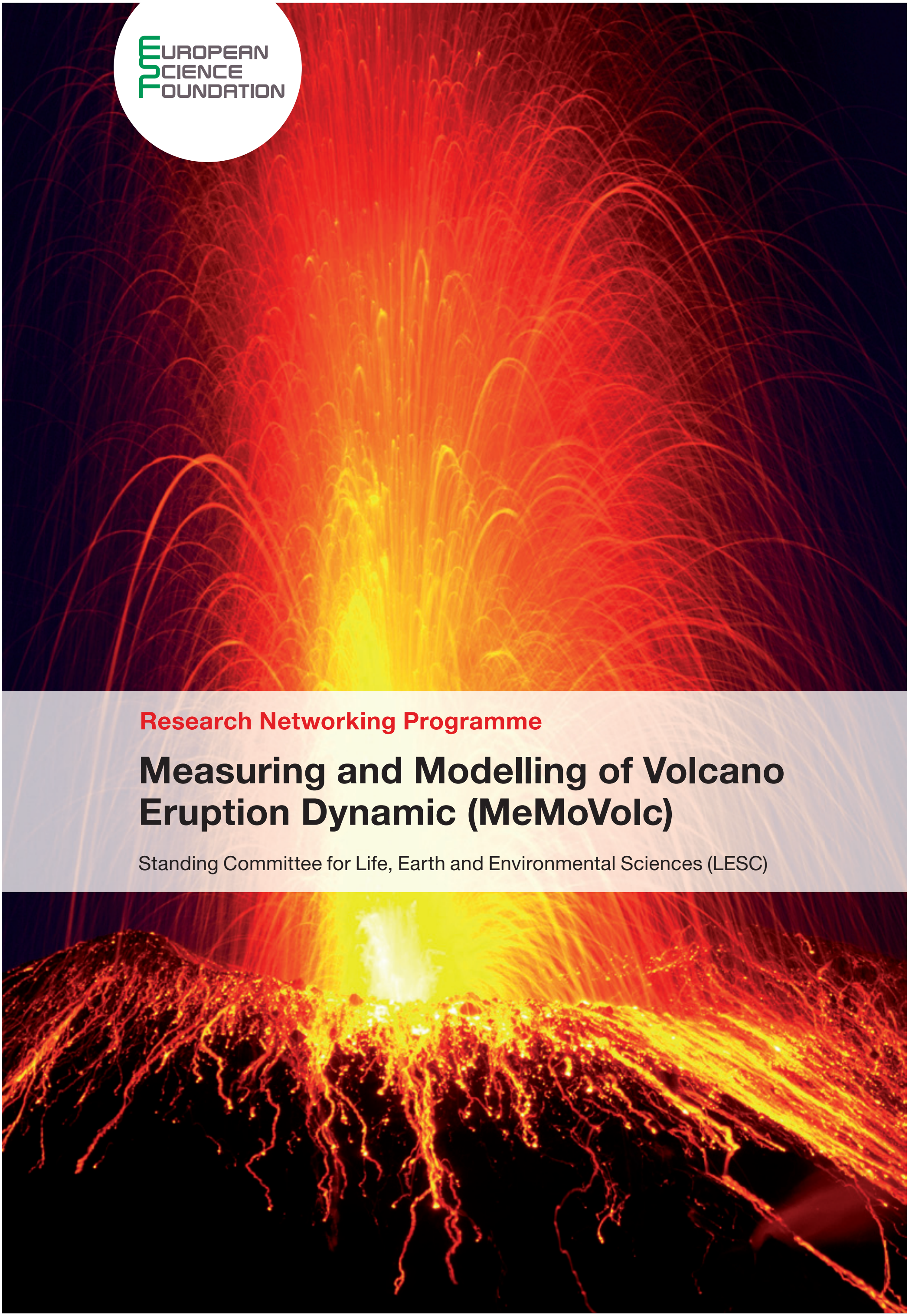


Research Networking Programme

Measuring and Modelling of Volcano Eruption Dynamic (MeMoVolc)

Standing Committee for Life, Earth and Environmental Sciences (LESC)

Europe is host to about 50 historically active volcanoes, many of which threaten populated areas and air traffic routes. Effective management of volcanic crises, and mitigation of the associated risk, requires combining high-quality data from volcano observatory monitoring systems with sound understanding of the physics of eruptive and pre-eruptive processes, without which interpretations of monitoring signals remain empirical. While the monitoring networks on many European volcanoes are highly sophisticated, understanding of volcano physics is still in its infancy. Erupting volcanoes are highly complex systems (multiphase magmatic fluids, high-temperature transonic flow in conduits and atmospheric plumes, multiple behavioural regimes) that present huge challenges to scientists set on quantitative understanding. This area of research has been transformed in recent years by the development of powerful computer codes that allow the nonlinear physics of eruption dynamics to be explored, as well as innovative new ways of measuring quantitative eruption parameters on active volcanoes and eruption products. However, full predictive capacity and real-time forecasting remain distant targets.

