GPS on the Web: GPS Volcano Deformation Monitoring

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This column provides the web-based GPS resources and their technical background information. Its purpose is to inform the reader about the data, software, electronic documents that are available on-line. This column is coordinated by Dr. Jinling Wang, The University of New South Wales, Sydney. Comments and suggestions are appreciated (Jinling.Wang@unsw.edu.au).

In this issue, the column provides the addresses of several websites containing information, GPS data, and updated baseline results concerned with GPS volcano deformation monitoring.

Introduction

Volcanoes are an awesome display of Nature's power. In addition, volcanic explosions are often very destructive events, having a massive impact on the natural and human environment. It is therefore necessary to closely monitor volcanoes in order to mitigate the hazards arising from an eruption. Ground surface deformation can give clues to magmatic processes at depth, and is a reliable indicator of an impending eruption. The GPS technology is well suited for volcano deformation monitoring because GPS measurements can provide three-dimensional positions, potentially at centimetre-level accuracy, independent of weather conditions, 24 hours per day. In addition, there is no requirement for intervisibility between stations within a GPS network, and measurements can be made over relatively long distances. Once a GPS network is installed, no human presence is needed at a potentially dangerous volcanic locale. By repeatedly measuring the same baseline vector to an accuracy commensurate to (and preferably much higher than) the expected baseline component changes due to deformation, the rate of change in the baseline components can be reliably determined.

The following is a collection of selected websites giving information about several GPS volcano deformation monitoring networks that enable the scientific community to access GPS data, baseline results and other useful information via the internet.

Kilauea volcano, Hawaii

The website located at **http://hvo.wr.usgs.gov/kilauea/update** contains daily updates of selected GPS measurements within the ground deformation network consisting of 16 continuous GPS sites used to monitor the Kilauea and Mauna Loa volcanoes in Hawaii. Two of the continuously operating GPS receivers span the crater of the Kilauea volcano and the data are processed daily. The baseline lengths, including standard deviations, are shown over a two-month period indicating long- and short-term deformation associated with volcanic activity. In addition, more than 100 other sites are surveyed intermittently using GPS campaigns. During a brief eruptive episode of the Kilauea volcano that began on 30 January 1997, continuously recording GPS receivers measured significant ground deformation near the eruption site. As magma forced its way up into the rift beneath the Napau Crater, two GPS sites located on either site of the east rift moved apart by 36cm. Information about this event can be found at **http://volcanoes.usgs.gov/About/What/Monitor/Deformation/GPSKilauea.html**.

A similar update of GPS measurements to detect movements on the nearby Mauna Loa volcano can be found at **http://hvo.wr.usgs.gov/maunaloa/current/main.html**. Links to long-term displacement results are also provided. GPS data collected at both volcanoes are made available via the UNAVCO archive at **http://archive.unavco.ucar.edu/cgi-bin/dmg/pss**.

Long Valley Caldera, U.S.A.

Information about the continuous GPS monitoring carried out at the Long Valley Caldera can be found at **http://quake.wr.usgs.gov/research/deformation/twocolor/lv_continuous_gps.html**. Data are processed with the GIPSY software on a daily basis, and time series of coordinate components in tabular and graphical form are available at **http://quake.wr.usgs.gov/research/deformation/gps/auto/LongValley**.

Yellowstone National Park, U.S.A.

The website located at **http://volcanoes.usgs.gov/yvo/monitoring.html** includes eruption updates and information about earthquake, GPS and levelling data used to monitor volcanic activity in the Yellowstone National Park area. Data from about 15 continuous GPS sites, as well as approximately 160 sites observed during campaign-style surveys conducted over the years, can be downloaded. Time series of station coordinates are obtained using daily BPE (Bernese Processing Engine) processing and IGS precise orbits, and are shown graphically. GPS station velocities are estimated using ADDNEQ and also published.

Arenal volcano, Costa Rica

Two permanent GPS sites are currently used to monitor ground deformation at the Arenal volcano. GPS data are processed using the GIPSY software and time series of the station coordinates and the baseline length over several years can be viewed at **http://www.geodesy.miami.edu/volcano.html**. This website also provides coordinate time series for other volcanoes. GPS data for these sites are available at **http://archive.unavco.ucar.edu/cgi-bin/dmg/pss**.

