GEOWARN:
A WEB-BASED ATLAS INFORMATION SYSTEM FOR VOLCANIC MONITORING

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ABSTRACT

Quiescent but active volcanoes represent a severe hazard and risk potential. Early warning systems can help prevent disastrous consequences of seismic and volcanic events. In this respect, the European Union funded project GEOWARN which had the goal to monitor volcanic activity on a test site and to develop a prototype of an early warning system. The system is an entirely web-based Atlas Information System (AIS), i. e. a tool for visualising and analysing very diversified volcanic data through the Internet. The user-friendly Atlas Information System offers access to databases, and features specialised analysis tools with cartographic visualisation of high quality.

The GEOWARN Atlas Information System allows for scientific analysis, and emergency and land use planning. The system helps disaster relief and civil defence organisations to take decisions in the event of a seismic or volcanic crisis. It is intended that national councils and civil protection agencies will use it as an early warning system. It includes the necessary tools for hazard assessment, vulnerability and risk studies as well as for emergency planning. In addition, it incorporates educational information accessible to the public in order to generate general awareness of the problem.

1. INTRODUCTION

Large parts of southern Europe are located in geodynamically active zones. They are increasingly vulnerable to the effects of earthquakes and volcanic activity as local populations and infrastructures grow. Two regions of major concern are the Nisyros / Kos volcanic field in Greece, and the Campanian volcanic area in Italy.

In 2000, scientists from Switzerland, Germany, Greece, and Italy began a 3.5-year project called "GEOWARN: Geo-Spatial Warning Systems", which was funded by the European Commission (web link GEOWARN 2005). The aim of GEOWARN was the development of methods and systems for the surveillance of quiescent but still active volcanoes in regions with geodynamic unrest (Lagios et al. 2001). A major part consisted of the development of a monitoring tool that embeds all relevant data sets of a volcanic field into a single cartographic system. Use cases of the application include monitoring, scientific analysis, and emergency and land use planning should allow casual users (civil protection) to make decisions in the event of a seismic or volcanic crisis.

The island of Nisyros was chosen as a test site. It is a Quaternary volcano located at the easternmost end of the Aegean Volcanic Arc, south of Kos. The island is almost circular, with an average diameter of 8 km, and covers an area of approximately 42 km^2 (central island in figure 1). Nisyros is a remnant of a prehistoric volcanic field, where 160,000 years ago the largest eruption in the eastern Mediterranean devastated the entire Dodecanese islands. Although the last magmatic volcanic activity on Nisyros dates back at least 25,000 years, the present geodynamic activity comprises high seismic unrest and widespread fumarolic activity. Violent earthquakes and steam blasts accompanied the most recent hydrothermal eruptions in 1871–1873 and 1887 and left large crater holes. In 1996 and 1997 seismic activity started with earthquakes of magnitudes up to 5.5 and with hypocenters down to 10 km depth, damaging several houses on the island. In 2001, a fissure opened in the Nisyros crater due to hydrothermal activity (figure 2). Today, the Nisyros volcano and the hydrothermal craters are visited daily by hundreds of tourists attracted by its fuming (degassing) hydrothermal explosion craters (figure 3).

The Italian Campanian volcanic area includes Vesuvius and the Phlegrean Fields (Campi Flegrei), a region that is densely populated by approximately 3.5 million people. Campi Flegrei served as a second test site to prove the transferability of the developed system.

