ACCESS11: Seamless Synthetic Aperture Radar (SAR) Archive for Interferometry Analysis

Final Technical Report

Submitted by Charles Meertens, PI
UNAVCO, Inc.
6350 Nautilus Dr.
Boulder, CO 80305

Performance Period: April 1, 2012 through March 31, 2016

NASA Grant Number NNX12AF62A

Submitted to

David Meyer, NASA Headquarters, Technical Officer
Project Accomplishments

Summary
The seamless synthetic aperture radar archive (SSARA) implements a seamless distributed access system for SAR data and derived data products (i.e. interferograms). SSARA provides a unified application programming interface (API) for SAR data search and results at the Alaska Satellite Facility and UNAVCO (WInSAR and EarthScope data archives) through the use of simple web services. A federated query service was developed using the unified APIs, providing users a single search interface for both archives. Interest from the international community has prompted an effort to incorporate ESA’s Virtual Archive 4 Geohazard Supersites and Natural Laboratories (GSNL) collections and other archives into the federated query service. SSARA also provides Digital Elevation Model access for topographic correction via a simple web service through OpenTopography and tropospheric correction products through JPL’s OSCAR service. Additionally, UNAVCO provides data storage capabilities for WInSAR PIs with approved TerraSAR-X and ALOS-2 proposals which allows easier distribution to US collaborators on associated proposals and facilitates data access through the SSARA web services.

SSARA has also developed a user-contributed InSAR archive for interferograms, time series, and other derived data products at UNAVCO. The InSAR archive is based on the hierarchical data format release 5 (HDF5) data format and provides storage, distribution, and sharing of research results within the geodesy community. HDF5 is the preferred format for InSAR data products because it provides a more robust set of features for storing InSAR data. HDF5 has been adopted by the Alaska Satellite Facility (ASF) and is also used in InSAR time series analysis software packages such as GIAnT from Caltech. Digital object identifiers (DOI) have been incorporated into the archive allowing users to assign a permanent location for their processed result and easily references the final data products. Further development has led to the adoption of the HDF-EOS5 specification that provides standards for data and metadata storage within HDF5. This provides easier integration with GIS software packages such as ArcGIS and GDAL and conversion to other data formats like NetCDF and GeoTIFF.

System Overview
SSARA Federated Search:
The goals of the SSARA project were to design and implement a seamless distributed access system for SAR data and derived interferometric SAR (InSAR) data products. A unified application programming interface (API) has been created to search the SAR archives at ASF and UNAVCO, 30 and 90-m SRTM DEM data available through OpenTopography, and tropospheric data from the NASA OSCAR project at JPL. The federated query service provides users a single access point to search for SAR granules, InSAR pairs, and corresponding DEM and tropospheric data products from the four archives, as well as the ability to search and download pre-processed InSAR products from ASF and UNAVCO.

The SSARA API provides a set of web services to search and retrieve metadata for pertinent SAR holdings using a simple calling convention. Initial development focused on searching for SAR data and providing a unified, consistent API between UNAVCO and ASF. Further API development and enhancements added more InSAR specific keywords and quality control parameters (Doppler centroid, faraday rotation, InSAR stack size, and perpendicular baselines). To facilitate InSAR processing, the federated query service incorporated URLs for DEMs (from OpenTopography) and tropospheric corrections (from the JPL OSCAR service) in addition to the
URLs for SAR data. The federated query service provides relevant QC metadata for selecting pairs of SAR data for InSAR processing and all the URLs necessary for interferogram generation. Queries are sent as HTTP GET or HTTP POST requests for resources based upon API parameters supplied in the request. Each query requires the base URL (http://web-services.unavco.org/brokered/ssara/), the resource (api/sar/search, api/insar/search, or api/insar/selectpairs), and a set of query parameters if desired (Fig. 2). The API returns the search result in the open, text-based data exchange format JSON that includes metadata for scenes as well as URLs for direct data downloading. The SSARA services can be accessed programmatically using a number of languages (Python, Perl, Java, etc.), common command line utilities such as wget or curl, or any web browser. A GitHub repository was create (https://github.com/bakerunavco/ssara) and provides a Python command line client, data utilities for converting DEMs, and a wiki with details about the API and query parameters. A SSARA viewer (Fig. 3) has also been developed to enable web-based queries and visualization the search results (http://web-services.unavco.org/brokered/ssara/gui).

