Rupture models of the 2019 M6.4-7.1 Ridgecrest earthquakes constrained by space geodetic data and aftershock locations

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Abstract

The July 2019 Ridgecrest earthquake sequence includes two major events, the M6.4 foreshock and M7.1 main shock that ruptured the nearly orthogonal intersecting strike-slip faults within one day of each other. Analysis of space geodetic observations including InSAR data from Sentinel-1A/B and ALOS-2, and field mapping reveals a complex pattern of surface rupture with several sub-parallel fault strands with moderate variations in strike.

We use the precisely located aftershocks to constrain the fault geometry below the depth of 3 km. The resulting fault geometry indicates a significant near-surface complexity around the epicentral area involving variations in both strike and dip of the seismic rupture.

The along-strike averaged slip distribution suggests a moderate shallow slip deficit consistent with models of the dynamically triggered off-fault damage (Kaneko and Fialko, 2011).

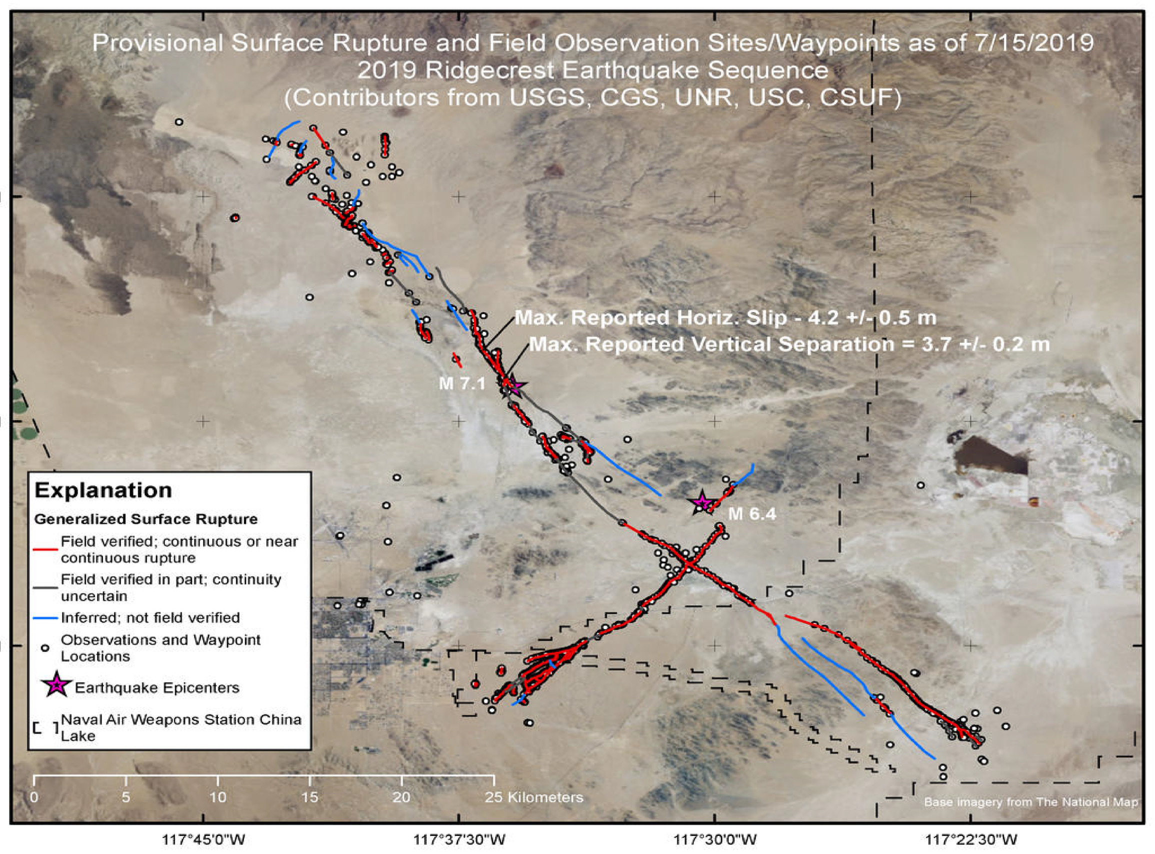


Figure 1: Surface mapping rupture of 2019 Ridgecrest Earthquake Sequences (contributed by USGS).