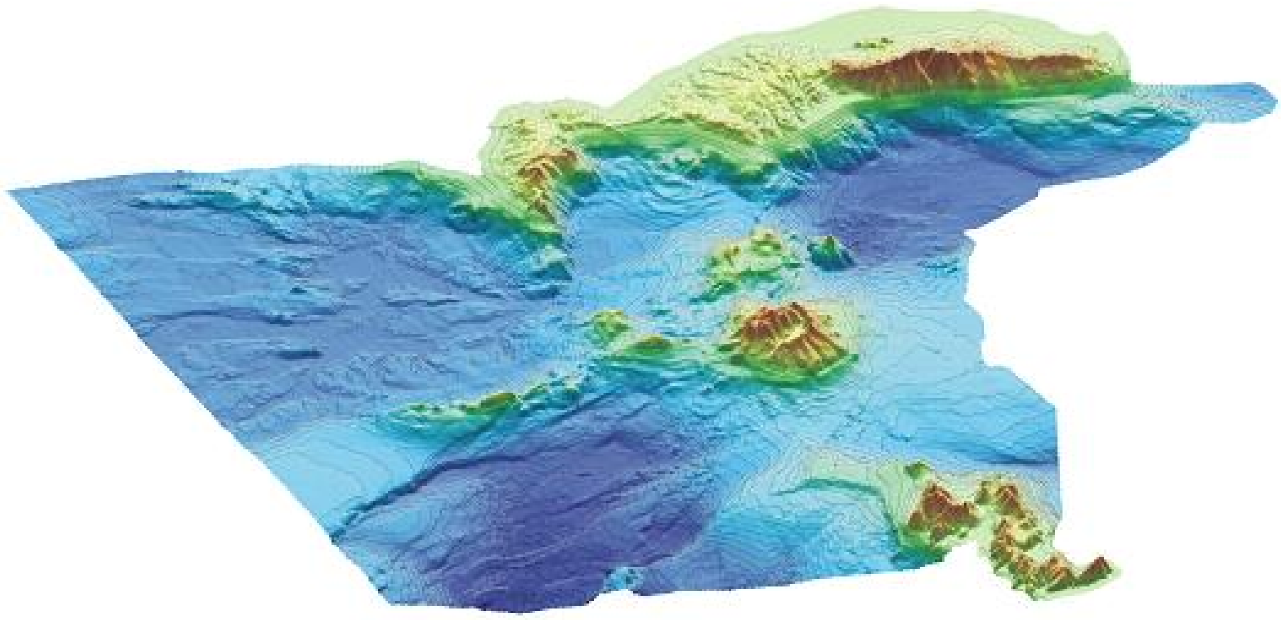

Fig. 1. Bathymetry and topography of the Nisyros / Kos volcanic field (National Centre for Marine Research NCMR, Hellenikon).

Fig. 2. Fissure in the Nisyros caldera in 2001.

