# Fault Zone Deformation from Topography

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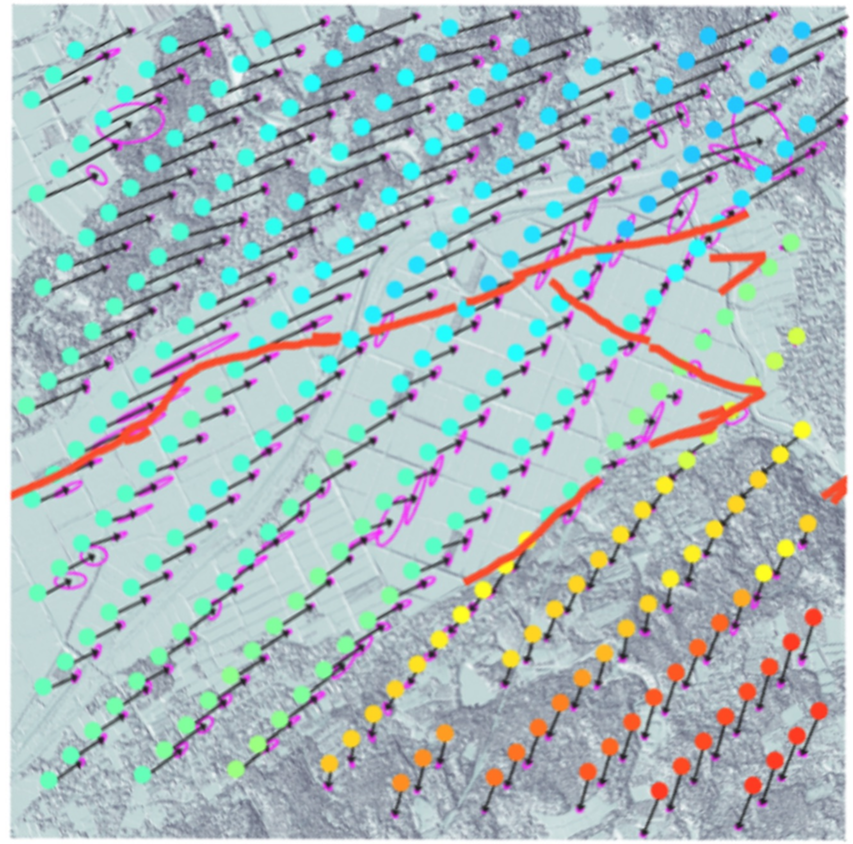
**Outline:**

- Topography data along faults
- Topographic differencing
- 2016 Kumamoto Earthquake- Coseismic strain field & Earthquake source inversion
- Central San Andreas Fault: Fault zone evolution
- Needs for observatory



3D Topographic Differencing
Kumamoto Earthquake: Scott et al. (2018)

# Lidar – Light Detection and Ranging

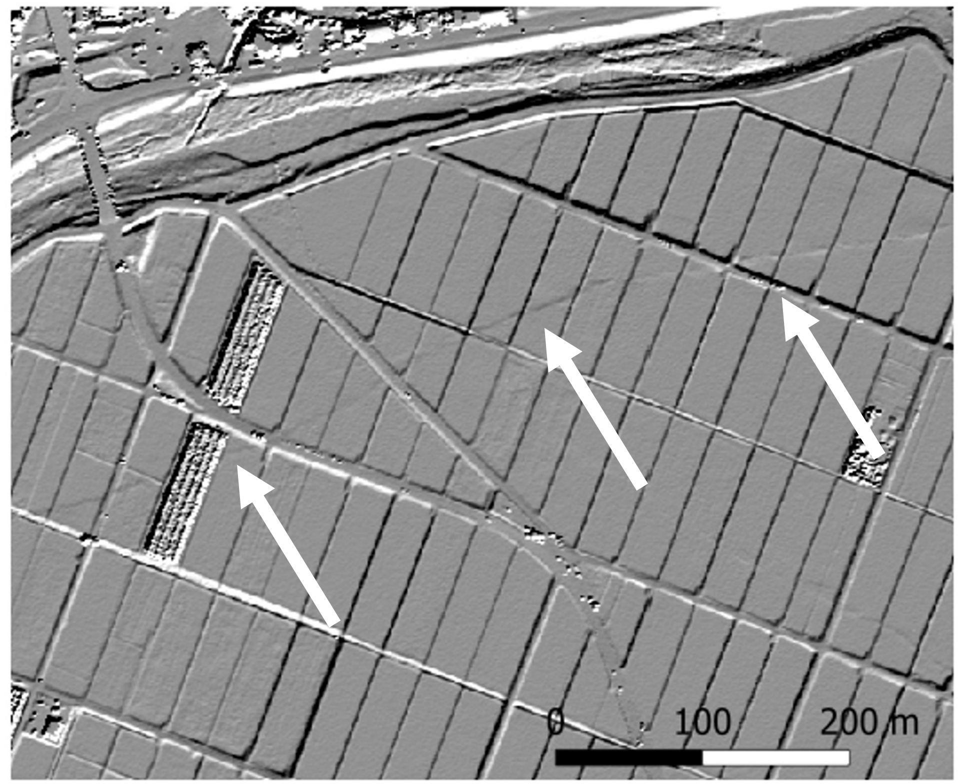
**B4 (2005) and EarthScope (2008):**

Community initiatives to collect lidar topography along the San Andreas Fault & other California Faults

