CSSI Element: Harnesing the InSAR Data Revolution: **GMTSAR**

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http://topex.ucsd.edu/gmtsar

Basic - Open Software Promotes a Large User Base

ABSTRACT: Monitoring crustal deformation using InSAR is becoming a standard technique for the science and application communities. Optimal use of the new data streams from Sentinel-1 and NISAR will require open software tools as well as education on the strengths and limitations of the InSAR methods. Over the past decade we have developed freely available, open-source software for processing InSAR data. The software relies on the Generic Mapping Tools (GMT) for the back-end data analysis and display and is thus called GMTSAR. With startup funding from NSF, we accelerated the development of GMTSAR to include more satellite data sources and provide better integration and distribution with GMT. In addition, with support from UNAVCO we have offered GMTSAR short courses to educate mostly novice InSAR users. Currently, the software is used by hundreds of scientists and engineers around the world to study deformation at more than 17,000 sites (Figure 1). The most challenging aspect of the recent software development was the transition from image alignment using the cross-correlation method to a completely new alignment algorithm that uses only the precise orbital information to geometrically align images to an accuracy of better than 7 cm. This development was needed to process a new data type that is being acquired by the Sentinel-1A/B satellites. This combination of software and open data is transforming radar interferometry from a research tool into a fully operational time series analysis tool (Figure 2). Over the next 5 years we are planning to continue to broaden the user base through: improved software delivery methods; code hardening; better integration with data archives; support for high level products being developed for NISAR; and continued education and outreach.

