Category-1 proposal submitted to the European Space Agency

Global earthquake cycle studies using the 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 earthquake cycle and tectonic deformation using the InSAR technique. Our approach is to use the full archive of InSAR data available for active faults to carry out systematic studies of co-seismic, inter-seismic and post-seismic deformation. In addition, we will combine InSAR results with GPS to produce regional strain maps. These data will improve our understanding of the earthquake loading cycle and will provide valuable data for improving estimates of earthquake 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 Tim Wright, a reader in Satellite Geodesy at the University of Leeds, UK. The Co-PIs are Falk Amelung, a professor of geophysics at the University of Miami, USA, Franz Meyer, professor at the University of Alaska in Fairbanks, USA, Eugenio Sansosti, senior scientist at IREA-CNR in Naples, Italy, Eric Fielding, senior scientist at the Jet Propulsion Laboratory in Pasadena, USA, Andrew Hooper, professor at the Delft Institute of Technology, Netherlands, Zhenhong Li, professor at the University of Glasgow, U.K., 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 tectonic strain on scales ranging from individual faults to whole deforming regions. 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 volcanoes, 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

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 time-series of SAR acquisitions. Studies of deformation occurring during earthquakes (co-seismic deformation) are now routine. For many earthquakes, post-seismic transients have also been measured using InSAR, and inter-seismic strain measurements have been made on numerous individual faults. We propose to use 20 years of ERS and Envisat data to increase the number of measurements of earthquake cycle deformation. These will lead to improve models of fault zones. Furthermore, we aim to combine measurements of strain from individual radar tracks with available GPS data to map strain over broad deforming regions. These regional strain maps will reduce uncertainties in studies of earthquake risk.

Tectonic faults undergo a cyclic behavior consisting of strain accumulation between earthquakes (inter-seismic period), the rupture of a fault during an earthquake (co-seismic period) and the relaxation of stress following an earthquake (post-seismic period). Estimating earthquake risk requires estimating the averaged slip rate from geodetic data. Inferring slip rates from InSAR is challenging because the surface displacements are small (a few millimeter/year for a slow moving fault) and distributed over a wide zone (several tens to hundreds of kilometers). The signal therefore can easily be confused with uncertainties of the satellite orbits or atmospheric or ionospheric contributions in the InSAR deformation products.

To address this problem requires the analysis of a large amount of SAR data, and, in some cases, combination with complementary data sets such as GPS deformation data.

We will proves the data into average deformation rate maps and time series using a variety of techniques including, but not restricted to, the Small Baseline (SB) approach of Beradino et al. (2002) and the multi-interferogram method of Biggs et al (2007). Individual rate maps will be combined with GPS to produce regional velocity fields and strain maps using the method of Wang and Wright (2011).

Our focus will be initially on arid regions of the Alpine-Himalayan belt (Turkey, Iran, Tibet) and Western USA. These areas both have good temporal coherence, good SAR coverage and large tectonic signals. Next we will focus on the global archive and aim to include all possible SAR data for which the temporal coherence is sufficient. Our ultimate objective is to produce a refined version of the global strain rate model of Kreemer et al. (2003).

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 deliveries

1. Co-seismic deformation maps and models for selected earthquakes.
2. Inter-seismic deformation maps and models for selected faults.
3. Regional strain maps for portions of the Alpine Himalayan Belt and Western USA.

References

Berardino, P., G. Fornaro, R. Lanari and E. Sansosti (2002). A new algorithm for surface deformation monitoring based on small baseline differential SAR interferograms. Ieee Transactions On Geoscience and Remote Sensing, 40, 2375–2383

Biggs, J; Wright, T; Lu, Z; Parsons, B (2007) Multi-interferogram method for measuring interseismic deformation: Denali fault, Alaska, *GEOPHYS J INT*, **170**, pp.1165-1179.

Kreemer, C., Holt, W. E., & Haines, A. J (2003). An integrated global model of present-day plate motions and plate boundary deformation. Geophysical Journal International, Volume 154, Issue 1, pp. 8-34.

Wang, H. & Wright, T. (2011). Satellite geodetic imaging reveals internal deformation of western Tibet, Nature Geoscience, In Review.

Schedule

August 2011. Start of project using repatriated data available in ESA's virtual archive (Tibet, Turkey, Iran, Western U.S.).

January 2012. Mapping of earthquake cycle deformation for selected faults.

August 2012. Production of strain maps for Tibet, Turkey, Iran and Western US.

August 2013. Production of updated version of global strain rate model.

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 tectonically deforming areas (defined according to the Global Strain Rate model), a total of ~500,000 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.

We request data provision in three phases. In the first phase (phase A) we request imagery of Tibet, Iran, Turkey and the Western US. In the second phase (phase B) we request data for the rest of the alpine-Himalayan belt. In the third phase (phase C) we request the remainder (all land imagery in areas of tectonic strain).