Complex fault geometry constrained by aftershock locations

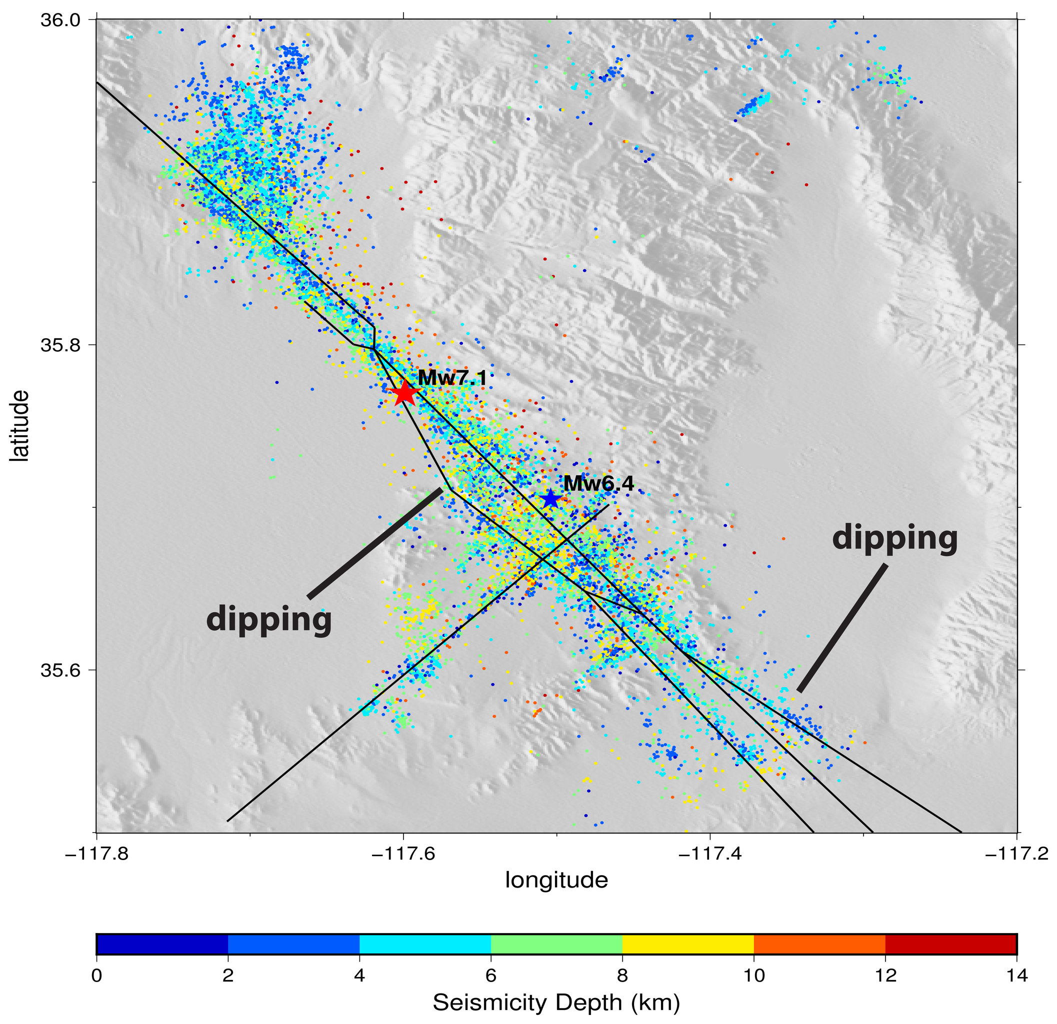


Figure 3: Precisely relocated aftershock catalog (Courtesy of E. Hauksson, Caltech). Because the resolution of geodetic inversions is decreasing with depth, we use the precisely located aftershocks to constrain the fault geometry below the depth of 3 km. The near surface fault geometry is defined by surface offsets derived from the space geodetic data and the assumption of rupture continuity as a function of depth. The resulting fault geometry indicates a significant near-surface complexity around the epicentral area involving variations in both strike and dip of the seismic rupture.

