ANNALS of GEOPHYSICS

[Special Issue_56_04_2013]

Vesuvius monitoring and knowledge: state of the art and perspectives.

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PREFACE

ARTICLES

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Mt. Vesuvius is one of the most hazardous volcanoes in the world, due to the highly populated surrounding area, where more than 800,000 people live. It experienced various regimes of eruptive activity, from effusive to Plinian. Its last eruption, a mild effusive event, occurred on March 1944. After that the volcano started a period of quiescence, characterized by low seismicity, low deformation pattern, widespread fumaroles emissions accompanied by diffuse CO_2 degassing in the crater area and CO_2-rich groundwater along the southern flank and in the adjacent plain. Despite the low level of activity, Vesuvius is one of the best-monitored volcanoes in the world. During the last decades many researchers have been involved in the volcano monitoring, covering a wide range of topics, in order to discover any signals that could contribute to understand the volcano dynamics. However, in spite of so much effort, an exhaustive comprehension of the volcano system, aimed at a reliable prediction of the future activity, is far from having been reached. On the other hand, the fast technological evolution makes new instruments and methodologies available for a more sensitive monitoring in the future.
The objective of this special issue, that appears 70 years after the last eruption, is to draw a precise picture of the state of the art about the monitoring of Vesuvius volcano, with detailed description of instruments, tools and methods used in the past and at present, the results achieved, and new ideas to develop in the future.
Thanks to the researchers that submitted their contributions, this special issue of Annals of Geophysics provides a more comprehensive picture of the Vesuvius status, its monitoring system, the current knowledge and the most innovative techniques currently applied and to be further developed in the near future. In particular, contributions are presented on the recent developments and open problems related to Mt. Vesuvius monitoring, from *in-situ* methods – such as seismic, geodetic and geochemical networks, geochemical survey – to remote sensing methods. The arguments treated in the various contributions cover a wide range of topics as briefly described below.

The most common precursors of volcanic eruptions recognized worldwide regard seismicity, ground deformations and increase and variations of gas emissions, while other anomalies such as ground temperature, electric, magnetic and gravity variations, have also been observed but are less documented. A continuous monitoring of any geophysical and geochemical parameters is therefore necessary for a high risk volcano, and it is currently realized at Mt. Vesuvius. Inside the special issue, one may found contributions describing the monitoring networks and the scientific results obtained from such advanced networks. The seismic monitoring network of Mt. Vesuvius is described by Orazi et al. The station distribution provides appropriate coverage of the area around the volcanic edifice, allowing for the location of seismic events with $M<1$. The real time broadcast of seismic data to the monitoring center of the Osservatorio Vesuviano (Istituto Nazionale di Geofisica e Vulcanologia) dates back to 1972. Therefore a detailed catalog of local earthquakes during the last 40 years is available, and it is the starting point for many detailed studies. A deep insight into the main features of the recent seismicity of Mt. Vesuvius, with particular emphasis on the period 1999-2012, is furnished by D'Auria et al. Two main seismogenic volumes inside the volcanic edifice have been recognized: one with hypocenters clustered below the Mt. Vesuvius crater at depths mostly between 1-6 km, and another, shallower, with hypocenters clustered within the Gran Cono.
The energy transported by hydrothermal fluids and dissipated by hot soils generally represents a main term of the total energy released from quiescent volcanoes. The monitoring of the thermal energy release through the IR automatic system, which operates at Vesuvius, and its technical evolution furnish a suitable tool for volcanic surveillance. Sansivero et al. describe the first results obtained by this evolution of the IR automatic system. Granieri et al., on the base of a measurement campaign of CO_2 soil diffuse degassing from the cone of Vesuvius, and comparing the data with those of a previous study, estimate the total budget of CO_2 released by diffuse degassing and describe the relationships with the main geologic structures.
Beside the eruptive phenomena, other causes may increase the hazard in volcanic environments. Among these,

floods and mudflows produced by heavy rain exacerbated by unconsolidated volcanic material constitute the highest risk at a number of volcanoes worldwide. A thorough and highly useful compilation of past rainfall data and related hazard for the Somma-Vesuvius region, represent a preliminary approach to mitigate the hazard posed by rain-induced floods (Alessio et al.).
The ground deformation topics are broadly described. A detailed description of the monitoring by classical leveling methods carried out for almost four decades is provided by Pingue et al., who describe also the year by year enlargement of the monitoring circuits. They observe that Vesuvius area is affected by a general subsidence that becomes more significant at the center of the volcano. The Somma caldera rim seems the limit between two zones with different subsidence velocities. Since the leveling measurements give information only about the elevation, several tiltmeters were installed on the volcano flanks to fill, at least partially, the gap left by leveling measurements (Ricco et al.). When the new GPS technology became available, a permanent GPS network was established, and now it ensure a continuous monitoring of the 3D ground deformations (Tammaro et al.). Results of GPS measurements carried out during the last decade indicate that Somma-Vesuvius is affected by a predominant slow contraction phase in the Gran Cono area. The analysis of ground deformation data collected during the last four decades by different methods indicates that Mt. Vesuvius is not affected by ground deformations attributable to magmatic sources. The interpretation of ground deformations is not a trivial matter, and its comparison with theoretical patterns is important to establish the expected deformations in case of future re-awakening of the volcano. Amoruso and Crescentini describe a method for estimating the volume change and the corresponding superficial displacements of a finite pressurized ellipsoidal source immersed in an elastic medium. They present equations not available in the common scientific literature, that can be implemented in computer codes.
Tightly related with ground deformations are the observations of the gravity field and its variations. An important contribution to our understanding of Mt. Vesuvius has been furnished by the 30 year high precision gravity measurements on the volcanic system (Berrino et al.). The extremely comprehensive gravity data set has allowed for both spatial and temporal analysis of changes that, without the baseline data, may have been misinterpreted as precursors of renewed eruptive activity. The fact that gravity changes cannot be easily explained by the deformation signal and therefore are better supported by fluid migration is an important contribution.
Di Maio et al. describe how the natural electric field pattern under the volcanic edifice showed significant variations in conjunction with the last active seismic tomography survey (Tomoves experiment).