(Bevis & Hudnut et al., 2005; Prentice et al., 2008)

**2016 Kumamoto Earthquake:**

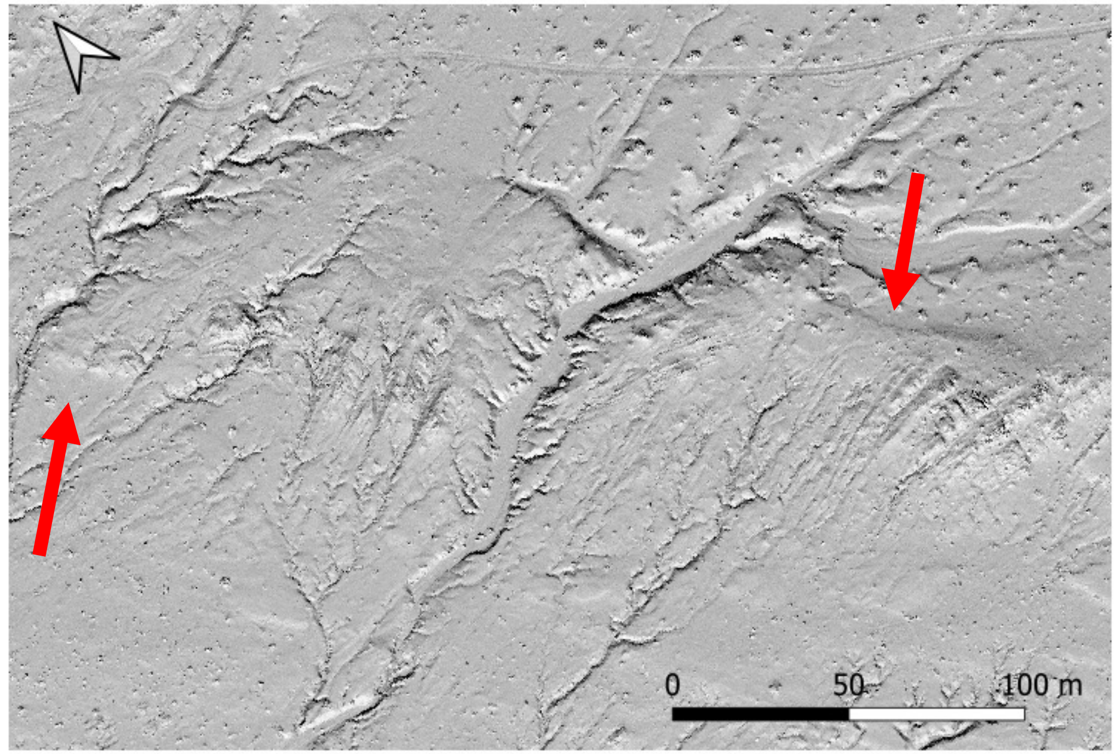
(Chiba, 2018)