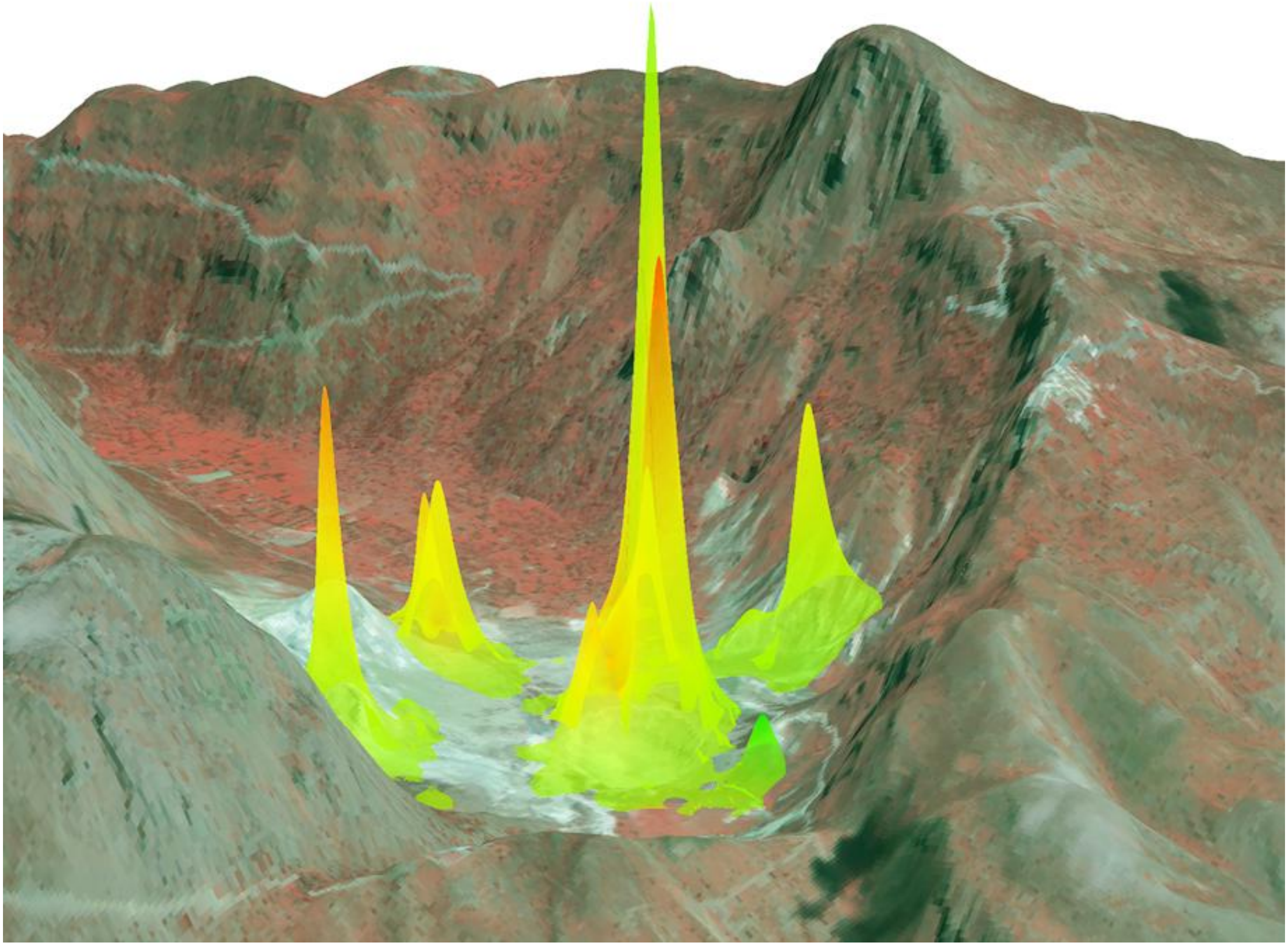

Fig. 3. Diagrams of CO_2 flux (height) and temperature (color) in the Nisyros caldera.

2. THE GEOWARN ATLAS INFORMATION SYSTEM

A major task of the GEOWARN project was the development of the GEOWARN AIS. Its users are threefold: scientists of the project, who wish to combine their partner's data with their own; emergency and land use planers; and civil protection organisations for volcanic monitoring, and for decision support in case of a volcanic crisis.

We identified the following requirements that drove us to develop a customisable Atlas Information System, rather than solely using a standard GIS:

- Information has to be easily readable. Cartographic presentations of high quality (with antialiasing and advanced symbolisation) have to offer access to the entire data set
- The system has to be "user-friendly"
- The user of the system should not be obliged to perform complicated GIS manipulations in an emergency situation
- Software quality must be controllable to assure further stable developments
- Independence of commercial software providers

To meet the requirements of the GEOWARN AIS, a flexible Atlas Information System framework was developed. It allows for easy and fast adaptation to different types of applications. The framework uses client side vector data for map rendering and accesses distributed sources to retrieve data. The GEOWARN AIS client uses the framework for map rendering, interaction with the map, or data access on servers. It extends the core framework by a set of custom-tailored components that offer specialised functionalities and an adapted user interface.

The client is integrated into a platform-independent Internet browser. The framework uses Java 1.4 technology. Java is a cross-platform object oriented programming language, complemented by a powerful set of functionalities. The recent .NET technology introduced by Microsoft is similar to Java, but was still unavailable at the time of writing for platforms other than Windows. For further information, see the Mono project (web link Mono 2005).

These components facilitate analysis and visualisation of a large amount of very diversified data that was collected for the GEOWARN project (Chiodini et al. 2002, Dietrich and Hurni 2002, Lagios et al. 2001, Vassilopoulou et al. 2002, Hurni et al. 2004). Examples include digital elevation models; topographic, volcanologic, and tomographic information; seismic events; geochemical measurement series; models of gas and heat flux; or measurements of relative surface deformation. The GEOWARN AIS stores most data in a relational database administered and pre-processed by a commercial GIS (Gogu et al. 2005). Apart from data stored in the database, data is also made available as cartographically treated vector data sets. The cartographic enhancement, performed with Adobe Illustrator, includes graphical generalisation, symbolisation of vectors, and storing the data in SVG file format. The custom-tailored components found within the GEOWARN AIS use additional data types: raster images, grids modelling geophysical phenomena, educational movies, HTML and other multimedia content.