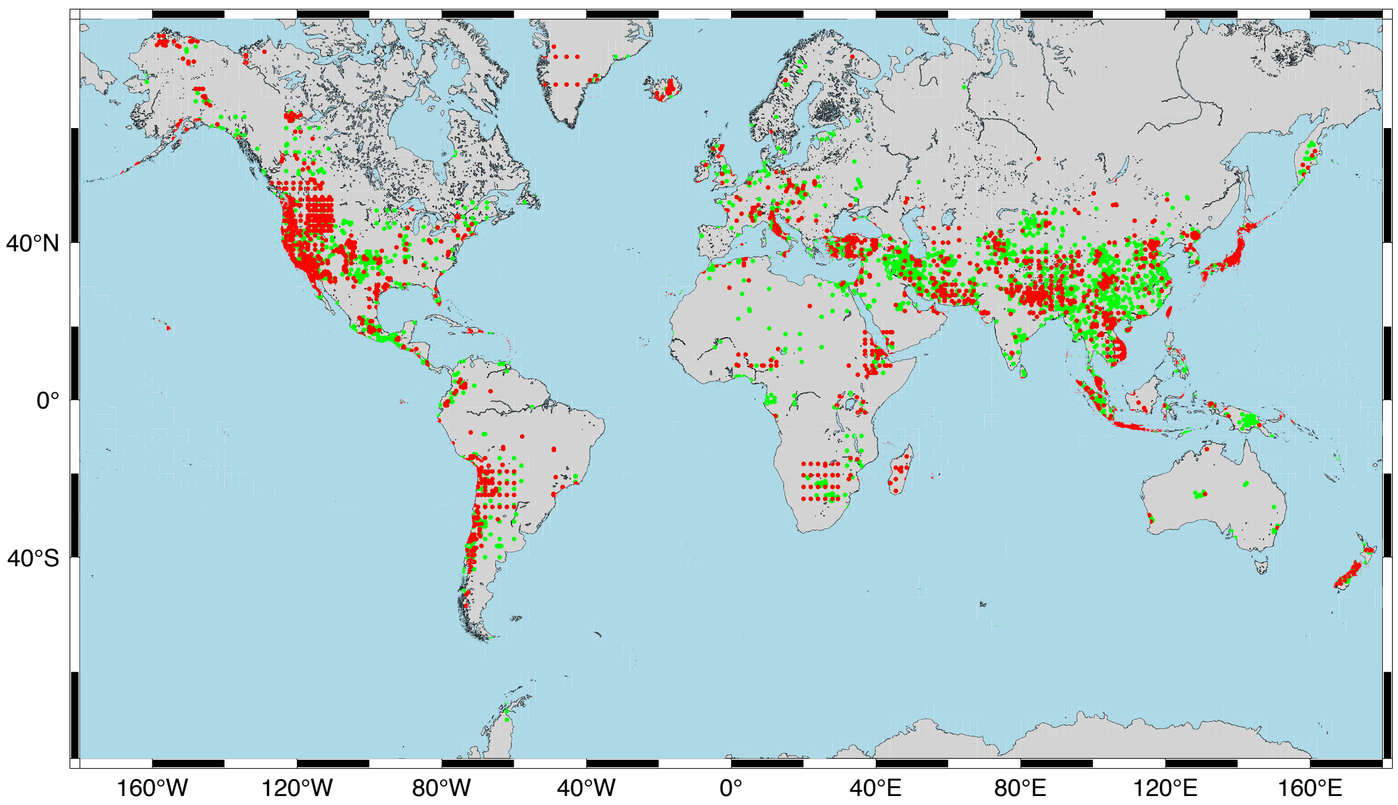


Figure 1. This map shows the 17,000 sites where users have constructed custom digital elevation models for GMTSAR processing since March 2013. We take this as a proxi for sites where GMTSAR users have constructed interferograms. The usage is rapidly expanding from 2013 (1255 sites), 2014 (1213 sites), 2015 (1603 sites), 2016 (3201 sites), 2017 (>4280 sites) and 2018 (7821-red). Most of the sites are tectonically active areas such as western North America, South America, all of Asia, Japan, and New Zealand. (The software download areas is completely open so we cannot track the number of downloads or users.)

Easy to Install

Installation of GMT and GMTSAR with Homebrew

1. Download and install orbit files in /usr/local/orbits:

```
http://topex.ucsd.edu/gmtsar/tar/ORBITS.tar
sudo -i
cd /usr/local
mkdir orbits
cd orbits
tar -xvf ~/Downloads/ORBITS.tar # (need full path to ORBITS.tar)
```

2. Install stable version 5.8 with Homebrew

```
xcode-select --install
brew tap dsandwell/homebrew-insar
brew install gmtsar
```

Installation of GMT and GMTSAR with Macports

1. Install stable version with Macports If you need ERS and Envisat orbits them put them in /usr/local/orbits as described in the Homebrew install. (make sure XCODE is installed)

```
sudo port install gmtsar
```

Installation of GMT and GMTSAR with package managers and GITHUB

1. Install GMT first with *all* optional libraries (GDAL and PCRE, plus FFTW3 and LAPACK for Linux).

- OS X (Macports):

```
sudo port install gdal +curl +geos +hdf5 +netcdf +tiff
sudo port install gmt5
sudo port install autoconf
```

4. Download GMTSAR GITHUB suitable directory:

```
sudo -i
cd /usr/local
git clone --branch 5.8 https://github.com/gmtsar/gmtsar GMTSAR
or
checkout the master version for more new but not stable features,
git clone https://github.com/gmtsar/gmtsar GMTSAR
```

5. Make and install GMTSAR (change the orbits directory if different):

```
cd GMTSAR
autoconf
./configure --with-orbits-dir=/usr/local/orbits
make
make install
```

Example data sets

Orbit Data

Download orbit data for ERS and Envisat
(If your orbit file is not complete, try anonymous ftp topex.ucsd.edu.)

Sample InSAR data

- Download Script to Test All Cases Below
- Download ALOS-1 L1.0 (standard format CEOS)
- Download ALOS-1 L1.0 (ERSDAC format)
- Download ALOS-1 L1.1
- Download ALOS-1 stack for SBAS time series test
- Download ALOS-2 L1.1
- Download ALOS-2 L1.1 ScanSAR
- Download Envisat
- Download Envisat SLC
- Download Envisat Stack Example
- Download ERS
- Download COSMOS-SkyMed raw (off line)
- Download COSMOS-SkyMed SLC (off line)
- Download RADARSAT-2 (off line)
- Download Sentinel-1A SWATH Napa postseismic
- Download Sentinel-1A TOPS Los Angeles
- Download Sentinel-1A TOPS Greece
- Download Sentinel-1 TOPS Larsen Ice Shelf
- Download Sentinel-1A TOPS Time Series
- Download TerraSAR-X (off line)

