Global volcano studies using ERS1,2 and Envisat SAR data archives.

Executive Summary

We request the online provision of nearly the entire ERS and Envisat SAR archives via ESA's "Virtual Archive" for systematic analysis of the volcanic cycle and related ground deformation using the InSAR technique. Our approach is to use the full archive of InSAR data available for active volcanoes to carry out systematic studies of pre-eruption and post-eruption deformation, as well as ground deformations related to flank instability and volcano related earthquakes. These data will improve our understanding of the volcano eruptive cycle and will provide valuable data for improving estimates of volcanic risk. This project takes full advantage of the capability of ESA's new "Virtual Archive" for convenient access to large amounts of remote sensing data.

This proposal is part of a coordinated sequence of four Category-1 proposals to the European Space Agency for fully exploiting the existing ERS and Envisat SAR archives for tectonics, volcano and climate change studies through online access visa ESA's "Virtual Archive".

Team composition

The PI of the project is Eugenio Sansosti, a senior scientist at IREA, an Institute of the Italian National research Council (CNR) located in Naples, Italy. The Co-PIs are Andrew Hooper, professor at the Delft Institute of Technology, Netherlands, Falk Amelung, a professor of geophysics at the University of Miami, USA, Paul Lundgren, senior scientist at the Jet Propulsion Laboratory in Pasadena, Franz Meyer, professor at the University of Alaska in Fairbanks, USA, Eric Fielding, senior scientist at the Jet Propulsion Laboratory in Pasadena, USA, Zhenhong Li, professor at the University of Glasgow, U.K., Tim Wright, a reader in Satellite Geodesy at the University of Leeds, UK, Andy Shepherd, professor at the University of Leeds, U.K. and Matt Prittchard, professor at Cornell University, Ithaca, USA.

Team Experience

Each of the team members has more than a decade of experience using InSAR to study crustal deformation and directs individual InSAR research groups. Recognizing the importance of on-line access to the ESA SAR data, the team is leading current efforts to repatriate previously produced data into ESA's virtual archive through the Geohazard Supersites initiative.

Innovation

This project is innovative for three reasons. First, this project exploits for the first time the full ESA SAR data holdings in an effort to characterize volcano behavior on a global scale. Second, this project presents the first global approach to InSAR processing. Third, the online data provision will bring ESA on par with common practice in optical remote sensing in which multi-decade imagery is conveniently available at the user's fingertips through Google Earth.

Contribution to Mission Objectives

This project contributes directly to ESA's mission objective "to better understand solid Earth processes".

The online availability of the ERS and Envisat "Virtual Archives" will be a critical element to accomplish ESA's core mission of providing long-term, continuous Earth Observation data sets for scientific research.

This project is timely because, in combination with its sister projects on earthquakes, climate change and InSAR accuracy, it will facilitate the full exploitation of the ESA SAR archives just prior to the arrival of new, unprecedented data amounts from the Sentinel-1 satellites.

Detailed Description

Volcanic systems are complex and largely non-linear systems that may suddenly change from one state to another. An eruption occurs when magma is able to propagate from its source (a magma chamber) to the surface through an open conduit or an underground fracture (dyke). If the magma becomes arrested on its path to the surface, no eruption takes place. However, prior to an eruption there are normally changes in magma pressure in the source chamber of the volcano, and these are reflected in associated gravity, geodetic, seismic, gas-emission changes. One might expect an awakening volcanic system, which has not erupted for many years or millennia, to undergo a gradual build-up of surface phenomena, including inflation, increasing seismicity, changes in the hydrothermal regime over many weeks to years. Alternatively, the transition to eruption may occur as rapidly as the underlying state of the volcanic system can allow, which can present a significant hazard.

Increased volcanic activity almost inevitably produces ground deformation before, during, between and after the events; moreover, ground deformation can be related also to gravitational processes induced by rapid growth of volcano edifices (Ruch et al., 2010). Over the last decade Interferometric Synthetic Aperture Radar (InSAR) has developed into a mature geodetic technique which retrieves ground deformation in satellite radar line-of-sight from a stack of SAR acquisitions (Neri et al., 2009); the technique has evolved from the measurements of a single deforming episode to the study of the temporal evolution of the detected displacements, by exploiting the availability of large SAR data archives (Berardino et al., 2002).