The SSARA API was released in June of 2013. In three years of production use, there have been 114651 SSARA queries submitted from 4243 unique IPs. A summary of metrics can be found here: http://web-services.unavco.org/brokered/ssara/metrics
Figure 1. SSARA system overview. New capabilities developed during this project are shown in green.

Figure 2: Web services developed as part of the SSARA project.

Figure 3: SSARA Graphical User Interface
SSARA Integration with Geohazards Supersites and Natural Laboratories

Part of the extend scope of SSARA incorporated integration with the Geohazards Supersites and Natural Laboratories (GSNL) and provided a federated data viewer (Fig. 4). The existing GSNL services are not compatible with SSARA, so metadata is harvested daily from ESA Virtual Archive 4 and DLR TSX Archive using OpenSearch and OGC CSW protocols. The metadata is stored in the UNAVCO SAR database as separate data collections (Supersites VA4 and Geohazard.Supersite.TerraSAR-X_SSC), and queries against these collections are available using the SSARA federated query service. Automated data downloads from ESA Virtual Archive 4 were integrated into the SSARA command line client using the secp download client. Work is in progress to incorporate download from DLR TSX Archive. The SSARA clients can be utilized directly in the Supersites Exploitation Platform (SSEP) for InSAR data processing.

UNAVCO developed a prototype viewer incorporating queries across SAR, GPS, and seismic datasets (Fig. 5). The viewer uses the existing web services (SSARA, GSAC, and IRIS/FDSN) to display available data for the defined Supersites. Further development could incorporate other data sources (optical and other in situ data) with established web services and provide better query and filtering capabilities within the viewer.

Figure 4: GSNL Integration and Federated Data Viewer
Figure 5: Federated data viewer utilizing SSARA API, GSAC, and IRIS/FSDN web services. The viewer is available at: http://web-services.unavco.org/brokered/ssara/dataviewer

SSARA InSAR Product Archive
As part of SSARA, a user-contributed InSAR archive (https://winsar.unavco.org/portal/insar/) for interferograms, time series, and other derived data products has been developed at UNAVCO. The InSAR archive is based on a standard HDF5 data format and provides storage, distribution, and sharing of research results within the geodesy community. The hierarchical data format release 5 (HDF5) [HDF Group, 2014] is the preferred format for InSAR data products because it provides a more robust set of features for storing data. HDF5 has been adopted by the Alaska Satellite Facility (ASF) and is also used in InSAR time series analysis software packages such as GIaNT from Caltech [Agram et al., 2013]. When dealing with a single geocoded interferogram, netCDF or HDF5 work equally well for storing the data. With more complicated scenarios such as stacks of interferograms or distribution of both geocoded and radar geometry interferograms, the hierarchical data features of HDF5 become important, in particular the ability to create groups within a single HDF5 file. Support for reading and writing HDF5 is available in many programming languages (C/C++, Fortran, Python, Java), and Matlab versions 7.3 and higher use an HDF5-based format for their MAT-file storage, thus providing native reading and writing of HDF5 files.
**Data Format Specification**

The standard HDF5 data products provide all the necessary datasets and relevant metadata in a single file for distribution. The product format specification describes the use of HDF-EOS5 data model for data products in the UNAVCO community-contributed InSAR data archive. Information in this document includes:

1. Definition of the datasets included in the data product
2. Naming convention for the data product
3. Required and recommended metadata included in the data product
4. Layout of the data products with examples for interferogram, time series, and velocity map products

Example HDF5 converters for ISCE, ROI_PAC, and GMTSAR are provided in a GitHub repository: https://github.com/bakerunavco/ProductArchive