3. GEOWARN AIS FUNCTIONALITY

As explained before, the GEOWARN AIS consists of a series of specialised components. Each component displays its own user interface, and reacts on user commands. At any time, the client of the Atlas Information System displays the interface of exactly one component. The user can select the this component from a menu list. This section describes exemplary components that can be used for general purpose Atlas Information Systems, as well as components that offer very specialised functionality for the particular needs of the GEOWARN AIS.

3.1 Map navigation and layer compositing

The ***Navigation Component*** is an elementary component to zoom and pan the map (figure 4). Using this component, the user can graphically or numerically enter the new centre of the view and the new map scale.

The ***Layer Editing Component*** shows and hides map layers, and changes their symbolisation (figure 5). When the *Layer Editing Component* is the active component, the user can load new map layers by selecting the desired one from a list. Currently, three different types of layers are supported: raster images, vector line work, and points. The component also allows the user to change the graphical appearance of vector layers by specifying colours, line widths and transparency.

3.2 Measurements in the map

Figure 6 shows another basic component for the measurement of distances and areas in a map.

3.3 Interactive diagrams

An important component of the GEOWARN AIS analyses time dependent measurements. The user selects a series of measurements and time intervals of interest (figure 7). The component then creates the diagrams. In figure 8 the diagrams show the evolution of temperature and electrical conductivity of three different springs over time.

3.4 Grid analysis

The screenshot in figure 7 illustrates the analysis of the values stored in a regularly spaced raster grid. The user starts by selecting a preview of the grid in the map – this example shows heat flux in a volcanic caldera. The grid is then loaded from the server and displayed using a customisable colour scale. Queries of single values and statistical measurements on the grid are possible, as are time series of grids displayed in an animation.

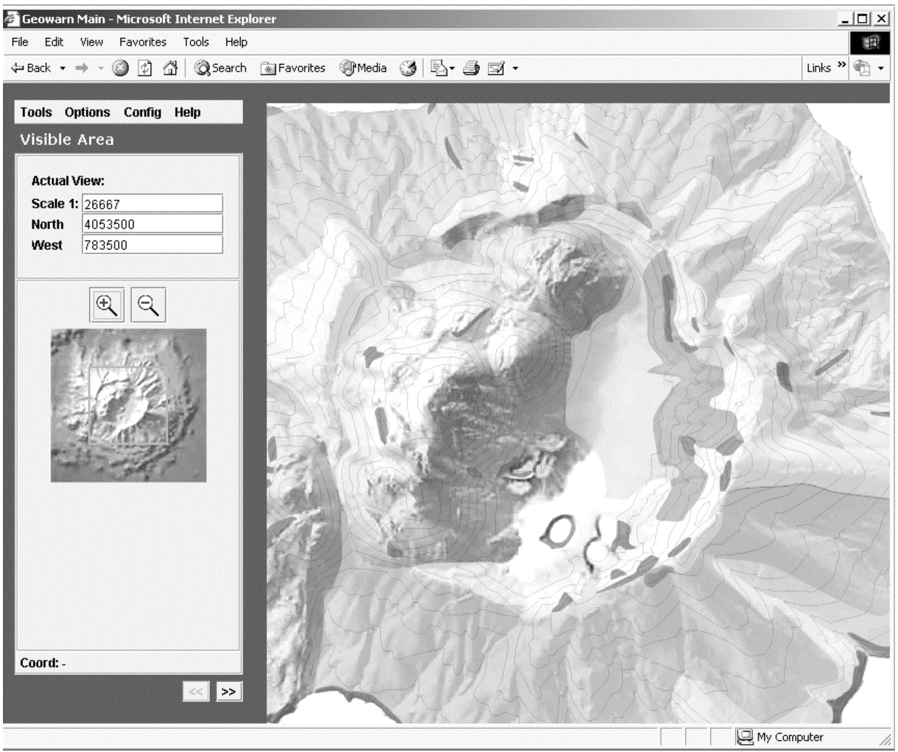

Fig. 4. Component for map navigation.