GEONET, Japan

Since 1994 Japan's Geographical Survey Institute (GSI) has operated the GPS Earth Observation Network (GEONET). The main purpose of this GPS array is to continuously monitor crustal deformation in order to study, and hopefully predict, earthquakes and volcanic events. It is the world's most dense permanent GPS network, spanning the entire country and consisting of almost 1000 GPS sites with an average spacing of about 30km. The data collected at each station are transferred to GSI's data processing centre in Tsukuba via telephone line. These data are processed with a cluster of workstations to yield the position of each station with an accuracy of a few centimetres or better. Daily variations of station position are monitored in order to detect any abnormal changes in estimated crustal strain that could indicate an impending earthquake or volcanic eruption. Displacement vectors and coordinate changes can be graphically displayed and downloaded in tabular form at **http://mekira.gsi.go.jp/ENGLISH/index.html**. GPS data and daily coordinates for all sites can be obtained by contacting the staff at GSI's Geodetic Observation Center by email: gsi-data@gsi.go.jp.

SCIGN, U.S.A.

The Southern California Integrated GPS Network (SCIGN) was introduced for the purpose of continuously monitoring crustal deformation in California in order to further earthquake research. At present the network consists of 250 permanent GPS sites in and around the Los Angeles basin. GPS data are transmitted to a processing centre via telephone lines, archived and made available for the public to download via the internet at **http://www.scign.org**. Daily coordinate solutions, periodic velocity solutions, and plots of resulting positions or position differences are also freely available to the scientific community.

Single-frequency GPS networks

The continuous, single-frequency GPS system developed by the University NAVSTAR Consortium (UNAVCO) is an example of a low-cost approach for volcano deformation monitoring. The use of single-frequency instrumentation and the resulting lower power requirements considerably reduce the cost of the monitoring network. This enables the design of a denser network around the volcanic edifice, thereby increasing the spatial resolution of the deformational signals observed. For short baselines the ionospheric delay can largely be ignored. As described by Meertens (1999), single-frequency GPS receivers continuously transmit carrier phase and pseudorange observations through a Time Delay Multiple Access (TDMA) radio data modem network to a central computing facility. Instead of sending logged data files, these 'intelligent' radios send GPS data epochs continuously according to pre-defined time slots. This system has been deployed at Popocatépetl volcano in Mexico (5 sites), Taal volcano in the Philippines (15 sites), Mt. Erebus in Antarctica (3 sites) and at the Hawaiian volcanoes mentioned earlier (13 sites). Information about the system can be found at **http://www.unavco.ucar.edu/science_tech/dev_test/receivers/l1.html** and **http://charro.igeofcu.unam.mx/L1/L1sys.html**. Data collected from these L1 networks can be downloaded from the UNAVCO archive at **http://archive.unavco.ucar.edu/cgi-bin/dmg/pss?L1=1**.

Another example is the commercially available Movement Monitoring System (MMS) developed by the University of Applied Sciences of Southern Switzerland and GEODEV. This system consists of a network of single-frequency GPS receivers which are connected to a base station via either a cable, cellular modem or a radio link. The system follows a repetitive sequence of measurement, communication and post-processing. Observation sessions are typically 15-30 minutes in length, and processing takes place at the base facility where the GPS data are also archived. The baseline results can be visualised using tables or graphs in relative or cummulative terms, and the software can automatically initiate the distribution of warning or alarm messages (e.g. via email or mobile phone) if the deformation exceeds a certain pre-set limit. The horizontal precision achievable for baselines up to 10km is claimed to be 7mm $\pm$ 1.5·(baseline length in km) (Knecht & Manetti, 2001). Although designed for monitoring buildings, dams, bridges and landslides, this system can also be utilised in a volcanic environment. Information about the MMS can be found on the GEODEV website at **http://www.geodev.ch**. Several publications describing the system architecture and giving technical details are also available for download.

Mixed-mode GPS network

During the past few years a mixed-mode GPS volcano deformation monitoring system has been developed at The University of New South Wales, Australia. This system consists of an inner network of single-frequency GPS receivers on the volcano surrounded by an outer dual-frequency network which is used to generate corrections in order to account for the ionospheric effect. Information about the system design and field testing on the Papandayan volcano in Indonesia, as well as a list of related publications, can be found on the Satellite Navigation and Positioning (SNAP) group's website at **http://www.gmat.unsw.edu.au/snap/work/volcano_indonesia.htm** and **../volcano_monitor.htm**.

References

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