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Development of a Google Maps-Based Tool to Quickly Visualize a Large Gravity Data Set Collected at Etna Volcano (Italy)

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Abstract.
Geophysical measurements provide a massive data source to investigate the behaviour of active volcanoes like Mt. Etna (Sicily, Italy). Here we present a new interface to visualize gravity variations, observed through time-lapse measurements, based on the Google Maps service, a choice motivated by its ease of use and the user-friendly interactive environment it provides. The tool allows to choose among the benchmarks of the Etna's gravity network, as well as to quickly visualize the gravity data since 1994. The integration of these measurements into a coherent visualization framework is important for their practical exploitation, providing a powerful environment for a quick and efficient processing of data time series.

INTRODUCTION

High-precision gravity measurements represent a useful tool for any volcano monitoring strategy. Indeed, they are essential for the detection of underground mass movements that might trigger a pre-eruptive state [1,2,3,4].

Since the 1980s, the Istituto Nazionale of Geofisica and Vulcanologia (INGV), Section of Catania, has used high-precision relative gravity measurements to determine significant correlations between the eruptive activity of the Mt. Etna volcano and temporal changes in the gravity field, which can occur with different patterns [2,4,5,6]. Conventionally, gravity measurements have been carried out using relative spring gravimeters that measure spatio-temporal gravity changes with respect to a fixed reference site. However, the accuracy of these gravimeters is largely limited by instrumental drift. This effect, together with influences arising from temperature and pressure variations, can prevent to accurately measure small variations in gravity related to volcanic activity. Recently, we had the opportunity to test an FG5 absolute gravimeter from Microg LaCoste (owned by Eni S.p.a.). In particular, a hybrid method has been developed for volcano monitoring that combines the use of absolute and relative gravimeters. This approach takes advantage of the low uncertainty of absolute gravity measurements along with the simplicity and speed of relative gravity measurements. We demonstrated that the inclusion of absolute stations within the existing gravity network for relative measurements represents an important step towards the improvement of the quality of the data acquired, which has obvious consequences for volcanic monitoring [3,7].

The gravity network at Mt. Etna (Figure 1) currently consists of 71 gravity benchmarks for relative measurements, including an east-west profile, a north-south profile, and a circular profile around the volcano edifice. The network also includes 13 absolute stations distributed on the volcano edifice between 1500 and 2850 m a.s.l. and 33 benchmarks for vertical gravity gradient measurements. The free-air vertical gradients are used to compare at the same height the gravity values acquired with two or more types of absolute gravimeters, to refer relative and absolute measurements to the same height when using the hybrid method, and to obtain further information about the underground mass distribution.

The profiles have different characteristics regarding the number of benchmarks, the accessibility (determined by snow coverage), and the time required to take measurements. Each profile can be occupied independently, optimizing the flexibility in taking measurements to accommodate the changeable activity and accessibility of the volcano.

Measurements over the whole network are routinely conducted once a year (during the summer). Some parts of the network are reoccupied more frequently (approximately monthly measurements along the east-west and north-south profiles, although snow coverage restricts measurements along the north-south profile to summer months), providing an ever-growing database. In order to look after the great amount of gravity data collected at Etna and to present

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them in a more user-friendly way, we developed a Google Maps-based tool with the aim to gather information about each gravity station, to display the most recent measurements and analyze the gravity variations over time.

GRAVITY DATA

Since 1986, the relative gravity readings collected at Etna volcano were usually related to several primary reference stations outside the volcanic area (about 20 km distance from summit craters), which are the least likely sites to be affected by volcanically induced gravity changes.

Since 2007, the absolute gravity measurements collected at 13 absolute stations were used as references for determining g at relative benchmarks by adding corresponding gravity differences (Δg). The relative data reduction included the removal of solid Earth tides and the gravimeters drift. The uncertainties on temporal gravity changes observed by combining absolute and relative gravity measurements, at the 95% confidence interval, are mostly less than 10 μGal, although uncertainties more than 10 μGal were obtained in a few sites with extremely unfavourable environmental conditions.

