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Short communication

# È VIVO: Virtual eruptions at Vesuvius; A multimedia tool to illustrate numerical modeling to a general public

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**Abstract**

Dissemination of scientific results to the general public has become increasingly important in our society. When science deals with natural hazards, public outreach is even more important: on the one hand, it contributes to hazard perception and it is a necessary step toward preparedness and risk mitigation; on the other hand, it contributes to establish a positive link of mutual confidence between scientific community and the population living at risk. The existence of such a link plays a relevant role in hazard communication, which in turn is essential to mitigate the risk. In this work, we present a tool that we have developed to illustrate our scientific results on pyroclastic flow propagation at Vesuvius. This tool, a CD-ROM that we developed joining scientific data with appropriate knowledge in communication sciences is meant to be a first prototype that will be used to test the validity of this approach to public outreach. The multimedia guide contains figures, images of real volcanoes and computer animations obtained through numerical modeling of pyroclastic density currents. Explanatory text, kept as short and simple as possible, illustrates both the process and the methodology applied to study this very dangerous natural phenomenon. In this first version, the CD-ROM will be distributed among selected categories of end-users together with a short questionnaire that we have drawn to test its readability. Future releases will include feedback from the users, further advancement of scientific results as well as a higher degree of interactivity.


*Keywords:* outreach; education; volcanic hazard; modeling; pyroclastic flows; risk perception; communication; computer animation

## 1. Volcanology and public outreach

Volcanoes and their eruptions are among the most fascinating and dangerous natural phenomena. This prompts a large interest in the public pertaining volcanoes, their activity and the scientific work that is carried out to monitor and understand volcanic processes. Institutions involved in the study of active volcanoes generally dedicate a relevant effort to public outreach. Educational activities not only answer a widespread request from the population, living or visiting volcanic areas, but are also an

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important step in building the local perception of volcanic hazard.

Cultural research on risk has repeatedly highlighted the difference existing between the perception of risk developed by the local population and that of the experts. In other words, the very idea of what is dangerous may vary incredibly and, in the case of the population, may depend on prejudgments, myths and all sorts of emotional reactions that no scientific data can counter. It has been recently recognized that awareness prompted by hazard education initiatives does not necessarily turn into an improved preparedness or into the adoption of appropriate mitigation measures (Johnston et al., 1999; Paton, 2000; Gregg et al., 2004). However, a proper understanding of natural phenomena and how they may affect communities is a first necessary step toward awareness and toward a correct hazard perception, which in turn are the sound bases required to establish a long-lasting confidence in the scientific community, its advice and its methods. Such a confidence may become crucial during an emergency, when the opinion of the scientific community may be difficult to accept. However, for any communicative relationship to be constructive and effective, the confidence must be mutual, whereby the two sides (the senders, the scientific community, and the receivers, the public) recognize themselves as legitimate and credible subjects. A mutual confidence between the scientific community, on one hand, and the population and its administrators, on the other, is thus obtained distinguishing among different types of public, with their diverse perceptions, values and motives, and paying particular attention to the verbal and the visual language used to describe the hazard and to explain the natural phenomena (Douglas, 1982; Lundgren and McMakin, 2004).

Such a sense of reliability grows if the population and its authorities recognize that the scientific community is working to understand and mitigate volcanic hazard, and that it is available to show its methodologies, and to share its results as well as the unavoidable scientific uncertainty. To this end, outreach and educational material should not only focus on a mere description of volcanic activity, but also on how we obtain the information we have, and how certain, or uncertain, our findings are. Commonly, however, outreach efforts are devoted to describe the past and present activity of a given volcano, with some emphasis on monitoring techniques, and on the future scenarios that can be expected. Rarely does educational material deal with more theoretical and technical aspects of the actual research that is carried out to quantitatively address volcanic hazard, because of its complexity.