**Uploading data products**

Since all necessary metadata is read from the HDF5 file directly, the user only needs to upload the data product file. A browsable REST interface for uploading interferograms (LOS velocities and LOS time series support in development) is provided in the WInSAR portal:

API_ROOT: https://winsar.unavco.org/portal/insar/api/

Data products can be uploaded to the archive either with a webform on the InSAR product page or with the API from the command line using cURL:

curl -i -F data_file=@DATA_FILENAME -u USERNAME:PASSWORD API_ROOT/interferometry/

Users only need to provide the "data_file" parameter via POST method along with their login credentials since all metadata pertaining to the product is contained within the HDF5 file.

**DOIs for data products**

Once the data products is uploaded, users can see all of their uploaded products and request assignment of a DOI. On the product detail page (Fig. 6) there is a map of the product coverage, metadata, and a “Request a DOI” button that the owner of the data product uses to request the DOI.
Figure 6: Product detail page in the InSAR archive at UNAVCO

Partner Collaborations
The teams from UNAVCO, ASF, JPL/Caltech, and SDSC/OpenTopography met in a face-to-face kickoff meeting in May 2012 at ASF in Fairbanks, AK. A follow-on face-to-face meeting occurred in project year two at UNAVCO in Boulder, Colorado, and informally at annual AGU meetings throughout the duration of the project. To facilitate API development during SSARA project years 1 and 2, quarterly month-long agile scrum development sprints and sprint review meetings were held between the team at UNAVCO and at ASF.

Open source software development was aided through the use of Github. SSARA software products can be found at:
https://github.com/bakerunavco/SSARA
https://github.com/bakerunavco/Archive-Tools
https://github.com/bakerunavco/ProductArchive

Project Participant Activities Summary

UNAVCO
UNAVCO was the lead institution on the SSARA project, responsible for technical coordination among the project partners, budget oversight, and reporting.
Major UNAVCO technical activities during the SSARA project, described above, were:
- Refactoring existing UNAVCO SAR Archive API to align with SSARA API agreed upon with ASF.
- Development and deployment of federated SSARA API query.
- Development of community-contributed InSAR product archive system (https://winsar.unavco.org/portal/insar/), and definition of standards for InSAR products.
Specifically, UNAVCO led efforts to adopt the HDF5 data format for storage, distribution, and sharing of research results within the geodesy community. A format product specification document on the use the HDF EOS5 data model was also produced and is available for community feedback (https://docs.google.com/document/d/1fm6RY8aL4hhRa88M9cd_Ejh6OL3YfibfjN1UQ7TWsmI/edit?usp=sharing)

- Integration of Digital Object Identifiers (DOIs) for InSAR products into the WInSAR product archive.
- Prototyping of integration of SSARA with Geohazard Supersites and Natural Laboratories data access.

As noted below, UNAVCO has also been the primary participant in the NASA ESDSWG process during the project.

**ASF**
The main achievements from ASF during the SSARA project were:

- Coordinated quarterly agile scrum sprints for SSARA software team
- Refactoring existing ASF DAAC APIs to align with SSARA API
- Updated InSAR processor to include topo correction provided by OpenTopography

All ASF standardized sample ALOS PALSAR InSAR products have been processed with a customized version of ROI_PAC (version 3.1, revision 172). The SAR interferometric products have been terrain corrected using a digital elevation model provided by OpenTopography. In the future, tropospheric effects will be corrected using water vapor model outputs based on MODIS data provided by the Online Services for Correcting Atmosphere in Radar (OSCAR) of the Jet Propulsion Laboratory (JPL).
JPL/Caltech

