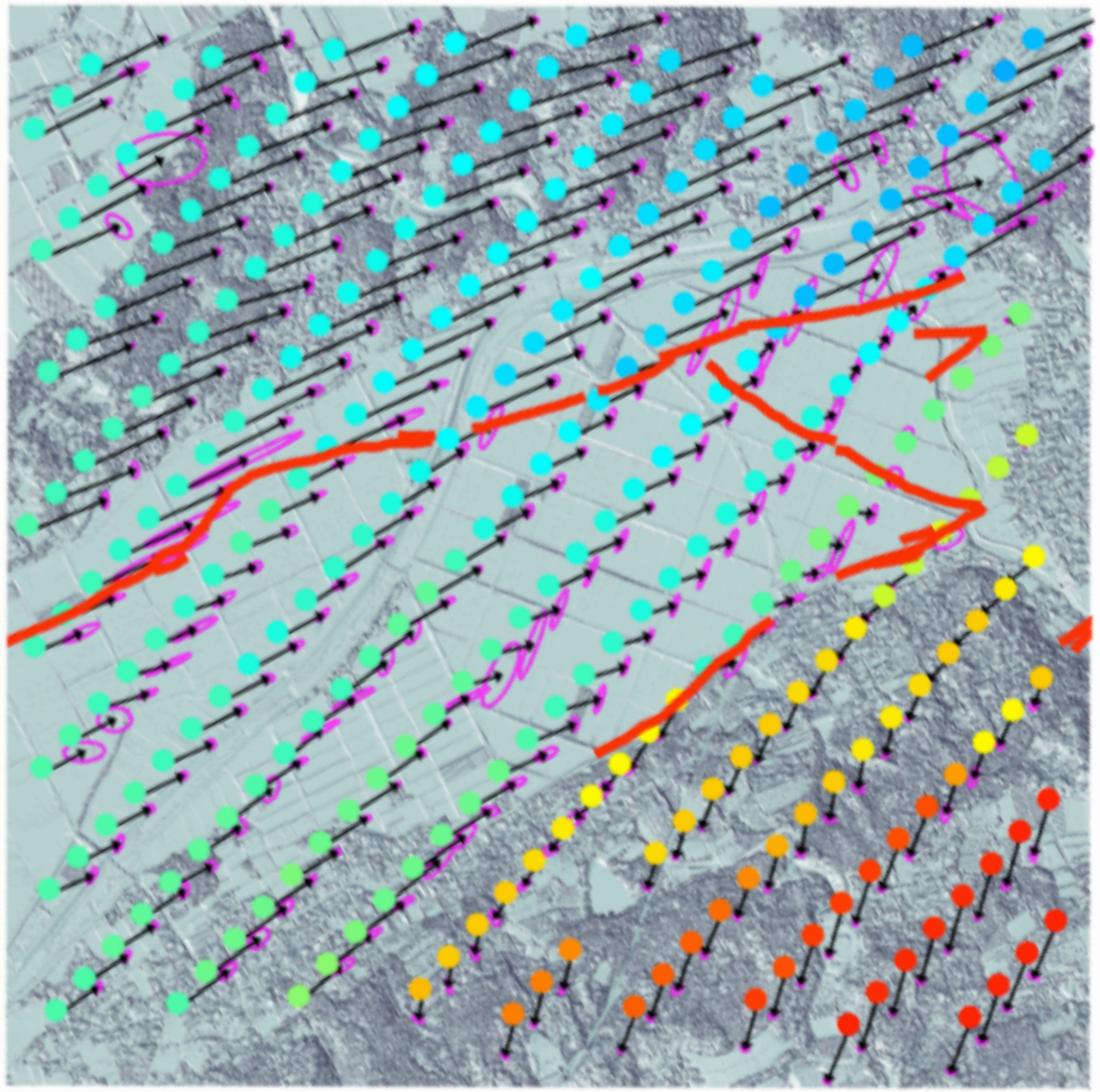
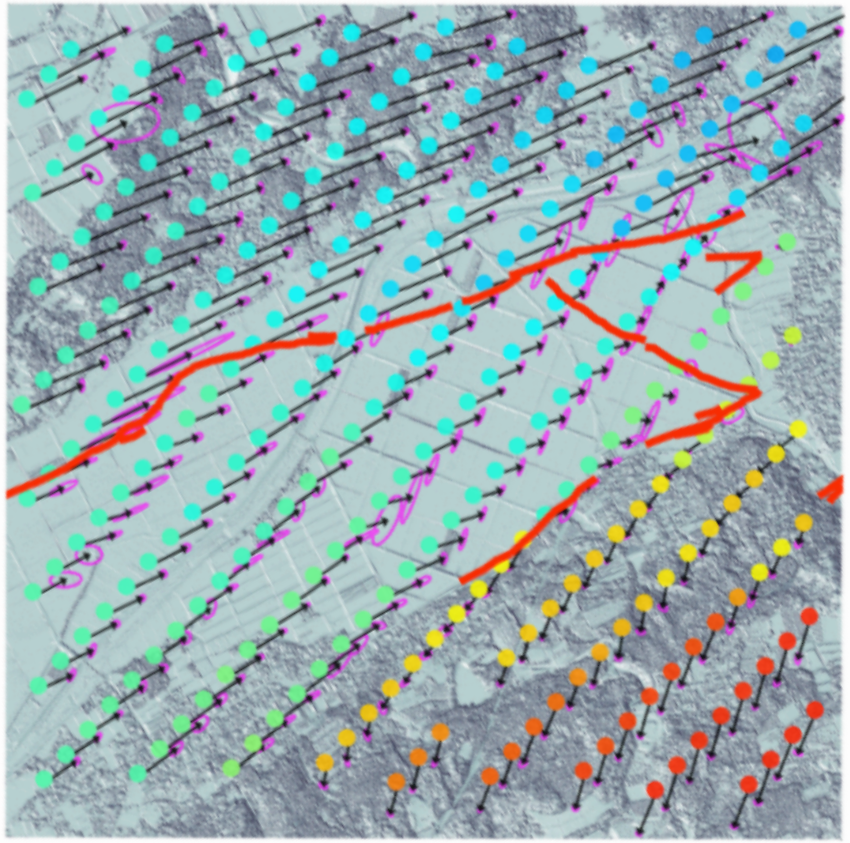


3D Topographic Differencing of Meter-Scale Topography

Chelsea Scott, Arizona State University

Edwin Nissen, University of Victoria

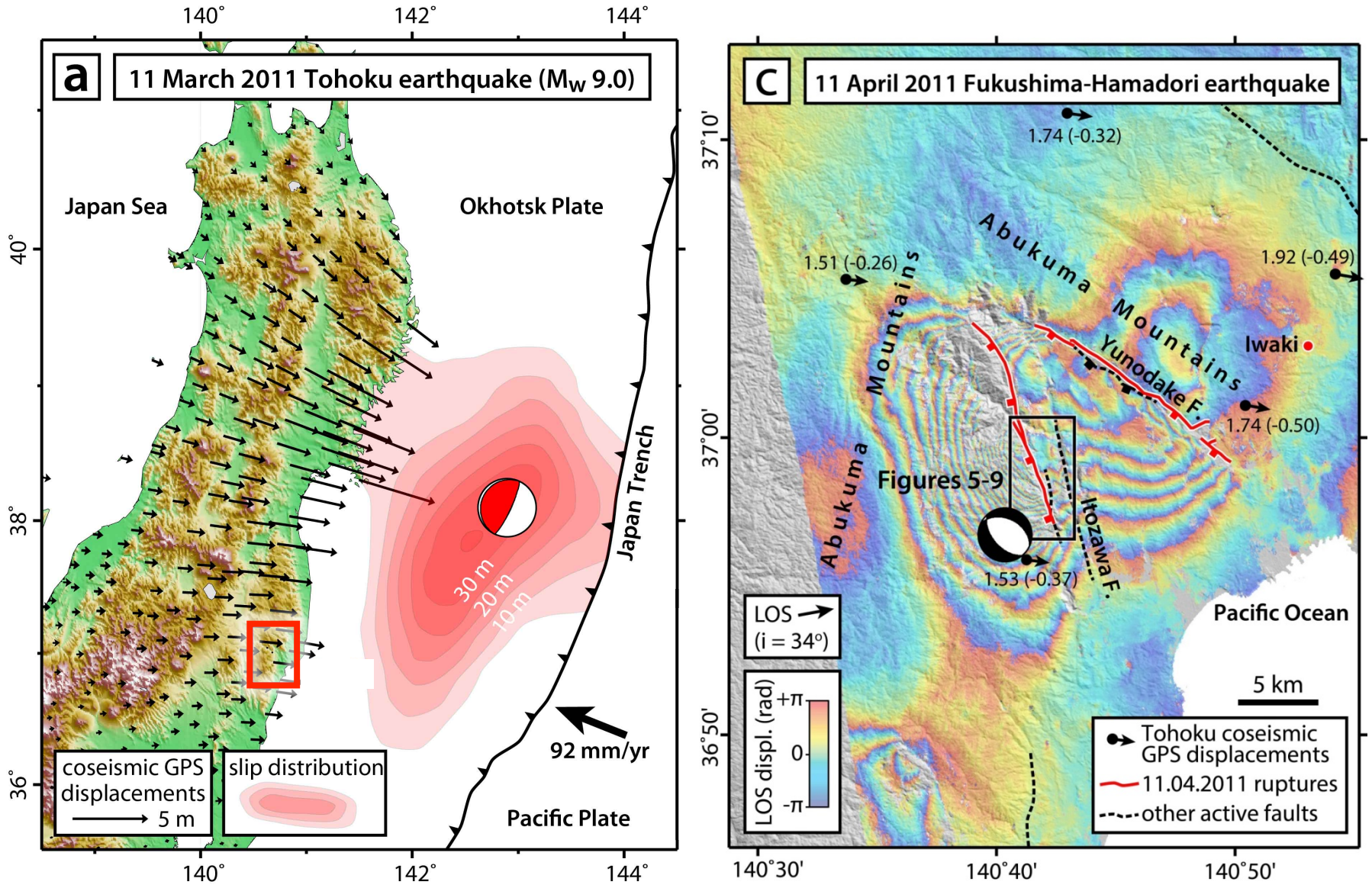
3D Topographic differencing



2016 M7 Kumamoto Earthquake (Scott et al., 2018)

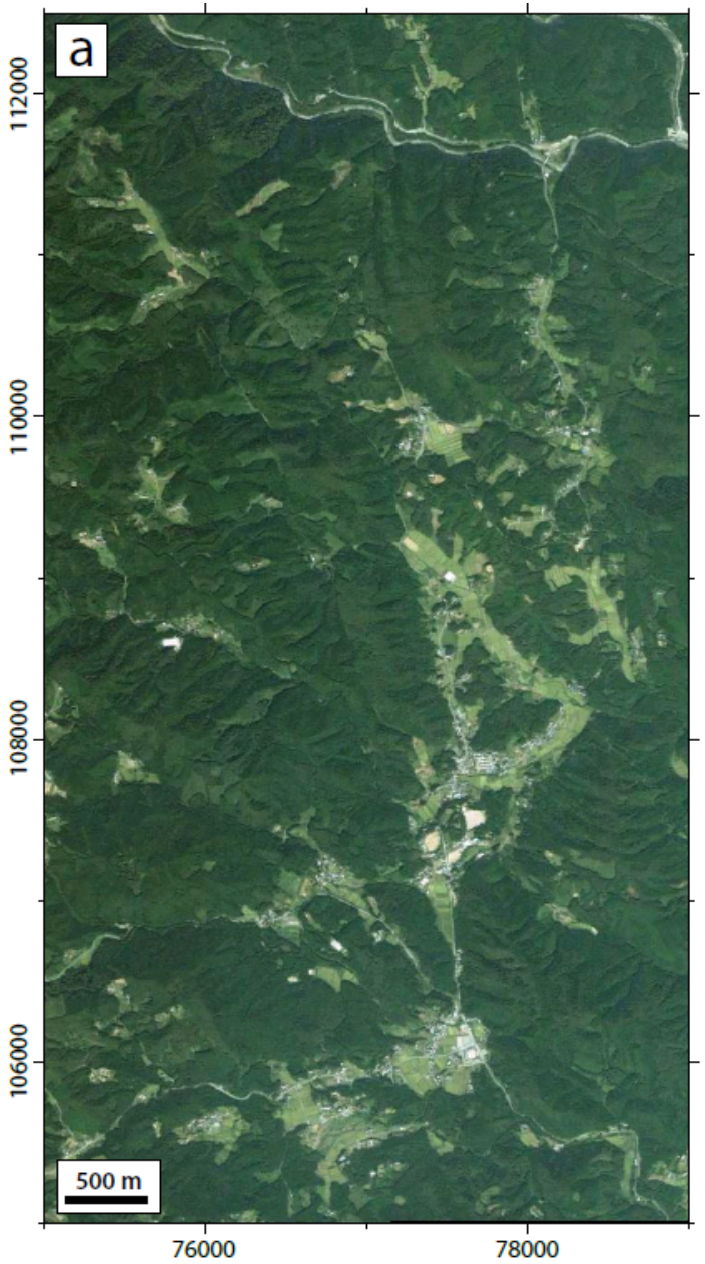
- Calculate surface deformation between two high resolution topographic datasets.
- Resolves on-fault slip and off-fault deformation.
- Fills near-fault data gap where other geodetic datasets commonly lack resolution.
- Learn about the behavior of the shallow fault volume.