OpenTopography
High-Resolution Topography Data and Tools

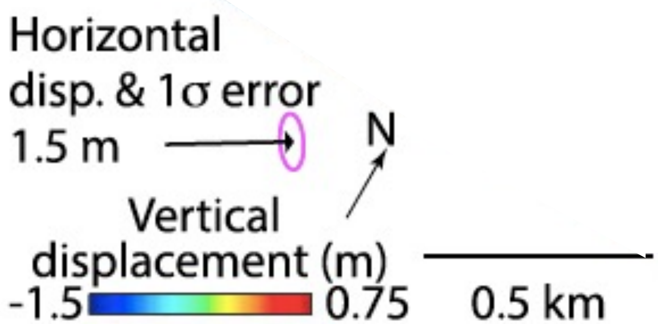
# sUAS/ Drone-derived topography

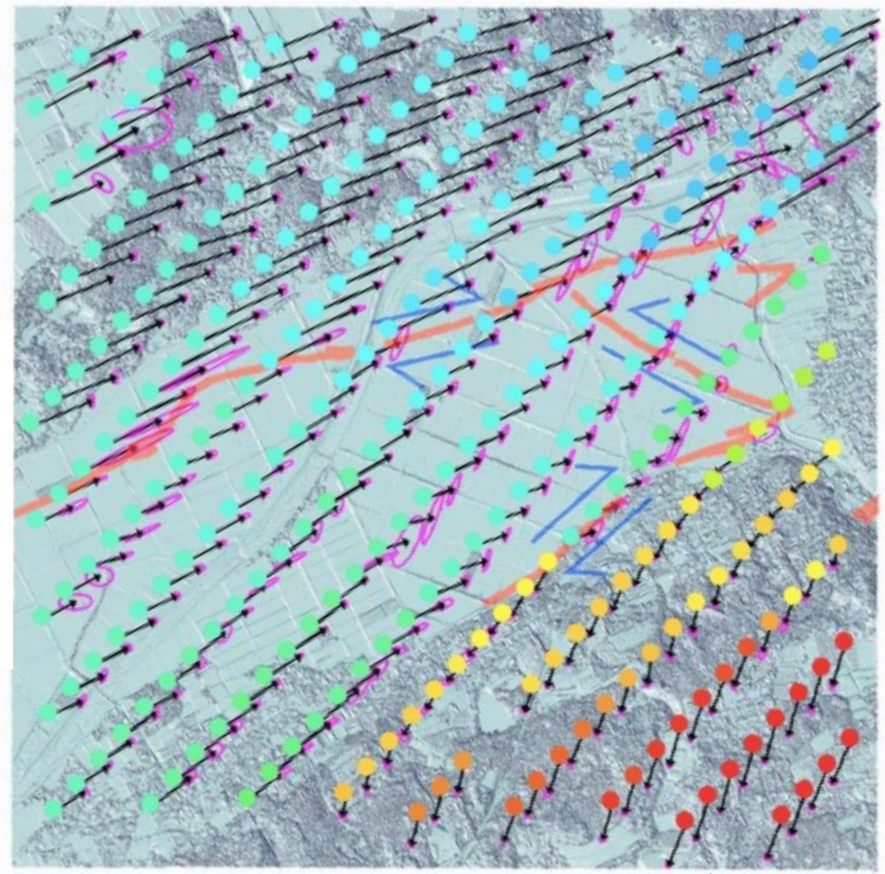
Very high resolution topography (>100 points/m$^2$) with color collected by small groups of researchers


Southern San Andreas fault: 40 km along strike collected in 3.5 days by Bunds, Scott et al., in 2020.

# 3D Topographic differencing

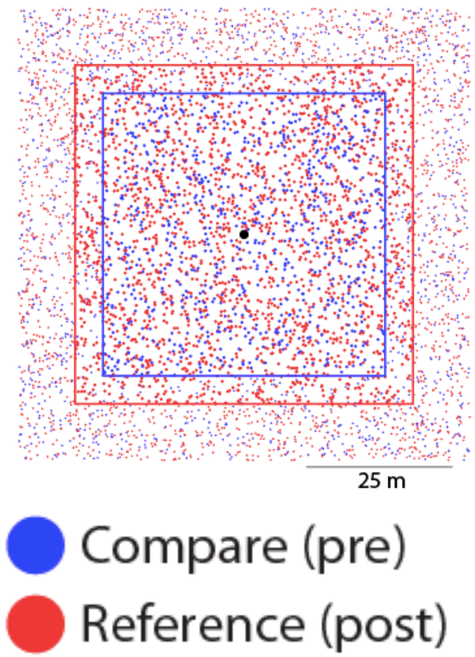


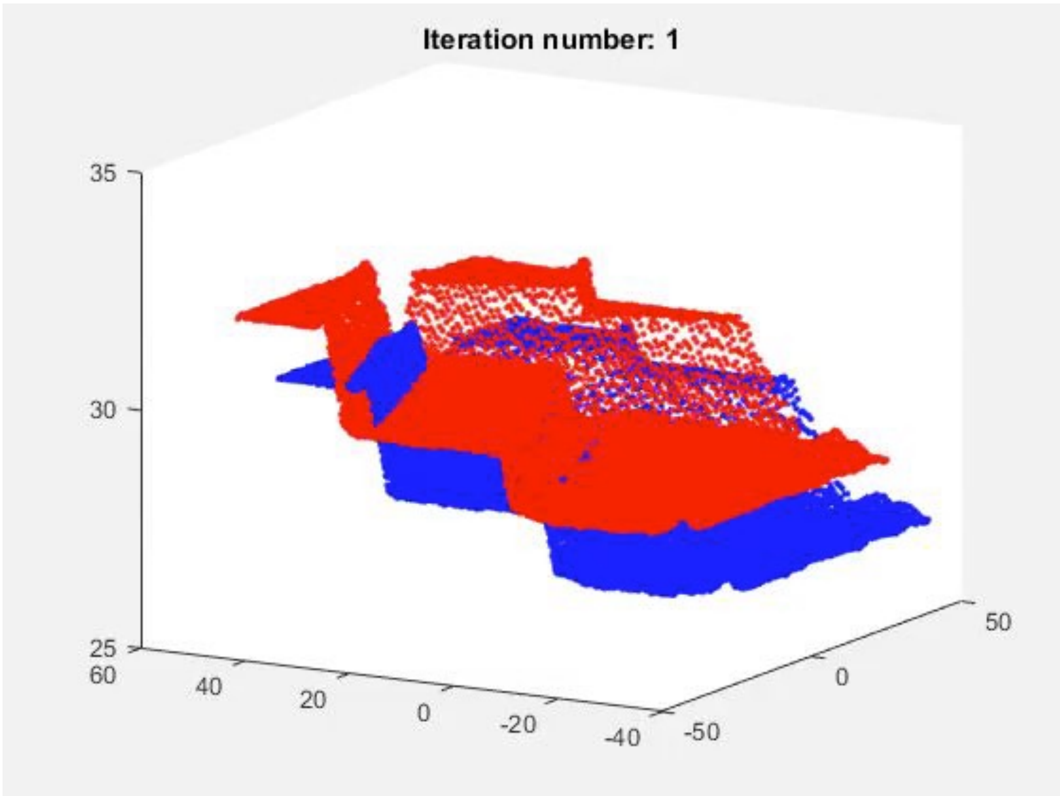
Besl and McKay (1992); Geiger et al., (2012); Nissen et al., (2012; 2014); Scott et al., (2018)