Two new services have been developed for the JPL Online Services for Correcting Atmosphere in Radar (OSCAR) server. These services will allow users of SAR (Synthetic Aperture Radar) data from SSARA doing interferometric SAR (InSAR) analysis to estimate the atmospheric effects on their data from tropospheric water vapor. Tropospheric water vapor variations are the largest source of errors in InSAR measurements in most areas. The estimates can often be used to correct a major part of the atmospheric effects in InSAR, and can also be used to screen the SAR data in the SSARA federated catalog to exclude the scenes most affected by water vapor variations. The new OSCAR services build upon the existing OSCAR services previously developed under the OSCAR AIST project completed in 2012 (PI Paul von Allmen). One new service calculates the zenith path delay (ZPD) map for a single date of a SAR acquisition derived from the NASA Terra or Aqua MODIS near-infrared precipitable water vapor product, useful for screening and time-series analysis of SAR interferometry data. The second service calculates the zenith path delay difference map (ZPDDM) for a pair of SAR images by taking the difference between the zenith path delay maps for the two dates and times of SAR acquisition. Final implementation of
the new OSCAR services was deferred due to the OSCAR system being installed on obsolete hardware and software. The OSCAR server uses the same JSON (Javascript Simplified Object Notation) syntax as the rest of the SSARA services, making integration straightforward. We also worked closely with the rest of the SSARA team to develop and test the SSARA federated search system. We defined the metadata and data formats that will be used for the InSAR products that will be produced at ASF and also archived at UNAVCO under SSARA.

SDSC/OpenTopography
A primary outcome of the SSARA project for the SDSC/OpenTopography team was the development of a web service for global digital elevation model delivery. As part of the SSARA project, OpenTopography ingested NASA’s Shuttle Topography Radar Mission (SRTM) 30 and 90 meter resolution datasets. These data are now accessible through the OpenTopography web interface (http://opentopography.org/srtm) and have also been integrated to the SSARA federated search for InSAR terrain correction. The SRTM web service developed for the SSARA project has also been exposed on its own as a resource for OpenTopography users (http://www.opentopography.org/developers) and has been extremely successful. In total, SRTM data have been accessed via the OT SRTM API developed for SSARA nearly 93,000 times.

ESDSWG Participation
UNAVCO has led participation in the ESDSWG process on behalf of the SSARA project. Through the ESDSWG process, C. Crosby provided review of the Open Geospatial Consortium (OGC) Keyhole Markup Language (KML) Encoding Standard as a candidate NASA Earth Science Data Systems (ESDS) community standard on request of the ESDIS KML technical working group. SSARA’s adoption of the HDF EOS5 standard, a NASA ESDS approved standard, is an excellent example of NASA standards forming the basis for new community cyberinfrastructure activities. More recently, D. Ertz, UNAVCO’s ESDSWG representative has attended timeseries XML group calls and has begun to investigate its use for UNAVCO timeseries services. The UNAVCO rep will also be participating in the geospatial working group this year.

Sustainability
This section summarizes the plan for post project sustainability of SSARA data and systems.

SSARA Federated Web Service & InSAR Product Archive
The SSARA federated web service and InSAR product archive are both now foundational components of the WinSAR cyberinfrastructure that supports the UNAVCO geodesy community. UNAVCO intends to sustain both of these components through core operational WinSAR efforts. The InSAR product archive is now integrated into the WinSAR Portal production environment (https://winsar.unavco.org/portal/insar/) and is accumulating a growing number of InSAR products. DOI generation for these products leverages UNAVCO’s EZID account and is aligned with efforts to facilitate data citation. Similarly, the SSARA federated search service is well aligned with UNAVCO’s efforts to provide web services for all data products managed by the facility. In the future, UNAVCO’s SAR archive infrastructure may use SSARA to directly access data and products. Finally, SSARA code and associated utilities are available on Github as open source software to allow community adoption and modification.

DEM web service at OpenTopography
The development of web services to deliver global topography data such as SRTM has had large impact for both SSARA InSAR users as well as the broader OpenTopography community. The service for topographic correction developed through SSARA is now integrated into production OpenTopography cyberinfrastructure, and the OpenTopography is committed to sustaining, and expanding the service. Going forward we intend to add additional datasets (e.g., ASTER GDEM), to benefit the OT community and the broader community of topographic data users.

