Biennial report for Permanent Supersite/Natural Laboratory

San Andreas Fault Natural Laboratory

History	*http://geo-gsnl.org/supersites/natural-laboratories/san-andreas-fault-natural-laboratory-safnl/*
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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.

CSK data has proven valuable in the study of slip, afterslip, poroelastic response, and mantle relaxation related to the 2019 Ridgecrest earthquake sequence in California, USA. The sequence involved two large shocks (Mw 6.4 and Mw 7.1) on two nearly orthogonal faults. The sequence was well covered by Sentinel 1 and ALOS-2 acquisitions, but the high-resolution CSK data revealed details not seen in other data. In particular, Azimuth offsets in the CSK SAR data were better constrained than those derived from SAR data from other satellite platforms because of the higher azimuth resolution. This enabled better constraints on N-S component of surface deformation from the sequence. Two ongoing studies are also using post-seismic CSK data to examine deformation caused by mantle relaxation about one year after the earthquakes.

2. Scientists/science teams

Tiampo/Univ. Colorado	***Kristy Tiampo, University of Colorado, 216 UCB Boulder Colorado 80309 USA, Kristy.Tiampo@colorado.edu, http://cires.colorado.edu/about/organization/fellows/kristy-tiampo/***

Roland Bürgmann/UC Berkeley	*University of California at Berkeley, Dept. of Earth and Planetary Science, 307 McCone Hall, Berkeley, CA, 94720-4767, USA,*

Scientists/science teams issues

Although I have identified and archived data for multiple targets in the Los Angeles area, the data requests and uses are largely event driven. The year 2020 was an anomalously slow year.

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*
Earthquake Catalog with moment tensors	*USGS*	*https://earthquake.usgs.gov/data/comcat/*	*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*	*https://www.usgs.gov/natural-hazards/earthquake-hazards/crustal-deformation-monitoring*	*unregistered public*
Strong motion data	*CESMD*	*https://www.strongmotioncenter.org/*	*unregistered public*
Quaternary fault and fold database of the United States	*USGS*	*https://www.usgs.gov/natural-hazards/earthquake-hazards/faults?qt-science_support_page_related_con=4#qt-science_support_page_related_con*	*unregistered public*

In situ data issues

none

2. Satellite data

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 through ESA*	*http://eo-virtual-archive4.esa.int/*	*ESA-SSO login (plus special access)*
TSX	*DLR*	*https://supersites.dlr.de/*	*Registered public*
ALOS-1 PALSAR	*JAXA through ASF*	*https://vertex.daac.asf.alaska.edu*	*Registered public*

Sentinel-1 a/b	*ESA*	*https://scihub.copernicus.eu*	*Registered public*
Sentinel-1 a/b	*ESA through ASF*	*https://vertex.daac.asf.alaska.edu*	*Registered public*

Satellite data issues

CSK data allotments have not been used up yet.

3. Research results

The 2019 Ridgecrest earthquake sequence ruptured a series of conjugate faults in the broad eastern California shear zone, north of the Mojave Desert in southern California (Figure 1). The average spacing between Global Navigation Satellite System (GNSS) stations around the earthquakes is 20–30 km, insufficient to constrain the rupture details of the earthquakes. Wang and Bürgmann (2020) used Sentinel-1 and COSMO-SkyMed (CSK) Synthetic Aperture Radar data to derive the high-resolution coseismic and early postseismic surface deformation related to the Ridgecrest earthquake sequence. Line of sight (LoS) Interferometric Synthetic Aperture Radar displacements derived from both Sentinel-1 and CSK data (Figure 2) are in good agreement with GNSS measurements. The maximum coseismic displacement occurs near the Mw 7.1 epicenter, with an estimated fault offset of ∼4:5 m on a northwest- striking rupture. Pixel tracking analysis of CSK data (Figure 3) also reveals a sharp surface offset of ∼1 m on a second northwest-striking fault strand on which the Mw 6.4 foreshock likely nucleated, which is located ∼2–3 km east of the major rupture. The lack of clear surface displacement across this fault segment during the Mw 6.4 event suggests this fault might have ruptured twice, with more pronounced and shallow slip during the Mw 7.1 mainshock. Both Sentinel-1 and CSK data reveal clear postseismic deformation following the 2019 Ridgecrest earthquake sequence. Cumulative postseismic deformation near the Mw 7.1 epicenter ∼2 months after the mainshock reaches ∼5 cm along the satellites' LoSs. The observed postseismic deformation near the fault is indicative of both afterslip and poroelastic rebound. Wang and Bürgmann (2020) provide data derived in these studies in various data formats, which will be useful for the broad community studying this earthquake sequence.