In this regard, our research work has quite a peculiar character: on the one hand, we deal with a very technical and highly specialized topic, such as numerical modeling of multiphase and multicomponent pyroclastic flow propagation. On the other hand, the results we get from our sophisticated physical model can be displayed as charming and colorful animations illustrating the temporal and spatial evolution of critical flow variables (temperature, ash concentration and dynamic pressure). This kind of graphical representation, informal and easily "readable", is particularly suited to show scientific results to the general public. We realized that our animations could be used to disseminate and explain some of our findings to the people living in or visiting the Vesuvian area. Animations alone, however, do not represent an appropriate educational tool: they are easily taken as a simple graphic exercise or a cartoon, whereas they represent scientific results. On the other hand, they should not be considered the true and real picture of what is certainly going to happen, as, again, they are the results of numerical modeling, with all the uncertainties that go along with this methodology. All these considerations must accompany the animations, if we want to use them as an educational tool. We therefore decided to produce some explanatory material and an appropriate framework to contain both animations and comments. In order to plan an effective communication strategy, the shape and contents of our outreach tool were planned in collaboration with researchers from the Communication Sciences Department of the University of Bologna. Together, we chose the format of hypertext, for its flexibility: it allows the user to obtain different degrees of information, according with his/her interests; it will allow us to add new materials, as they become available, or to modify some of it according to specific needs (high schools, public officials, etc.). This format is also potentially suited for the web. The name of the hypertext (È VIVO', in Italian: It's alive) is an acronym for Virtual Eruptions at Vesuvius (in Italian: Eruzioni VIrtuali al VesuviO). The computer animations presented in the hypertext specifically illustrate the numerical simulations of pyroclastic flow propagation that we published in 2002 (Esposti Ongaro et al., 2002; Todesco et al., 2002).

## 2. Our research methodology

Our research work on Vesuvius is aimed at assessing the pyroclastic flow hazard in the Vesuvian area. Several scientific papers have been published on this topic during the last 15 years. In these works, a physical model of pyroclastic density currents has been developed and applied to study conditions leading to the generation and collapse of volcanic columns, and the subsequent propagation of pyroclastic density currents along the flanks of Vesuvius. The model applied is a transient, two-dimensional, multiphase flow model, based on the solution of the generalized Navier–Stokes equations for multiphase mixtures, that accounts for the mechanical and thermal non-equilibrium effects between gas and various particulate phases (Gidaspow, 1994). Early application of the model focused on the general evolution of a hot mixture of water vapor and particles of a single size being injected into a standard air atmosphere (Dobran et al., 1993). More simulations were carried out to evaluate the relevance of various eruption parameters in controlling the development and propagation of pyroclastic flows (Neri and Dobran, 1994) and to assess the role of eruption intensity and Vesuvian topography on the maximum runout reached by the flow (Dobran et al., 1994). Further model developments allowed us to account for the presence of different classes of particles, each one characterized by given size, thermal and rheological properties, leading to complex non-equilibrium effects (Neri and Macedonio, 1996; Neri et al., 2003). Additional improvements derived from the introduction of an explicit description of terrain roughness, ensuring a better definition of the boundary conditions along the ground (Esposti Ongaro et al., 2002; Todesco et al., 2002). In these papers, the model was applied again to study the Vesuvian region, and particular attention was paid to the definition of the magmatic system feeding the eruption, and vent conditions were calculated by modeling the magma ascent along the volcanic conduit. Nowadays, further work is in progress to extend the applicability of the code to other volcanoes (Clarke et al., 2002) and to three dimensional problems (Cavazzoni et al., 2005), within the framework of the European project Exploris (http://exploris.pi.ingv.it).

Numerical simulations describe the temporal evolution of important flow variables, such as temperature, dynamic pressure or particle concentration, according to the selected scenario. Based on the calculated ranges of variation for these variables, it is possible to provide a first order assessment of the pyroclastic flow impact on human beings and buildings (Baxter et al., 1998, 2005; Esposti Ongaro et al., 2002).

Post-processing of numerical results is usually performed to better evaluate modeling results. In particular, a color scale can be assigned to each given flow variable (such as gas temperature, particle concentration, flow density or pressure, etc.), to describe its range of variation at any point in the computational domain and at any time (Fig. 1). Raster images derived from such post-processing can be mounted to form an animation, describing the temporal evolution of the flow, as simulated by the model. Three of these color animations are presented and illustrated within our hypertext. They describe the evolution of flows generated by a large-scale eruption in terms of volumetric particle fraction and temperature along the southern slope of Vesuvius, and along the northern slope, where the topographic obstacle of Mount Somma is represented.

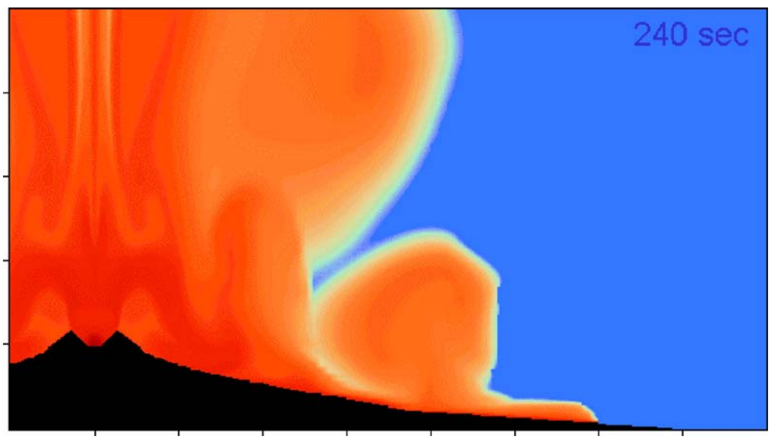


Fig. 1. Volumetric particle fraction after 240 s of simulation, for a large scale eruption along the southern slope of Vesuvius. Numerical results are rendered through a color scale, which represents the range of variation of the selected variable: in this image, blue color represents absence of solid particles (volumetric fraction occupied by particles is less than $10^{-8}$), whereas red color highlights regions of maximum particle concentration (volumetric fraction higher than $10^{-1}$). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