High resolution on- & near-fault displacements that do not decorrelate

# 3D Topographic differencing- Iterative Closest Point




*Scott et al. (2021). Measuring change along the Earth's surface: On-Demand vertical and 3D topographic differencing hosted by OpenTopography. Geosphere. https://doi.org/10.1130/GES02259.1*

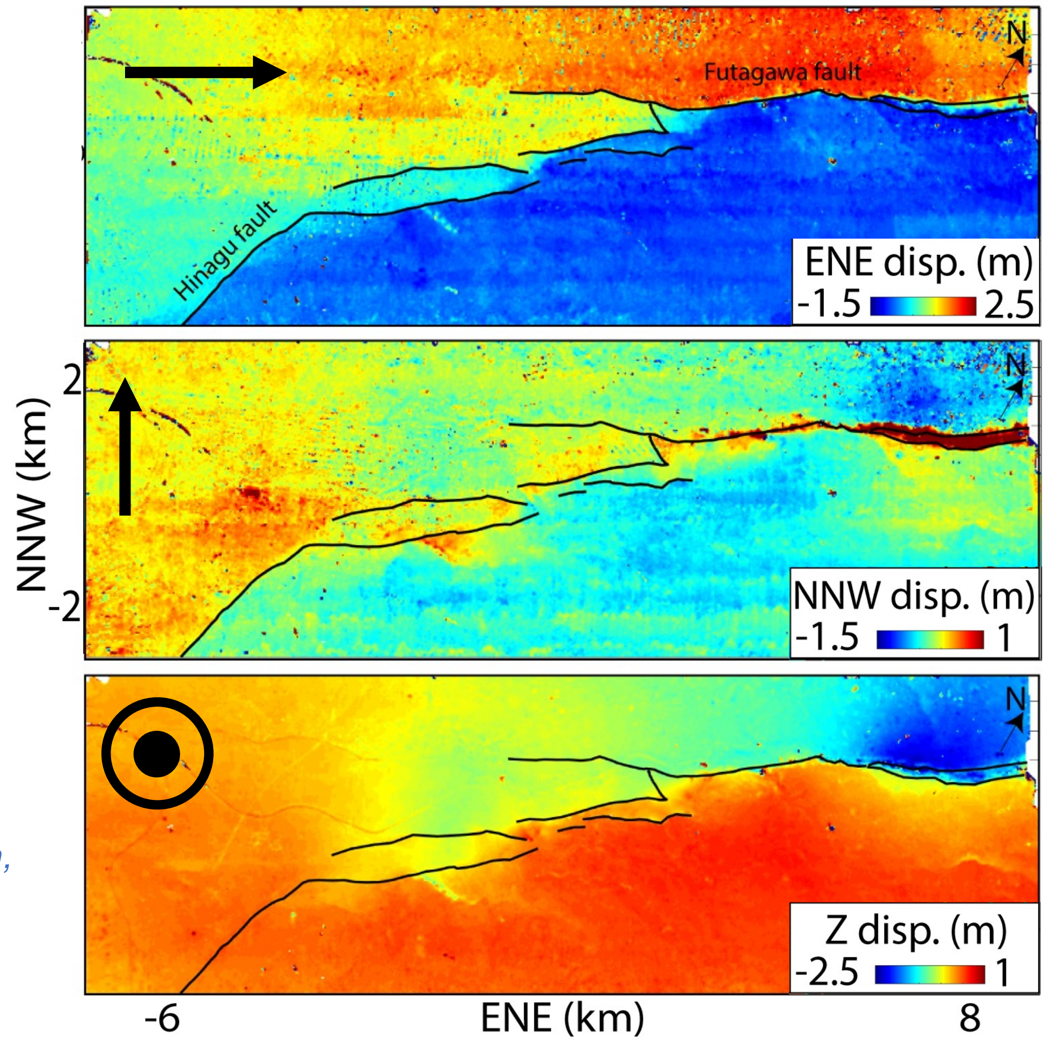



Align pre- and post- event point clouds with a rigid-body transformation

