Form 1a

Proposal No.
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Proposal Cover Sheet
For
ALOS First Research Announcement

Information of Applicant

Principal Applicant:

Name: David T. Sandwell

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Co-applicants: - See list attached

Name Organization E-mail

Biographical Information, Experience, Papers in Related Fields of Principal Applicant:

The PI is the current Chair of the WINSAR Consortium and he represents the interests of the Co-applicants. Many of the Co-applicants are leaders in the fields of interferometric SAR processing and crustal dynamics research. See Section 5 Personnel.

Signature of principal applicant : ____________________

Co-Applicants

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Form 1b

Poposal No.
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Information of Proposal Contents

1. Research Category (check one)* [√]

[ ] Calibration and Validation [ ] Utilization Research [√] Scientific Research

→[ ] Calibrate Individual Sensors

[ ] Develop and Validate Algorithms for Extracting Physical Parameters

* Our priority for the proposal selection will not be judged from your selected category.

2. Main Sensor (check one or more)

[ ] PRISM [ ] AVNIR-2 [√] PALSAR [ ] none

3. Supplemental Sensor (check one or more)

[ ] PRISM [ ] AVNIR-2 [ ] PALSAR [√] none

4. Data Requirements

[√] Required [ ] not Required

→ Satellite Data (Enter the maximum and minimum number of required scenes)

	MOS	JERS	ADEOS	TRMM	ADEOS-II	ERS	SPOT	LANDSAT	RADARSAT	IRS	ALOS
Minimum											300/yr
Maximum											600/yr

→ ALOS Simulation Data (check one or more.)

[ ] For the Optical Sensors [√] For the SAR

5. Research Title:

___Western North America Crustal Dynamics Research: WINSAR Consortium__

6. Abstract of Proposal

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.

We are pleased that NASDA plans to provide limited quantities of data for scientific research. Members of WInSAR would like to, participate in, and promote the ALOS mission. Our approach and expect results follow:

- Modify existing InSAR processing algorithms to accommodate PALSAR data for change detection and DEM generation. (2002 through 2003)
- Work with the ALOS team to schedule PALSAR data acquisitions over western North America. (2002 launch through 2005)
- 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. (2003 through 2005)
- Publish and present scientific results in journals, scientific meetings, and at ALOS team meetings. (2002 through 2005).

Western North America Crustal Dynamics Research: WInSAR Consortium

I. Objective

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. For example, the characterization and more complete understanding of the plate boundary deformation system, and its relationship to the occurrence of earthquakes, is a rich scientific problem that may ultimately lead to a reduction in seismic risk. Other natural processes that induce surface deformation such as land subsidence induced by water or oil extraction are also at work in western North America. The technique of spaceborne Interferometric Synthetic Aperture Radar (InSAR) provides an excellent means of observing deformation over broad areas. It is capable of 10's of meters spatial resolution at monthly or greater intervals. 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. And it is an ideal tool for measuring land subsidence and improving digital terrain models. 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 over western North America for their mutual benefit. The major objectives of WInSAR are to:

- Promote 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.
- Acquire SAR imagery in western North America, archive and catalog the data, and disseminate it for use by member organizations.
- Provide value-added InSAR products and software for use by the scientific community.
- Advocate the open exchange of SAR data by seeking to enlarge the number of member organizations.
- Solicit funds and promote programs and space missions to meet these objectives.

TABLE 1 WInSAR Institutions:

Bryn Mawr College
California Institute of Technology
Central Washington University
Cornell University
Jet Propulsion Laboratory
Lawrence Livermore National Laboratory
Massachusetts Institute of Technology
San Diego State University
Stanford University
University of Alaska
University of Hawaii
University of Miami
University of Memphis
University of Colorado, Boulder
University of California, Los Angeles
University of California, San Diego
University of California, Berkeley
University of California, Santa Cruz
University of Southern California
University of Utah
U.S. Geological Survey
University of Texas, Austin

WInSAR was initially formed to obtain ERS SAR data in sufficient quantity and at an acceptable price from agents of the European Space Agency (ESA - owner and operator of satellites ERS1 and ERS2) for shared academic purposes. The ability to share data among this research group offers a method to crosscheck research findings without having to go through the time and expense of duplicating data sets. Funding for WInSAR activities is provided by the US National Science Foundation, NASA, and the USGS through the Southern California Earthquake Center (SCEC).