## 3. The multimedia tool

Computer animations and our explanatory comments are presented as a multimedia tool, composed by images, figures and written text (at this stage, in Italian). A short introduction on volcanoes, people and our research work opens the hypertext. Then, the user enters the home page, where the aims and main contents are briefly described (Fig. 2). A big effort was made to keep the text simple and short, to provide the necessary information but avoiding tedious details. The text is subdivided into short paragraphs, with relevant words highlighted to improve the readability. In a future version, some of these highlighted terms could be linked to a glossary. Other keywords in the main text are active links that open images with captions, or connect to pages with additional explanatory material, such as short graphics or further comments. A minimum background on volcanic eruptions is provided within two pages, respectively devoted to Vesuvius activity and to pyroclastic flows. The page dedicated to Vesuvius contains a short description of the different kinds of activity characterizing this volcano, pointing out that the volcano is still active, and very dangerous. A few sketches and images from real erupting volcanoes show the differences between explosive and effusive activity. The nature of pyroclastic flows is described on the second page, where text, pictures and animated drawings illustrate how these flows are generated from partial or total collapse of the volcanic column. The text also emphasizes that our model does not describe the entire eruption, but only the generation and propagation of pyroclastic flows.

Further pages are devoted to the methodology used in our research. A page entitled "virtual eruption" is about physical models and it describes how, since the time of Galileo Galilei, scientists have translated the physical laws governing natural processes into mathematical expressions. This is also the case for pyroclastic flow propagation. Due to the complexity of this topic, further information is

