Distinguishing slip from the M6.4 and M7.1 Ridgecrest earthquakes using campaign GPS and InSAR data

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Abstract

The 2019 Ridgecrest earthquakes pose interesting questions about the nature of intersecting conjugate ruptures, and also the possibility of re-rupture of fault segments. Aftershocks of the July 4th M6.4 event suggest the possibility of a secondary rupture along the fault that subsequently ruptured in the July 5th M7.1 event. Unfortunately, neither InSAR nor rupture mapping will be able to resolve this question, as no SAR acquisitions were made between the two earthquakes, and the critical 'nexus' of the two ruptures was located on the China Lake Navy base, and was not accessible between the events. Campaign GPS data and seismic data may provide clues to resolving these questions. We reoccupied 5 previously surveyed GPS benchmarks in the hours following the M6.4 event, meaning that we can separately measure the deformation from the two earthquakes at those locations. We construct a joint inversion of our campaign GPS data, along with the daily displacements of nearby continuous GPS stations, and ascending and descending Sentinel-1 InSAR data, in order to separate the fault geometry and slip of the two earthquakes, and address the question of re-rupture. This approach also allows us to precisely estimate the contribution of the early postseismic deformation to the InSAR data.

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The 2019 Ridgecrest earthquakes occurred in an area in which we had collected campaign GPS data five months previously.

We remeasured these sites after the 4th July M6.4 event, but before the 5th July M7.1 event. Thus, our data can distinguish between the two events, unlike InSAR data, which span a 6-12 day period.

Here we explore the constraints that our data place on coseismic slip for the two events, and their ensuing postseismic deformation.

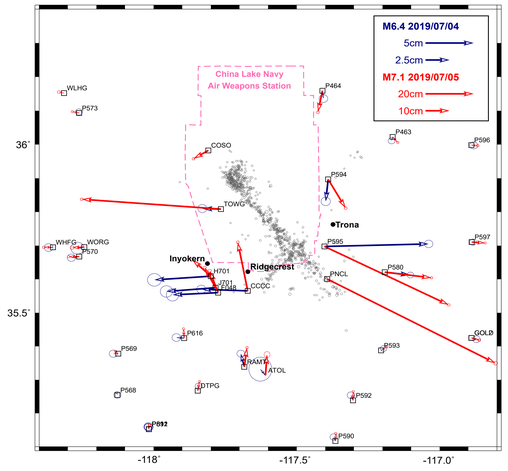
Campaign GPS response

In February 2019, we occupied four campaign GPS sites in the Ridgecrest area (H701, J701, ATOL, F048).

In the immediate aftermath of the M6.4 earthquake (on 4th-5th July) we reoccupied these sites along with PNCL. They remained standing and operating during and after the M7.1 event!

In subsequent days and weeks, we, along with groups from Scripps, UNR and the USGS, continued to densify campaign GPS coverage in order to capture any transient postseismic deformation.

Site H701 occupied in February 2019 (left) and 4th July 2019 (right)



Separated coseismic displacements of the M6.4 (blue) and M7.1 (red) Ridgecrest earthquakes, at stations where the events can be distinguished (continuous stations and our campaign sites).

Coseismic slip modelling

We set up the inverse problem (right) to separate the slip of the two earthquakes. Coseismic GPS displacements are used as constraints on each separate event. Downsampled InSAR displacements constrain the combined slip of both events. We test three different model geometries:

$$\begin{pmatrix} A_{GPS6} & 0 \\ 0 & A_{GPS7} \\ A_{InSAR6} & A_{InSAR7} \end{pmatrix} \begin{pmatrix} m_6 \\ m_7 \end{pmatrix} = \begin{pmatrix} d_{GPS6} \\ d_{GPS7} \\ d_{InSAR} \end{pmatrix}$$

slip in the M6(.4) event

displacement data

Green's functions for M6(.4) event

Green's functions for M7(.1) event

slip in the M7(.1) event

2 faults, separated

(M6.4 on NE-striking fault, M7.1 on NW-striking fault)

2 faults, together

(Both faults – NE-striking and and NW-striking– can slip in both earthquakes)

3 faults, separated

(M6.4 on NE-striking fault and NW-trending splay, M7.1 on main NW-striking fault)

Total slip

Slip per fault

Slip patterns cross-cut

Slip on NW-trending fault in M6.4!

M6.4

M7.1

Slip on splay in M6.4!

Error per fault

Fit to data

GPS

InSAR

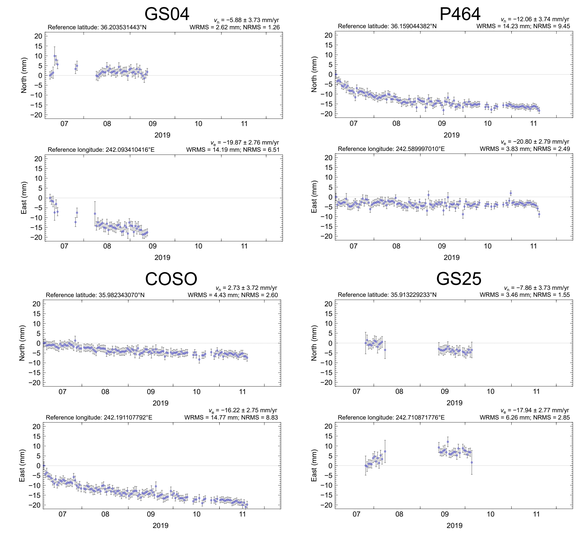
WRSS (misfit) = 556

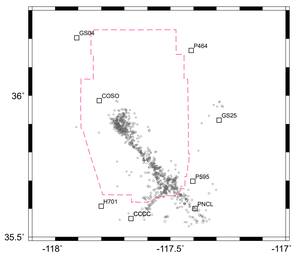
WRSS = 478 (for double the model parameters...)

WRSS = 515 (modest increase in model parameters)

Postseismic deformation

We continue to maintain stations in the field, and retrieve data approximately monthly. Below we show results of preliminary time series processing of both campaign and continuous sites of interest.





3 cm of near-field displacement!

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