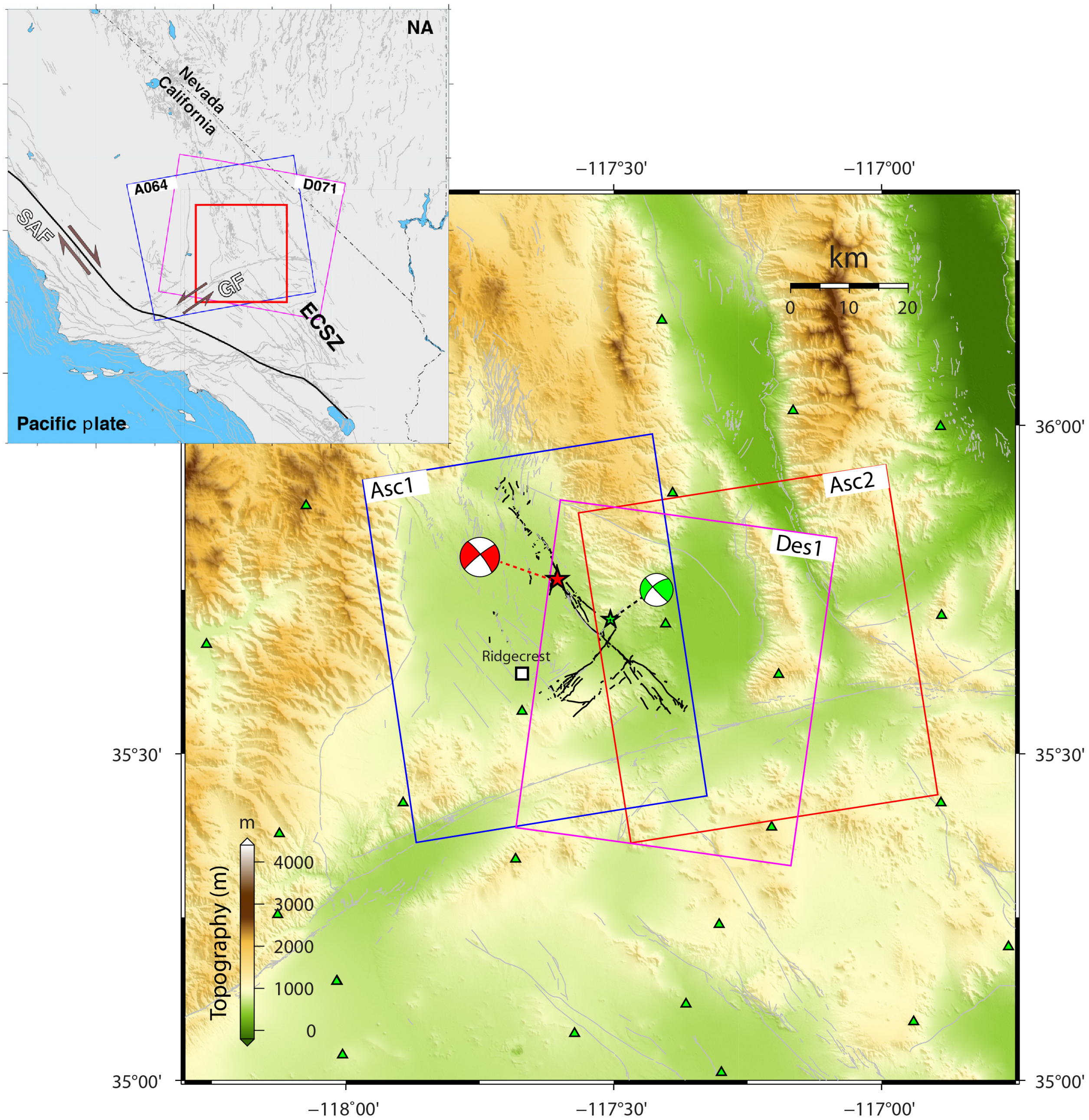

***Figure 1** (from Wang and Bürgmann, 2020) Ground coverage of Interferometric Synthetic Aperture Radar (InSAR) observations for the 2019 Ridgecrest earthquake sequence. The colored boxes denote the footprints of the CSK observations. Sentinel-1 scenes are shown in the inset map. Black lines show the surface traces of the 2019 Ridgecrest rupture sequence. Green and red stars denote the epicenters of the Mw 6.4 foreshock on 4 July and the Mw 7.1 mainshock on 5 July, respectively. Green triangles represent the Plate Boundary Observation (PBO) continuous Global Navigation Satellite System (GNSS) stations. Inset shows the overall tectonic setting of the 2019 Ridgecrest earthquake. ECSZ, eastern California shear zone; GF, Garlock fault; SAF, San Andreas fault.*

