UNAVCO Report

FACILITY SUPPORT OF THE WINSAR ARCHIVE FOR CRUSTAL DYNAMICS RESEARCH

Final Report

NSF Grant EAR-0733437

Submitted to:

Russell Kelz
National Science Foundation, Instrumentation and Facilities Program

And

John LaBrecque
NASA Headquarters

Submitted by:

Charles Meertens
Frances Boler
UNAVCO

Eric Fielding
Jet Propulsion Laboratory

Rowena Lohman
Cornell University
1.0 Executive Summary

The activities of the Western North America InSAR (WInSAR) Archive and Consortium are described in this report. This grant funds the UNAVCO Facility to support the WInSAR Consortium in its activities, to operate the WInSAR Archive, including data acquisition through ordering of SAR data, tasking of SAR satellites, and archiving and distribution of SAR archive data to the WInSAR Consortium members and data users. The grant also partially funds an archivist to handle data and metadata archiving and data ordering; a technician to place satellite tasking orders; and a software developer to enhance the underlying archiving software and the user interface for data search, access, and delivery to the WInSAR community. The WInSAR Archive leverages the data purchased or acquired mainly from the European Space Agency (ESA) to maximize the number of users and the potential for exciting science results to be generated based on the data.

The WInSAR Consortium membership has grown to 76 US Members and 33 Adjunct members from around the globe. The membership meets annually at the Fall American Geophysical Union meeting to conduct business and to elect the WInSAR Executive Committee on a biannual basis.

In the first two years of the grant, most funds were directed towards purchase of data and tasking fees. Beginning in 2010, data and tasking costs were waived by ESA. From that point, grant funds were directed towards labor for ongoing ordering, data management and archiving, and towards improving the SAR archive software and hardware infrastructure at UNAVCO.

During this grant, an additional 11,194 scenes (1.8 Tb) were ordered from ESA and were archived and made available to WInSAR membership. The membership picked up 31,600 scenes (4.4 Tb) during the report period.

WInSAR scientists have utilized the WInSAR archive to produce 111 publications since the proposal for this work was written in 2007; these publications detail innovations in WInSAR analysis methods and their application to a wide range of Earth science problems.

2.0 PI Science Investigations

The Western North America InSAR (WInSAR) Consortium is a collaboration among universities and public agencies created to manage the acquisition and archiving of spaceborne InSAR data. WInSAR is a collective organization coordinating the interests
of many scientists in different fields. We concentrate primarily on geophysical investigation and modeling of shallow crustal processes such as earthquakes and volcanoes, but consortium members have ongoing research in hydrology, cryospheric studies, vegetation science, and oceanography, as well as sponsoring research in as yet untested application areas.

Most recent innovation has been in the development of new data analysis methods and their application to geophysical problems. In particular, we have pioneered the use of advanced modeling and inverse methods, quantifying detailed deformation fields in order to learn about processes at depth in the crust. Much of our work involves numerical and analytical modeling of deformation phenomena, and now is moving toward incorporating extensive time series analysis into data reduction methods. The large volume of data acquired under this proposal has also allowed development of such innovations as the improvement of InSAR time series through combination with models of atmospheric noise based on GPS data and weather models, further improving the potential signal to noise ratio of such products. Many of the analysis methods developed using WInSAR data are then applied to data worldwide, as happened for the recent New Zealand earthquake sequence.

The main purpose of WInSAR is to facilitate research in these many areas using pooled data, enabling science to be accomplished without requiring each individual proposer to request data for each investigation. This approach saves considerable effort on the part of data providers in servicing requests from the U.S. research community, as WInSAR catalogs and maintains data for all consortium members. WInSAR’s approach is also helpful for U.S. sponsoring agencies, as data requests are coordinated and internally peer-reviewed for adherence to WInSAR’s goal of facilitating basic research, reducing the need for the agencies to conduct extensive reviews of many disparate requests.

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. The technique of spaceborne Interferometric Synthetic Aperture Radar (InSAR) provides an excellent means of observing deformation over broad areas. WInSAR members have used InSAR data for the following primary objectives:

- Monitor strain accumulation and release along the North American/Pacific plate boundary with an emphasis on the San Andreas fault zone.
- Monitor the deformation of volcanic systems in the western US.
- Monitor crustal deformations at selected sites in the Basin and Range province and along the Baja California peninsula.
- Assess anthropogenic deformation associated with extraction and injection of fluids (water and hydrocarbons)

Increasingly, WInSAR members are also exploring InSAR data from actively deforming regions worldwide, and we expect that both the scope and membership of WInSAR will become increasingly global. As part of the research and development efforts of WInSAR
members we have: promoted the use and development of InSAR technology for scientific investigations, in particular but not limited to, seismic and magmatic processes, plate boundary deformation, land subsidence, and topographic mapping; provided value-added InSAR products and software for use by the scientific community; and advocated the open exchange of SAR data by seeking to enlarge the number of member organizations.