This proposal to the ALOS Research Announcement is to obtained PALSAR data over Western North America to be shared among the members of the WInSAR Consortium. Our main scientific objectives are to:

- Modify InSAR processing algorithms to accommodate PALSAR data for change detection and DEM generation.
- Reduce the errors in PALSAR interferograms by modeling ionospheric and atmospheric artifacts.
- 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.

We are pleased that NASDA plans to provide limited quantities of data for scientific research. Members of WInSAR would like to, participate in, and promote the ALOS mission.

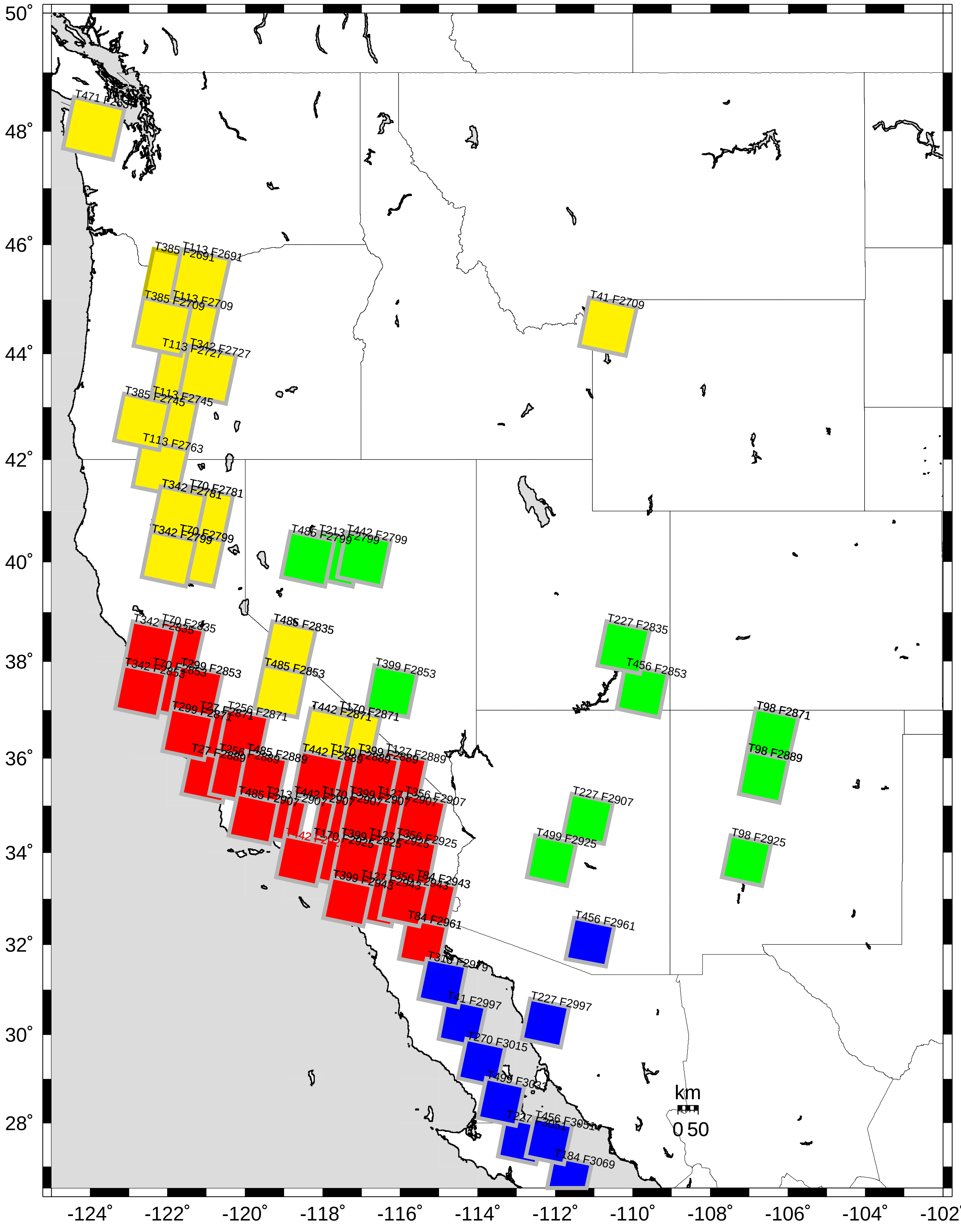
Figure 1 (next page) illustrates the areas of interest as defined by the members of WInSAR for the acquisition of ERS SAR data. We propose that NASDA collect ALOS PALSAR data in these same areas to enhance and extend the 8-year ERS time series. (red - San Andreas, yellow – volcanoes, green – Basin and Range, blue – Baja California). Later we can provide more complete track/frame information based on the operating characteristics of ALOS. Many of these crustal dynamic applications would benefit from frequent re-acquisitions to minimize atmospheric noise and other systematic errors. The L-band SAR aboard ALOS will offer a new and improved capability with respect to the C-band SAR's on ERS and Envisat. The most important improvements are the longer decorrelation time of the L-band sensor and the increased look angle of 35 degrees. These factors will promote investigations in mountainous, tree-covered areas that were inaccessible to the C–band SAR's.