# 2016 M7 Kumamoto Earthquake: 3D Displacement Fields

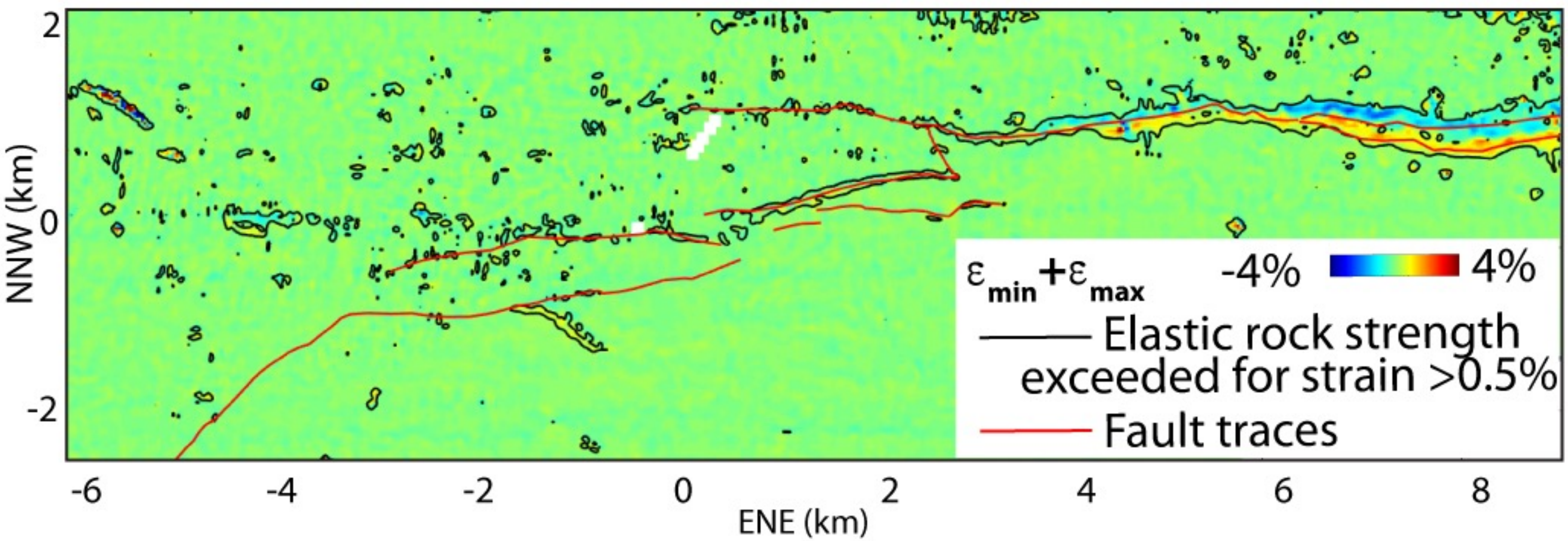
- Displacement
- Off-fault deformation
- Strain
- Slip inversions

Scott et al (2018): The M7 2016 Kumamoto, Japan, Earthquake: 3D deformation within the fault and damage zone constrained from differential topography: JGR: doi:10.1029/2018JB015581.



# Coseismic strain

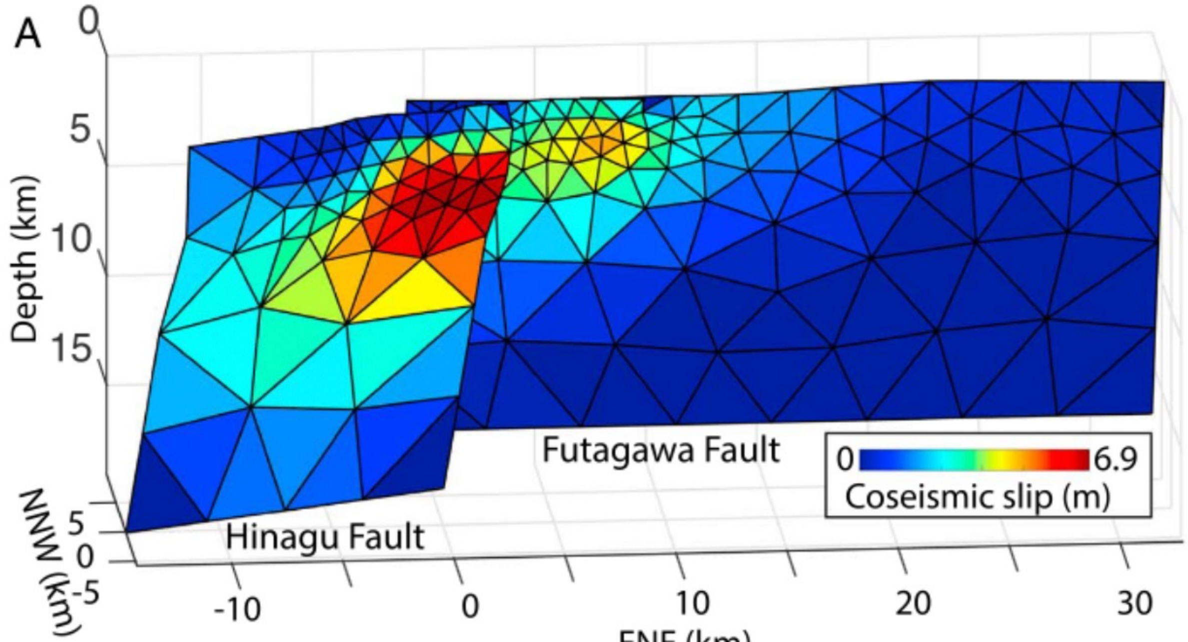
First invariant of the 2D strain tensor (horizontal area change)