11 April 2011 M_w 6.6 Fukushima-Hamadori earthquake

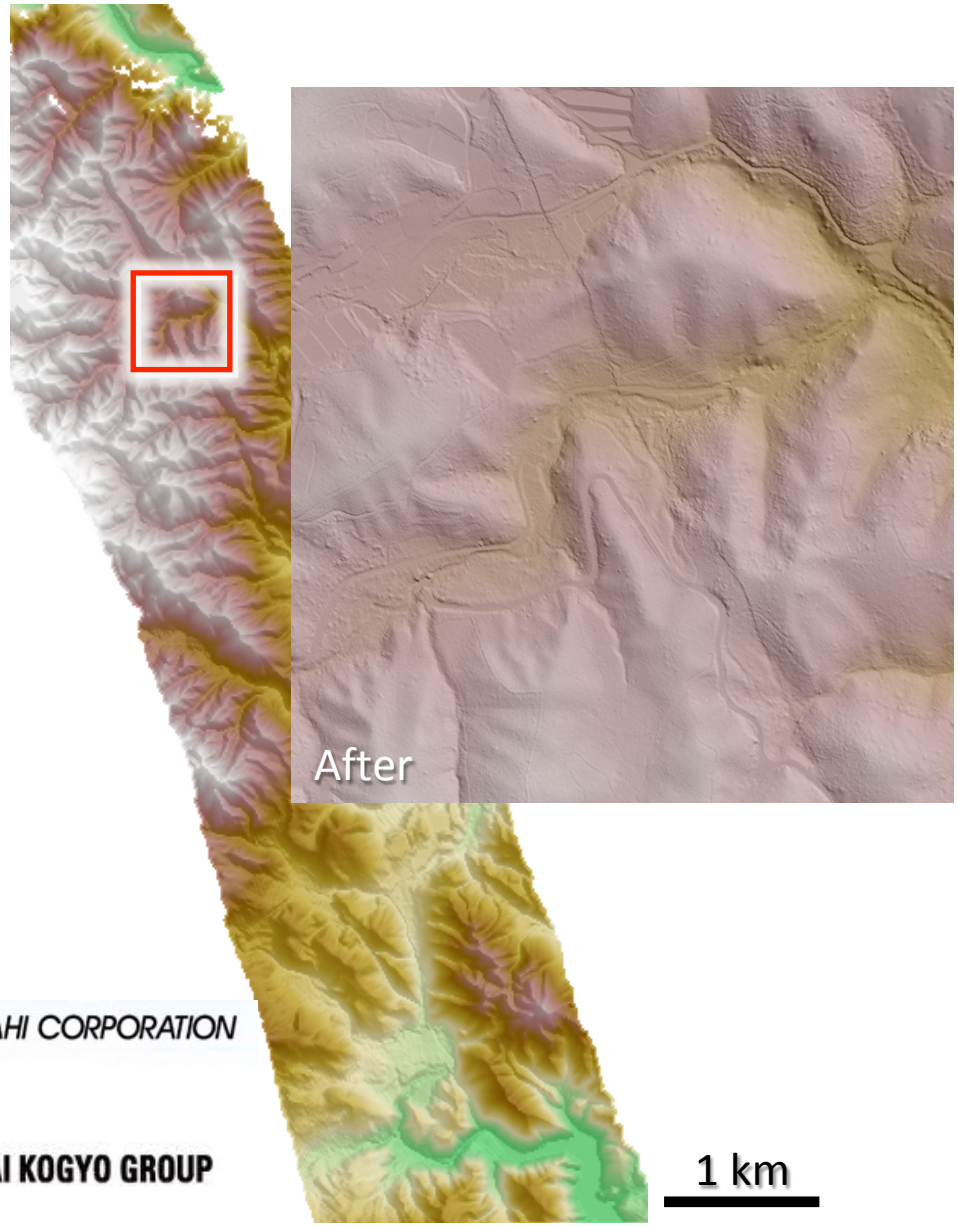


Nissen et al. (2014), *Earth Planet. Sci. Lett.*

11 April 2011 Fukushima-Hamadori earthquake

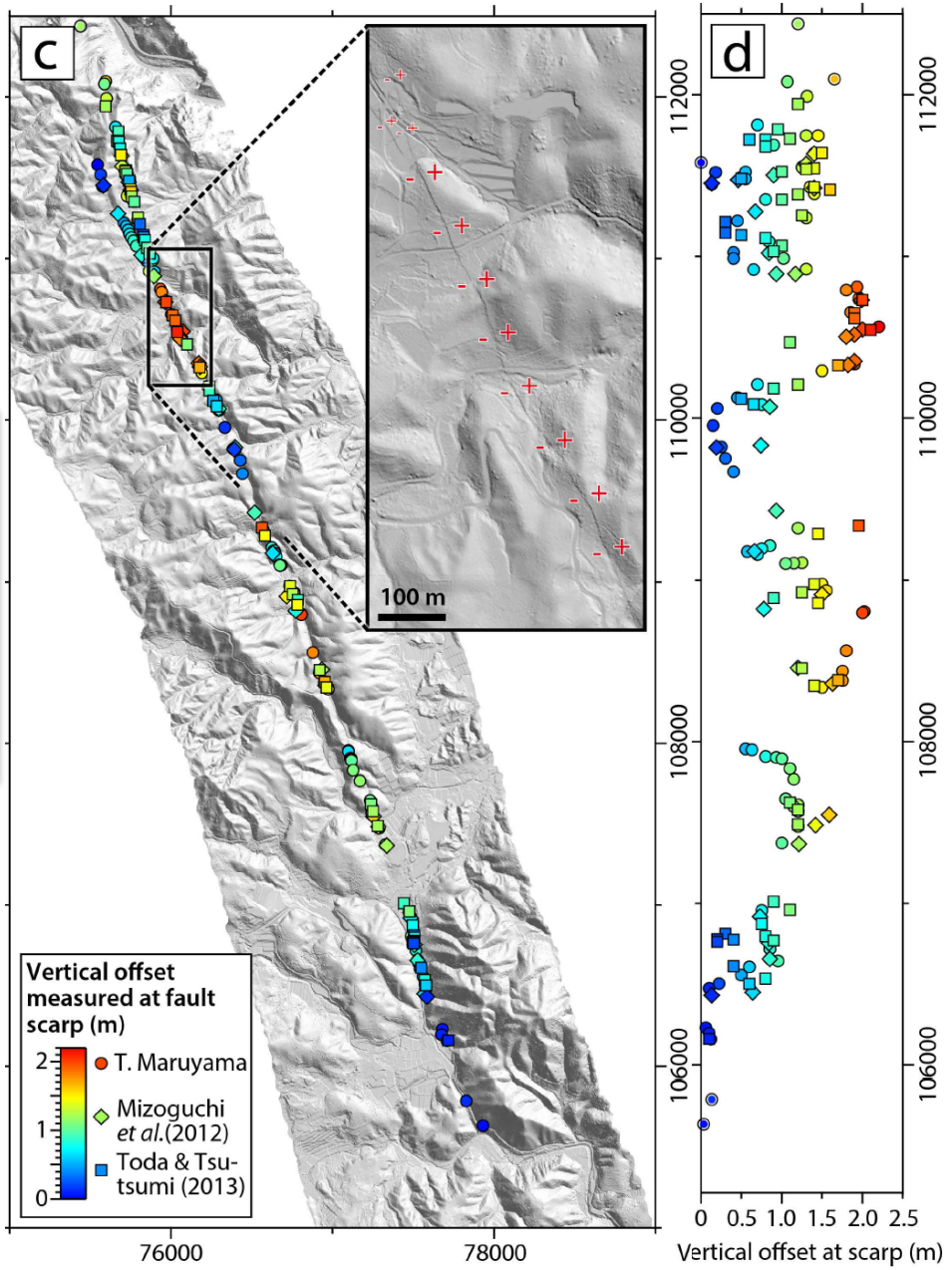


Tadashi Maruyama (AIST)

