Western North America Crustal Dynamics Research: WInSAR Consortium

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Abstract

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. The Western North America InSAR (WInSAR) Consortium is a collection of universities and public agencies created to manage the acquisition and archiving of spaceborne InSAR data. We propose to use ALOS PALSAR data, with its unique L-band capabilities, for the following:

- 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.

Keywords: crustal deformation, PALSAR interferometry.

1. RESEARCH OBJECTIVES

Our approach and expect results follow:

- Modify existing InSAR processing algorithms to accommodate PALSAR data for change detection and DEM generation.
- Work with the ALOS team to schedule PALSAR data acquisitions over western North America. This will be done in co-ordination with the Alaska Satellite Facility (ASF).
- Compare L-band PALSAR-derived interferograms with C-band interfereograms from ERS/Envisat as well as GPS measurements.
- Reduce the errors in PALSAR interferograms by modeling ionospheric and atmospheric artifacts.
- Publish and present scientific results in journals, scientific meetings, and at ALOS team meetings.

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Notes on list of Co-Investigators. This is a rather long list of CI's since it includes all the active members of the WInSAR consortium. WInSAR has worked with NASA, NSF, and USGS to obtain significant funding to pay for the distribution of ALOS data at the Alaska Satellite Facility. This is called UPASS. Part of this agreement was that the data would be shared by the WInSAR membership in a password-protected archive at ASF and UNAVCO. We already maintain about 4000 scenes of ERS and ENVISAT data in our password-protected WInSAR archive. Each CI on this list has a particular interest in using ALOS data over their research area and is responsible for their own funding and activities. Each investigator has signed an agreement with ASF and UNAVCO stating that the data will be used for research purposes only and cannot be distributed outside of the WInSAR membership list. The Alaska Satellite Facility has approved this list of investigators on this PI investigation. The CI's will acknowledge JAXA and ALOS PALSAR in their publications. In addition we proposal to have several CI's attend the JAXA meetings. PALSAR data acquisition requests will be compiled at the Alaska Satellite Facility. For more information about WInSAR, please visit our web site (http://winsar.unavco.org).

2. PROGRESS

2.1. Algorithms and Software Development

Our first research task was to modify existing InSAR processing algorithms to accommodate PALSAR data for change detection and DEM generation. We have developed/modified three software tools related to ALOS.
1) The first tool contributed by Rob Mellors and David Sandwell consists of 4 programs for preparing the raw L1.0 signal data for interferometric processing. The software consists of the following tools and is freely available at http://www-rohan.sdsu.edu/~rmellors/ALOS_preproc.tar.gz
ALOS_pre_process - Takes the raw ALOS PALSAR data and aligns the data in the near range. In addition it produces a parameter files in the SIOSAR format containing the essential information needed to focus the data as Single Look Complex (SLC) images.
ALOS_baseline - Takes two parameter files of an interferometric pair and calculates the approximate shift parameters needed to align the two images as well as the accurate interferometric baseline at the beginning and end of the frame.
ALOS_merge - Appends two raw image files and eliminates duplicate lines. In addition it makes a new PRM file representing the new longer frame.
ALOS_fbd2fbs - Converts a raw image file in FBD mode (14 MHz) to an FBS mode (28 MHz) by fourier transformation of each row of the image file (one echo) and padding the spectrum with zeros in the wavenumber domain. A new parameter file is created to reflect the new data spacing and chirp parameters. A complementary *ALOS_fbs2fbd* program is also available but not

automatically compiled with the makefile. The interferograms made from the FBD2FBS conversion have lower noise than the interferograms made from the FBS2FBD conversion.
2) The second software tool is a script contributed by Eric Fielding and Yuri Fialko to take the pre-processed data and process it in ROI_PAC. This addition to ROI_PAC is also freely available at http://roipac.org/ALOS_PALSAR
3) The third tool is the modification of our in-house software SIOSAR to process PALSAR interferograms including the special capabilities for the longer-wavelength characteristics of L-band. This code is also freely available by request (dsandwell@ucsd.edu) although the documentation is incomplete.

