustal levels (9-11 km) and carry almost primary isotope signatures (O, Sr, Nd, He), while feldspar crystals form dominantly at shallow levels (< 5km) and display unequivocal isotopic evidence for late stage contamination (Fig. 2; O, Sr, Nd). This observation places a significant element of magma-crust interaction into the uppermost, sediment-rich crust beneath the volcano. Magma storage in the uppermost crust can thus offer a possible explanation for the compositional modifications of primitive Krakatau magmas that likely provides extra impetus to temporarily increased explosivity at Anak Krakatau.

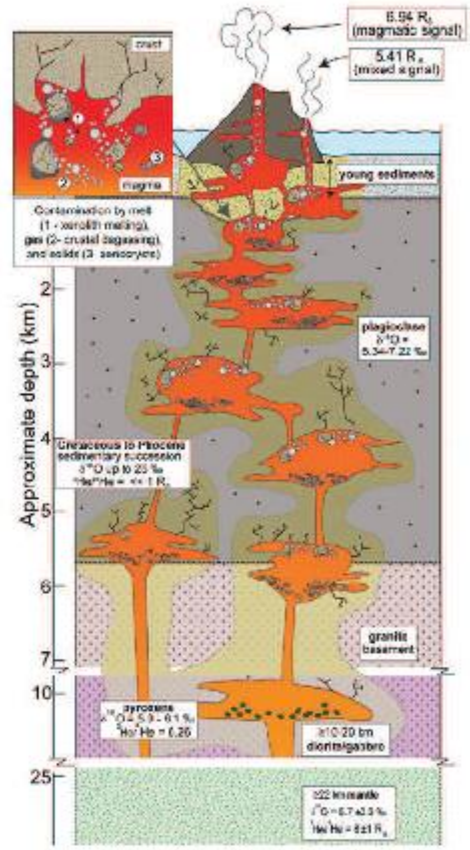

Figure 2. Schematic Anak Krakatau plumbing system. Magma ascent is slowed down in the mid crust (9-11 km), where the main crystallisation of pyroxene takes place, which carries a mildly contaminated, isotope signature. In the top 4-6 km of the local crust, magma encounters Cretaceous to Pliocene sedimentary strata of the Sunda Strait. Temporary magma storage and interaction with the sedimentary crust is documented by seismic tomography, mineral barometry, isotope variations in plagioclase crystals (Sr, O), and by the extensive xenolith record in the erupted lavas of both, the Anak Krakatau as well as in the 1883 products.

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Acknowledgments

The work reported in this publication was financially supported by the European Science Foundation (ESF), in the framework of the Research Networking Programme MeMoVolc.

New strategies for estimating erupted volume, determining mass flow rate and classifying explosive eruptions

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The characterization of the source term is crucial to the understanding of volcanic explosive eruptions, to the real-time forecasting of the spreading of the associated clouds and to the long-term assessment of their impacts. In particular, erupted mass, plume height, mass flow rate and initial grainsize distribution are all fundamental physical parameters that need to be determined in order to describe an explosive event. Strategies for quantifying these physical parameters might differ whether they need to be estimated in real-time or for long-term hazard assessments and might be characterized by different levels of uncertainties. Here we present various strategies for the characterization of the source term and propose a new empirical method for the calculation of tephra-deposit volumes that is based on the integration of the Weibull function. The new method shows a better agreement with observed data than existing strategies, reconciling the debate on the use of the exponential versus power-law method. In addition, we show how values of the largest lithics versus square root of isopleth areas can also be well fitted with a Weibull function and how plume height correlates strongly with corresponding Weibull parameters. Weibull parameters derived for both the thinning of tephra deposits and the decrease of lithic diameter with distance from vent can then be combined to classify the style of volcanic eruptions. We also introduce a novel analytical expression that allows for fast assessment of mass flow rate of both vertically-rising and bent-over volcanic plumes as a function of their height and that accounts for the effect of wind. This relationship is compared with a one-dimensional plume model to demonstrate its flexibility and validated with observations of the 1980 Mount St. Helens and of the 2010 Eyjafjallajökull eruptions. The influence of wind on the dynamics of volcanic plumes is quantified by a new dimensionless parameter and it is shown how even vertically-rising plumes, such as the one associated with the Mount St. Helens 1980 eruption, can be significantly affected by strong wind. This new expression has important implications both for current strategies of real-time forecasting of ash transport in the atmosphere and for the characterization of explosive eruptions based on the study of tephra deposits.

The work reported in this publication was financially supported by the European Science Foundation (ESF), in the framework of the Research Networking Programme MeMoVolc

Remote sensing of eruptive plumes – implementation of scientific expertise into volcano observatories

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Ash plumes can adversely affect population and infrastructures surrounding active volcanoes and cause direct hazards to aviation and severe economic costs, as highlighted by the 2010 eruption of Eyjafjallajökull. Volcanic ash transport and dispersion models are used to forecast the extension and movement of ash clouds over hours to days in order to mitigate risks. Parameters needed in inputs are location of the vent, eruption duration, column height, mass eruption rate, total grain-size distribution at the vent, vertical distribution of the mass in the column and mass fraction of fine ash. The source term, usually based on scenarii determined from past eruptions, is frequently unconstrained in the first moments after the eruption onset, and also changes during an eruption, requiring rapid reevaluation. Hence the strong need for real-time validated measurements and enhanced exchanges between modelers and remote sensing community.