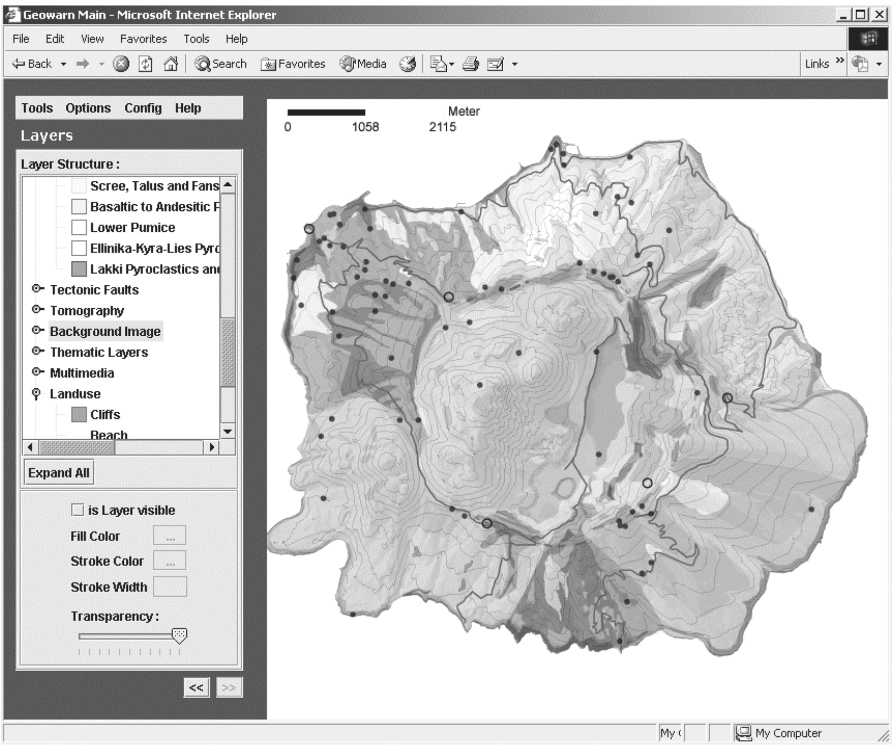

Fig. 5. Screenshots of the Layer Editing Component.

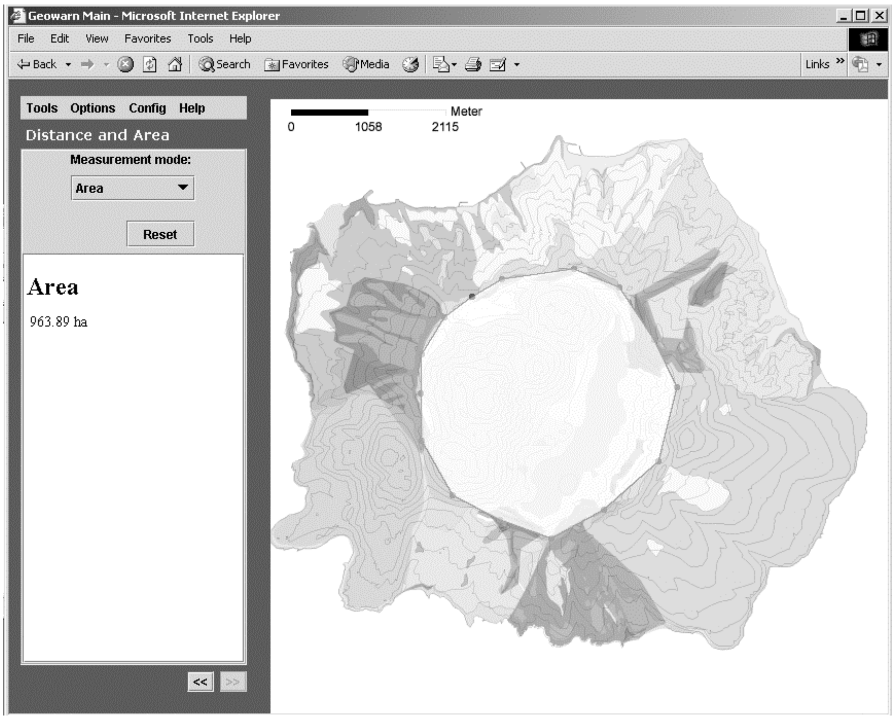

Fig. 6. Measurement of an area.