II Methodology

The WInSAR consortium currently manages a password-protected data archive of over 400 scenes of raw ERS SAR data for Western North America (see http://topex.ucsd.edu/winsar). Depending on guidelines from NASDA, we propose to manage ALOS data in the same confidential way. A proposed scenario follows: WInSAR members would make a priority list of PALSAR data acquisitions. These data requests would be submitted to NASDA and executed according to NASDA priorities and quotas. For most of our research applications, rear-real time access is not requited. However, in case of a large earthquake, a pending volcanic event, or other natural disaster WInSAR would submit a detailed acquisition plan to NASDA and make special arrangements for rapid data delivery. In all cases, one copy of the relevant data would be mailed to the WInSAR archive. Authorized WInSAR users would have access to ALOS data in the WInSAR archive for scientific research; NASDA would continue to own the ALOS data in the archive and any copies made by members. We anticipate that this approach would maximize the scientific use of these data and minimize the impact on the ALOS data distribution system.

III Algorithm to be used

Members of the WInSAR group have developed software and archive capabilities for processing many scenes of raw ERS and JERS SAR data to interferograms, DEM's and crustal strain maps. This involves: pre-processing of Level 1.0 raw data and merging with the most precise orbital information available; focussing of SAR images; sub-pixel alignment of images; formation of interferograms and removal of topographic phase. More advanced analysis related to phase unwrapping, stacking of interferograms, DEM generation and crustal dynamic modeling are also available in the group.



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T98 F2871
T98 F2889
T227 F2907
T499 F2925
T98 F2925
T456 F2961
T84 F2961
T227 F2997
T41 F2997
T270 F3015
T184 F3069

We propose to modify this capability to accommodate the PALSAR raw data and ALOS orbital information. Depending on copyright restrictions, we will submit software developed for PALSAR processing to the ALOS Research Team and make it freely available to interested scientists.

IV Anticipated Results

Our main product will be scientific research in the form of publications, meeting presentations, and participation in the ALOS team meetings. All publications will contain an acknowledgement such as "ALOS PALSAR data were generously provided by NASDA" and figure captions will acknowledge the data source. Depending on travel budgets, the PI and other WInSAR members will attend the NASDA meetings. The WInSAR PI will submit and interim report during FY2002 and a final report. In addition to an overview of the research results, the Final Report will contain reprints of relevant scientific research. At the request of NASDA, higher-level data products and results will be provided.

In the process of meeting these scientific objectives, we will perform basic and applied research in the following areas outlined in the AO:
3.1.1 High resolution DEM's will be generated in the radar co-ordinate system of ALOS. These will be based on a combination of the best available DEM's from the USGS along with unwrapped residual phase from PALSAR. Stacking will be needed to reduce phase artifacts due to changes in the atmosphere and ionosphere between the reference and repeat passes.
3.6.1 Diastrophism – this is the primary focus of our research.
3.6.2 Volcano Monitoring – the secondary focus of our research
3.8.1 Interferometric methods applied to ALOS – this is addressed in the modification of our basic InSAR codes.
4.3.2 Accuracy improvement for InSAR data – improved accuracy will require the best possible orbital information, models of ionospheric delay based on the regional GPS array, and stacking of interferograms to reduce atmospheric delay.