Documentation

PDFs of Course Materials

- 00 - Agenda [pdf]
- How to make an InSAR time series from Sentinel-1 TOPS data: Kilauea [2 MB pdf]

PDFs of Course Presentations

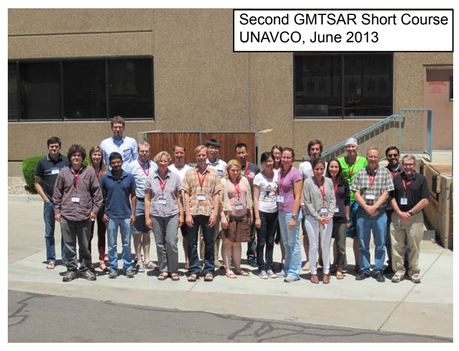
- 01 - Introduction & Homework [19 MB pdf]
- 02 - Applications of InSAR [74 MB pdf]
- 03 - Introduction to GMT [2 MB pdf]
- How to Select Data at UNAVCO/ASF
  - 04 - SAR Data Access [9 MB pdf]
  - 04 - 2-Pass Processing [3 MB pdf]
- Appendices
  - 05 - Appendix A: An InSAR processing system based on Generic Mapping Tools GMT: Principles of Synthetic Aperture Radar [2 MB pdf]
  - 05 - Appendix A (part b): An InSAR processing system based on Generic Mapping Tools GMT: Principles of Synthetic Aperture Radar [19 MB pdf]
  - 06 - Appendix B: SAR Image Formation [6 MB pdf]
  - 07 - Appendix C: InSAR [19 MB pdf]
- 08 - Simplified version of Theory and practice of phase unwrapping [28 MB pdf]
- 09 - ScanSAR and TOPS [65 MB pdf]
- 10 - GMTSAR Batch Processing [26 MB pdf]

PDFs of Student Presentations

- Lai - InSAR Processing and Theory with GMTSAR [2 MB pdf]
- Afeez - ALOS Baja California Earthquake [5 MB pdf]
- Antropova - InSAR Processing Results [18 MB pdf]
- Otto - Subsidence Monitoring [4 MB pdf]
- Crandall-Bear - Kern County Deformation Anomalies [16 MB pdf]
- Lindsay - The 2016 Mw 7.8 Kaikoura earthquake [42 MB pdf]
- Chi and Flores - 2018 Oaxaca, Mexico Earthquake [12 MB pdf]
- Saber and Gaudreau - Southwest Michigan Lakeshore, USA [192 MB pdf]
- Burkhard - 2018 Kilauea eruption and Mw 6.9 Leilani Estates Earthquake [21 MB pdf]
- Kilauea InSAR Ascending (Konvertiert) [3 MB QuickTime movie]
- Kilauea InSAR Descending (Konvertiert) [3 MB QuickTime movie]
- Ashokkumar - Velocity measurements of glaciers and ice-sheets [95 MB pdf]
- Mason and Bormann - Looking for inflation near the Long Valley Caldera, California [81 MB pdf]
- Cakir - NAPA Earthquake Example [1 MB pdf]
- Gomez - Coastal retreat and subsidence [10 MB pdf]
- Slead - Okmok Volcano Deformation Imaged by InSAR [3 MB pdf]
- Thuy Du and Mukherjee - Processing Sentinel 1A TOPS using GMTSAR in Los Angeles [5 MB pdf]