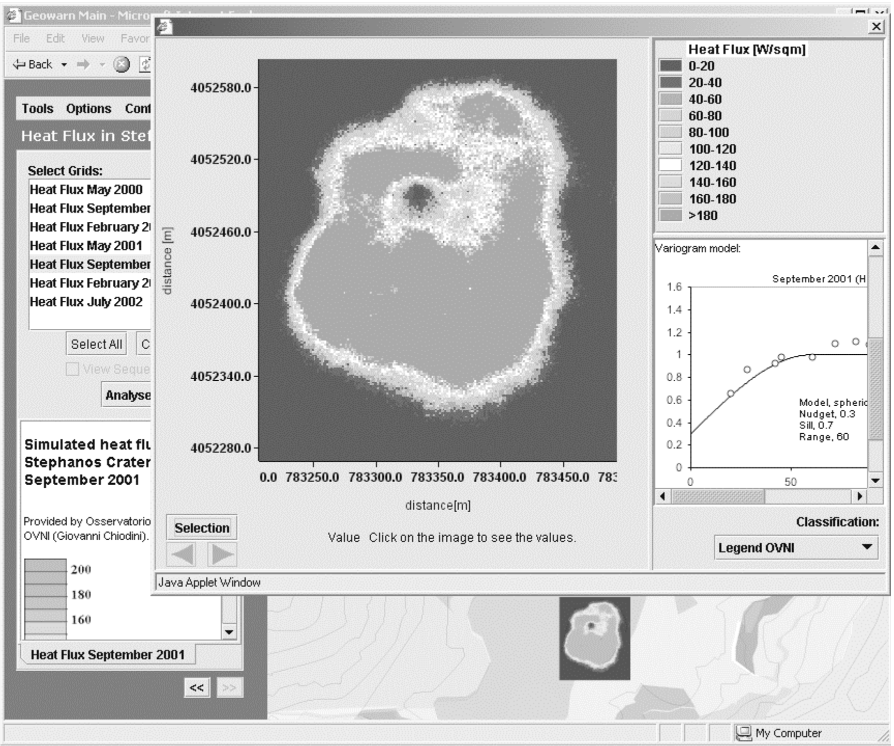

Fig. 7. Analysis of raster grid.

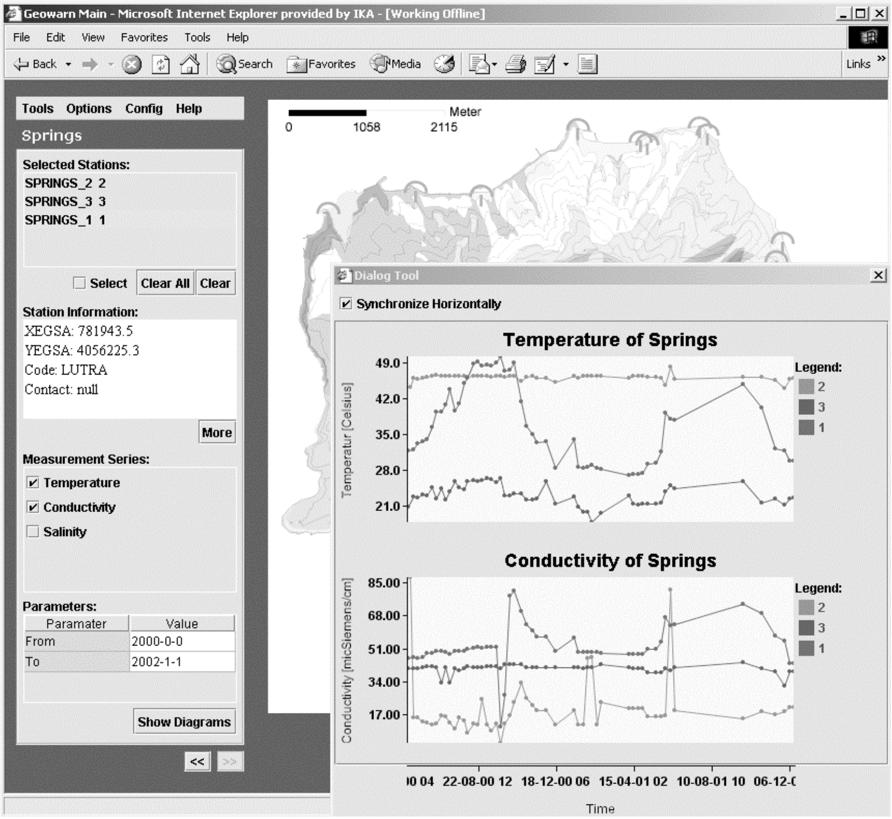

Fig. 8. Display of measurements as diagrams.