Static Model Inversion

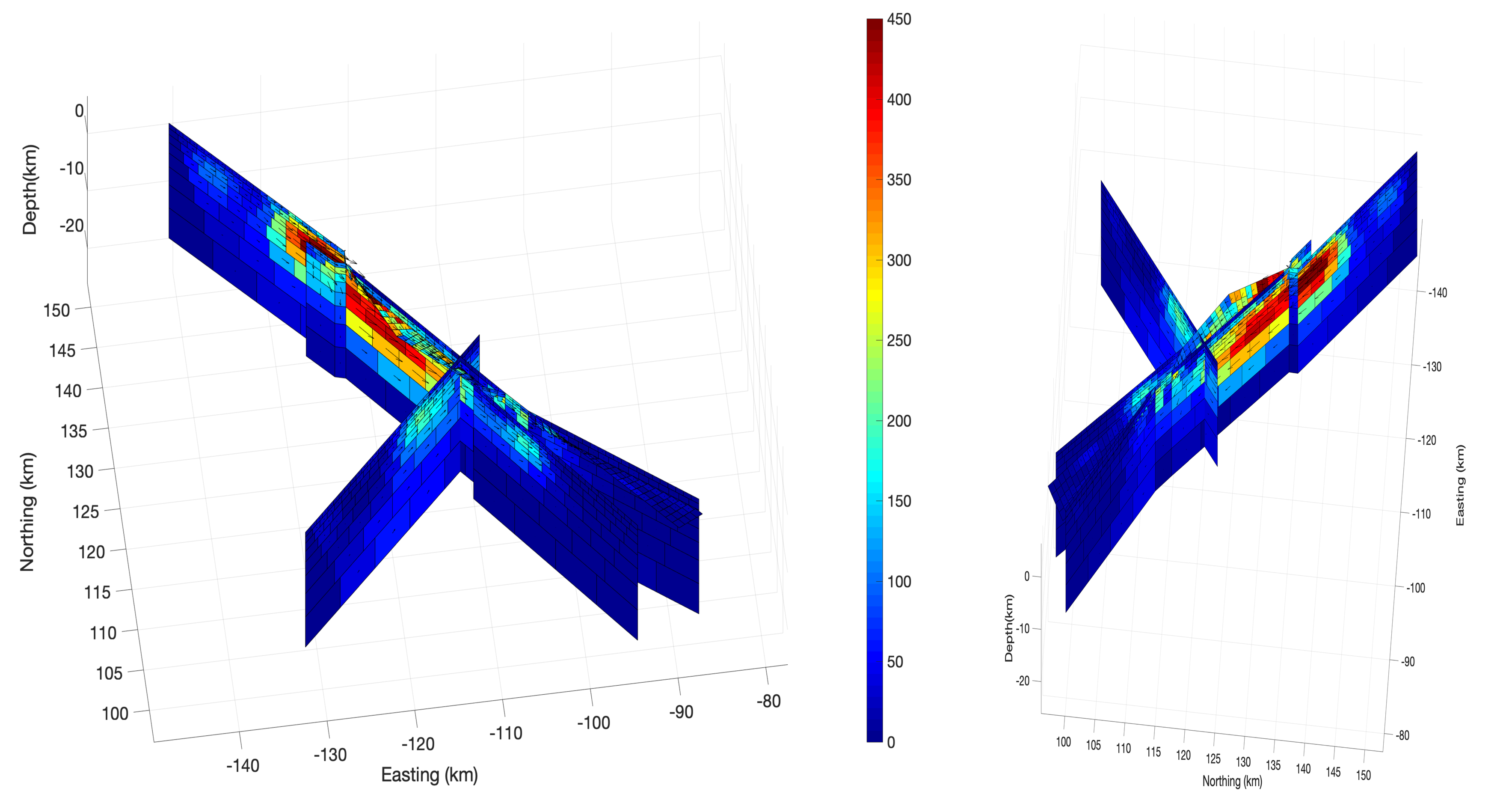