2.2 Compare L-band PALSAR interferograms with C-band intefereograms

We assess the spatial resolution and phase noise of the L-band radar aboard the ALOS spacecraft using 9 repeat SAR images in California and compare these results with corresponding C-band measurements from ERS. Based on cross-spectral analysis of phase gradients we find that the spatial resolution of ALOS interferograms is 1.3 times better than ERS interferograms. The phase noise of ALOS, (i.e., line-of-sight (LOS) precision of over the 100 m to 5000 m wavelength band) is only 1.6 times worse than ERS (3.3 mm vs. 2.1 mm) and not 4 times worse as one would expect from 4 times lower fringe rate. In both cases the largest source of error is tropospheric phase delay. Vector deformation maps associated with the June 17, 2007 (Father's day) intrusion along the east rift zone of the Kilauea volcano were recovered using just 4 ALOS SAR images from two look directions. Comparisons with deformation vectors from 19 continuous GPS sites show rms line-of-site precision of 14 mm and an rms azimuth precision (flight direction) of 71 mm. This azimuth precision is at least 4 times better than corresponding measurements made at C-band. Phase coherence is high even in heavily vegetated areas in agreement with previous results. This improved coherence combined with similar or better accuracy and resolution suggests that L-band ALOS will outperform C-band ERS in the recovery of slow crustal deformation.

2.3 PALSAR Acquisitions over Western North America and Hawaii

We are working with JAXA to schedule FBD and FBS PALSAR acquisitions along both ascending and descending passes along the San Andreas Fault System. Figure 1 shows the 658 repeat images already freely available (password protected) to all U.S. investigators in the ASF L1 data pool (https://ursa.asf.alaska.edu/cgi-bin/login/guest/). Most of these swaths have only 2-3 acquisitions, although both the ascending and descending swaths over Pinon Flat have 9 acquisitions. The current acquisition plan for November 2007 through October 2009 was delivered by JAXA in November of

2007 and is available at the WInSAR UNAVCO web site (http://geoes-insar.unavco.org/newsletters.php). Over the next two years, JAXA has scheduled an average of 8.6 repeats out of a possible 15.8 repeats along all ascending passes (5253 scenes) and 3.6 repeats along descending passes (1791 scenes). Note that there is almost 50% overlap of adjacent tracks so the number of ascending/descending repeats will be 17 and 7, respectively over two years. Seven to 17 SAR images are a relatively low number to stack to reduce atmospheric noise [1]. However, there are two reasons that the atmospheric noise may be reduced to below 2 mm/yr where InSAR could provide a major contribution. First, the expected increase in temporal baseline possible at L-band wavelengths will increase the time span and thus the signal to atmospheric noise ratio. Second, the spectrum of atmospheric noise is "red" [1, 2]. The expected RMS noise is 25 mm for wavelengths shorter than 200 km, but only 8 mm for wavelengths shorter than 20 km. The creep signals of interest have maximum deformation within about 5 km of the fault zone thus a cumulative stack time of only 16 years will be needed to reduce the atmospheric noise to 2 mm. This can be achieved with to 4 independent 4-year interferograms, which correspond to 8 independent SAR acquisitions.

3. CONTINUED RESEARCH

We will continue these areas of research during the next year. Our focus will be on scientific applications using ALOS data. We will continue to publish the results in scientific journals and make presentations at national and international meetings. In addition at least one member of the WInSAR Consortium will attend the ALOS PI meetings.

2.4 Reduce path-delay errors in PALSAR interferogram

So far we have not completed research on this topic.