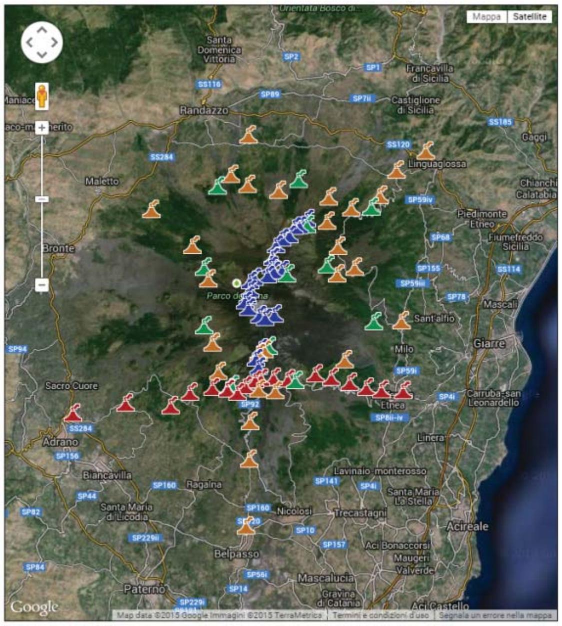


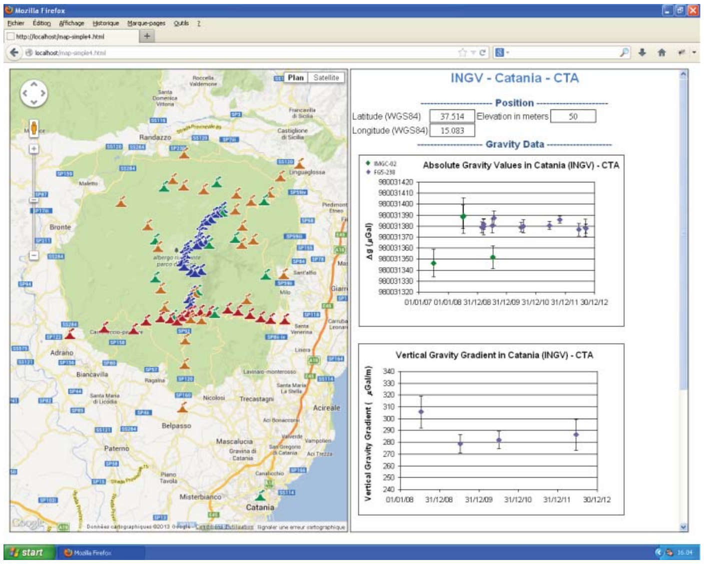
FIGURE 1. Map of Mt Etna showing the current gravity network for absolute (in green) and relative measurements: the east-west profile (in red), the north-south profile (in blue), and the circular profile around the volcano edifice (in orange).

THE INTERFACE

The use of a geophysical data (e.g. microgravity measurements) for volcano monitoring purposes implies the need for the operators to easily access the time sequences and learn, from the comparison with the ensuing activity and from cross-analysis with other signals, which anomalies can be considered meaningful. To this end, a new suitable designed tool was needed mainly to:

- handle easily and quickly a large database continuously evolving;
- allow quick cross-visualization and analysis of time sequences.

The data visualization system is built on the popular Google Maps application programming interface (API), which has been proved to be effective for real-time monitoring and hazard assessment at Etna volcano [8]. The web interface is divided in two sections (Figure 2). On the left side, there is the Google Maps with the markers corresponding to all gravity benchmarks on Etna volcano. By clicking one of them, a description window opens on the right side of the web page. The information window displays the name of the benchmark and its acronym, the latitude and longitude in decimal degrees (WGS84 datum), and the altitude above sea level in meters. Moreover, if available for the gravity benchmark selected, the information window includes three graphs.



INGV - Catania - CTA

---------------------- Position ----------------------

Latitude (WGS84) 37.514 Elevation in meters 50

Longitude (WGS84) 15.083

-------------------- Gravity Data --------------------

FIGURE 2. Web-interface of the tool. On the left, there is the Google Maps showing the location of the gravity benchmarks on Etna volcano. On the right, there is an information window displaying the position and the charts with gravity variations at each station.

