Biennial report for Permanent Supersite/Natural Laboratory

Name of Supersite

History	*http://geo-gsnl.org/supersites/natural-laboratories/san-andreas-fault-natural-laboratory-safnl/*
Supersite Coordinator	*Charles Wicks* *345 Middlefield Rd.* *U.S. Geological Survey* *Menlo Park, California USA 94025, USA* *cwicks@usgs.gov*

1. Abstract

The San Andreas Natural Laboratory (SANL) was accepted as an entity in May of 2017 to encourage collaborative research on the San Andreas Fault system with the goal of better understanding earthquake processes. Through a more detailed study of these processes the aim is mitigate seismic hazards not only to citizens of California, but also to people living near similar fault systems in different parts of the world. Although the area of the SANL is highly instrumented with GPS stations the TerraSAR-X (TSX) and Cosmo-skyMED (CSK) data made available through the auspices of the SANL offer the best opportunity to conduct high-resolution deformation multi-year studies near active faults.

The CSK and TSX data also enable seismic event studies such as the study of slip and afterslip related to the M6 2014 Napa earthquake…the first study associated with the SANL. This study uses GPS, seismic and InSAR data to locate areas of slip and afterslip in the subsurface that are important for assessing hazards to housing and infrastructure. The hazard from continuous afterslip after a moderate sized earthquake is a relatively new area for risk assessment.

2. Scientists/science teams

<In the table below please list all scientists/science teams who used/received data >

Tiampo/Univ. Colorado 1	***Kristy Tiampo, University of Colorado, 216 UCB Boulder Colorado 80309 USA, Kristy.Tiampo@colorado.edu, http://cires.colorado.edu/about/organization/fellows/kristy-tiampo/***
Wicks/USGS-Menlo Park 2	*Charles Wicks, U. S. Geol. Survey, 345 Middlefield Rd, California 94025 USA, cwicks@usgs.gov, http://www.usgs.gov*

Scientists/science teams issues

The number of active participants has been lacking. Out of the 19 team members only two have asked for data. Tiampo and Wicks have both requested CSK data covering the 2014 Napa earthquake in the north San Francisco Bay area. Tiampo has started a project in southern California using CSK data to investigate strain partitioning in the Santa Inez fault system.

To improve participation I have begun a different (proactive) approach where I will put together datasets that can be used to conduct time series investigations in certain areas. After I get the datasets, I will broadcast to the SANL team a description of the dataset and links to download the data. I have started with the transition zone of the San Andreas Fault near Parkfield California. This area is best covered by an extensive data set of TSX data. The TSX data span from 2012-2019 and comprise over 100 acquisitions in each of the descending and ascending directions. I have ordered all the descending scenes and have started ordering the ascending scenes. Two other areas well covered by CSK data appropriate for time series analysis in the Los Angeles basin are the Sierra Madre Fault (that includes the area of the 1994 Northridge earthquake and the 2015-2016 Aliso Canyon Gas Leak) and the Hollywood Fault. After the data from these three areas are made available to the team, I will work on other areas that have an abundance of data appropriate for time series studies.

1. In situ data

Type of data	Data provider	How to access	Type of access
Seismic Waveforms and GPS data	*USGS, Berkeley Seis. Laboratory*	*http://www.ncedc.org*	*unregistered public.*
Seismic Waveforms, GPS data, and earthquake catalogs	*CalTech*	*http://scedc.caltech.edu/*	*unregistered public*
Seismic Waveforms	*IRIS*	*http://www.iris.edu*	*unregistered public*
GPS data and processed results	*UNAVCO*	*http://www.unavco.org*	*unregistered public*
GPS data and processed results	*USGS*	*http://earthquake.usgs.gov*	*unregistered public*

In situ data issues

2. Satellite data

<In the table below please list all satellite data types available for the Supersite>

Type of data	Data provider	How to access	Type of access
ERS, ENVISAT	*ESA*	*http://esar-ds.eo.esa.int* *http://eo-virtual-archive4.esa.int/*	*ESA SSO login* *ESA SSO login*
RADARSAT-1, 2	*CSA*	*https://www.eodms-sgdot.nrcan-rncan.gc.ca/index_en.jsp*	*Registered Public*
CSK	*ASI*	*http://eo-virtual-archive4.esa.int/*	*ESA-SSO login*
TSX	*DLR*	*https://code-de.org*	*Registered Public*
ALOS-1 PALSAR	*ASF*	*https://vertex.daac.asf.alaska.edu/*	*Registered Public*
Sentinel 1 a/b	*ESA*	*https://scihub.copernicus.eu/*	*Registered Public*
Sentinel 1 a/b (alternate)	*ASF*	*https://vertex.daac.asf.alaska.edu/*	*Registered Public*

Satellite data issues

Ordering large CSK datasets is a little cumbersome.