3.0 WInSAR Consortium

3.1 Executive Committee

UNAVCO provides organizational and operational support for WInSAR activities. The WInSAR Executive Committee acts as an Advisory Committee of the UNAVCO Board of Directors. The WInSAR Executive Committee (EC) is elected every two years by the WInSAR Consortium membership. UNAVCO's operational support includes membership administration, financial management, data management and archiving, and software tools for data exploration and access. Current EC members are Eric Fielding, Chair, Rowena Lohman, Vice Chair, David Schmidt, Secretary, Rob Mellors, At Large, and Shimon Wdowinski, At Large. The WInSAR EC holds regular teleconferences. 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 (http://winsar.unavco.org) “Documents” section, which also contains links to reports on InSAR research by WInSAR scientists.

UNAVCO hosts the WInSAR Annual Business Meeting at AGU each year. Reports presented at the Annual Business Meeting are also posted on the UNAVCO WInSAR website (http://winsar.unavco.org) “Documents” section. The next WInSAR election for new Executive Committee members is scheduled to take place prior to the 2012 Business Meeting in December.

3.2 Membership

Institutional membership stands at 109, including 76 Full members (US institutions), 5 Adjunct I members (North American institutions outside of the US), and 28 Adjunct II Members (outside North America). There are 223 data users. At the time the proposal for this award was written in March 2007 there were 40 Full member institutions, three Adjunct I members, and approximately 128 data users. The Adjunct II member category was created with the WInSAR Bylaws change in December, 2007 and all 28 Adjunct II members have been added since then. The WInSAR EC approves all applications for WInSAR membership.

4.0 UNAVCO Data Support

UNAVCO provides data support to the WInSAR Consortium by ordering data requests from WInSAR full members, submitting tasking orders, archiving the data ordered, and distributing WInSAR data. During 2008-2009, UNAVCO ordered and purchased 2,200
scenes from ESA, and tasked and paid the tasking fee for over 4,000 scenes from the ESA Envisat satellite. In 2010 ESA revised their policy for data use for scientific purposes, eventually waiving data acquisition (tasking) fees and costs associated with ordering archived data. Ordering of scenes and tasking for data acquisition continued throughout the remaining grant period, but no further expenditures for data or tasking were made after January, 2010. During the grant period over 11,000 scenes were obtained from ESA and approximately 8,600 scenes were tasked for the Envisat satellite (prior to its failure in April, 2012) on behalf of WInSAR at no cost from ESA.

During 2011, the opportunity to task the TerraSAR-X satellite at no charge arose when the German Space Agency (DLR) made a quota of 1,000 scenes available for tasking by WInSAR. The WinSAR EC solicited tasking targets from the membership, and eventually 20 targets were identified for tasking (Figure 1). UNAVCO staff members submit tasking requests on a monthly basis.

![Figure 1. Google Earth images of TerraSAR-X tasking footprints. Not shown are a site in Hastings, TX, and Galapagos footprints.](image)

Early in 2011 the WInSAR EC voted to redirect unused data purchase budget towards infrastructure investments, to include storage and processing hardware upgrades, development of an Application Programming Interface, database and web upgrades, and expansion of capacity to handle additional SAR platform data types. The sponsors approved this plan for utilization of the budget, along with phasing the expenditures to support operations through September, 2013. Funds from the related EarthScope Comprehensive SAR Archive grant were also approved to support this effort.
4.1 Data Holdings

The WInSAR data collection at UNAVCO includes 18,438 scenes available to the users through the UNAVCO SAR Archive search website (http://facility.unavco.org/SarArchive/flexweb/SearchSarScene.html). Figure 2 shows Google Earth images of the SAR scene footprints for WInSAR holdings. Table 1 shows the holdings within in each mission and overall total.

![Envisat](image1)

![ERS1](image2)

![ERS2](image3)

**Figure 2.** Google Earth images of data holdings in the WInSAR Archive for the ESA Envisat, ERS1, and ERS2 missions.

**Table 1.** WInSAR holdings by mission through May 31, 2012.

<table>
<thead>
<tr>
<th>Satellite Mission</th>
<th>Scenes</th>
<th>Size, Gigabytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERS1</td>
<td>3,970</td>
<td>750</td>
</tr>
<tr>
<td>ERS2</td>
<td>7,386</td>
<td>1,156</td>
</tr>
<tr>
<td>ENVISAT</td>
<td>7,082</td>
<td>1,132</td>
</tr>
<tr>
<td>Total</td>
<td>18,438</td>
<td>3,038</td>
</tr>
</tbody>
</table>

Placement of orders to ESA and downloads and ingests were executed regularly. During the grant, the holdings more than doubled due to regular ordering activity. Table 2 shows the data ordered and received during the grant. Data pickups by WInSAR data users during the report period are summarized in Table 3.
Table 2. Data orders for June 2008 - May 2012.