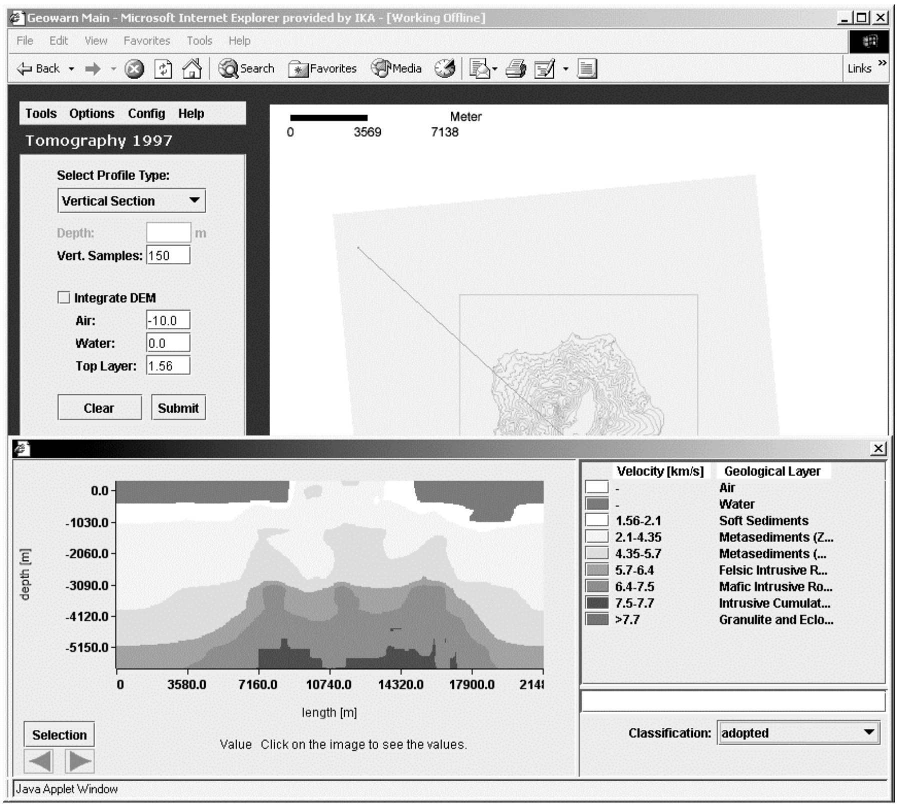

Fig. 9. Extraction of 3D model

3.5 Profiles from geological 3D-model

The component illustrated by figure 9 extracts user definable profiles from a three-dimensional tomographic model of subsurface geology below Nisyros. The user defines the position of the desired profile either graphically or numerically. The component then sends this information to a servlet that extracts the profile from a tomographic voxel model. The servlet returns the resulting profile as a thematic grid to the active component. The user finally analyses this grid with the functionality described above.

3.6 Seismic Sections

Microseismic events (i.e. seismic events with a magnitude of 3 or less on the Richter scale) are important for the understanding of volcanic processes. A seismic event is defined by a three dimensional position and a magnitude. The component of figure 10 projects seismic events on a vertical profile, which is then shown in a diagram. The position of the profile can be interactively chosen on the map. Only points that are within a certain distance to the profile are included in the diagram.

