Challenges facing the WInSAR Consortium from the coming tsunami of SAR observations

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Introduction

Interferometric Synthetic Aperture Radar (InSAR) provides an excellent means of observing surface properties and change over broad regions of the ground with applications in the study of the solid earth, cryosphere, biosphere, and atmosphere. In the measurement of deformation from tectonic processes, InSAR has revolutionized our ability to make observations in space and time, and is highly complimentary to GPS measurements. Rapid growth in the number of InSAR-capable satellites in the next years, combined with advanced techniques capable of handling multiple images to yield improved temporal and spatial resolution is expected to generate petabytes of raw data and higher level data products. Improved computational infrastructure will be essential to be prepared for this data tsunami to extract useful results and conduct monitoring on a global scale. InSAR data and processing is therefore a natural fit for the proposed EarthCube initiative.

The primary source of InSAR data for the solid earth community in the US is the Western North America InSAR Consortium (WInSAR). The main objective of WInSAR is to facilitate and promote research activities that involve the use of SAR data to measure surface deformation. NASA, USGS, and NSF have provided funding for WInSAR operations and data acquisitions. What began as a small consortium focused on InSAR in the western US, WInSAR has grown to an organization with close ties to the international InSAR community and become an important advocate for the geodetic science community. As both the number and the capabilities of SAR satellites increase over the next decade, the consortium will serve an important role in shaping future data sharing policies and will need to prepare for an order-of-magnitude increase in the data collected for scientific study.

History and Governance

WInSAR was originally organized in 1999 as a consortium of universities and research institutions administered by the NSF+USGS Southern California Earthquake Center (SCEC) with data archives mirrored at three universities. It currently operates as a self-organizing consortium of the UNAVCO Board of Directors (see http://winsar.unavco.org). WInSAR was a grass-roots organization self-organized by several InSAR scientists to share access to SAR data under the license conditions of the data providers. SAR data from foreign space agencies, unlike most geophysical data, had to be purchased so efficient sharing of data was the early motivation for WInSAR. As the archive and membership expanded, the WINSAR Consortium voted to transfer administration to UNAVCO in 2006. In recent years, WInSAR's international clout has grown with increased membership and the success of our members in utilizing the data for scientific applications. WinSAR members include universities, Federal agencies (e.g., USGS), and national laboratories (e.g., LLNL).

UNAVCO's primary role is to provide administrative and logistical support for WInSAR activities such as financial management, data orders, and data archiving. UNAVCO WInSAR online archive activities began in Fall 2006. The WInSAR Executive Committee (WInSAR-EC) is responsible for managing the affairs and business of WInSAR, and assures that operations conform to policy set by the WInSAR membership. WInSAR-EC has the authority to set operational goals (data purchases, data distribution, archiving, and data products). WInSAR-EC reviews and makes recommendations on all proposals related to WInSAR operations before review and approval by the UNAVCO Board.

The WInSAR-EC is elected every two years by the WInSAR Institutional Representatives of the Full Member institutions that are based in the USA. WInSAR also allows institutions from outside the USA to join as Adjunct Members, who may have access to WInSAR data and software depending on the license agreements but cannot vote. Institutional membership stands at 96 in 2011, including 72 full members (US institutions), 5 Adjunct-1 members (North American institutions outside of the US), and 19 Adjunct-2 Members (rest of the world). There are 236 data users from the full member institutions who have passwords to download data.

The WInSAR EC holds regular teleconferences that include UNAVCO staff and usually the liaison from the UNAVCO Board of Directors. With advice from UNAVCO on operational implications, the EC makes decisions regarding the use of WInSAR funds and the operational priorities for UNAVCO. WInSAR telecon notes are posted on the UNAVCO WInSAR website “Documents” section (http://winsar.unavco.org/documents.php), which also contains links to reports on InSAR research by WInSAR scientists to space agencies.

The WInSAR Annual Business Meeting is held every year at the AGU Fall Meeting, hosted by UNAVCO. In December 2010, the bi-annual election of Executive Committee members was held. The annual meeting is an opportunity for the WInSAR community to learn about new WInSAR resources and discuss the strategies for the future. Community input is also gathered throughout the year through email to the WInSAR membership mailing list. Requests for data acquisition over specific sites can be entered by full members on the WInSAR website through the “ESA ordering” page, which requires authentication.