Although field observations and common geophysical methods remain essential, there is a high synergetic potential of integrated remote-sensing techniques for ash plume monitoring and eruptive parameter quantification. One the one hand, ground-based techniques such as transportable Doppler radars and infrared cameras help to constrain the source term by pointing at the source and measuring at-vent kinetic and mass loading parameters at high rate (ejection velocities, mass fluxes, particle sizes). In certain cases fixed weather radars with various characteristics (polarimetric, Doppler, dual frequency, etc) may opportunely provide volumetric scans of the ash plume over a few tens of kilometers from the vent, leading to characterize the mass transport rate of volcanic particles in the atmosphere and column height. Disdrometers (micro rain radar or laser) may help monitor fallout, through measurements of particle fall velocities and sizes, to be cross-validated by data from ash collectors and tephrostratigraphy. On the other hand a number of techniques, in particular infrared satellite imagery and lidars, allow measurements inside the distal part of ash clouds (tens to hundreds of kilometers), providing size, concentration, mass and optical thickness of micron-scale particles in the atmosphere, along with the SO_2 mass.

Among these techniques, a number can be deployed quickly and help local observatories in volcano monitoring during a crisis. Sharing of technical and scientific expertise should be promoted, along with observatory staff training at modern techniques implemented at active volcanoes. Other perspectives include (i) coupling of geophysical, remote sensing and field observations on targeted field sites, (ii) more inter-calibration of techniques to validate inferred eruptive parameters, (iii) strengthened integration of volcanological data from existing instruments, particularly those used in meteorology, like weather radars (e.g. the Opera network in Europe, airport radars, etc.) or lidars (e.g. Earlinet), (iv) development of multi-sensors instruments, and (v) creation of a European pool of remote-sensing and geophysical instruments potentially available for quick deployment during a volcanic crisis. The instrument capacities and limits should be listed, and the conditions for their deployment further investigated.

Acknowledgments:
The work reported in this publication was financially supported by the European Science Foundation (ESF), in the framework of the Research Networking Programme MeMoVolc.

Volcano Acoustic: state of the art and perspectives

Maurizio Ripepe

Volcanoes are quite a prolific radiator of infrasonic waves (<20 Hz). Gas rapidly expanding in the atmosphere produce infrasound providing valuable insights into eruption dynamics. Linear theory of sound explains acoustic pressure in terms of mass flow rate and this has strong implications for explosive dynamics. According to the explosive mechanisms acoustic waves can be modeled as a monopole, dipole or quadrupole source, each with a different wave field directivity and velocity of the outflow mass. Large explosive volcanic eruptions typically generate a plume of hot ash and debris ejected into the atmosphere and inducing pressure perturbation with frequency content ranging from 0.1-4 Hz down to 1-2 mHz typical of gravity waves. These waves can be recorded thousands of kilometers away by distant stations. At distances of few km acoustic wavefield can be used to track the ash plume evolution providing the time history of the excess pressure and reflecting the explosive gas emission. This information could be used as input parameter in the simulations of the ash cloud dispersal in the atmosphere and could contribute to a correct risk assessment for civil aviation. Infrasound can be generated also by non-explosive non-point sources such as pyroclastic flows, providing crucial information to volcano monitoring and risk management. Volcano acoustics integrated with other geophysical measurements, particularly seismic, may assist with their interpretation leading to important understanding of the volcano dynamics.

The work reported in this publication was financially supported by the European Science Foundation (ESF), in the framework of the Research Networking Programme MeMoVolc

Understanding crustal deformation patterns at volcanoes: Constraints on volcano behaviour from inflation/deflation patterns and modelling – examples from Iceland

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Understanding of the magmatic plumbing system of volcanoes is a key feature for the forecasting of eruptions and their behaviour. In the very simplest cases, an eruptive cycle is comparable to a simple version of the earthquake cycle, with gradual build-up of stress in the roof a magma chamber until a critical limit is reached, followed by an intrusion or eruption associated with drop in magma pressure. If magma flow from depth to a magma chamber is constant and the failure criterion remains constant, this process may be repeated in a cyclic manner, associated with gradual inflation due to magma accumulation in a magma chamber, followed by sudden deflation as pressure in the magma chamber drops. Seismicity is a primary indicator of the state of a volcano and can reveal stress increase associated with magma accumulation. Crustal deformation measurements through repeated geodetic measurements are though needed to estimate the scope and volume of magma flow. In Iceland, such measurements have revealed the inflation/deflation pattern of a number of Icelandic volcanoes, including Krafla, Askja, Grimsvotn, Hekla, Katla and Eyjafjallajokull. The measurements include GPS, InSAR, optical leveling, tilt and borehole strain. Extensive measurements and long time series of deformation reveal a more complicated behaviour than the simple model explained above. Some of the deviations from this model include: i) Recharging of volcanoes may not take place through magma flowing into a single chamber but rather into separate intrusions, ii) Magma flow from depth to recharging magma chambers is variable and episodic, iii) Effects of tectonic stress and host rock strength are variable and evolve through multiple eruptions and intrusions, iv) Compressibility of magma varies so the relation between surface volume change and the volumetric flow of magma is variable, v) inflation/deflation may relate to other processes than magma flow. Evaluation of the state of a volcano requires thus a detailed monitoring program including geodetic measurements, in conjunction with careful modelling of the magmatic plumbing system and volcano behaviour.

The work reported in this publication was financially supported by the European Science Foundation (ESF), in the framework of the Research Networking Programme MeMoVolc