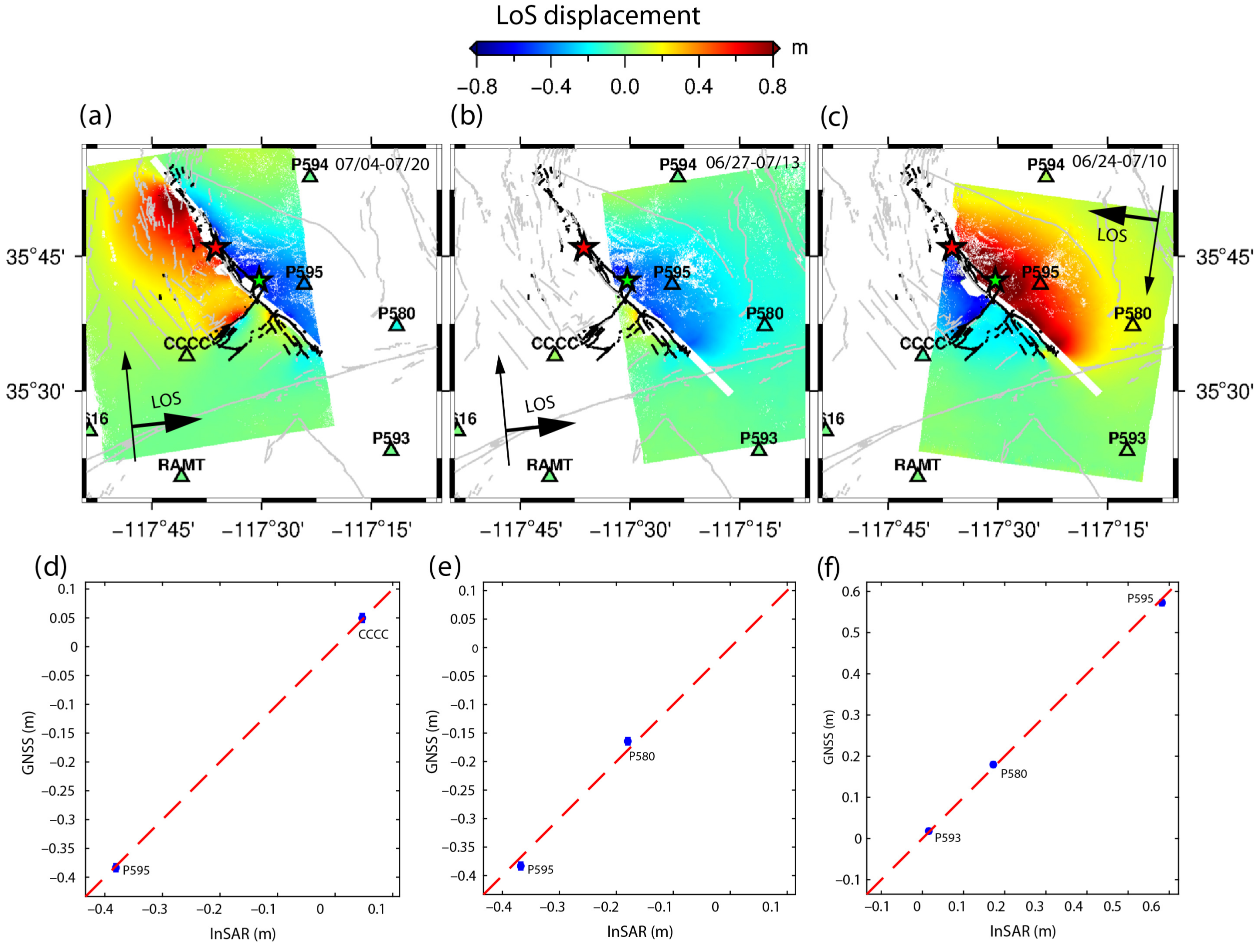

Figure 2 *(from Wang and. Bürgmann, 2020). LoS displacements due to the 2019 Ridgecrest earthquake sequence derived from CSK data along the ascending tracks (a) Asc1 and (b) Asc2 and the descending track (c) Des1. (d-f) Show comparison between InSAR observations and GNSS displacements projected onto the LoS of corresponding SAR acquisitions. Symbol notations are the same as in Figure 2.*