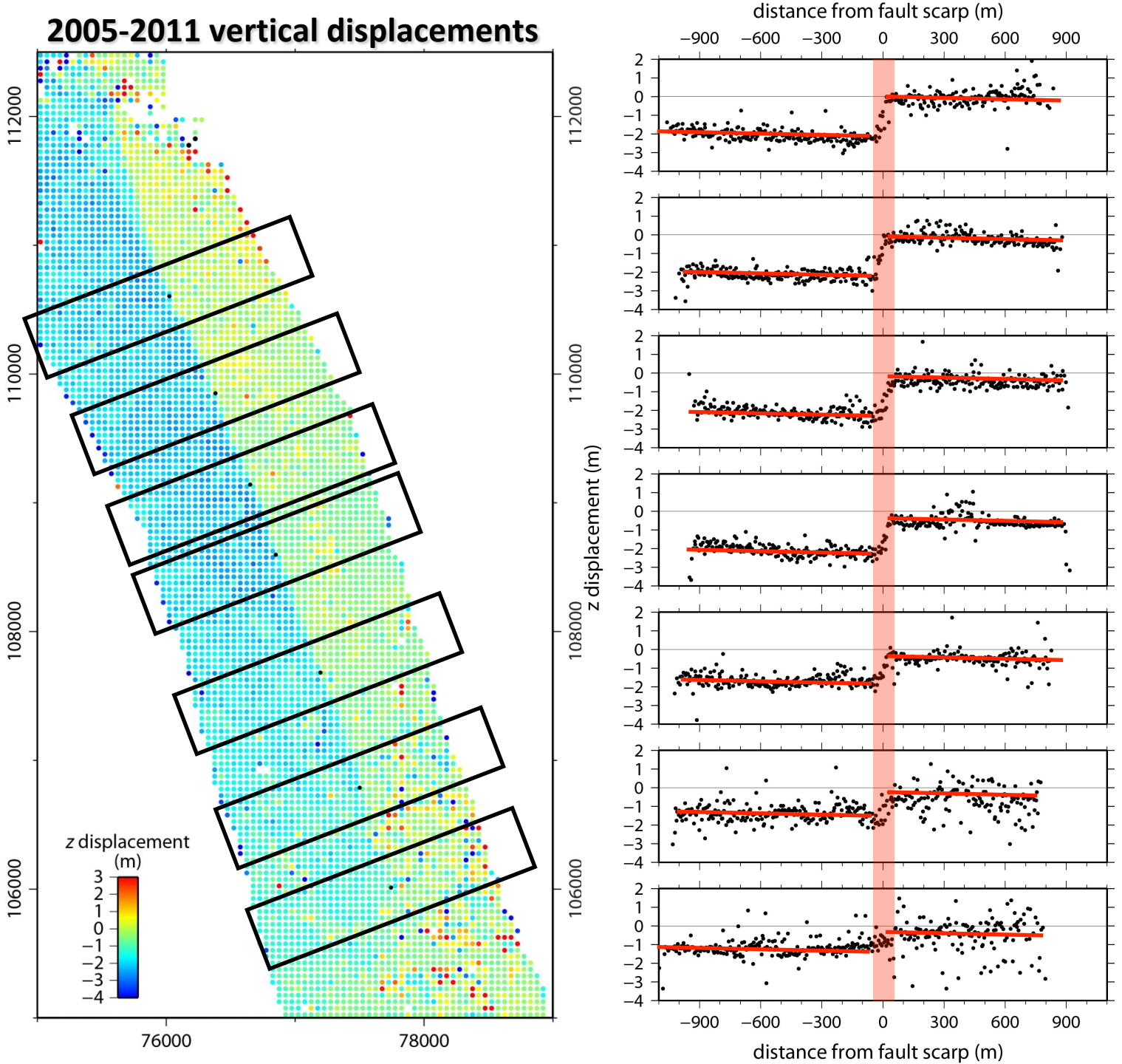


2011 post-event 1 m DEM AERO ASAHI CORPORATION

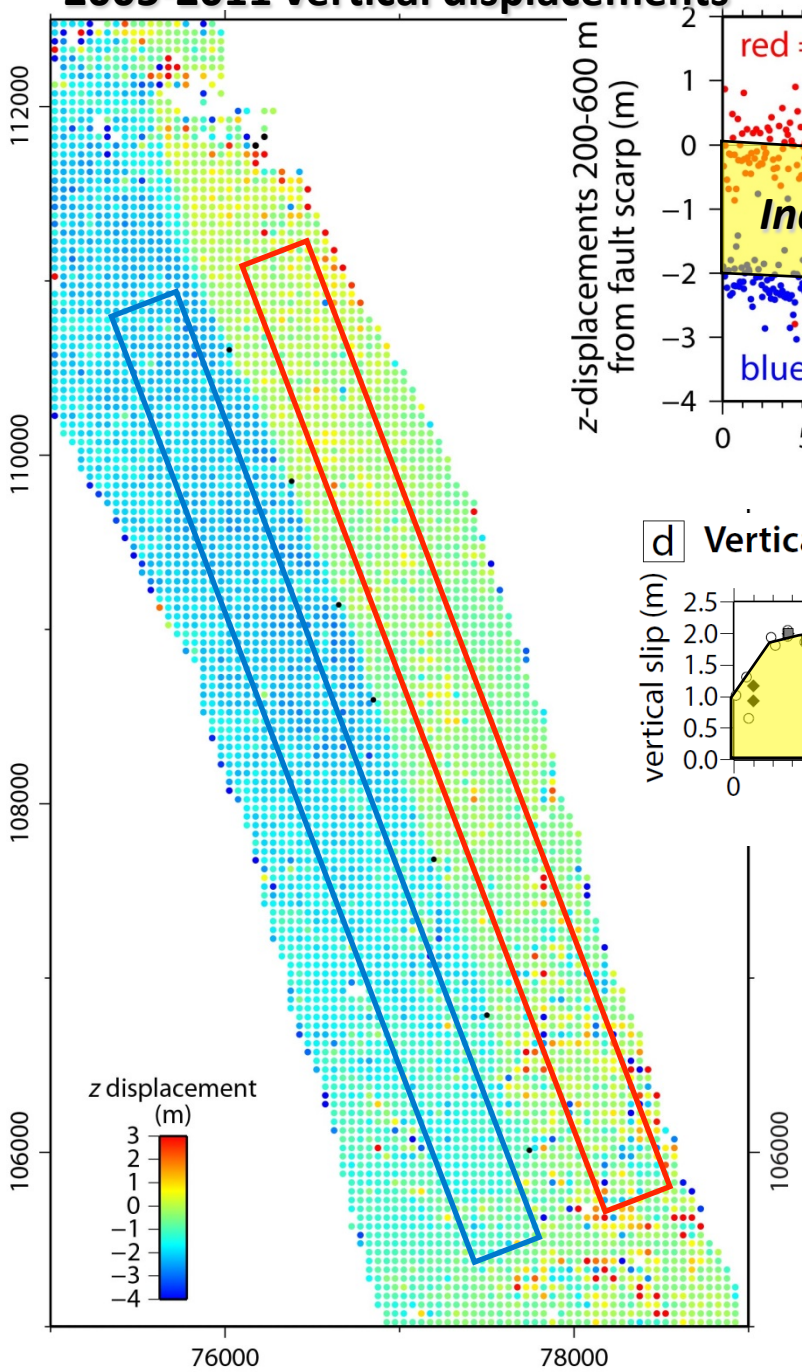
11 April 2011 Fukushima-Hamadori earthquake

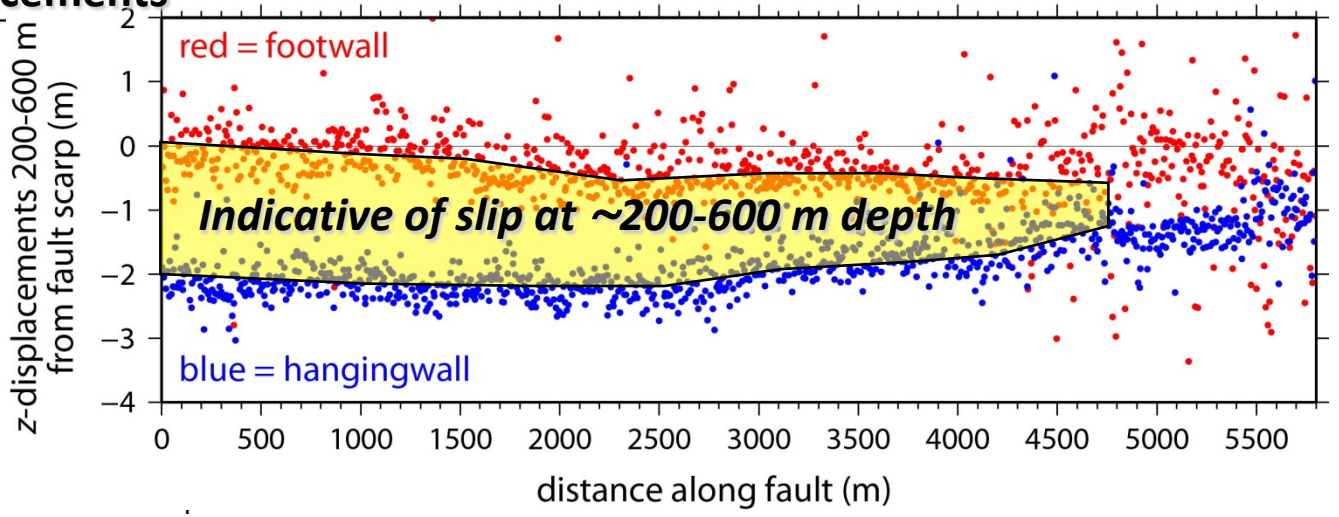


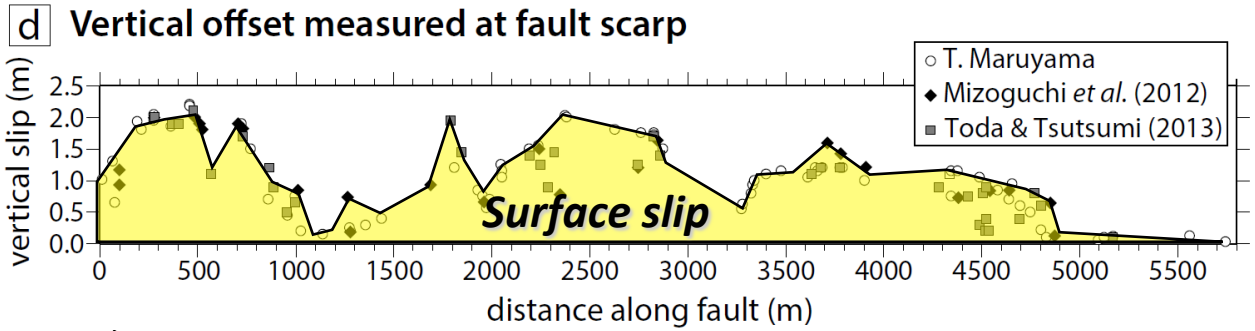
Photos from Toda & Tsutsumi (2013), *BSSA*


2005-2011 vertical displacements
112000
110000
108000
106000
76000
78000
z displacement (m)
3
2
1
0
−1
−2
−3
−4
distance from fault scarp (m)
−900
−600
−300
0
300
600
900
z displacement (m)
distance from fault scarp (m)