V Ground Truth Data

Two types of ground-truth data will be provided by the Southern California Earthquake Center. In particular, regional ionospheric delay models derived from the existing GPS array in California will be used to suppress phase-delay errors in PALSAR data. Two-way delays at L-band (35 degree incidence angle) will be typically 65 m [*Curlander and McDonough*, 1991, p381]. Relative delays within the PALSAR swath will be much smaller but may still be important at the cm-level. Three-dimensional displacement vectors from the GPS-array will be projected into the ALOS line-of-sight and compared with interferograms. Comparison ALOS L-band interferograms with C-band interferograms from ERS-2 or Envisat will provide additional ground-truth. Ground truth for the DEM's will be provided by known locations of GPS monuments and radar reflectors on California as well as SRTM-derived DEM's.

VI Product Utilization Plan

We are requesting two types of information from the ALOS program. Precise orbital information will be needed to compute interferometric baselines. Post-processing of the planned GPS tracking data may provide orbital accuracies of better than 0.1 m in radial and cross-track position but even the nominal 1.0-m accuracy will be quite good. The second data type is the raw PALSAR data and accurate clock information. The Research Announcement indicates that the PALSAR data will mostly be available on the night passes so as not to conflict with the optical imaging. Nightime data will have lower ionospheric and tropospheric errors so these would be best for our experiment as well. Figure 1 shows descending (daytime) passes from ERS orbits but if ALOS has nightime passes along ascending passes, our plan is easily modified. Some descending passes may be needed for improved strain recovery on the northwest-trending San Andreas fault.

FORM 2

FORM 3a
No pre-ALOS data requested

Form 3b ALOS data requested (see Figure 1)

Area	min	max
San Andreas Fault Zone	140/yr	280/yr
Volcanoes	60/yr	120/yr
Basin and Range	60/yr	120/yr
Baja California	30/yr	60/yr

5. Personnel

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PRESENT POSITION:
Professor of Geophysics, Scripps Institution of Oceanography

EDUCATION:
Ph.D., 1981, University of California at Los Angeles, Geophysics and Space Physics.
M.S., 1978, University of California at Los Angeles, Geophysics.
B.S., 1975, University of Connecticut, Major Physics, Minor Mathematics

PROFESSIONAL EXPERIENCE:
1989-93 Scripps Institution of Oceanography. Associate Professor.
1985-89 The University of Texas at Austin. Research Scientist, joint appointment, Institute for Geophysics and Center for Space Research.
1982-85 National Geodetic Survey, Rockville, MD. Research Geophysicist.
1976-81 University of California, Los Angeles, Research Assistant.

RECENT EXPERIENCE:
10/99-present Chair of Western North America InSAR Consortium (WInSAR)
9/98-present Member of NRC Space Studies Board, Committee on Earth Studies

AWARDS/MEMBERSHIPS:
12/97 Fellow of the American Geophysical Union
9/98-present Society for Exploration Geophysics
6/77-present American Geophysical Union
6/80-present International Association of Geodesy

PI - RELEVANT PUBLICATIONS (82 total)

Sandwell, D. T. and W. H. F. Smith, Marine Gravity from Geosat and ERS-1 Altimetry, *J. Geophys. Res.*, 102, 10039-10054, 1997.
Smith, W. H. F. and D. Sandwell, Global seafloor topography from satellite altimetry and ship depth soundings, *Science,* v.277, p.1956-1962, 1997.
Price, E. J. and D. T. Sandwell, Small-scale deformation associated with the Landers 1992 California earthquake mapped by InSAR Phase Gradient, *J. Geophys. Res.,* v.103, p. 27001-27016, 1998.
Sandwell, D. T. and E. J. Price, Phase gradient approach to stacking interferograms, *J. Geophys. Res.,* v. 103, p. 30,183-30,204, 1998.
Baer, G., D. Sandwell, S. Williams, and Y. Bock, Coseismic Deformation Associated with the November 1995, Mw=7.1 Nuweiba earthquake, Gulf of Elat (Aqaba), Detected by SAR Interferometry*, J. Geophys. Res.,*.
Sandwell, D. T., L. Sichoix, D. Agnew, Y. Bock, and J-B. Minster, Near-real-time radar interferometry of the Mw 7.1 Hector Mine Earthquake, *Geophys. Res., Lett., submitted*, November 4, 1999.