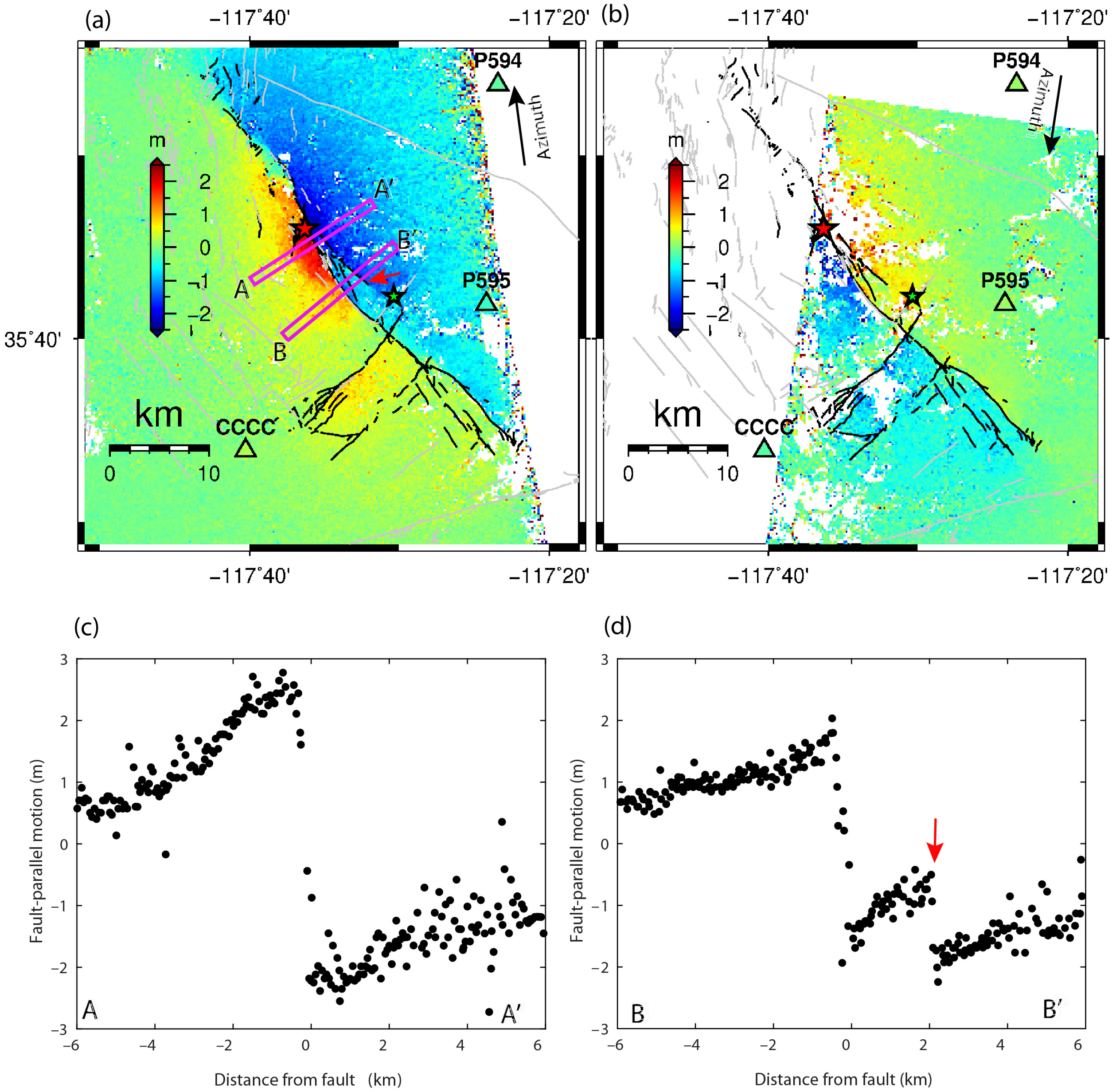

***Figure 3** (from Wang and. Bürgmann, 2020). Azimuthal offsets derived from CSK data along the (a) ascending track Asc1 and (b) descending track Des1. Scenes from Asc2 only cover the southern half of the rupture, which largely overlap with Asc1 (Fig. 3b), so results from this track are not shown. Colored triangles represent the GNSS displacements projected onto the satellites' azimuthal directions. The differences of the azimuthal displacements derived from GNSS and CSK data are less than 15 cm at the GNSS stations. Fault-parallel motions along transects A–A′ (near the Mw 7.1 epicenter) and B–B′ are shown in (c) and (d), respectively. Red arrow (in panel d) marks the location of an eastern fault strand that was possibly involved in both the Mw 6.4 foreshock and the Mw 7.1 mainshock. Note that the offset across this fault strand reaches over 1 m.*

Publications

Peer reviewed journal articles
Wang, K., and R. Bürgmann (2020). Co- and Early Postseismic Deformation Due to the 2019 Ridgecrest Earthquake Sequence Constrained by Sentinel-1 and COSMOSkyMed SAR Data, Seismol. Res. Lett. XX, 1–12, doi: 10.1785/0220190299.
Wang, K., Dreger, D. S., Tinti, E., Bürgmann, R., & Taira, T. (2020). Rupture Process of the 2019 Ridgecrest, California Mw 6.4 Foreshock and Mw 7.1 Earthquake Constrained by Seismic and Geodetic Data. Bulletin of the Seismological Society of America. https://doi.org/10.1785/0120200108
Conference presentations/proceedings
Wang, K., & Bürgmann, R. (2020, 08). Modeling of postseismic deformation following the 2019 Ridgecrest earthquake sequence. Poster Presentation at 2020 SCEC Annual Meeting. SCEC Contribution 10423
Wang, K., & Bürgmann, R. (2019, 08). Modeling of co- and early postseismic deformation due to the 2019 Ridgecrest earthquake sequence. Poster Presentation at 2019 SCEC Annual Meeting. SCEC Contribution 9887