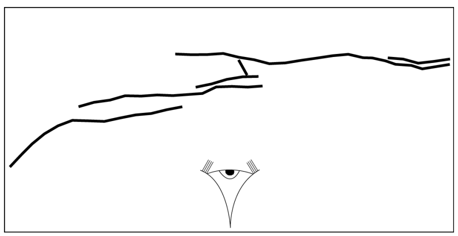



Elastic strain limit: $\varepsilon_{yield} = \sigma_{yield} / E \approx 0.5\%$

# Joint Distributed slip inversion

3D differencing, optical correlation and InSAR



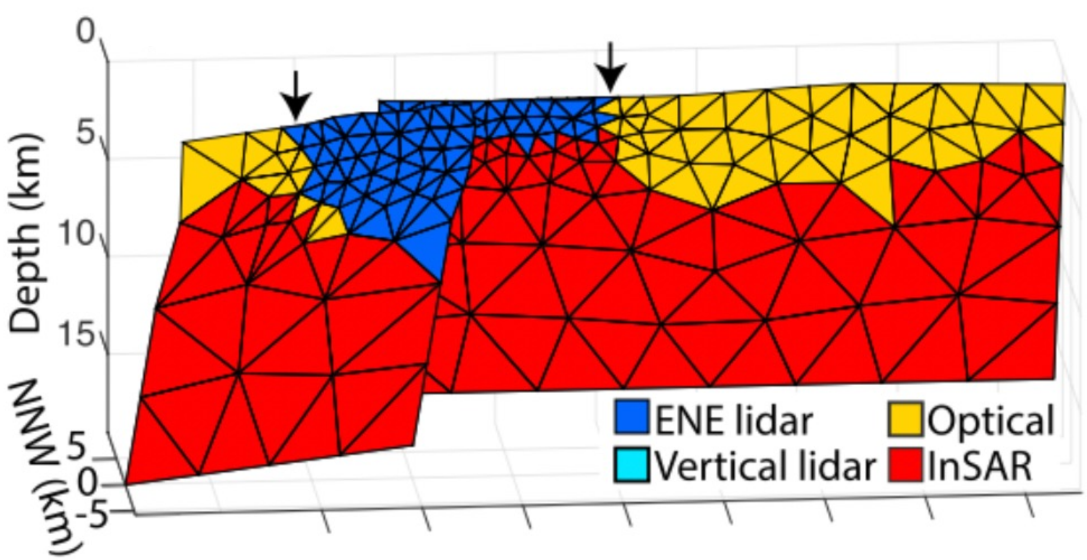
Gains from differential topography:

Add complexity to the shallow fault geometry

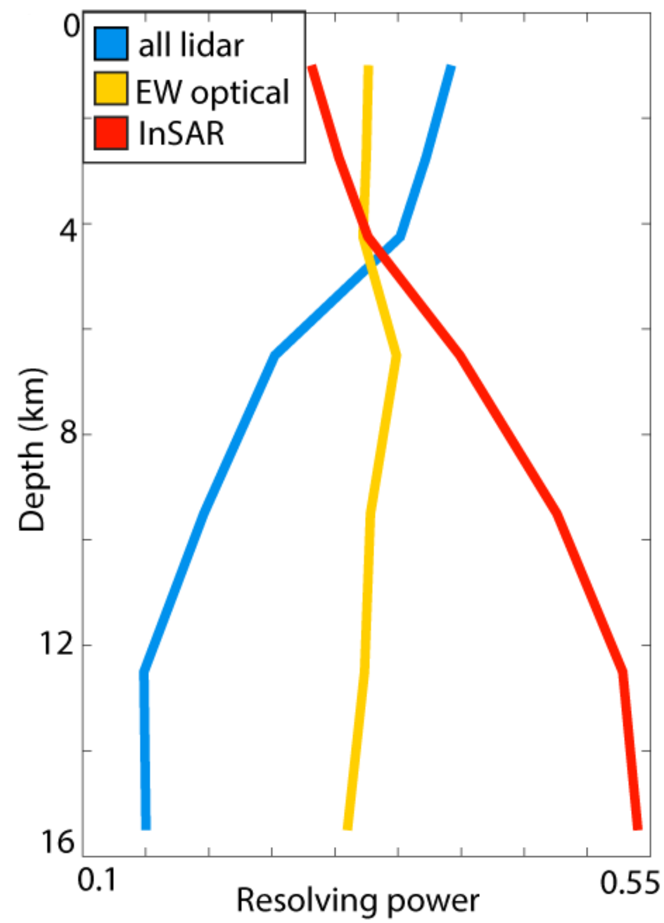
Resolve more shallow slip than with far-field displacements or strong-motion & teleseismic data