4. DISCUSSION AND PROSPECTS

We have completed the initial phase of our research, which involved developing software for interferometric processing of ALOS and assessing the spatial resolution, phase noise, and combined accuracy of the crustal deformation measurements. As shown in Figure 1 ALOS has acquired enough data to begin studying interseismic deformation along the San Andreas Fault System as well as to monitor deformation of volcanoes in North and South America. The high quality of the PALSAR radar data along with the imbedded high accuracy orbit data make production processing feasible.
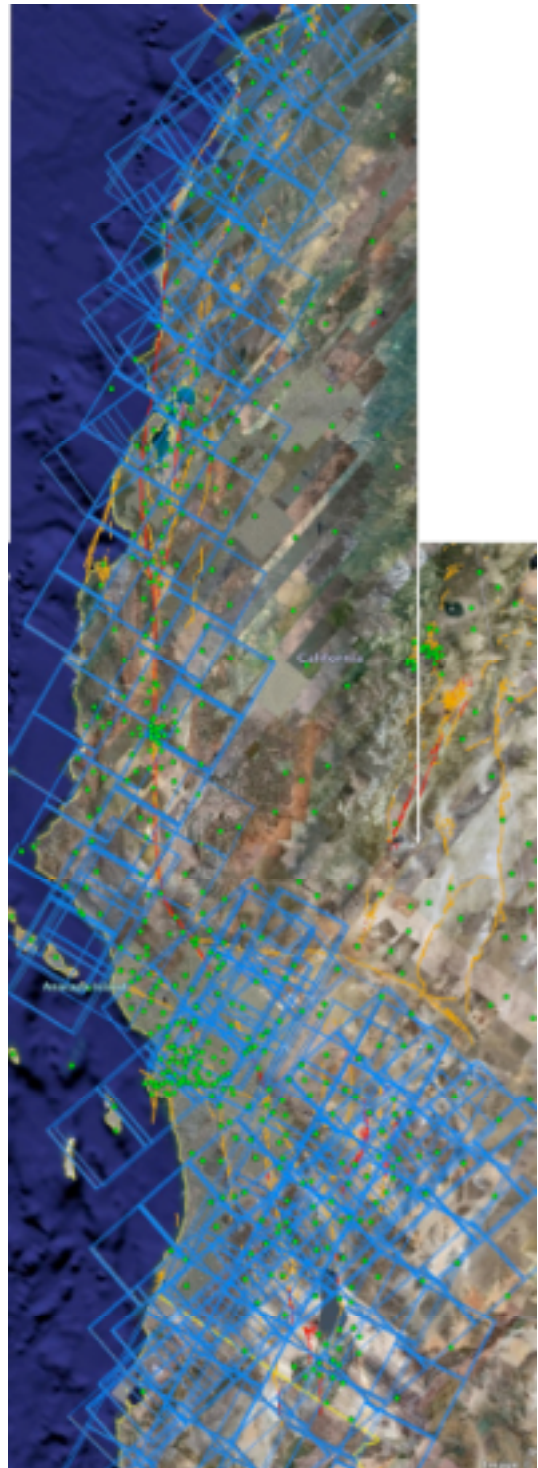
Figure 1. *Distribution of 658 ALOS repeat only SAR images (blue boxes) along the SAFS collected during the first 1.5 years of the ALOS mission. Red lines mark currently active faults and the yellow lines are active faults that have not ruptured in historical times. The coverage is best on the southern and northern ends of the fault system, but poor along descending orbits in central California. The green dots mark the locations of the continuous GPS receivers of the PBO.*

List of data used in the research

Our research is based on a variety of geodetic tools including vector GPS measurements, C-band interferometry from ERS, ENVISAT, and RADARSAT. The ASF L1 data pool currently contains about 2200 scenes of ALOS PALSAR (L1.0) data. Approximately 1500 of these data were selected by WInSAR investigators and paid for using the UPASS system described above. Periodically we ask the WInSAR members for new data requests. The 50 scenes per year available under this PI investigation provide more timely data access (~4 days) in case of events. The turnaround time for access to ALOS UPASS data is typically 3 weeks. An important aspect of our investigation is the ability to directly access the JAXA AUIG catalog.

Papers published in the research

Abstracts and Symposium Presentations:

Myer, D., D. Sandwell, B. Brooks, J. Foster, and M. Shimada, Inflation of Kilauea Along the Southwest Rift Zone in 2006, presented at the meeting of the American Geophysical Union, San Francisco, California, December 2007.

Sandwell, D., M. Wei, ALOS Interferometry, presented at the annual meeting of the Southern California Earthquake Center, Palm Springs, California, September, 2006.

Sandwell, D., M. Wei, ALOS Interferometry, presented at the Meeting of the American Geophysical Union, San Francisco, California, December 2006.

Sandwell, D. T., M. Shimada, B. Brooks, InSAR Results from PALSAR: Southern San Andreas Fault and Hawaii, presented at the IUGG Symposium, Perugia, Italy, July, 2007.

Sandwell, D. T., M. Shimada, B. Brooks, InSAR Results from PALSAR: Southern San Andreas Fault and Hawaii, presented at the IGARSS symposium, Barcelona Spain, August, 2007.

Sandwell, D., M. Wei, Y. Fialko, R. Mellors, and M. Shimada, Accuracy and Resolution of ALOS Interferometry, presented at the annual meeting of the Southern California Earthquake Center, Palm Springs, California, September, 2007.

Sandwell, D., D. Myer, M. Shimada, B. Brooks, and J. Foster, Vector Deformation Maps of the Father's Day Intrusion at Kilauea: Constraints on Magma Injection, not presented at the Meeting of the American Geophysical Union, San Francisco, California, December 2007.

Publications:

Sandwell, D. T., D. Myer, R. Mellors, M. Shimada, B. Brooks, and J. Foster, Accuracy and resolution of ALOS interferometry: Vector deformation maps of the Father's Day Intrusion at Kilauea, submitted *to IEEE Trans. Geosciences and Remote Sensing*, November, 2007.

Myer, D., D. Sandwell, B. Brooks, J. Foster, amd M. Shimada, Inflation along Kilauea's southwest rift zone in 2006, submitted to *J. Volcanology and Geothermal Research*, January, 2008.

5. REFERENCES

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