**OSCAR web service at JPL**
We have been discussing the ongoing operation of the OSCAR web server at JPL with two NASA SAR missions, the airborne UAVSAR mission and the NISAR mission. Both have expressed great interest in sustaining the OSCAR service, including updating it to run on modern servers or virtual machines. The OSCAR server was one of the key sources of global atmospheric water vapor maps used by the NISAR mission in their Phase B development of an InSAR performance model. The OSCAR atmospheric corrections have also been shown to greatly improve UAVSAR repeat-pass interferometry processing, so they are considering integrating it into their system.

**Remaining Work**
No work remains to achieve the goals defined by the project. A prototype federated data viewer utilizing SSARA API, GSAC, and IRIS/FSDN web services has been developed as part of the SSARA effort. If there is continued interest from other parties as well as the UNAVCO community, future work on this viewer is possible.

**Project Presentations & Publications**

**2012**

**2013**
SSARA work presented and services demonstrated in a special topics session at the UNAVCO Science Workshop: *Science powered by WInSAR – Achievement and opportunities of accessible InSAR data*

Short courses held at UNAVCO for GMTSAR in June and ROI_PAC in July, S. Baker introduced the SSARA project, and demonstrated the SSARA federated query, ensuring that key users of the new capability are recruited to begin using the service.

IG29-A004 *The Seamless Synthetic Aperture Radar (SAR) Archive (SSARA) Project and Other SAR Data Support Activities at UNAVCO*.

David Phillips, Scott Baker, Christopher Crosby, Charles Meertens, Eric Fielding, Gwendolyn Bryson, Brian Buechler, Jeremy Nicoll, Chaitanya Baru, AOGS 11th Annual Meeting, 28 July to 01 August, 2014 Sapporo, Japan

Southern California earthquake Center Annual Meeting:
[http://www.scec.org/meetings/2013am/presentations/poster049.pdf](http://www.scec.org/meetings/2013am/presentations/poster049.pdf)

ALOS-2 PI Workshop
SSARA project made at JAXA: “Federated archive web services provided by the Seamless SAR Archive (SSARA) project”

Fall AGU IN31C-1519. Federated query services provided by the Seamless SAR Archive project. Scott Baker; Gwendolyn Bryson; Brian Buechler; Charles M. Meertens; Christopher J. Crosby; Eric J. Fielding; Jeremy Nicoll; Choonhan Youn; Chaitanya Baru 8:00 AM - 12:20 PM; Hall A-C (Moscone South)

SSARA demonstrations at the WInSAR business meeting and at the UNAVCO exhibit hall booth during AGU.

2014
Presentation and demonstration of SSARA federated search and download capabilities at two UNAVCO InSAR short courses:
InSAR Processing and Theory with GMTSAR
InSAR: An introduction to Processing and Applications using ISCE and GIAnT


Baker, et al., 2014, The Seamless SAR Archive (SSARA) Project and Other SAR Data Support Activities at UNAVCO, Fall AGU

SSARA demonstrations at the WInSAR business meeting and at the UNAVCO exhibit hall booth during AGU.

2015

Overview of InSAR products and SSARA at the UNAVCO Advanced InSAR Processing Short Course (https://www.unavco.org/education/advancing-geodetic-skills/short-courses/2015/advanced-insar/advanced-insar.html)

Poster presentation on the InSAR product archive at the 2015 Southern California Earthquake Center (SCEC) annual meeting

Baker et al., 2015, A Community-Contributed InSAR Product Archive at UNAVCO, AGU fall meeting.

SSARA demonstrations at the WInSAR business meeting and at the UNAVCO exhibit hall booth during AGU.
2016
SSARA project update during SAR special topics session at the 2016 UNAVCO Science Workshop


Acknowledgements
Report written by Christopher Crosby and Scott Baker, UNAVCO; Eric Fielding, JPL.

Inventions Negative Statement

No inventions have resulted from this research.