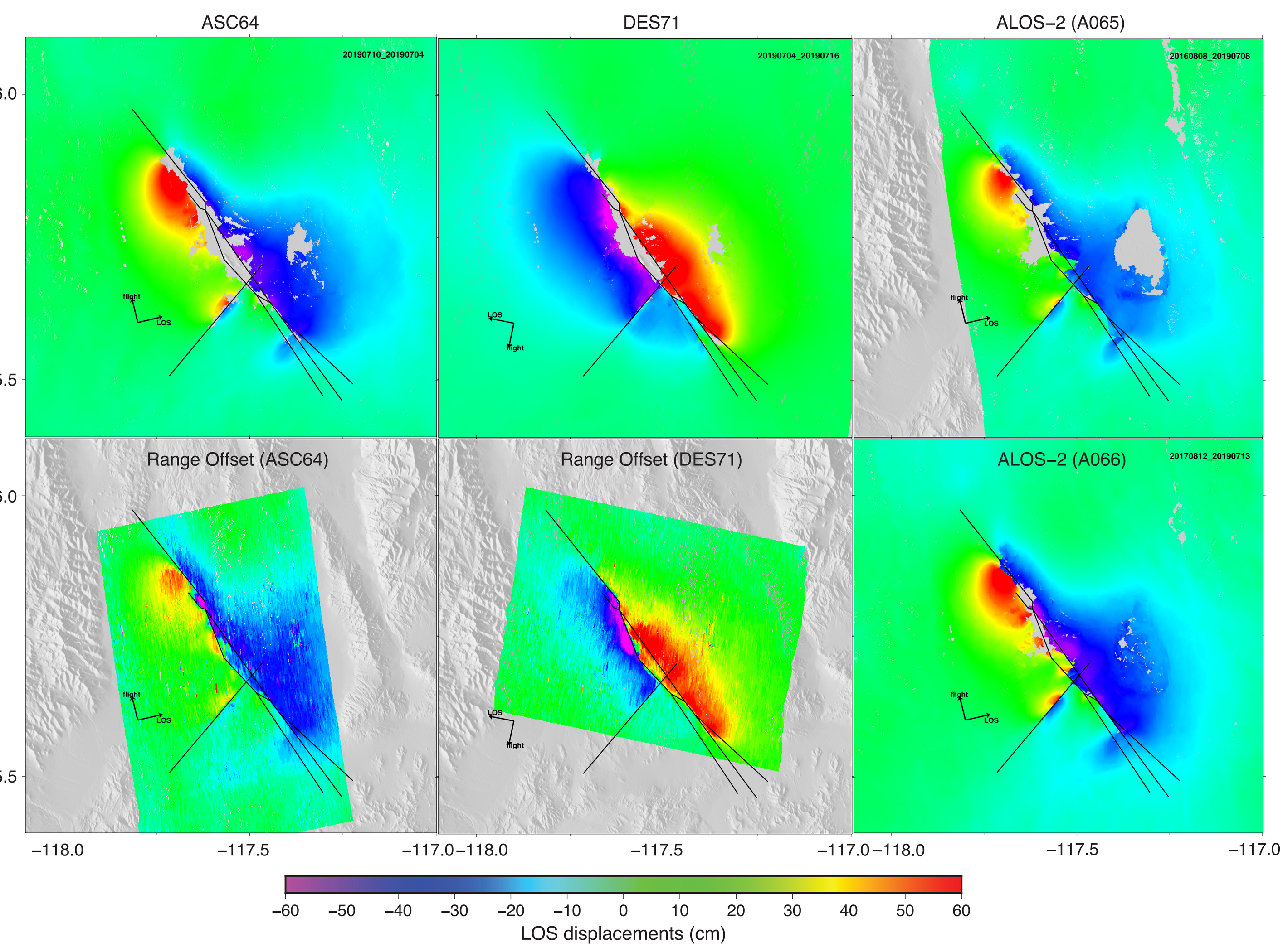