*Scott et al. (2019). 2016 M7 Kumamoto, Japan, Earthquake Slip Field Derived From a Joint Inversion of Differential Lidar Topography, Optical Correlation, and InSAR Surface Displacements. GRL. https://doi.org/10.1029/2019GL082202*

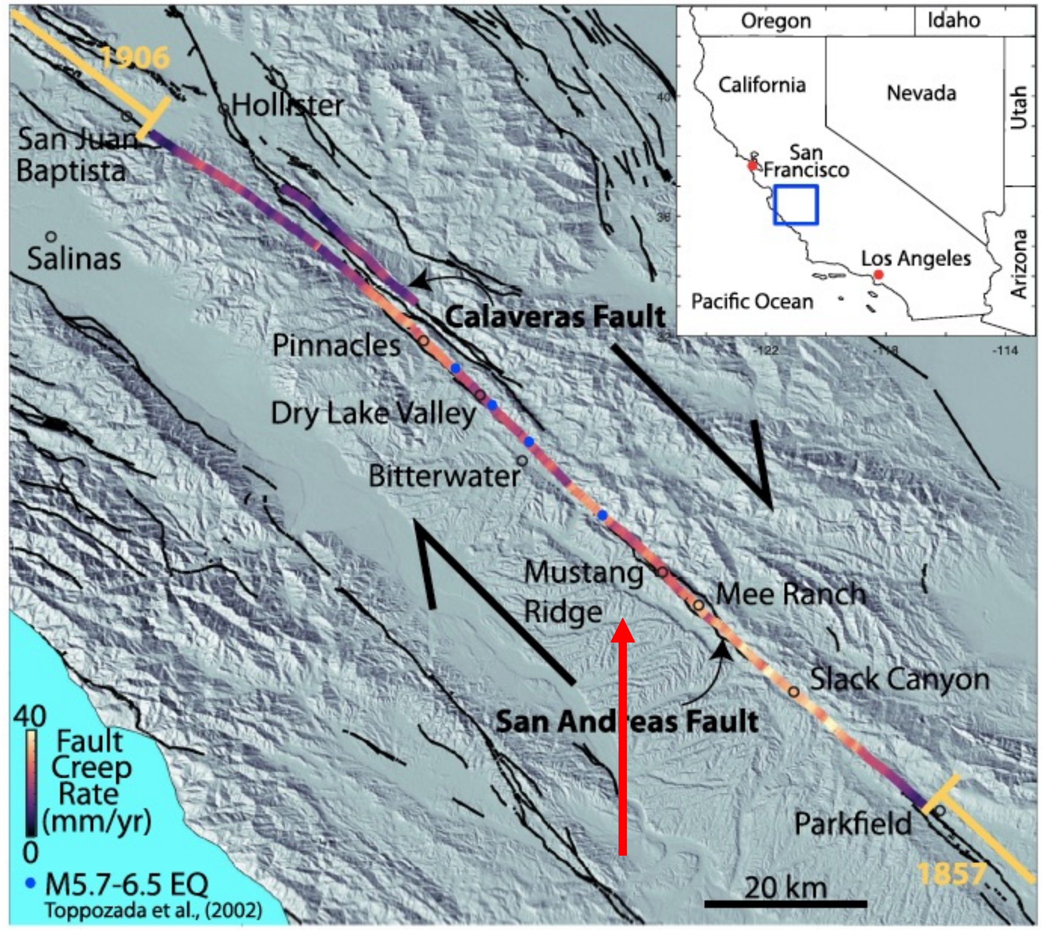
# Quantify the impact of near-field displacements