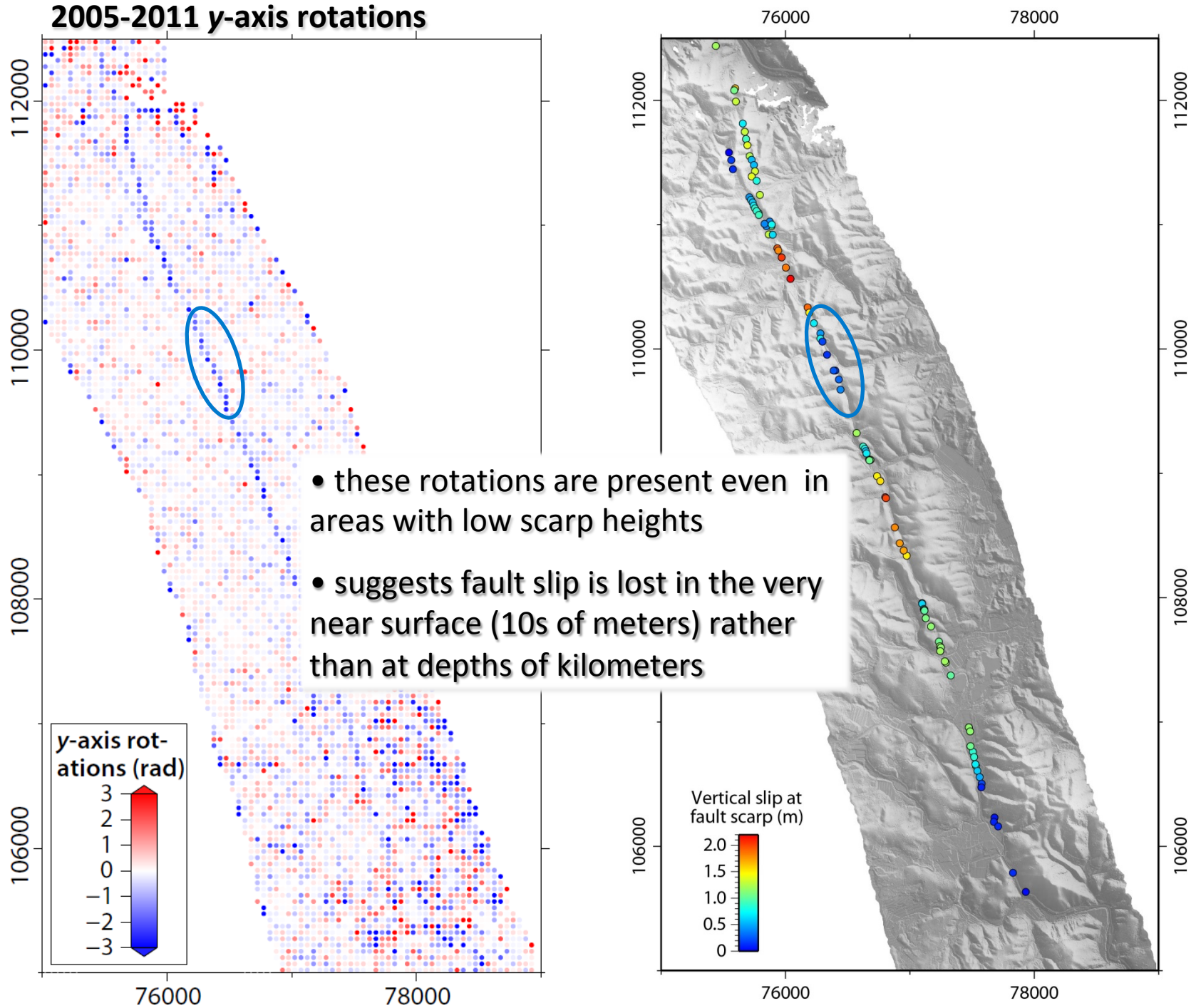
2005-2011 vertical displacements





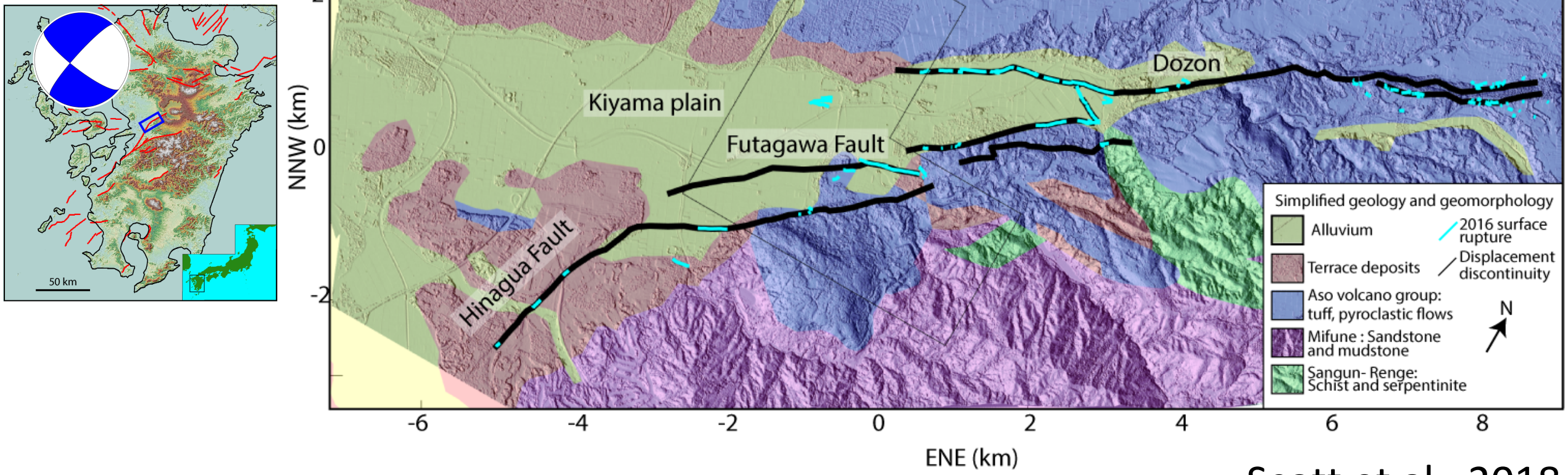


- In many places, only a small proportion of the slip makes it to the surface
- However, slip at depths of a few hundred meters appears to vary smoothly



- these rotations are present even in areas with low scarp heights
- suggests fault slip is lost in the very near surface (10s of meters) rather than at depths of kilometers

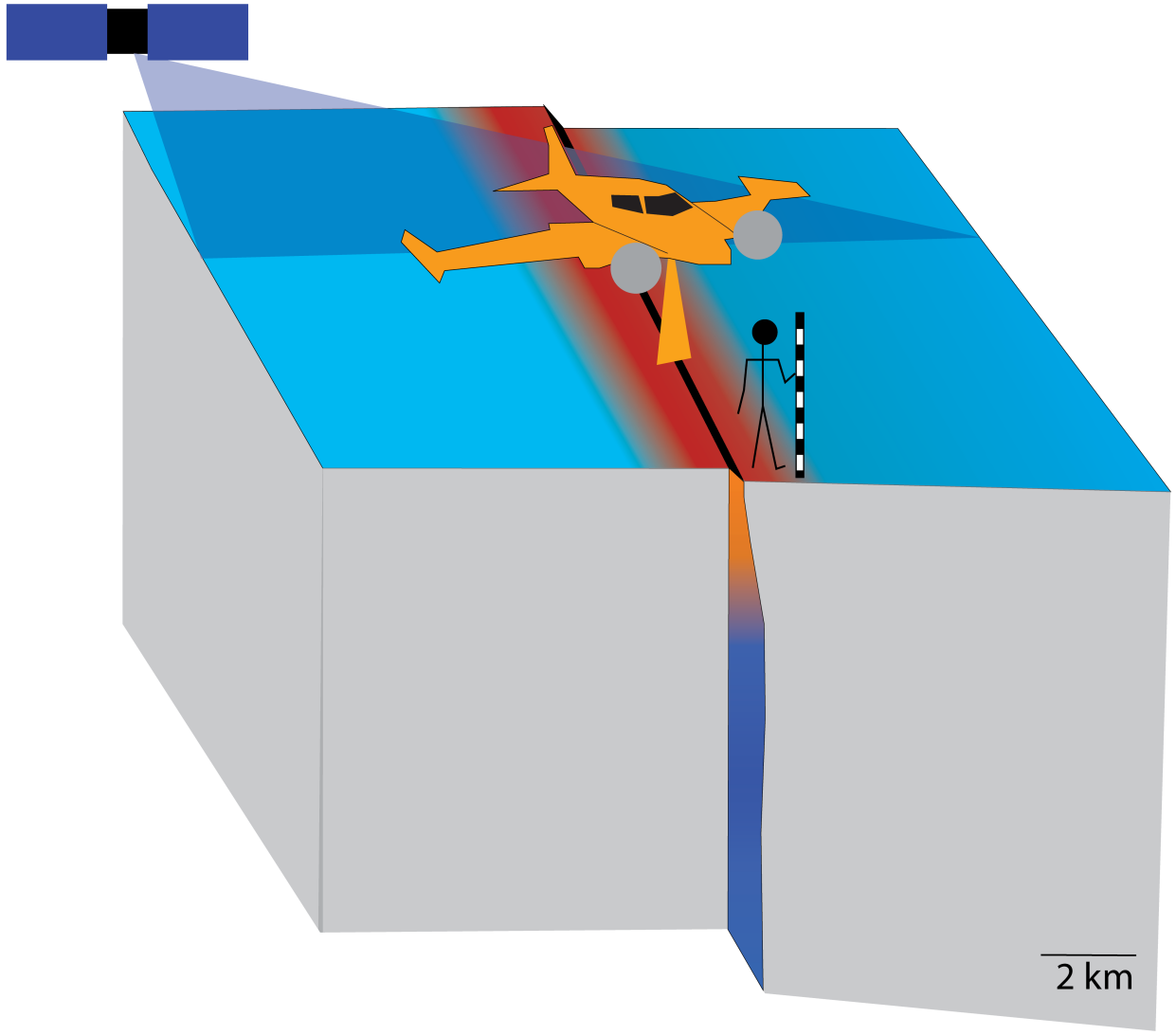
2016 M7 Kumamoto Earthquake



Scott et al., 2018

Scott, C. P., Arrowsmith, J. R., Nissen, E., Lajoie, L., Maruyama, T., & Chiba, T. (2018). The *M* 7 2016 Kumamoto, Japan, Earthquake: 3-D Deformation Along the Fault and Within the Damage Zone Constrained From Differential Lidar Topography. *Journal of Geophysical Research: Solid Earth*. https://doi.org/10.1029/2018JB015581