<table>
<thead>
<tr>
<th>Satellite Mission</th>
<th>Scenes</th>
<th>Size, Gigabytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERS1</td>
<td>1,969</td>
<td>374</td>
</tr>
<tr>
<td>ERS2</td>
<td>2,929</td>
<td>457</td>
</tr>
<tr>
<td>ENVISAT</td>
<td>6,296</td>
<td>1,006</td>
</tr>
<tr>
<td>Total</td>
<td>11,194</td>
<td>1,837</td>
</tr>
</tbody>
</table>

Table 3. Data pickups by WinSAR users for June 2008-May 2012.

<table>
<thead>
<tr>
<th>Satellite Mission</th>
<th>Scenes</th>
<th>Size, Gigabytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERS1 &amp; 2</td>
<td>12,455</td>
<td>1,962</td>
</tr>
<tr>
<td>ENVISAT</td>
<td>19,170</td>
<td>2,482</td>
</tr>
<tr>
<td>Total</td>
<td>31,625</td>
<td>4,444</td>
</tr>
</tbody>
</table>

4.2 Data Management System and Web Site

Through its data management system, UNAVCO supports the archiving, distribution, and ordering of SAR data on behalf of WinSAR. The WinSAR web site at UNAVCO is the focal point for users to search and gain access to data holdings, to place order requests, and for the membership to gain information about WinSAR activities. At the inception of this grant, the WinSAR archive at UNAVCO was operating on aging processing hardware with limited RAID storage capacity, and using a database and web site that was originally inherited from the founding WinSAR archives at Stanford and Caltech. Because the WinSAR grant incorporated funds mainly for data purchase and archivist support of the archive, the ability to invest in upgrades to hardware, database, web site, and supporting software was limited. When funds targeted for data purchase were no longer needed due to ESA’s data policy change, the WinSAR EC approved realigning remaining WinSAR funds to support infrastructure upgrades, with a request for an Application Programming Interface (API) to be part of the upgrade. In February, 2011, NSF and NASA also approved this realignment for remaining WinSAR funds and a similar realignment for funds remaining in the EarthScope Comprehensive SAR Archive grant.

Planning and execution of the upgrade began in April 2011. An InSAR specialist was hired in a temporary part-time capacity to provide domain knowledge for database improvements and the API development. To better support the entire SAR archive, the plan included merging of the GeoEarthScope and WinSAR databases and storage so that the same search and access mechanism could be used for both. To provide for adequate storage for several years into the future, the disk drives on the RAID systems purchased to support GeoEarthScope were replaced, doubling the capacity to 90 Tb. The database was migrated to Postgres/PostGIS to support spatial queries. The underlying web services provide a RESTful API that can be accessed directly; a python client that utilizes the API
was developed as well. A web GUI that also utilizes the web services API (Figure 3) provides search capability and access to the multiple collections that make up the SAR archive. The system rollout took place just after the end date of this grant. The successful completion of this effort is further detailed in the Annual Report for the EarthScope Comprehensive SAR Archive grant.

![Figure 3](image-url)

**Figure 3.** Web GUI for data search and access utilizes an API and spatial query capability.

### 4.3 GEO Supersites Data Management and Web Site Support

For the GEO Supersites and Natural Laboratories initiative, UNAVCO provides data ordering (from the European Space Agency), along with data management (download and repackaging) of the orders received, and upload of the orders to the ESA supported cloud storage (Level 3 and Terradue/Hetzner storage services).

In addition to this data management operational activity, UNAVCO provides web site content management and hosting for the Supersites main page and for Supersite Event pages, the most recent cases being event pages covering the Van, Turkey earthquake in October 2011, the Northern Italy earthquake sequence of May 20-29, 2012 and the pair of earthquakes in NW Iran on August 11, 2012.
4.4 ISCE Software Support

In June, 2011, the WInSAR EC approved a proposal from JPL that WInSAR support the distribution of the InSAR Scientific Computing Environment (ISCE) software that is the next generation follow-on software to JPL’s popular ROI_PAC InSAR processing code. UNAVCO worked with JPL and Stanford to come up with license language that would allow WInSAR/UNAVCO to distribute the software. At the end of the award, all of the distribution mechanisms were in place at UNAVCO and several WInSAR Full Members had executed ISCE licenses. Going forward, JPL will provide some training to UNAVCO staff who will then be able to provide first level user support. A preview of the ISCE software was demonstrated in the UNAVCO InSAR for Beginners Short Course in August 2012.

5.0 Science Publications by WInSAR Researchers Since 2007


Li, Z., E.J. Fielding, and P. Cross, Integration of InSAR time series analysis and water vapour correction for mapping postseismic deformation after the 2003 Bam, Iran Earthquake, *IEEE Trans. on Geosci. and Remote Sens.*, 47, 3220-3230, 2009.