Education and Training


First GMTSAR Short Course
SIO, June 2011


Second GMTSAR Short Course
UNAVCO, June 2013

Third GMTSAR Short Course
UNAVCO, June 2014


Fourth GMTSAR Short Course
SIO, August, 2015


Fifth GMTSAR Short Course
SIO, August, 2016

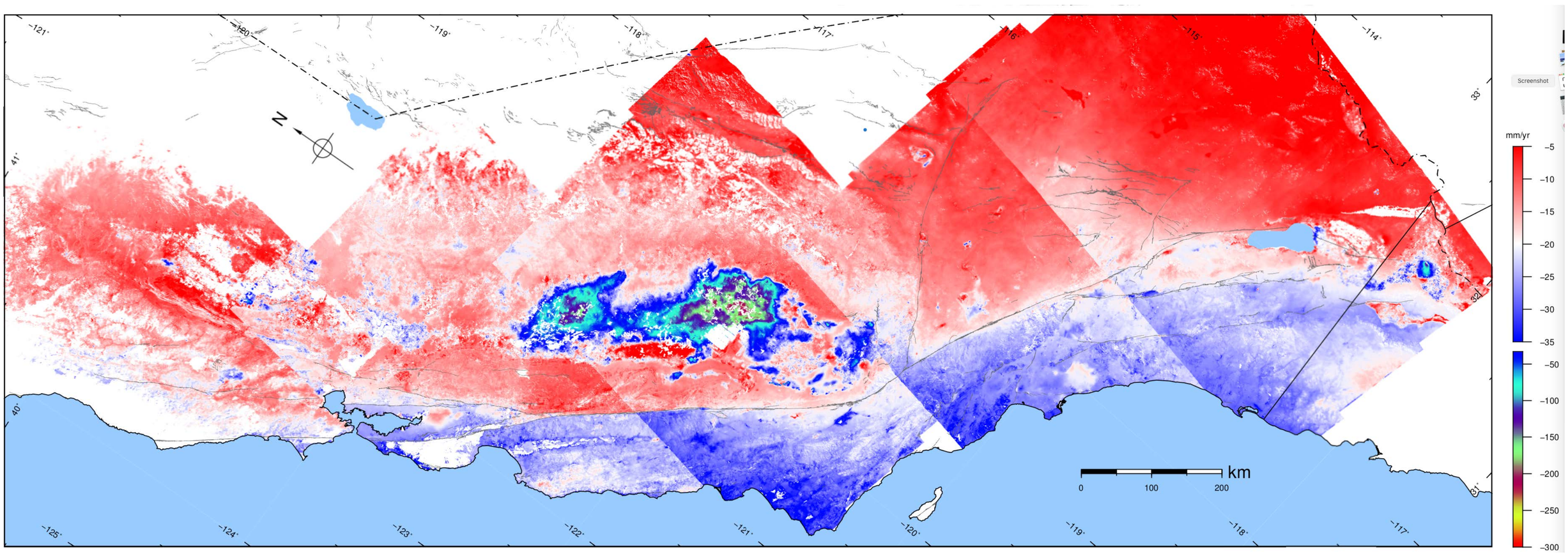

Sixth GMTSAR Short Course
Chinese Academy of Sciences
June, 2017


Seventh GMTSAR Short Course
SIO, August, 2017


Eighth GMTSAR Short Course
SIO, August, 2018


Nineth GMTSAR Short Course
SIO, August, 2019

Advanced - Sentinel-1 Time Series



Crustal deformation velocity along the San Andreas Fault System by combining measurements from Sentinel-1 Interferometric Synthetic Aperture Radar (InSAR) and Global Positioning System (GPS) data. We assembled 9 tracks of Sentinel-1 InSAR data spanning 2014.11-2018.12, and produced 3758 interferograms, each of which covers roughly 250km x 420km area (~60 bursts). These interferograms are unwrapped using SNAPHU [Chen & Zebker, 2002], and then corrected with GPS solutions provided by Scripps Orbit and Permanent Array Center (SOPAC). We used coherence-based small baseline subset (SBAS) method [Tong & Schmidt, 2016] together with atmospheric correction by common-scene stacking (CSS) [Tymofyeyeva and Fialko, 2015] to construct deforma- tion time series [Xu et. al., 2017]. By applying these approaches, one can acquire accurate line-of-sight deformation time-series that are precise in both large and small spatial scales. This product is now available on https://topex.ucsd.edu/gmtsar/insargen/ [Xu and Sandwell, in prep].