Surface displacements at increasing apertures



Surface

Field measurements

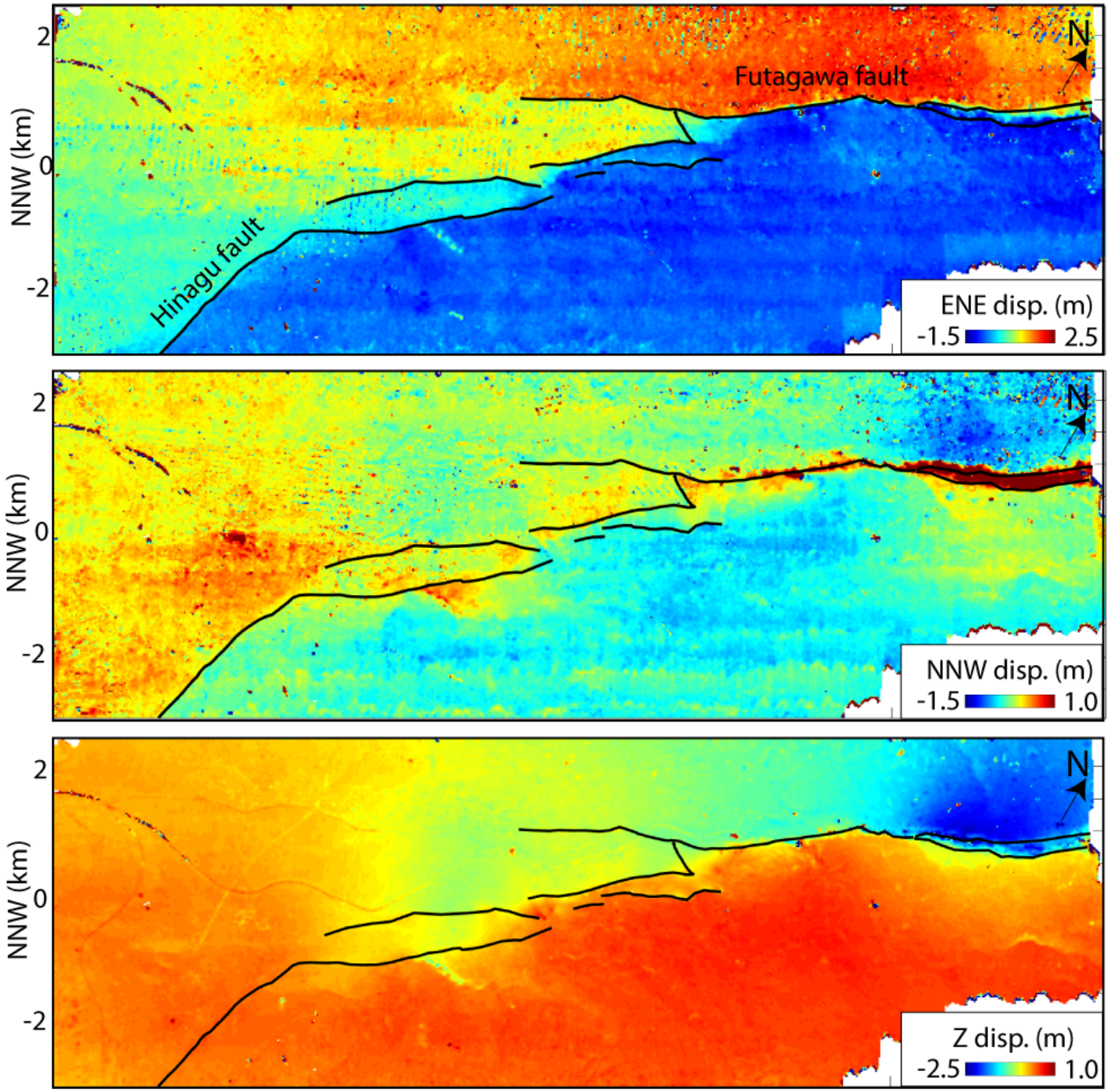
Tens of meters depth

Lidar displacement discontinuity

To the depth of the seismogenic zone

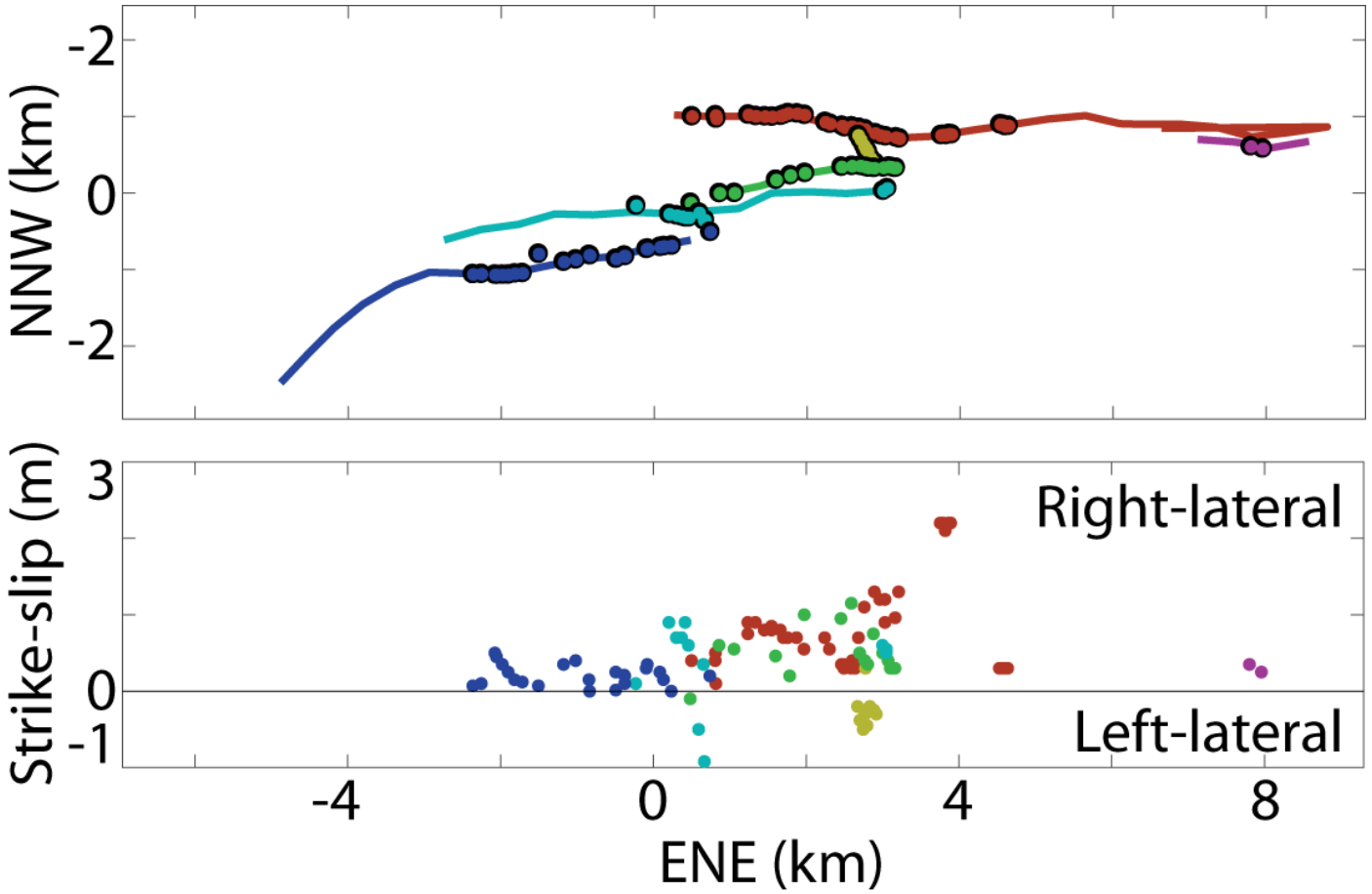
Joint lidar-optical-InSAR Earthquake source inversion

Surface displacement

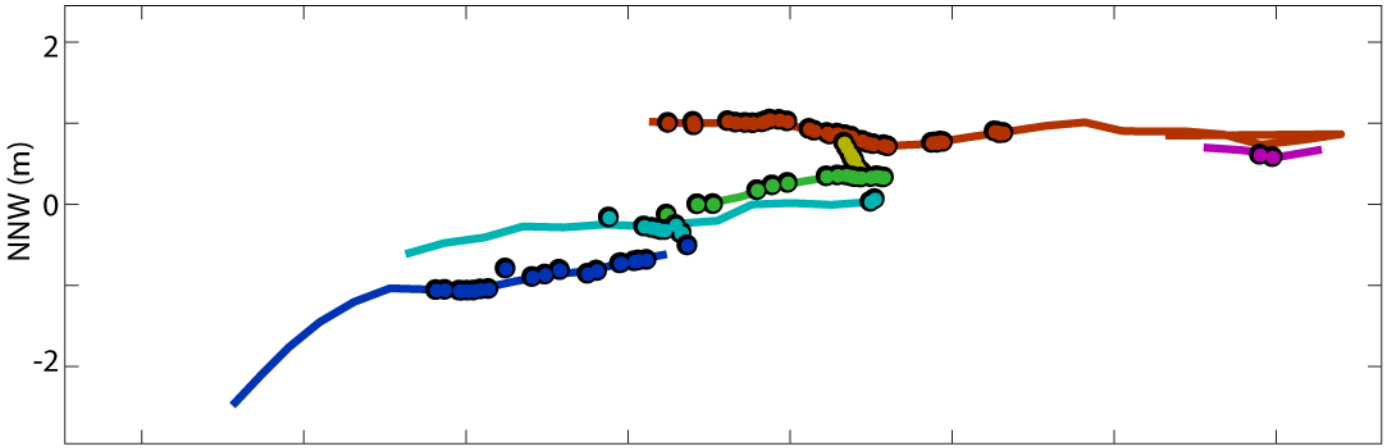


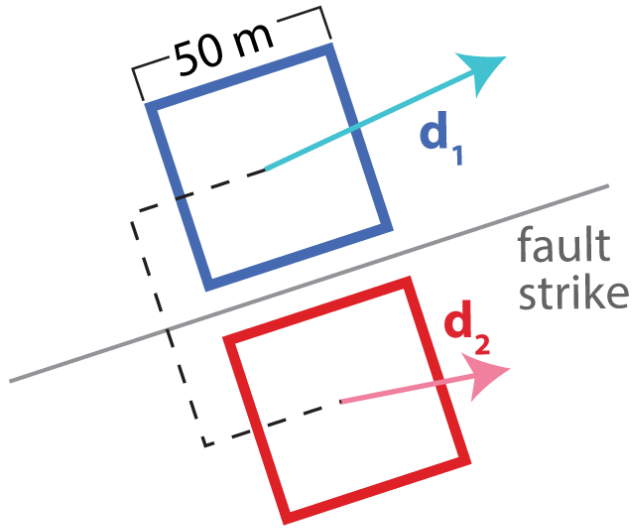
Surface offset measurements

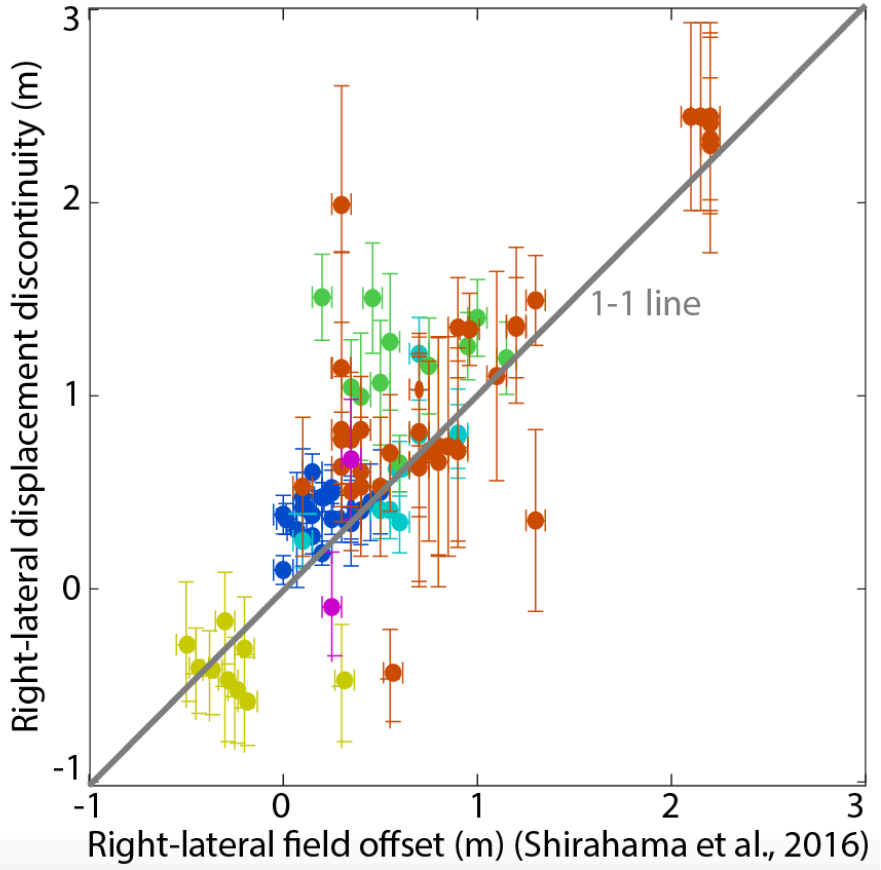
From Shirahama et al. (2016)