3. Research results

In a study of slip and afterslip related to the M6 August 24, 2014 Napa, California earthquake, we employed strong motion seismic acceleration recordings combined with static offsets estimated from GPS, InSAR and other observations in order to derive a kinematic coseismic slip and afterslip model of the M6.0 August 24, 2014 South Napa earthquake. This earthquake ruptured a ~10 km long portion of the West Napa fault with predominantly right-lateral strike slip. In the kinematic seismic slip inversions, we prescribe a priori a range of local rupture velocities, allowing for arbitrary shape of the local source-time function but bounding the effective rise time as measured by the second temporal moment of slip. We also couple the coseismic slip and afterslip distributions by requiring both distributions to involve predominantly right-lateral strike-slip motion with positive amplitude, with the net static slip being the sum of the two. We consider two candidate fault geometries: one involving two steeply east-dipping planes, and the other involving one steeply west-dipping plane. The data are better fit using the east-dipping fault geometry. The resulting coseismic slip distribution involves up to ~1.2 m slip on a dominant shallow asperity about 10 km north of the hypocenter, associated with relatively long rise times, and on deeper asperities on the southern part of the rupture, associated with much shorter rise times. These high-slip zones define a unilateral rupture along a narrow slip zone that emanated up-dip and northward from the hypocenter to the maximum slip area. Afterslip of up to 1 m is concentrated along the southern part of the rupture at depths <~5 km,

consistent with surface observations of afterslip. Seismic moments associated with coseismic slip and afterslip are 1.13x10^{18} N m (Mw 6.00) and 3.64x10^{17} N m, respectively.