Studies on the seismic waveform features allow for a better knowledge of both the dynamics related with the hydrothermal system, as well as of the volcanic structure. Many active volcanoes show seismic signals different from "classical" shear failure earthquakes. Cusano et al. (*The first Long Period earthquake...*) describe detailed analysis of the first local seismic event classified as LP earthquake, recorded by the local network in 2003. The classification of seismic events may be a demanding task for seismologists, particularly when the seismicity rate is high (e.g. hundreds of events per day). Fortunately modern software can provide a great help in such cases, as pointed out by Esposito et al., who describe the most advanced automatic analysis of seismic data based on neural network, able to recognize and classify many kinds of seismic signals.
A wavefront distortion across Mt. Vesuvius, observed by a temporary deployed seismic array, has been attributed to the propagation through a non-homogenous velocity structure (Galluzzo and La Rocca) by computing synthetic wavefront propagation in two different velocity models, one homogeneous, the other heterogeneous. The heterogeneous model gives better results, also in agreement with the results of previous tomographic studies.
The continuous improvement of computing power, analysis tools and graphical software give important support to the Earth sciences, permitting new analysis and new methods of displaying, and hence interpreting the results. An example in this special issue is provided by Del Pezzo and Bianco, who show new interpolations of tomographic pictures.

Several contributions on multidisciplinary approaches, which are becoming more and more important for the comprehension of volcanic systems, are included in this special issue. The contribution by Cusano et al. (*Seismic activity and thermal regime...*) is an interesting attempt to study the correlation between the seismicity and the features of gases emitted by fumaroles. On the other hand, a geochemical-geophysical approach based on data of

groundwater from the Vesuvius aquifer collected from 1998 to 2011 and geophysical signals, provide a more comprehensive conceptual model of the fluids circulation in the volcanic system and the possible relations with the stress field variation (Federico et al.). Del Pezzo et al. analyze tomographic images of Vp and Q, the hypocenter distribution of volcano-tectonic earthquakes and geochemical measurements. The authors suggest an interaction between patches of magma and the hydrothermal system to explain the behaviour of seismic and geochemical parameters.
Capuano et al., through a simultaneous inversion of travel times, hypocentral parameters of local earthquakes and gravity data, provide a high-resolution image of the shallow (300-500 m) edifice of Mt. Vesuvius as well as a critical review of a number of previous studies focused on the detection of a shallow magma chamber and interpretation of the present local seismicity.

Descriptions of the past activity and discussion on the possible future dynamical behavior are commented inside the issue. The analysis of historical earthquakes is also important to evaluate the maximum expected magnitude in the area. Cubellis and Marturano provide an interesting analysis of historical seismicity based on the earthquake effects described by old sources.
A comprehensive understanding of the volcano status and its possible evolution cannot be separated from detailed study of past eruptions. Accordingly, Cioni et al. analyze the eruptive period preceding the explosive eruption of A.D. 472. Understanding the dynamics of past eruption is crucial for a correct interpretation of possible precursors, as pointed out by Scandone and Giacomelli. The last eruption, occurred in 1944, was not much different or larger than others before, and it occurred at the end of a long period characterized by a decreasing trend of eruption explosivity. Most of the uncertainty on the duration of the present stage and character of a future renewal of activity derives from the basic questions regarding the nature of the current repose: due to a diminished supply of magma, related with structural condition, or to a sealing of the upper ascent path to the surface? A debate on this question is enclosed (Scandone and Giacomelli).
The volcanic risk perception is also commented, since a survey on this topic, described by Ricci et al., was carried out during the October 2006 European Civil Protection Exercise MESIMEX (Somma Vesuvio Mesimex, Major Emergency SIMulation Exercise). The obtained results strongly suggest that a continuous and effective effort has to be done by both scientific community and Civil Protection, also turning particular attention to education and outreach activities, as well as in involving people in risk mitigation procedures, also through more frequent exercises.

The 23 papers included in this special issue of Annals of Geophysics present a clear view of any monitoring networks, tools and methodologies currently used to survey Vesuvius volcano. Any fields of possible research are discussed, from very technological topics to human related questions, from events occurred 20 centuries ago to very recent ones. Moreover, in these papers the reader will find exhaustive references to the most important papers regarding Mt. Vesuvius as well as to general topics. The editors appreciate the efforts of the many colleagues who provided critical reviews of the papers included in this special issue, significantly contributing to increase quality and contents. Without their efforts, the volume could not have been completed in the present form.

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ANNALS OF GEOPHYSICS, 56, 4, 2013, S0433;
doi:10.4401/ag-6439.