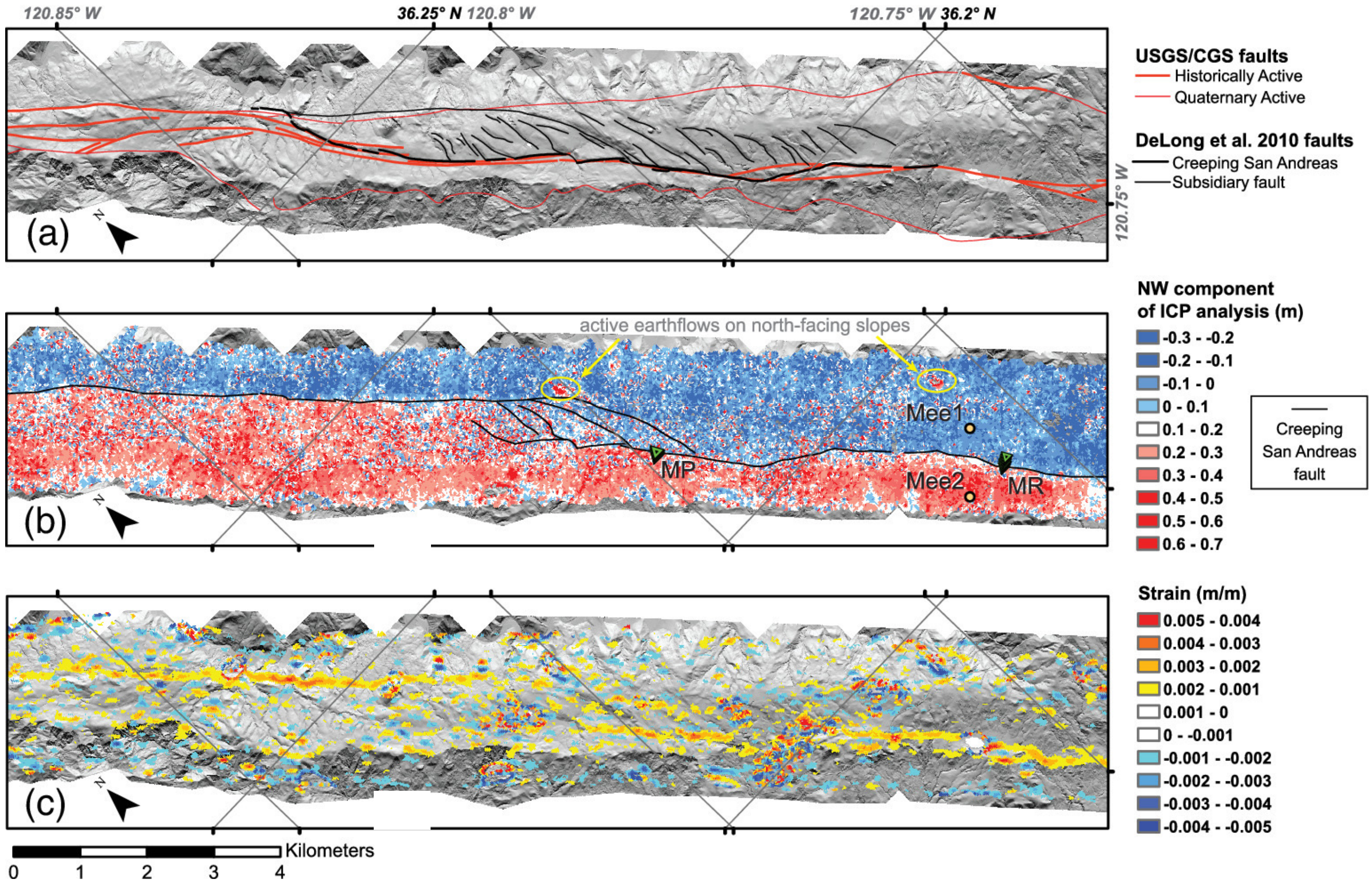

Near-field topography adds critical constraints to shallow crust deformation



# Creeping Section of the Central San Andreas Fault




*Scott et al (2020). Distribution of Aseismic Deformation Along the Central San Andreas and Calaveras Faults from Differencing Repeat Airborne Lidar. GRL. https://doi.org/10.1029/2020GL090628*


120.85° W
36.25° N
120.8° W
120.75° W
36.2° N
120.75° W
USGS/CGS faults
Historically Active
Quaternary Active
DeLong et al. 2010 faults
Creeping San Andreas
Subsidiary fault
(a)
NW component
of ICP analysis (m)
-0.3 - -0.2
-0.2 - -0.1
-0.1 - 0
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
Creeping
San Andreas
fault
active earthflows on north-facing slopes
Mee1
MP
Mee2
MR
(b)
Strain (m/m)
0.005 - 0.004
0.004 - 0.003
0.003 - 0.002
0.002 - 0.001
0.001 - 0
0 - -0.001
-0.001 - -0.002
-0.002 - -0.003
-0.003 - -0.004
-0.004 - -0.005
(c)
Kilometers
0
1
2
3
4

# Topography Needs for Observatory

**Map** tectonic faults based on the landscape topography

**Measure** Vertical and 3D change from coseismic and postseismic deformation

**Pre-event topography:**

- Airborne Lidar: Large aperture (>10 km), established quality levels
- sUAS/ Drone: Along-fault very high resolution, needs good georeferencing
- Updated every few years

**Post-event topography:**

- ASAP following the earthquake
- Monthly acquisitions to capture post-seismic deformation