Figure 4: We performed joint inversions of surface displacement data, including line of sight displacements from Sentinel-1 and ALOS-2, pixel tracking, GPS data, and fault geometry constrained by the aftershock and surface offsets to estimate the sub-surface slip distribution. Inversions are performed using homogeneous Okada model. The model suggests a moderate shallow slip deficit at off-fault damage zone.

Geodetic Data



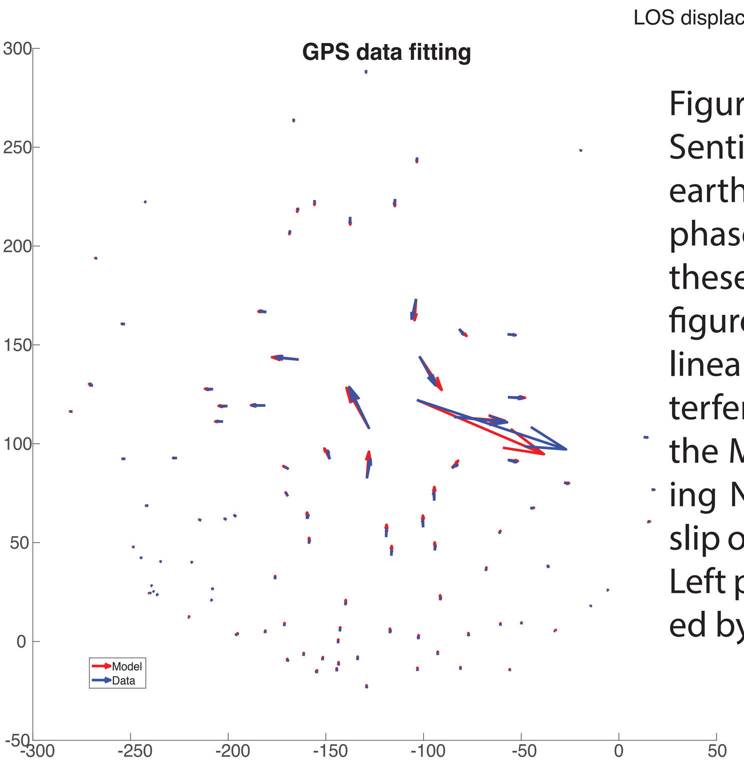
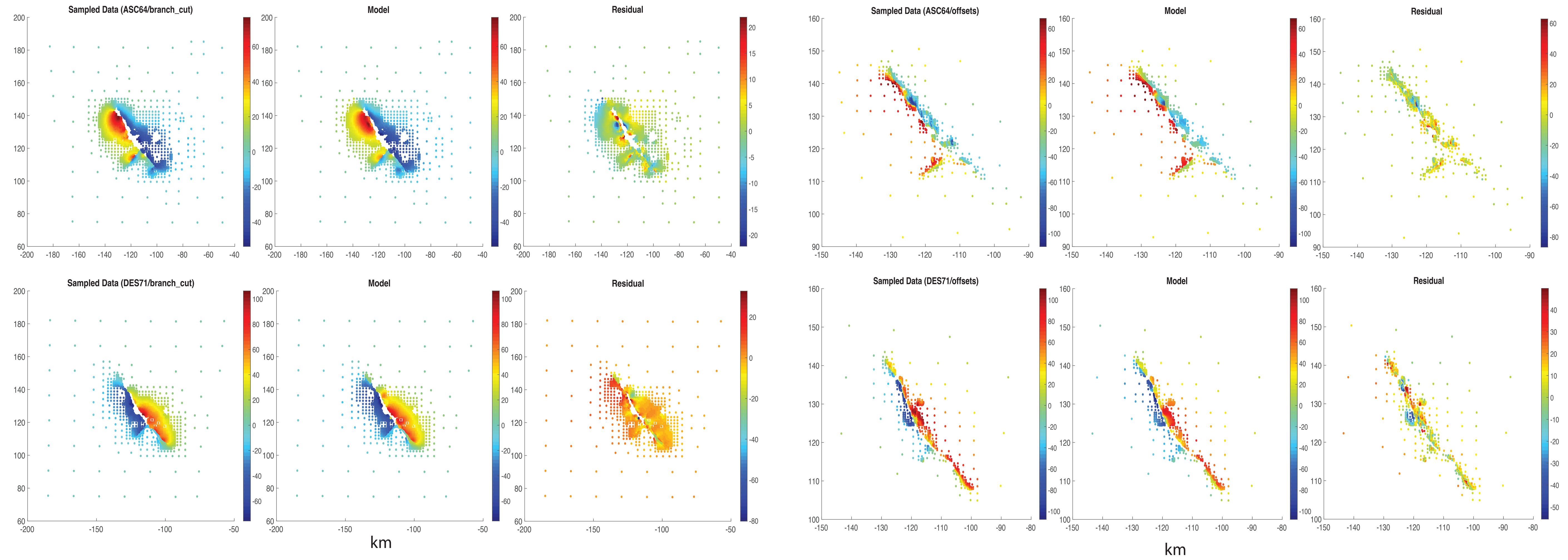


Figure 2: Top panels show line of sight (LOS) displacements from Sentinel-1, ALOS-2 and range offsets. Because the damage zone of earthquake rupture is really in low coherence, the unwrapping phases are unwrapped with Goldstein's branch-cut method. All these InSAR data are detrended with continuous GPS data (left figure, courtesy of by Peng Fang). The black lines denotes surface linear fault segments digitized from range offsets and along-track Interferometry (Courtesy of Xu et al., 2019). All these data display that the Mw 6.4 earthquake rupture was left lateral slip on a plane striking NE-SW, while the Mw 7.1 earthquake rupture was right lateral slip on the nearly orthogonal intersecting fault plane striking NW-SE. Left panel shows the continuous GPS data and fitting results predicted by Okada model.