Lidar displacement discontinuity







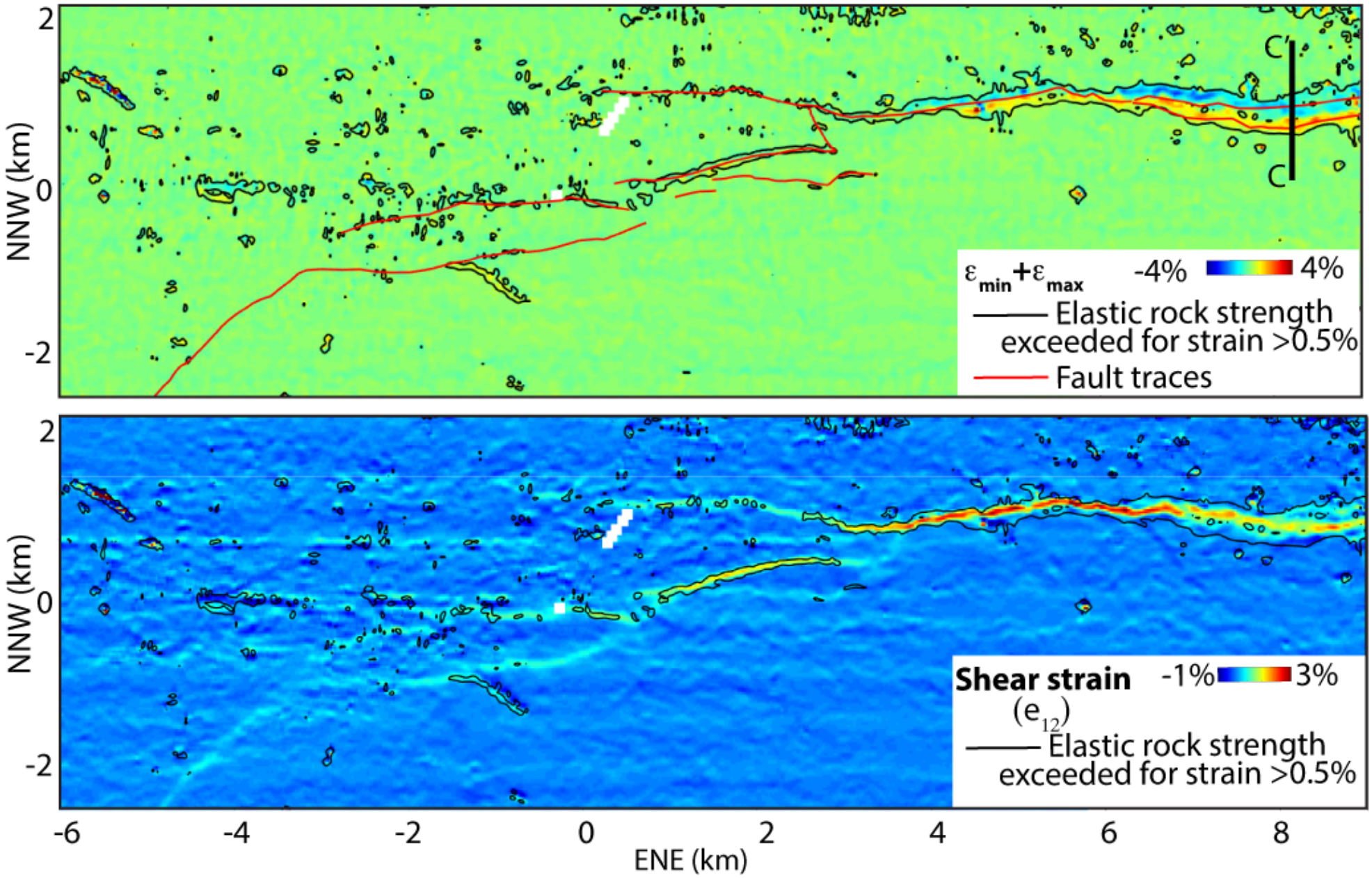
Coseismic surface strain

1st invariant of 2D strain

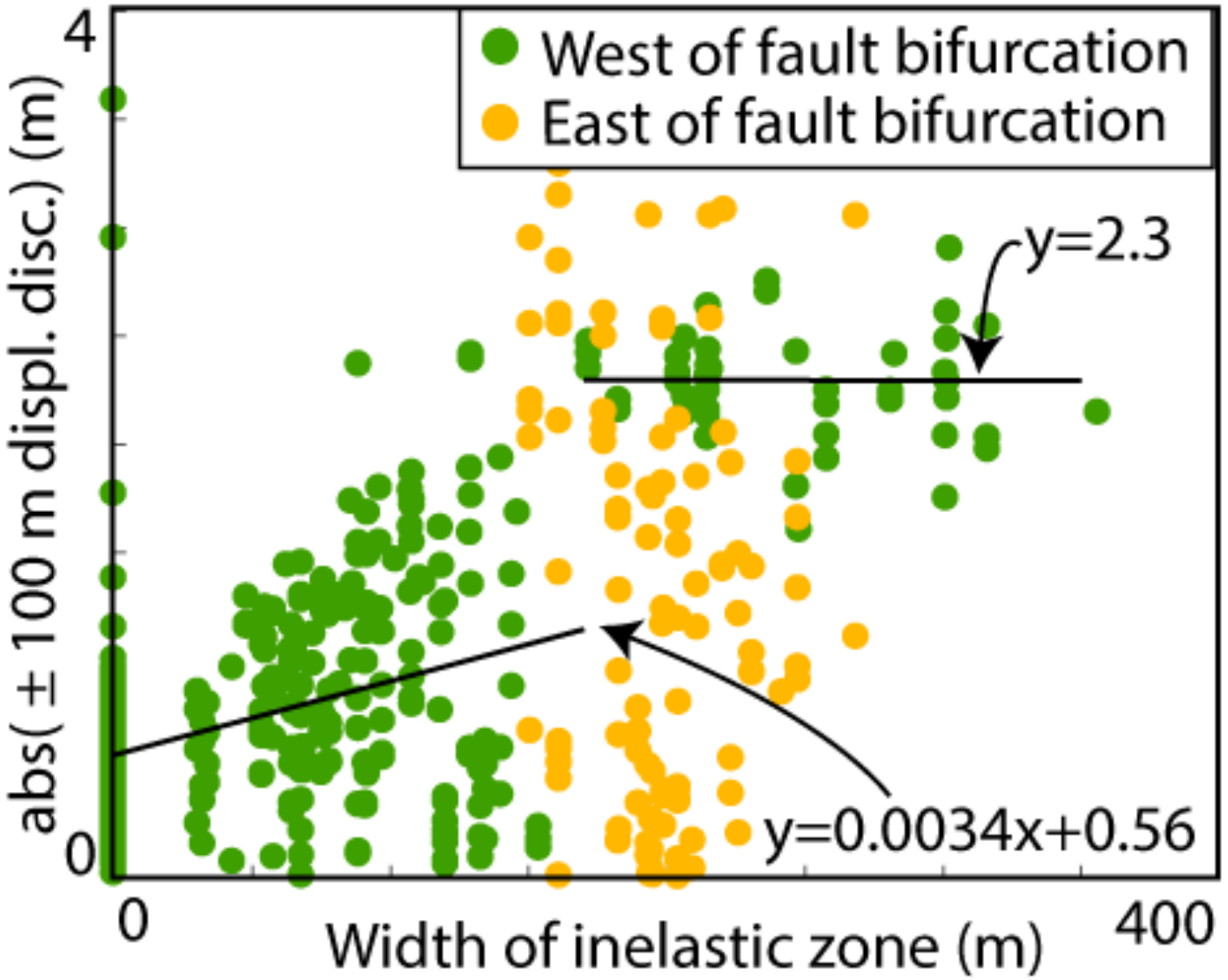
Elastic strain limit:

$$\varepsilon_{yield} = \sigma_{yield} / E$$

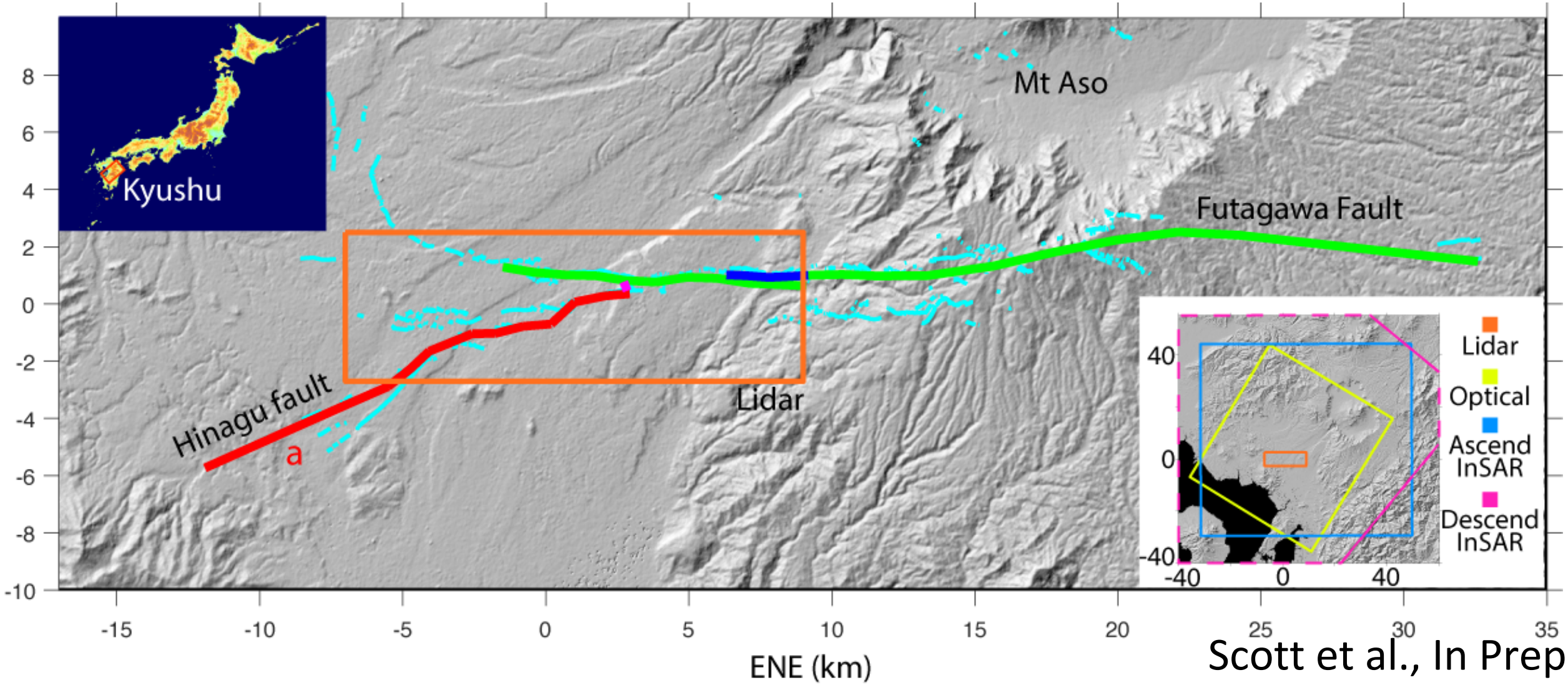
Shear strain



Displacement vs. width of inelastic zone

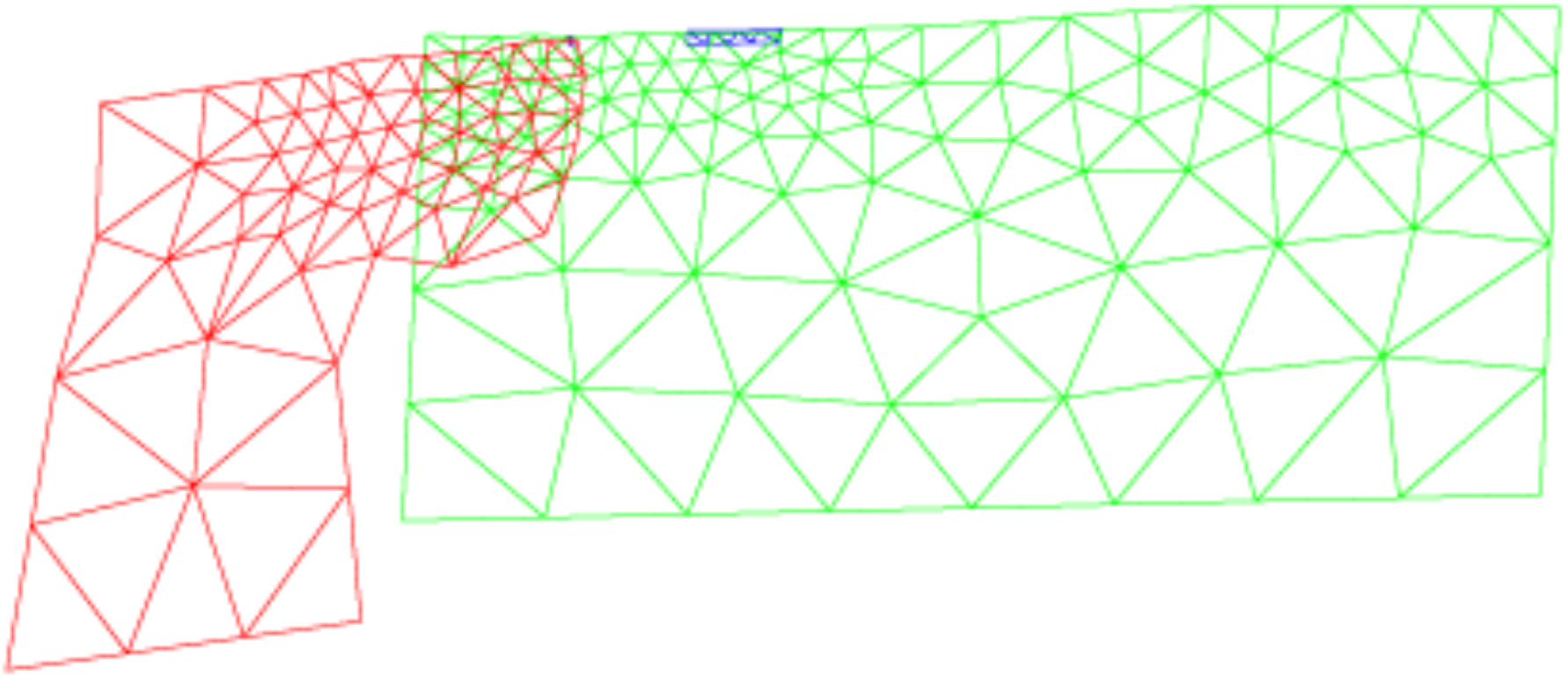


Lidar-optical-InSAR Earthquake Source Inversion



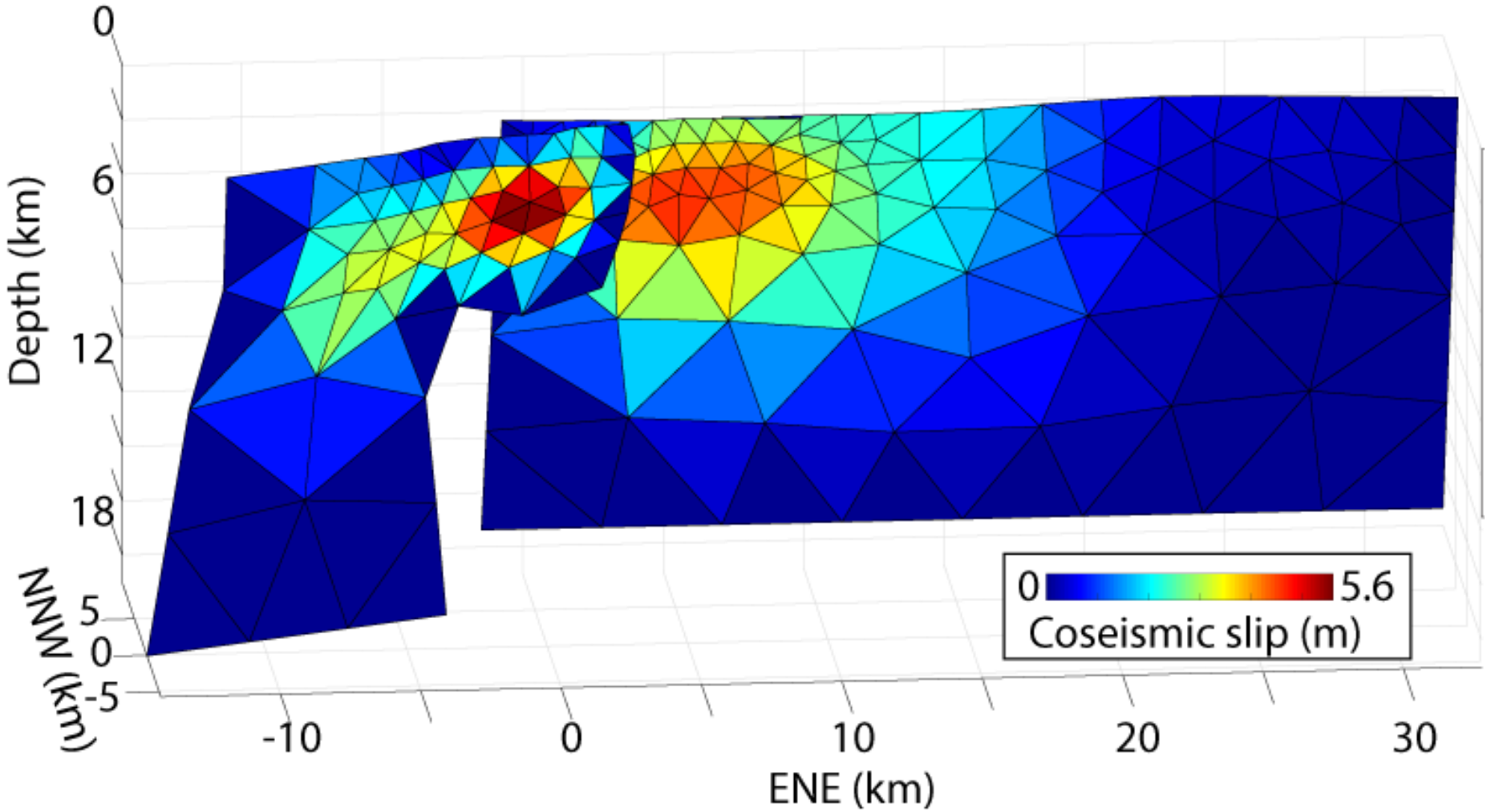
Scott et al., In Prep

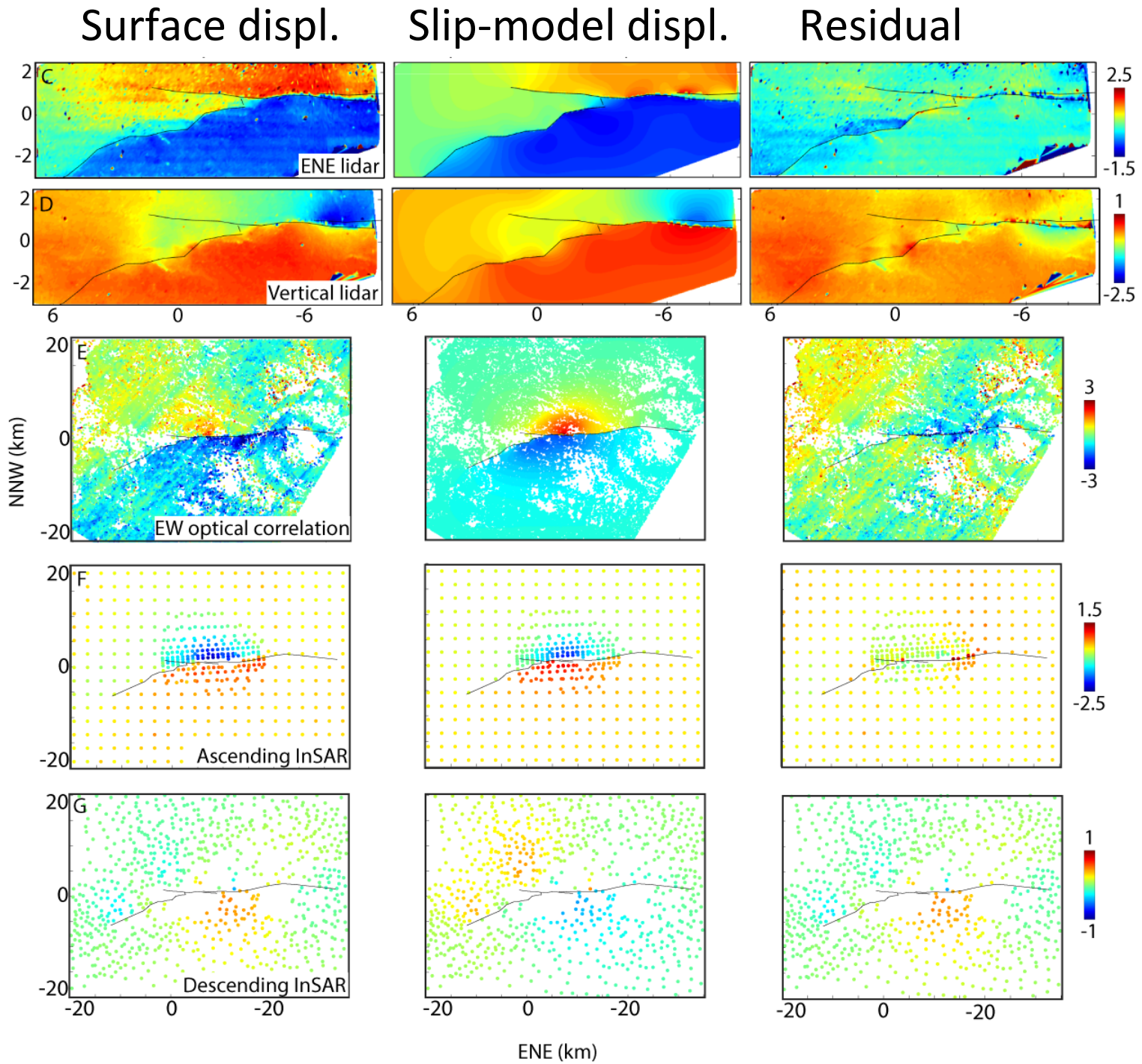
Fault geometry



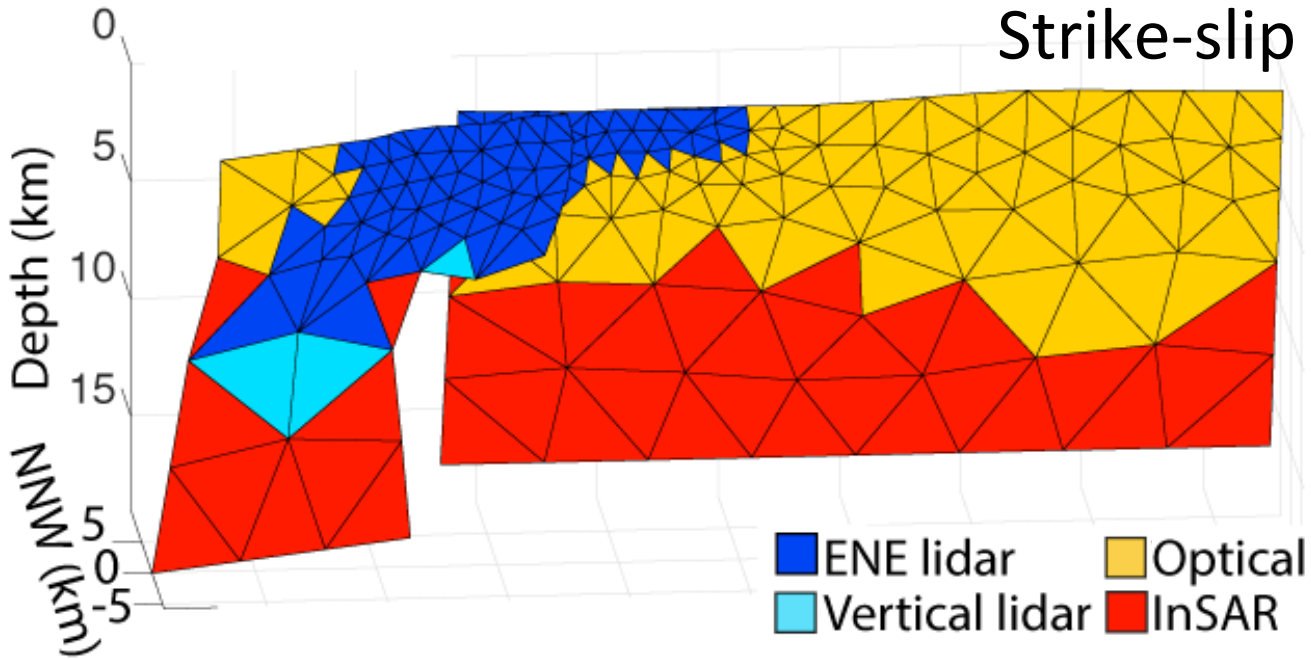
Slip inversion fault geometry must kink to follow the surface trace of the fault