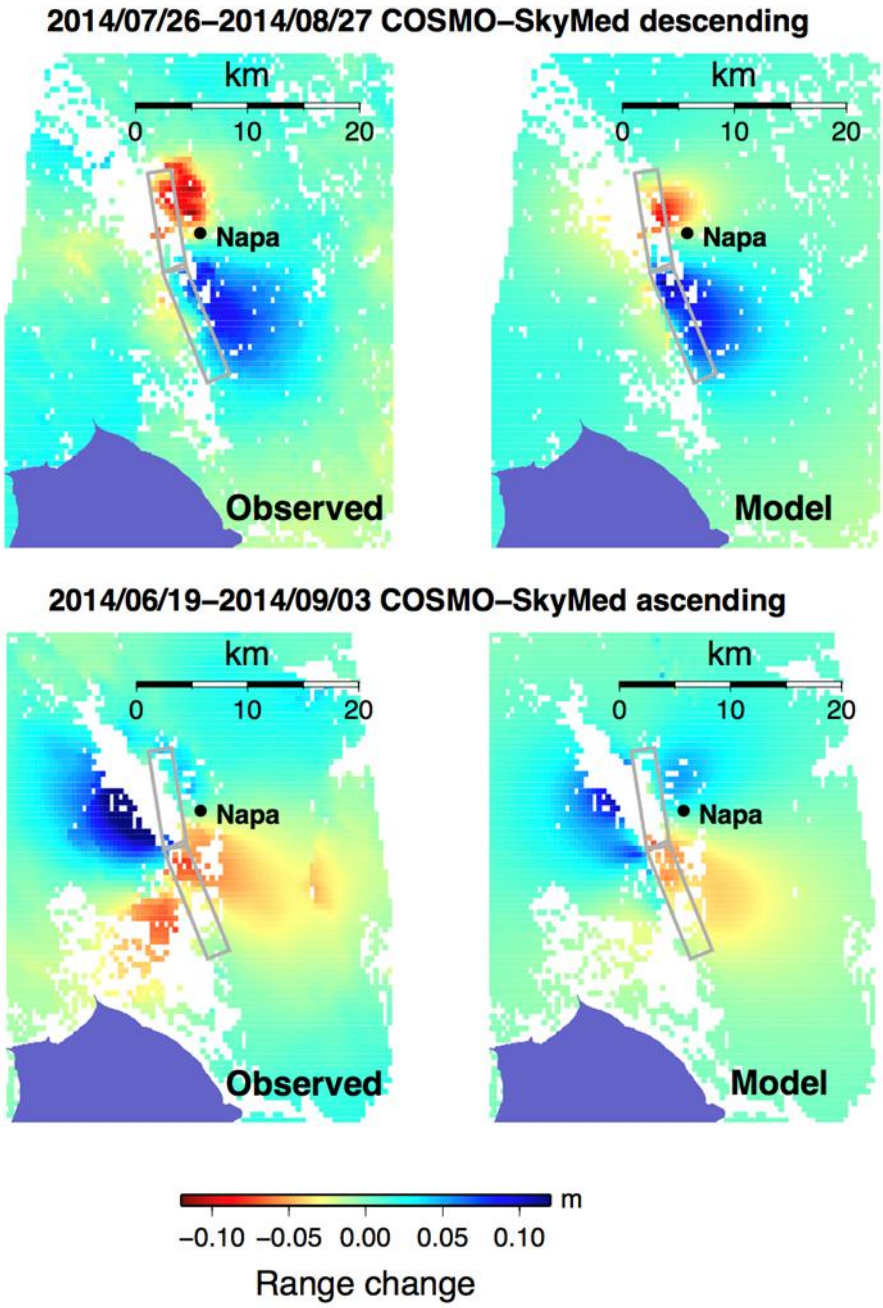

Figure 1 CSK interferograms, acquired through the GSNL, used in the study, compared to synthetic interferograms generated from the model.