The MeMoVolc research network involves top-level researchers from research organisations and volcano observatories across Europe. It brings together specialists from different research domains (geophysics, geochemistry, volcanology, remote sensing, petrology, mathematical modelling) in order to tackle fundamental problems of volcano eruption dynamics synergistically at the interfaces between traditional disciplines. It will forge collaborations, share resources and build international working groups through scientific workshops and inter-laboratory mobility. It will also communicate trans-disciplinary concepts and approaches to young scientists through a series of innovative summer schools. Training courses will be published first online for free access, then as a textbook.

The running period of the ESF MeMoVolc Research Networking Programme is five years, from June 2011 to May 2016.

Scientific Background

Scientific context

Volcanoes can switch rapidly from dormancy to eruption, and from one eruptive regime to another, with potentially catastrophic consequences. In order to provide accurate, real-time expertise for risk mitigation, volcanologists need to understand not only the fundamental processes governing different eruption states, but also the signals or behavioural patterns indicative of impending regime transitions. The ability to use measurements and models to understand physically what is happening within the volcano, and hence to be able to anticipate changes in eruptive regime in near-real-time, is one of the principal aims of modern volcanology.

Volcanic activity is governed by processes occurring in the reservoir, conduit and plume, with complex feedbacks. The magma reservoir exerts a strong influence on eruption state through changes in pressure and in the physical properties of magmas extracted. As magma ascends through the conduit, dissolved gases exsolve to form bubbles; the magma vesiculates, then fragments explosively into a spray of gas-entrained particles. The gas phase is the motor of explosive volcanic activity, and its behaviour is central to understanding eruption dynamics. The rate at which gas is able to segregate from ascending magma is a major factor governing the effusive-explosive transition. Outgassing raises magma viscosity and drives crystallisation, forming rheologically stiffened plugs that can fail suddenly in transient explosions. Eruption plumes are advected far from the vent by high-level winds, the particles falling out to form tephra deposits. The physics of volcanic plumes are only partially understood, and there is a need for better information on the physical parameters governing their behaviour. Scaling laws for plume ascent are needed in order to reliably invert plume measurements and infer source parameters. We also need to understand better how plumes interact with mesoscale and global atmospheric motions in the far field, so as to improve models of plume dispersal relevant to aviation hazards.

The tools available

Advancing our understanding of volcano eruption dynamics requires combining the wide range of tools available to the network programme.

The increasing use of remote sensing technologies in volcanology has transformed our ability to make measurements on active volcanoes of the quality and number needed to test models. Many of these techniques have sampling frequencies of 1 Hz or more, allowing us to capture the details of even transient explosions, and in some cases the speed of data processing is approaching near-real-time. Ground-based techniques such as high-speed infra-red and ultra-violet imagery, infrasonic arrays and microbarometers, Doppler radar, differential optical absorption spectroscopy (DOAS), ultra-violet cameras and open-path Fourier transform infra-red spectroscopy provide information on a wide range of eruption parameters such as eruption speed, particle mass loading, discharge rate, gas content and gas composition. Remote sensing from satellites enables us to track plumes over large distances and extract heights, particle and gas loadings and geometric parameters for input into plume dispersion models. Volcano observatory monitoring networks have greatly increased in sophistication, with dense arrays of highly sensitive broadband seismometers, gravity and magnetic stations and deformation sensors.

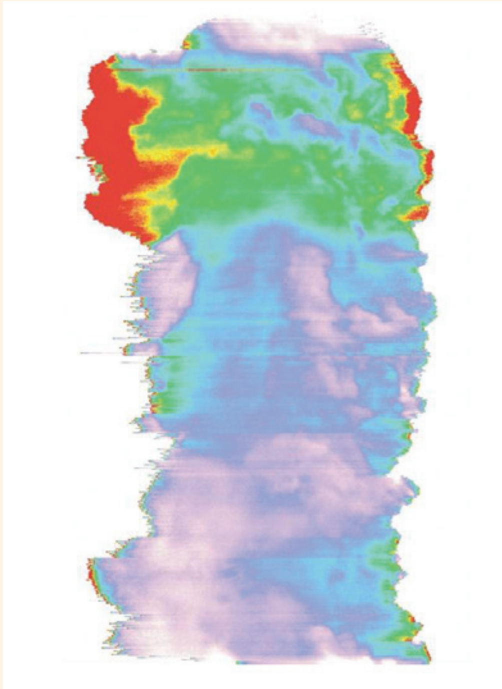
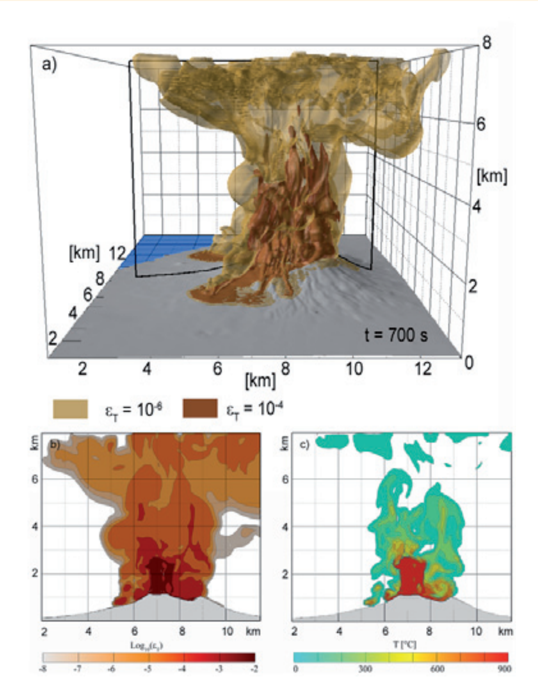