The original plan for NSF’s Major Research Infrastructure initiative EarthScope had four “legs”: the Plate Boundary Observatory GPS network, the US Array seismic network, the San Andreas Fault Observatory at Depth (SAFOD) drilling project, and an InSAR satellite mission. The EarthScope InSAR satellite mission concept was to be lead by NASA in partnership with the NSF and the USGS, but it was deferred. During the EarthScope “build” phase from 2003-2008, some resources from the GeoEarthScope sub-project were devoted to purchasing SAR data from satellite data providers and building an archive at UNAVCO. Due to data license restrictions at the time, the GeoEarthScope and WInSAR data archives were kept separate. In the last few years, the data policies, especially of the European Space Agency (ESA), have changed so now the GeoEarthScope SAR data archive is in the process of being merged with the WInSAR archive. The two archives combined contain about 17 TB of SAR data from the three ESA satellites ERS-1, ERS-2 and Envisat, plus the Canadian Space Agency (CSA) satellite Radarsat-1.

WInSAR has recently started an effort to implement an application-programming interface (API) to the WInSAR/GeoEarthScope archive to enable more efficient access to the data and metadata through machine-machine interfaces to supplement the existing web-based access. This will enable more efficient large-scale and time-series analysis of the archive data and is described in another white paper. The WInSAR consortium has an ALOS-1 PALSAR data allocation under the US Government Research Consortium Data Pool that is hosted at the Alaska Satellite Facility (ASF), covering parts of North America and some other regions in the Americas. The ASF has also built an API in the last year to enable more efficient access to their archive, and the WInSAR API is designed to be compatible with the ASF API to allow interoperability. A recent proposal between UNAVCO, ASF, OpenTopography and JPL proposes to ‘virtually’ merge the two archives into a Seamless SAR Archive (described in more detail in another EarthCube White Paper).

UNAVCO sponsors an annual InSAR for Beginners Short Course to teach people about how InSAR works and how to use a popular software package to process InSAR data. This course has been very popular, rapidly filling up the 25 places for attendees each year since 2008. The instructors have all been WInSAR members, and every year many of the attendees immediately join WInSAR to become active participants in the WInSAR community. The sample datasets used in the short course come from the WInSAR and Supersite data archives. UNAVCO has also recently signed a software license with Caltech-JPL to enable distribution of a new second-generation software package called the InSAR Scientific Computing Environment (ISCE) to WInSAR members.

Recent Science and Collaboration Results

WInSAR and UNAVCO have also helped to create and maintain a prototype archive and website for the Group on Earth Observations (GEO) Geohazard Supersites (http://supersites.earthobservations.org/main.php). This international data sharing and collaborative website and virtual archive system has proven extremely popular in the rapid early analysis phases of several recent large earthquakes. Special Event Supersites were rapidly created for the 2010 Haiti, 2010 Maule, Chile and 2011 Tohoku-oki, Japan earthquakes and many scientists from around the world sent their first InSAR, GPS, seismic and other results to the Supersite page to be shared with other researchers (Figure 1). ESA, the Japanese Aerospace Exploration Agency (JAXA), and the German space agency (DLR) all contributed SAR data to the Supersite virtual archive to enable InSAR and related analysis.

The InSAR technique is capable of measuring deformation over large areas at spatial resolutions from order a meter to 10's of meters and intervals from days to months. These attributes are useful for studying fundamental scientific problems as well as more applied topics. For example, the western part of North America is the focus of intensive scientific research into a variety of plate boundary processes including earthquakes, volcanism, mountain building, and micro-plate tectonics. InSAR has proven to be a powerful tool to characterize large-scale deformation associated with active faults. It also can resolve small-scale deformation features such as shallow creep, postseismic and interseismic deformation. InSAR data has lead to the characterization and more complete understanding of the plate boundary deformation system. This in turn provides insight into the to the occurrence of earthquakes, a poorly understood scientific problem that, if understood, may ultimately lead to a reduction in seismic risk. InSAR is useful for studying both natural and anthropogenic processes that induce surface deformation such as landslide movement, land subsidence due to water or oil extraction, all of which are at work in North America.