For these reasons, InSAR techniques are excellent tools to follow and study the non-linear behavior characteristics of volcanoes and to detect deformation phenomena that are precursor to an impelling eruption (Solaro et al., 2010). In fact, the application of InSAR methods to study volcano deformation is becoming nowadays routine.

We propose to use 20 years of ERS and ENVISAT data to study the volcano behavior worldwide. This will allow comparing the eruption cycles of different volcanoes, thus improving the understanding of the magma recharge mechanism leading to an eruption. In addition, we will study also non-erupting (bur still active) volcanoes to investigate conditions that prevent the rise of magma until the surface.

To address this problem requires the analysis of a large amount of SAR data, including combination of ascending and descending orbit data in order to separate vertical and horizontal (East-West) component of the deformation. We will prove the data into average deformation rate maps and time series using the so-called "advanced DInSAR techniques" (Sansosti et al., 2010).

Our focus will be initially on well known volcanic areas, such as Etna and Campi Flegrei in Italy, Hawaii and Long Valley in USA, Tenerife in Spain, Piton de la Fournaise in France and Iceland. These areas are known to have good temporal coherence, good SAR coverage and large volcanic deformation signals. Next we will focus on the global archive and aim to include all possible SAR data for which the temporal coherence is sufficient to generate deformation time series. Our ultimate objective is to picture the eruption cycle of several volcanoes, to correlate it with the corresponding deformation history and to compare different volcano behaviors considering their different geomorphologic aspects. The 20year time span of ERS and ENVISAT archives will likely cover a sufficiently long time to include more than one eruption cycle for most of the active volcanoes.

Our approach will build experience of working with large data volumes that will be essential after the launch of Sentinel-1. We will use knowledge of InSAR errors gained from a parallel proposal to estimate our uncertainties reliably.

Project deliverables

1. Average deformation rate maps and deformation time series for selected volcanic sites.
2. Average deformation rate maps and deformation time series at other volcanic sites.
3. Comparative study on the eruption cycles at several volcanoes over the world.

Related Projects

The project is part of a sequence of four proposals aimed at exploiting the global ESA SAR archives. The other three are “Orbital, atmospheric and ionospheric noise in InSAR data inferred from the global ERS1,2 and Envisat SAR data archives” (led by PIs Falk Amelung and Franz Meyer), “Global earthquake cycle studied using the ERS1,2 and Envisat SAR data archives” (led by PIs Tim Wright and Zhenong Li), and “Changes of the Earth’s climate from 20 years of ERS1,2 and Envisat SAR data” (led by PIs Andy Shepherd and Franz Meyer).

This sequence of proposals has been inspired by the success of the Group of Earth Observation’s (GEO) geohazard Supersites project. The data requested are of interest for the worldwide geohazard and climate change communities. We anticipate that many PIs involved in these areas of research will join these projects once they are in place.

References

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Schedule

August 2011. Start of project using repatriated data available in ESA's virtual archive for selected volcanoes (Etna, Campi Flegrei, Hawaii, Long Valley).

January 2012. Mapping of deformation related to eruptive cycle for the selected volcanoes.

August 2012. Extension of the analysis to other volcanoes worldwide.

August 2013. Production of updated analyses of the deformation related to eruptive cycles at additional volcanoes.

July 2014. Project completion.

Data requirements

We request the provision of the entire interferometrically usable ESA SAR archive (into ESA's Virtual Archive in a consistent format (framed, RAW, Envisat format (including for ERS), all ERS1,2 and Envisat land tracks in volcanic active areas, a total of ~100,000 frames. We also request software applications to support the selection and download of large amounts of data such as an Application Programming Interface (API).

Online data provision and rapid download speeds are absolutely critical for the success of this project. At the end of the project we anticipate automated processing of several thousand SAR scenes per day.