SELECTED CO-I PUBLICATIONS (CO I's names **boldface**)

Bock, Y., D. C. Agnew, P. Fang, J. F. Genrich, B. **H. Hager, T. A. Herring, K. W. Hudnut, R. W. King,** S. Larsen, **J. B. Minster**, K. Stark, S. Wdowinski, and F. Wyatt, Detection of crustal deformation from the Landers earthquake sequence using continuous geodetic measurements, *Nature, 361*, 337-340, 1993.

Feigl, K., D. C. Agnew, **Y. Bock**, D. Dong, A. Donnellan, **B. Hager, T. Herring, D. D. Jackson,** T. H. Jordan, **R. W. King**, S. Larsen, K. M. Larson, M. H. Murray, Z. Shen, and **F. Webb**, Space Geodetic measurements of crustal deformation in Central and Southern California, 1984-1992, *J. Geophys. Res., 98*, 21677-21712, 1993.

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Nerem, R. S. e. a., Gravity model development for the Topex/Poseidon: Joint gravity models 1 and 2, *J. Geophys. Res., 99*, 24421-24447, 1994.

Peltzer, G., P. Rosen, F. Roges, and **K. Hudnut**, Postseismic rebound in fault step-overs caused by pore fluid, *Science, 27*3, 1202-1204, 1996.

Peltzer, G; Crampe, F; King, G., Evidence of nonlinear elasticity of the crust from the Mw7.6 Manyi (Tibet) earthquake., Science, 286, 272-276, 1999

Rosen, P. A., S. Hensley, H. A. **Zebker, F. H. Webb, and E. Fielding**, Surface deformation and coherence measurements of Kilauea Volcano, Hawaii from SIR-C radar interferometry, *J. Geophys. Res., 101*, 23109-23125, 1996.

Thatcher, W., Nonlinear strain buildup and the earthquake cycle on the San Andreas Fault, *J. Geophys. Res., 88*, 5893-5902, 1983.

Wicks, C and Thatcher, W; Dzurisin, D., Migration of fluids beneath Yellowstone caldera inferred from satellite radar interferometry, *Science, 282,* 458-462, Oct, 1998.

Zebker, H. A., and R. M. Goldstein, Topographic mapping from interferometric synthetic aperture radar observations*, J. Geophys. Res., 91*, 4993-4999, 1986.

Zebker, H. A., and Y. Lu, Phase Unwrapping Algorithms for Radar Interferometry: Residue-Cut, Least Squares, and Synthesis Algorithms, *J. Opt. Soc. Am., 15*, 586-598, 1997.

Zebker, H. A., P. A. Rosen, and R. M. Goldstein, On the derivation of coseismic displacement fields using differential radar interferometry: The Landers earthquake*, J. Geophys. Res., 99*, 19617-19634, 1994.

Zebker, H. A., P. A. Rosen, and S. Hensley, Atmospheric effects in interferometric synthetic aperture radar surface deformation and topographic maps*, J. Geophys. Res., 102*, 7547-7563, 1997.

6. Data processing and analysis equipment

Currently the WInSAR archive of ERS data is stored on two mass storage systems at Caltech and SIO. The Caltech system primarily holds geodetic and seismic data for the Southern California Earthquake Center. The 12 terabyte system at SIO is primarily used for global seismic data, reflection seismic data, GPS data and SAR data from ERS. We anticipate that these systems will be more capable by the time ALOS data start to flow. Both systems are funded by the US National Science Foundation, NASA, and the US Geological Survey. In addition to the mass storage devices, each investigator in the WInSAR Consortium has access to modern workstations capable of processing multiple scenes of raw SAR data. Funding for these systems will also come from US agencies. The speed of the internet in the US, and especially the Western US, easily accommodates transfer of 300 Mbyte files of raw SAR data so all data access will be by ftp.