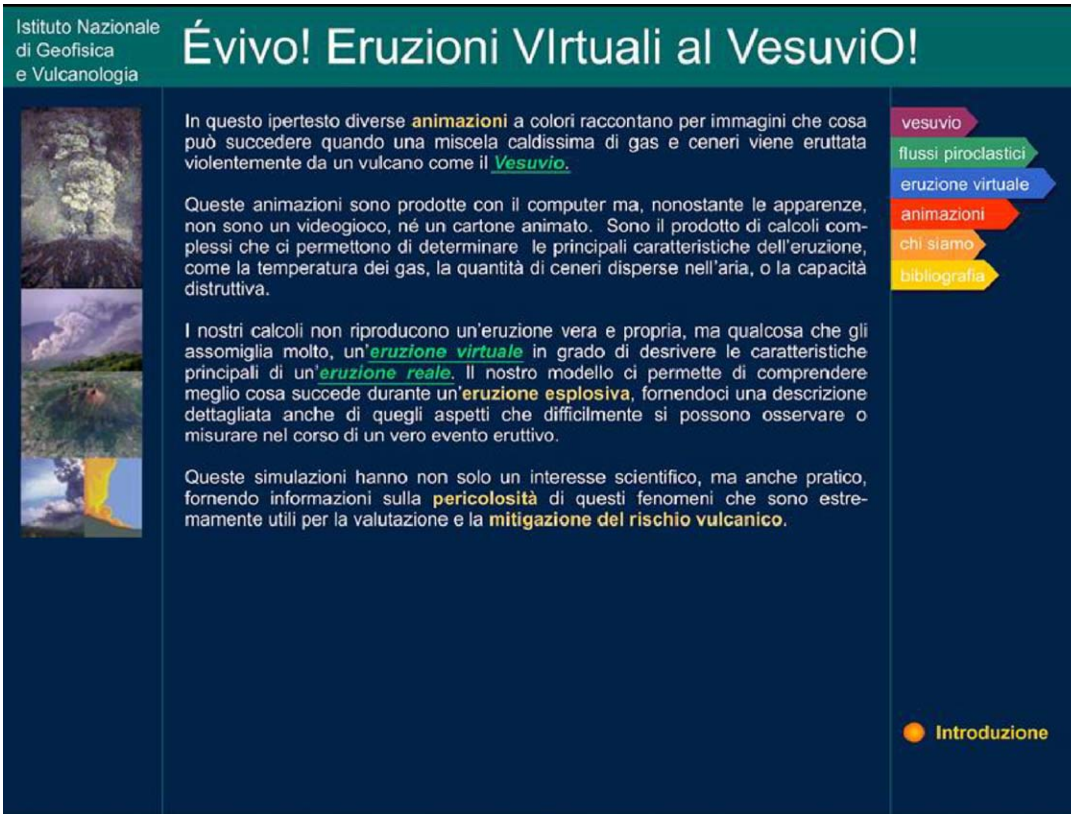


Fig. 2. Home page of the hypertext ÈVIVO. Text (in Italian) introduces the concept of virtual eruptions as the product of computer simulation of explosive events. Some relevant terms are highlighted in yellow, whereas green words are active links to the images on the left, which open and show a short caption. In other cases, active links may lead to additional explanatory material on both volcanic activity and numerical models. Buttons to the right open further pages in the hypertext devoted to: Vesuvius, pyroclastic flows, virtual eruptions, computer animations, who we are and bibliography. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

provided, for the interested user, within two different sub-levels: one on physical models in general and the other on the physical model of pyroclastic flows in particular. In the first one, mention is made of some common examples of physical models, such as those applied for weather forecasting. A few comments highlight the need to simplify the natural complexity and stress the lack of knowledge on particular aspects of natural phenomena, both introducing some degree of uncertainty and reducing the accuracy of modeling results. In the page dedicated to the physical model of pyroclastic flow propagation, the multiphase nature of these flows is briefly described and mention is made of the complexity of the mathematical formulation, which requires the adoption of numerical techniques. An animated graphic is provided to describe the spatial discretization of the computational domain. The interested user can read about conservation and balance equations, which can be fully viewed upon request.

Finally, the last page is dedicated to computer animations and shows how numerical results are converted into color movies. A short introduction describes the three animations in terms of topographic profile (with or without the presence of Mount Somma) and represented flow variable (gas temperature or particle concentration). The text also describes the meaning of the color table associated with each animation. When a given animation is selected, the associated topographic profile and flow variable are highlighted on the screen and a new window opens, where the user can run the animation and see how the volcanic column forms, collapses and pyroclastic flows are generated. A timer placed within each animation frame provides a measure of the time scale involved. The user can stop the animation at any time and move through it manually to better capture details of thermal plumes rising from the flow or the complex dynamics of the atmosphere. A sub-level, accessible from this page, also illustrates how numerical simulations can be applied to study the physics of the phenomenon, or to evaluate pyroclastic flow impact on people and buildings, with some examples taken from the literature.

## 4. Conclusion

Vesuvius is certainly one of the most dangerous volcanoes in the world, due to its explosive nature and to the large density of population on its slopes. Mitigation of volcanic risk requires a direct and active participation of the population potentially involved, who should be aware of the hazard and willing to act in order to mitigate it. Hazard perception and preparedness depend on several complex features, which are not easily defined and whose discussion is beyond the aim of this short communication. Certainly, however, risk reduction is enhanced when individuals and their communities have a proper understanding of the threatening hazard. Becoming accustomed to what the scientific community is doing to evaluate and mitigate risks is also useful, and sharing scientific results with the general public is a good way to establish or reinforce the mutual confidence that is necessary to achieve an effective communication. For this reason, the Osservatorio Vesuviano has always given a great emphasis to scientific education and outreach activities. Now, the Osservatorio Vesuviano belongs to the Istituto Nazionale di Geofisica e Vulcanologia, and we believe that researchers should participate to this effort by sharing knowledge and results. To this purpose, we developed this multimedia tool. We tried to enlarge the subject of educational activity to include not only the traditional lectures on volcanic rocks and different eruptive styles, but also some hints on the methodology presently driving the scientific research. In order to choose an appropriate communication strategy, the structure of the CD-ROM was planned by both scientists and experts in communication sciences. However, as it is very difficult to predict how scientific contents can be perceived by the general public, we consider this product as a first prototype that we will use to get feedback from selected categories of end-users. In particular, even if the present product was not specifically designed to be an educational tool, high school students and their teachers represent a very important target of our outreach effort. A short questionnaire was prepared and will be distributed together with the hypertext to evaluate its readability and simplicity. Future releases will certainly include an English version and will incorporate not only feedback from end-users but also new scientific results that are being produced. In particular, a three-dimensional version of the model has been developed within the framework of the EU founded project EXPLORIS and 3D animations of pyroclastic flows will certainly be incorporated into the next version of the multimedia tool. Efforts will also be made to increase the interactivity, to allow for a greater involvement of users and to produce a version suited for educational purposes, to be planned together with the teaching community.

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