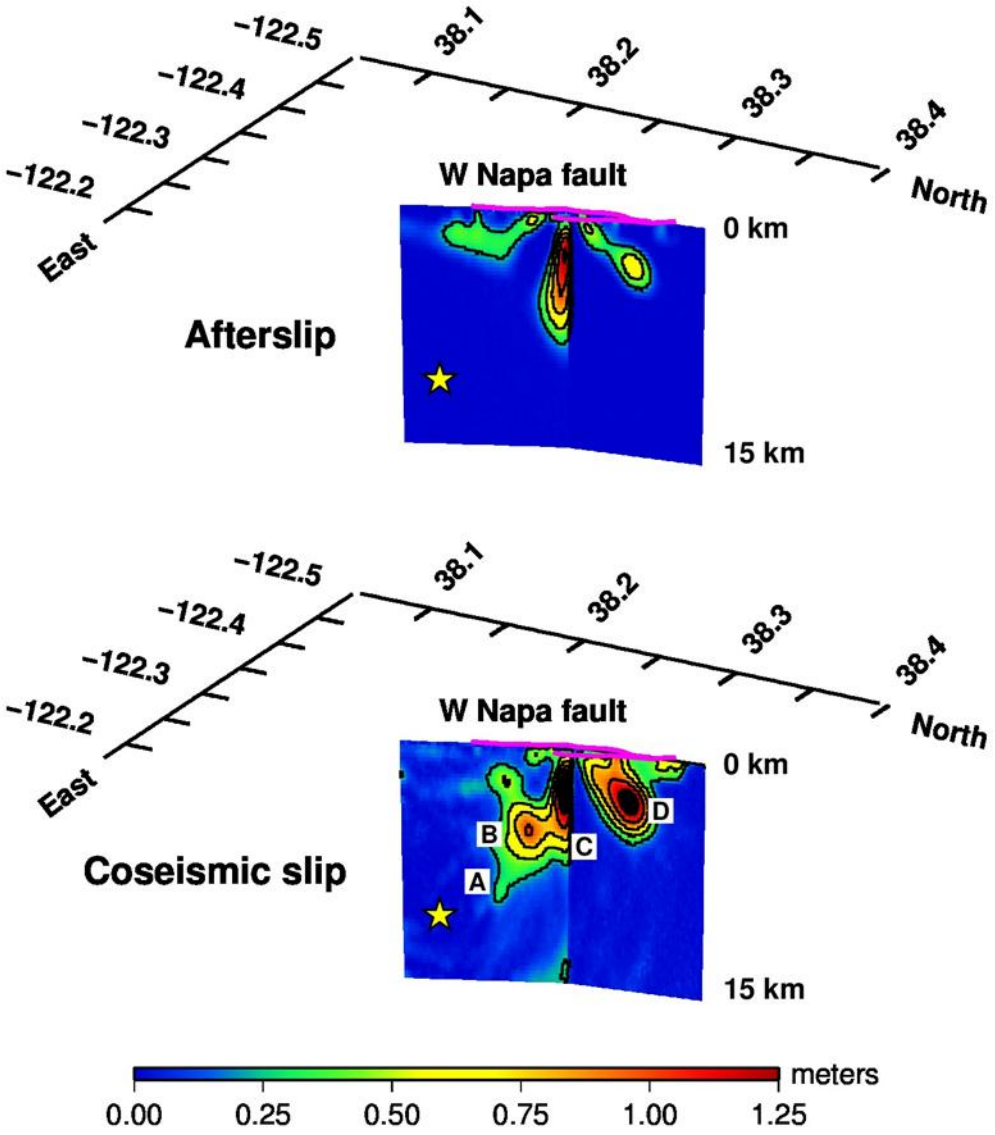

Figure 2 Slip and afterslip modeled on two fault planes.

Publications

Peer reviewed journal articles
Fred F. Pollitz, Jessica R. Murray, Sarah E. Minson, Charles W. Wicks, Gerald L. Svarc, and Benjamin A. Brooks, Coseismic Slip and Early Afterslip of the M6.0 August 24, 2014 South Napa, California, Earthquake, in prep. For submission to Journal of Geophysical Research..
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Conference presentations/proceedings
Fred F. Pollitz, Jessica R. Murray, Sarah E. Minson, Charles W. Wicks, Gerald L. Svarc, and Benjamin A. Brooks, Coseismic Slip and Early Afterslip of the M6.0 August 24, 2014 South Napa, California, Earthquake, Seismologial Society of America 2019 Meeting.

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Research products

Type of product	Product provider	How to access	Type of access
Ground Deformation and Source model for Napa earthquake.	*Fred F. Pollitz, Jessica R. Murray, Sarah E. Minson, Charles W. Wicks, Gerald L. Svarc, and Benjamin A. Brooks*	*Not yet accessible*	*Will be public*
…	…	…	…
…	…	…	…

Research product issues

Making the products available to other scientists is a problem right now. Rather than responding to individual requests for data (such as an unwrapped interferogram) a platform for hosting the data would be nice. I will investigate in house solutions.

4. Dissemination and outreach

After the publication of the Napa earthquake study, there will be chances to promote the results to the public. The television and radio stations in the San Francisco area are always interested in presenting earthquake related studies, especially local ones. The USGS also holds an "Open House" every two years where we interact directly with the public, presenting and discussing the results of scientific studies.

5. Funding

No funding is dedicated by the U. S. Geological Survey in direct support of the San Andreas Natural Laboratory. The Earthquake Hazards Program of the USGS supports the supersite through salary and material support to the coordinator.

6. Stakeholders interaction and societal benefits

The immediate societal benefits from the unpublished Napa earthquake study have not been realized, but two things are clear. (1) The Napa earthquake study delineates sizeable afterslip in an urban setting. Earthquake response planning has not included afterslip as a hazard and this study quantifies the need for including the effects as a hazard. (2) The study also highlights an area of slip deficit, meaning this is an area of heightened earthquake hazard.

The stakeholders are the state and local governments, utilities and property owners. In particular the high amount of afterslip shows risks to buildings and infrastructure (such as bridges and natural gas transmission pipelines) continue after the main earthquake.

7. Conclusive remarks and suggestions for improvement

The main achievement is probably getting the SANL off the ground. I have a plan to move forward mainly by gathering and promoting TSX and CSK datasets that are dense in time and can be used for time series analysis of low amplitude deformation events in combination with in situ data. My theory is that many of the team is busy with Sentinel 1 data and that by promoting the potential of the CSK and TSX data, interest can be piqued.