Research products

Type of product	Product provider	How to access	Type of access
Ridgecrest ground deformation from CSK SAR data (InSAR LOS and Azimuth offsets)	*Wang, K., & Bürgmann, R.*	*https://zenodo.org/record/3475633#.YlyJ1KFlCCr*	*Open Access*

Research product issues

none

4. Dissemination and outreach

I have identified datasets for different targets in the Los Angeles area. The data have been archived and the location broadcast to the CoIs.

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

Outside of the scientific community, the stakeholders are mainly the state and local governments, utilities and property owners. Studies of this earthquake are important for assessing the possible increased hazard on the Garlock Fault (Figure 1), which is a ~200 km long left-lateral fault that connects the main San Andreas Fault strand to the Eastern California Shear Zone and the Basin and Range. The Ridgecrest sequence terminated at the Garlock Fault and triggered shallow slip on it. An earthquake of Mw 8 is possible on the Garlock Fault. The southern terminus of the Mw 7.8-7.9 1872 Owens Valley earthquake was about 10-20 km north of the northern terminus of the Ridgecrest sequence. The study of the influence of the Ridgecrest sequence (coseismic and postseismic) on surrounding major faults is important especially considering increased risk to the Los Angeles aqueduct, eastern California communities, agriculture and several military installations.

7. Conclusive remarks and suggestions for improvement

My efforts to gather and promote TSX and CSK datasets that are dense in time and can be used for time series analysis have not been met with much interest. The entirety of 2020 saw zero data requests from CoIs, although in the last few months I have seen some renewed interest in CSK data.

8. Dissemination material for CEOS (discretionary)

See section 3.