Sub-sampled data and Residuals



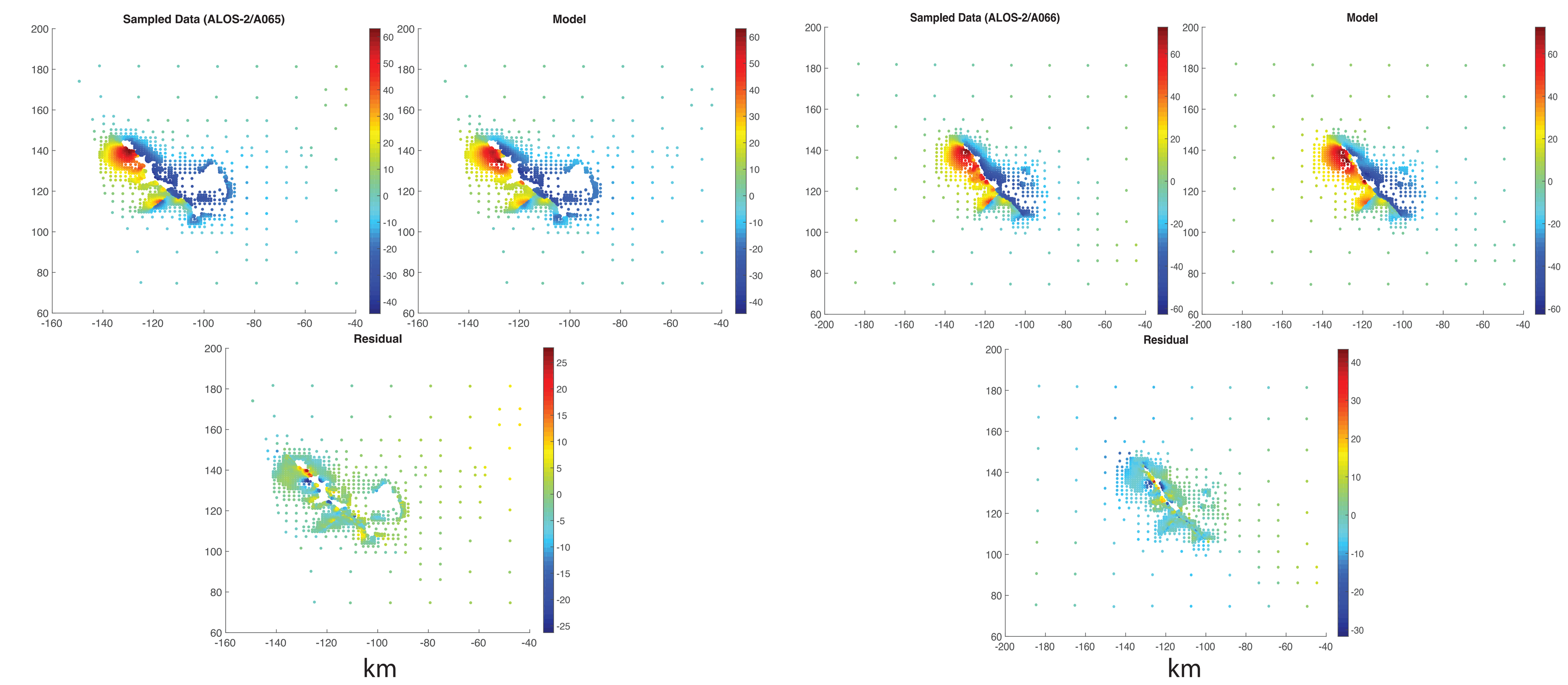


Figure 5: Sub-sampled InSAR data implemented with quad-tree curvature-based algorithm iteratively using model predictions. The overall data fitting is good, except at the near-fault area due to unwrapping errors or other noise. The offsets provide useful near-fault constraint, but the data are noisy. There is also small localized residual at the end of NW fault plane.

References

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2. Goldstein, Richard M., Howard A. Zebker, and Charles L. Werner. "Satellite radar interferometry: Two-dimensional phase unwrapping." Radio science 23.4 (1988): 713-720.
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Acknowledgments

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