The first graph (Figure 3) displays the absolute gravity variations in μGal (adjusted for earth tides, local atmospheric and polar-motion effects), collected since 2007. The second graph shows the vertical gravity gradient variations in μGal/m collected since 2008 (Figure 3). Finally, the third graph includes the gravity variations in μGal, collected since 1994 (Figure 4). These graphs are automatically generated thanks to a link of the tool with the gravity database.

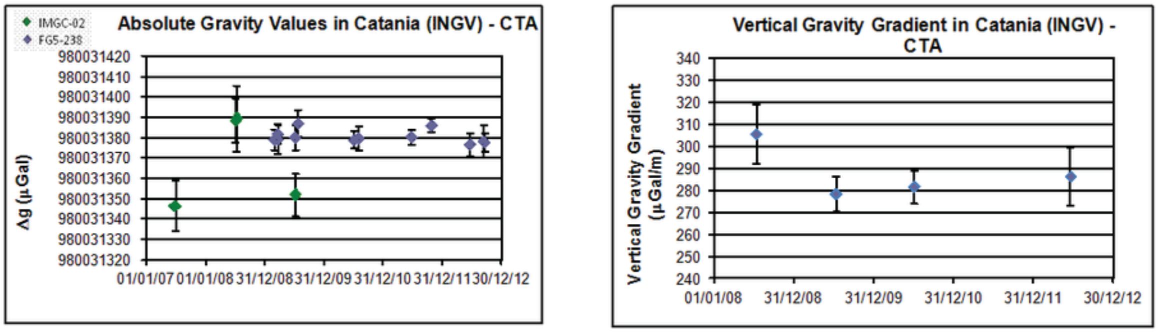


FIGURE 3. Absolute gravity variations since 2007 at the station CTA, i.e. at the INGV of Catania, using two different absolute gravimeters (left). Vertical gravity gradient variations at the station CTA, i.e. at the INGV of Catania, since 2008 (right).

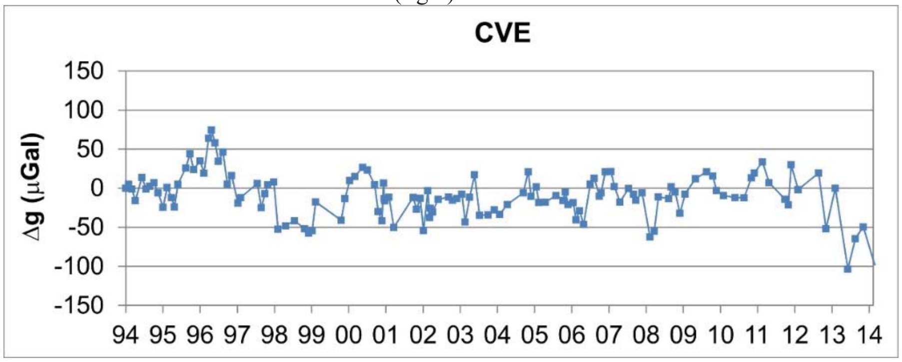


FIGURE 4. Gravity variations since 1994 at the station CVE, i.e. at the shelter of Casa Del Vescovo (southern flank of the volcano).

CONCLUSIONS

The ever-expanding use of geophysical monitoring techniques of volcanoes generates a huge amount of data, which require an intuitive way to be visualized. With this in mind, we developed a new tool based on the common Google Maps API to promptly visualize the microgravity data obtained through discrete measurements at Etna volcano. The application is a tool intended for both research and monitoring purposes. Thus, it should be utilized remotely by expert operators, as well as by personnel involved in the volcano surveillance tasks.

Thanks to a user-friendly interface, the tool allows the visualization of the location of the gravity benchmark, as well as the variations of gravity field occurred in the last 20 years. This indubitably allows the improvement of the direct human perception of their meaning. Indeed, the visualization of all data available at a selected gravity benchmark can be a valuable instrument to determine significant correlations between the eruptive activity of the Mount Etna and temporal and spatial changes in the gravity field. Moreover, it can facilitate the joint interpretation of the signals, especially during a volcanic unrest.

Future improvements could include the implementation of free and open source GIS technologies, both desktop and web [e.g. 9-13] to integrate georeferenced raster cartographies with gravimetric data in real-time.

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