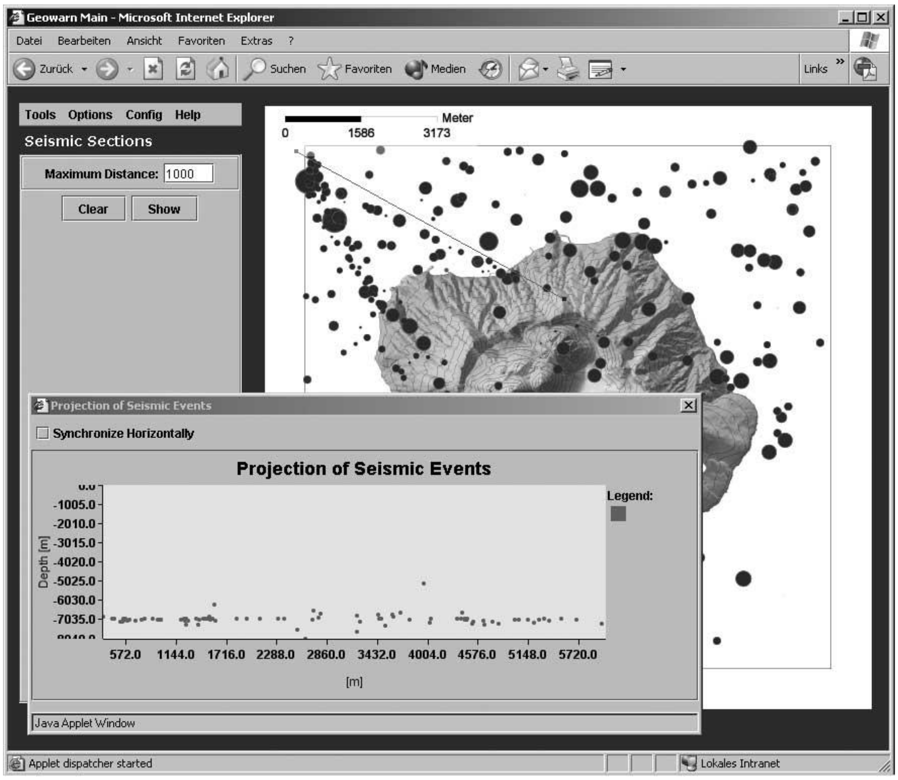

Fig. 10. Projection of seismic events on a profile.

4. RESULTS AND CONCLUSIONS

Investigations on dormant volcanoes are relying on scientific modelling and on monitoring systems which are based on remote sensing data, field measurements and terrestrial sensor data. Such large amount of data must be analysed and combined in order to better investigate and evaluate direct and indirect volcanic exposures. The presented application which bases on the data side on a commercial Database/GIS solution and on the application side on our own development is focused on the monitoring on dormant volcanoes in areas with high geodynamic unrest. The experiences gained in the project covered in a first part the design and the development of a spatial database including the programming, design and set up of query forms for spatial and temporal analyses. In order to be able to carry out well-founded data analyses and correlation, the different, rather heterogeneous data sets have been harmonised and classified (Gogu et al. 2005).

In the second part of the project – which is the focus of this paper – an Internet-based Multimedia AIS has been developed which operates independently from commercial software. The programme accesses the same relational database as it would be possible by commercial GIS. The Multimedia AIS of GEOWARN uses a client–server architecture which is based on a component based concept. The components can even be geographically or physically distributed. The project has shown the feasibility of a distributed, multi-thematic data management, analysis, and visualisation system for volcanological applications and for diverse user groups. For volcano observatories, but also for civil protection organisations and political authorities such a system is indispensable. Further developments could include an improved automation and harmonisation of data flows and the inclusion of real time data.

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WEB LINKS

Mono (2005). URL: http://www.mono-project.com/ (accessed 28.04.2005)
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REMARK

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BIOGRAPHY OF THE PRESENTING AUTHOR

Lorenz Hurni, born in 1963, has been Professor of Cartography and director of the Institute of Cartography at the ETH Zurich since 1996. He is editor-in-chief of the ATLAS OF SWITZERLAND. In his doctoral thesis at ETH Zurich, he developed the first programme for automatic generation of cartographic cliff drawing. He then served as project leader for computer-assisted cartography at the Federal Office of Topography, working mainly on the implementation of an interactive graphic system for the digital processing of national maps. The emphasis of Hurni's research lies in cartographic data models, cartographic 3D visualisation and tools for the production of printed and multimedia maps. Currently he is preparing the third edition of the multimedia version of the "ATLAS OF SWITZERLAND" which has won many awards, among them the Award for “Excellence in Cartography 2003” from ICA. Hurni is chairman of the ICA Commission on Mountain Cartography, member of the board of the Swiss Society of Cartography, Contributing Editor of “Kartographische Nachrichten” and “Cartographica” and member of the German Leopoldina Academy.