Figure 1. Three means of imaging an eruption plume. Left. Photo of an explosion of Soufrière Hills Volcano, Montserrat, in 1997. Middle. Ash distribution in a plume from Santiaguito Volcano, Guatemala, measured using ultra-violet imagery. Right. 3D numerical simulation of a partially collapsing eruption plume at Vesuvius.
Images courtesy of (left to right) T. Druitt (France), M. Watson (UK) and A. Neri (Italy)

Measurements of eruption parameters are also made by quantitative analysis of eruption products. The dispersal and grain size of tephra deposits are used to estimate plume heights and mass fluxes by model inversion. Cooling of particles through the liquid-glass transition ‘locks in’ a range of physical and chemical parameters that can be measured by microbeam analysis and used to probe conditions inherited from the reservoir and conduit. Sub-micron-resolution tomography allows 3D quantification of sample textures, and reconstruction of bubble and crystal nucleation/growth histories.

High-temperature laboratory experiments allow measurements to be made on samples of natural magma, such those pertaining to magma rheology, vesiculation, crystallisation and fragmentation. Phase-equilibria experiments are used, along with petrological characterisation of natural samples, to constrain pre-eruptive conditions of pressure, temperature and volatile content. Analogue experimentation allows us to derive phenomenological laws and scalings governing conduit flow and volcanic plumes.

Mathematical and numerical models range from approximate theoretical analyses to highly complex numerical codes of multiphase flow in reservoirs,



conduits, plumes and pyroclastic flows. Multiphase codes are now passing from 2D to 3D, opening up new possibilities in simulation capability, and models linking conduits to plumes, and plumes to large-scale atmospheric motions, are now being developed.

Objectives

The networking programme will:

- Forge collaborations and build international and trans-disciplinary working groups through scientific meetings and mobility between laboratories and observatories;
- Tackle fundamental problems of volcano eruption dynamics synergistically at the interfaces between traditional disciplines;
- Combine diverse measurement capabilities in multi-parameter analyses of eruptions, and work to generate the necessary theoretical and experimental frameworks for extracting quantitative eruption parameters from field and laboratory measurements with increasing accuracy and temporal resolution;
- Build physically robust eruption models, using increasing computer power to move to 3D, benchmark laboratory experiments and improved theoretical treatments to validate the component physics, and multi-parameter datasets to seek first-order consistency between models and measurements;
- Communicate trans-disciplinary concepts and approaches to young volcano scientists, making them aware of the rich possibilities available to them.

Activities

Participation in MeMoVolc activities will be subject to open call on the websites www.esf.org/memovolc and www.memovolc.fr.

Short and exchange visits

Scientific travel grants for short and exchange visits between laboratories and volcano observatories for the purposes of networking on specific projects. Travel grants will form the backbone of the network by building collaborations and sharing data, resources and analytical, computational and monitoring facilities. About 10-15 scientific visits will be funded per year.

Conferences and special sessions at international meetings

These will form the platform for exchanging ideas and creating collaborative working groups. Two major conferences are planned for the lifetime of the network:

- 'Measuring and modelling volcano eruption dynamics 1' (Clermont-Ferrand, France, January 2012). The aim of this initial strategic conference is to launch the network, identify key scientific objectives, set up working groups, and plan practical details of networking campaigns.
- 'Measuring and modelling volcano eruption dynamics 2' (spring 2016). This closing conference will act as a forum for the presentation of the programme's achievements.

Workshops

Workshops will bring together small groups of experts in order to focus on a specific issue or scientific question.

Figure 2. Explosive fragmentation of magma in a high-temperature laboratory experiment.
Image courtesy of B. Zimanowski (Germany)

Summer schools

These will be problem-based, trandisciplinary, and will involve looking at a given system from different perspectives and using different methods. They will be aimed at researchers at PhD and postdoctoral levels, and will involve round-table brainstorming initiatives on specific cutting-edge problems. Three summer schools are planned:

- 'Volcanic ash: from magma to aviation impact' (Catania, Italy, 2012)
- 'Magmatic volatiles: from reservoir to atmosphere' (2013)
- 'Volcanic unrest: linking subsurface physical processes to surface signals' (2014)

Publications

- Special issues of journals resulting from conferences and workshops
- Summer school courses made available online for free access
- A graduate-level textbook on techniques in modern volcanology

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Figure 3. Studying a lava lake in Hawaii by infra-red imagery.
Image courtesy of A. Harris (France)

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For the latest information on this Research Networking Programme consult the MeMoVolc websites:
www.esf.org/memovolc
www.memovolc.fr

Cover picture:
Eruption of the volcano Stromboli by night.

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