Recent scientific results by WInSAR scientists are based largely or in part on analysis of SAR data from European Space Agency (ESA) ERS and Envisat satellites, with additional SAR data from the JAXA Advanced Land Observation Satellite (ALOS), CSA Radarsat-1, DLR TerraSAR-X, and Italian Space Agency (ASI) COSMO-SkyMed satellites and the NASA airborne InSAR system called UAVSAR. Studies have addressed deformation related to the earthquake cycle in the plate boundary system at the western edge of North America, including the San Andreas Fault (SAF) system, the Basin and Range province and the Cascadia subduction zone. The continuation of the SAF system into northern Mexico was the site of the Mw 7.2 El Mayor-Cucapah earthquake in April 2010. In addition to imaging coseismic deformation and damage, triggered slip, slip transients and postseismic processes are being studied, along with the interseismic buildup of stress on faults in the diffuse plate boundary. WInSAR scientists are also studying volcanic processes in the Cascade volcanic change, Long Valley, Yellowstone and the Big Island of Hawaii. Other research covers landslides, subsidence due to groundwater withdrawal and other subsurface processes, and wetland dynamics in a number of locations across North America. These studies target assessment of geologic hazards in response mode and risk of future events and also address fundamental questions of geological and geophysical structure of the Earth.

Figure 1. Screenshot of the Supersite for the Tohoku-oki, Japan earthquake (http://supersites.earthobservations.org/sendai.php) showing the rapid evolution of data and results within a few days after the event. Images and geodetic data from GPS were used for both scientific use as well as disaster assistance (e.g. images of possible floating objects).

Future of InSAR, a data tsunami

By 2020, we expect that most of the Earth will be imaged almost every day by SAR satellites that are InSAR-capable, forming a virtual tsunami of data. ESA is planning to launch two SAR satellites, Sentinel-1a and Sentinel-1b as part of the European Commission Global Monitoring for Environment and Security (GMES) program, with the first launch in 2013 and the second in 2015. Each of these satellites is designed to acquire up to a terabyte of SAR data every day, rapidly dwarfing the 17 TB of data now in the WInSAR/GeoEarthScope archive. JAXA is planning to launch ALOS-2 in the same time frame, the Canadian Space Agency is working on launching the Radarsat Constellation Mission of three satellites in the middle of the decade, and the Argentine Space Agency is planning to launch two satellites (SAOCOM-1A, -1B). NASA also plans to launch an L-band InSAR satellite, presently called the Deformation, Ecosystem Structure, and Dynamics of Ice (DESDynI) mission concept. The capabilities of some of these satellites are yet to be defined, but each may generate another terabyte of SAR data per day. By the end of the decade, a flood of terabytes per day and petabytes per year of SAR data will increase the flow of data to scientists by several orders of magnitude over the rates that WInSAR and GeoEarthScope have faced in the past (17 TB acquired over 12 years).

As the approaches for processing and ingesting InSAR observations into time series analysis improve, one of the remaining hurdles to new users of SAR imagery is simply the ability to sort through the data to identify which areas have (or will soon have) sufficient imagery to meet their needs. This could include understanding the detection thresholds for long-term deformation signals, or whether data exists (and is coherent) spanning a single event. The API interface is one step towards making the archive of existing data more accessible to both experienced and new users.

To date, WInSAR has only provided data in the Level 0 or raw radar data form. Because processing the raw radar data into interferograms and other higher-level InSAR products can be challenging, this has limited the pool of potential users. The Seamless SAR Archive proposal mentioned above would also archive contributed interferometry products in WInSAR and to provide a basic InSAR production-on-demand system. In the future, systematic processing of InSAR data, in a way similar to the systematic processing of GPS data from the Plate Boundary Observatory, could provide a standard set of processed interferometry products, which would greatly increase the number of potential users. Even better would be integrated processing of InSAR and GPS data into a joint geodetic product for tectonic deformation and other measurements.

Conclusions

The EarthCube collaborative framework would provide an optimal means to address these challenges and the WinSAR governance model may provide a low-cost and effective way of achieving these goals. By enhancing the InSAR data accessibility and enabling large-scale processing for a new generation of earth scientists, we expect this will lead to a new set of exciting discoveries.