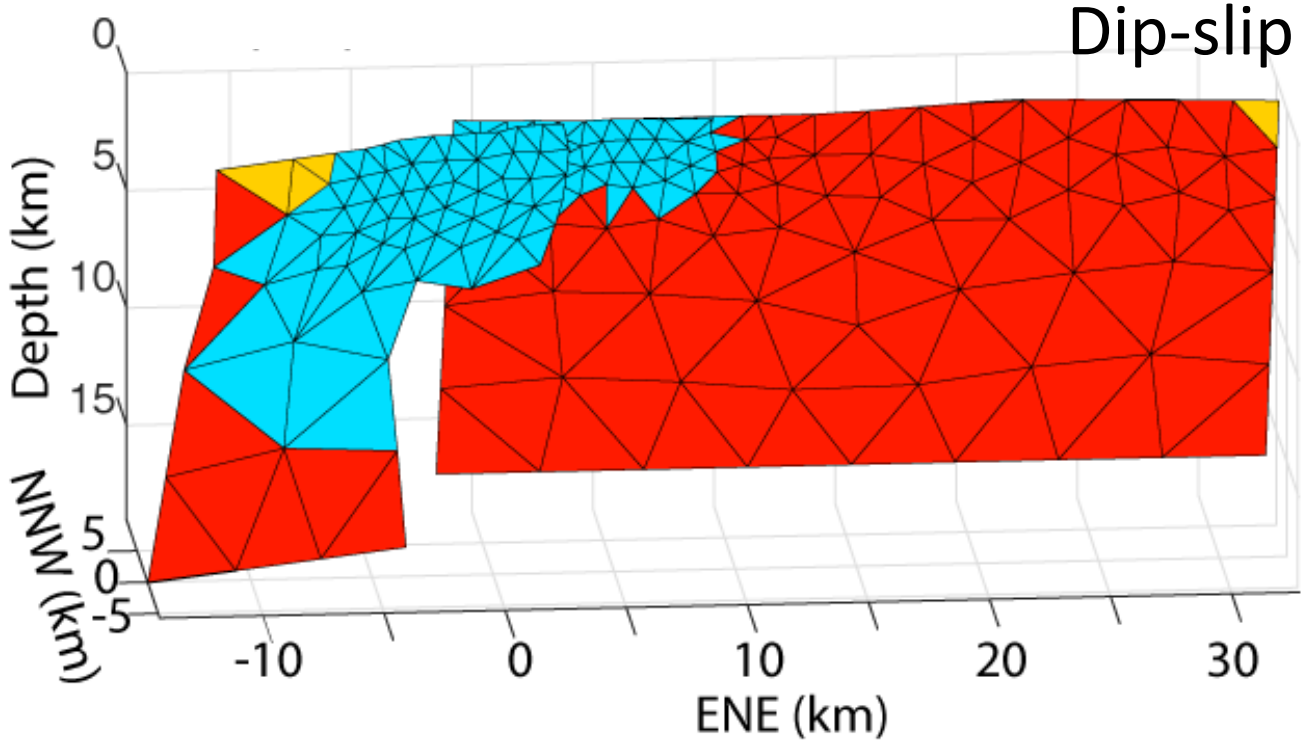
Distributed slip inversion: Mw 6.97

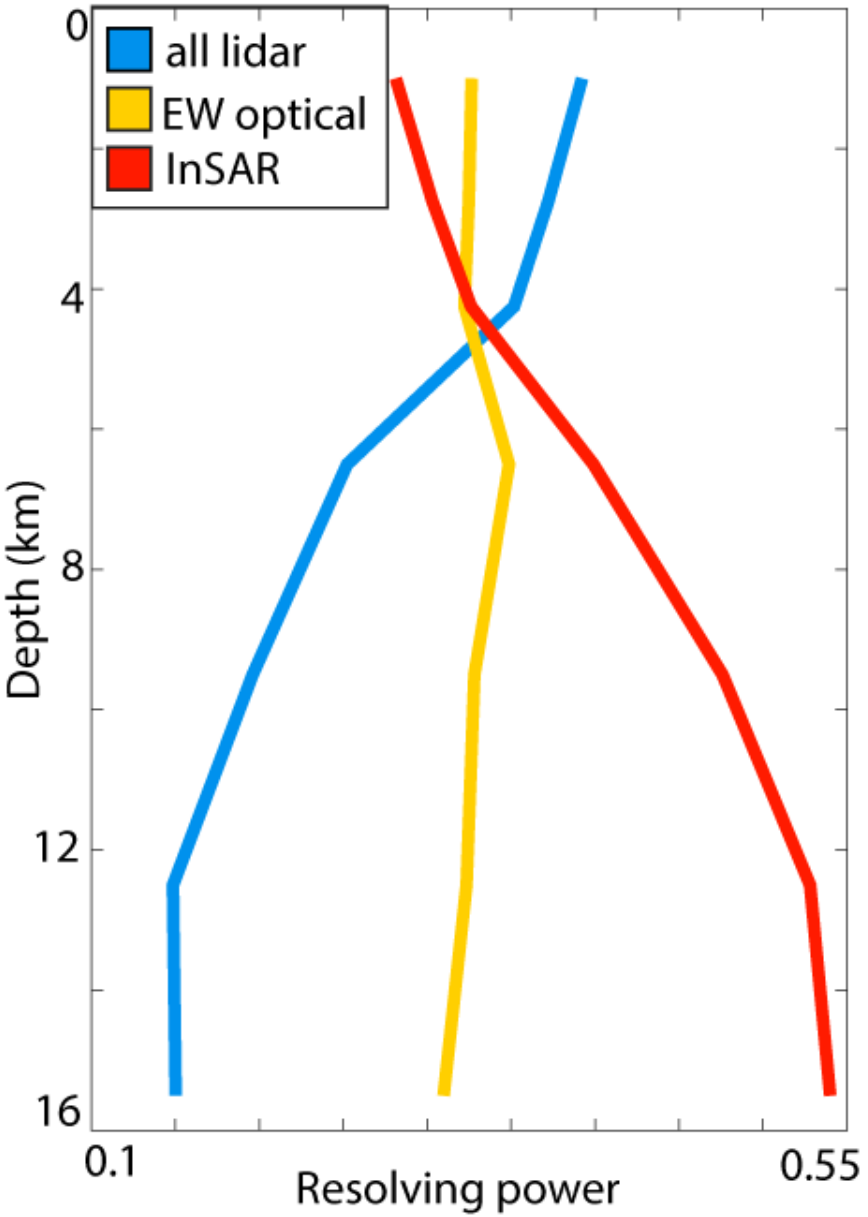



Surface displ.
Slip-model displ.
Residual
Lidar
Optical
InSAR
C
ENE lidar
D
Vertical lidar
E
EW optical correlation
F
Ascending InSAR
G
Descending InSAR
NNW (km)
ENE (km)
2.5
-1.5
1
-2.5
3
-3
1.5
-2.5
1
-1

Fault slip constraints

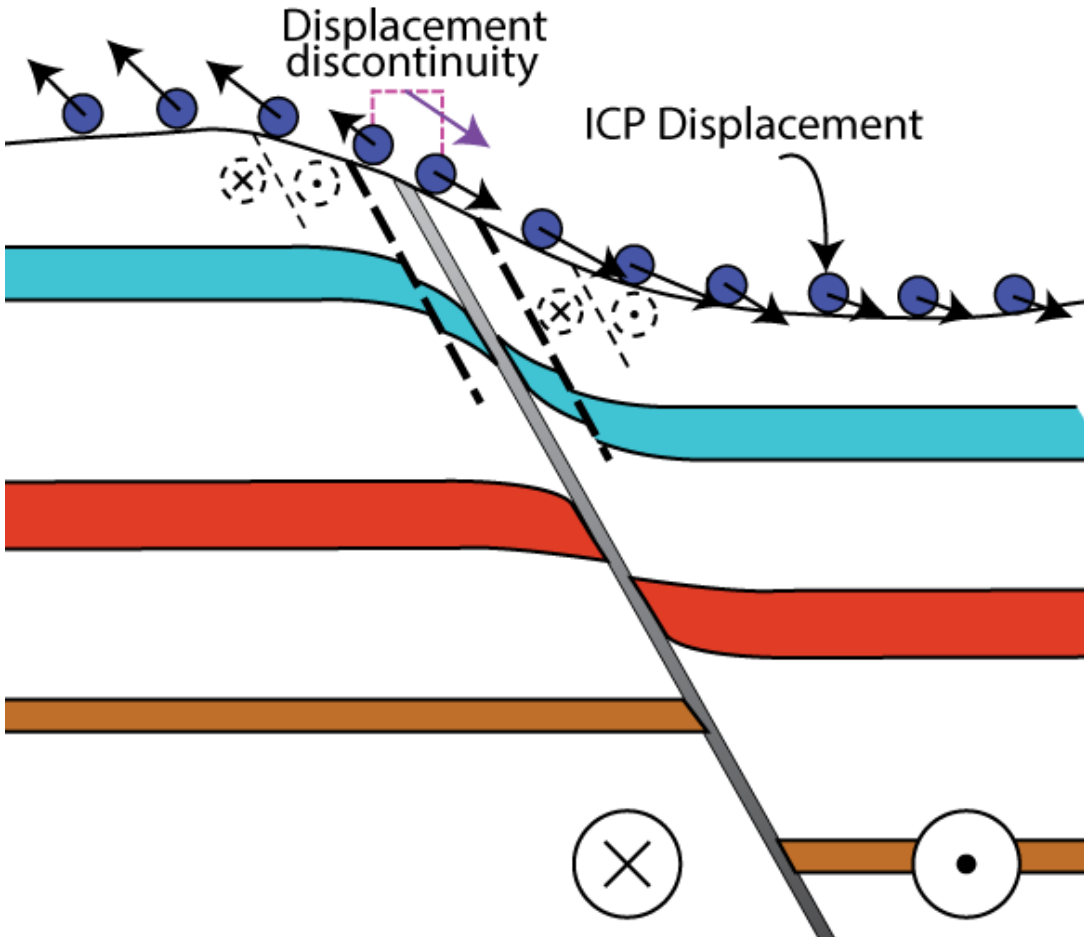






Conclusions

- We examine fault slip variations in the upper crust from a joint lidar-optical-InSAR earthquake source inversion.
- The high near-field strains suggest that the depleted shallow slip is accommodated along secondary structures.



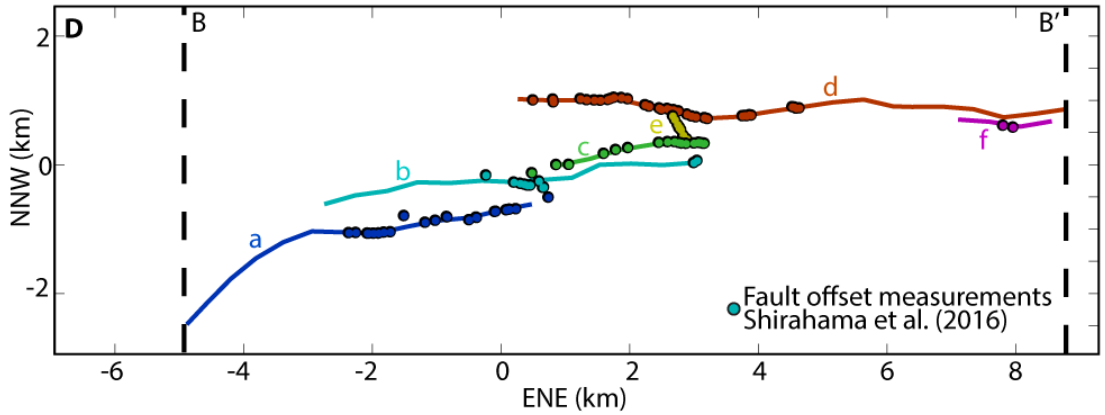
The inelastic failure of damaged fault zone rocks caused by the high dynamic strains produces a distributed deformation signal.

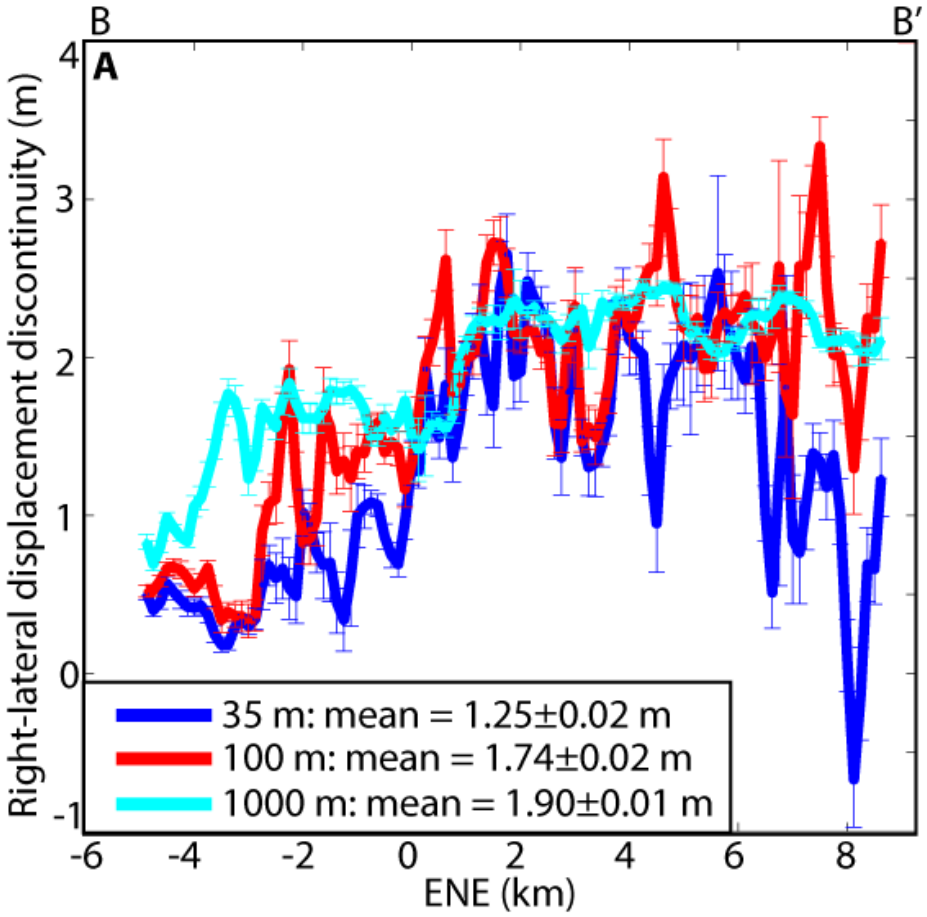
Future opportunities for ICP differencing

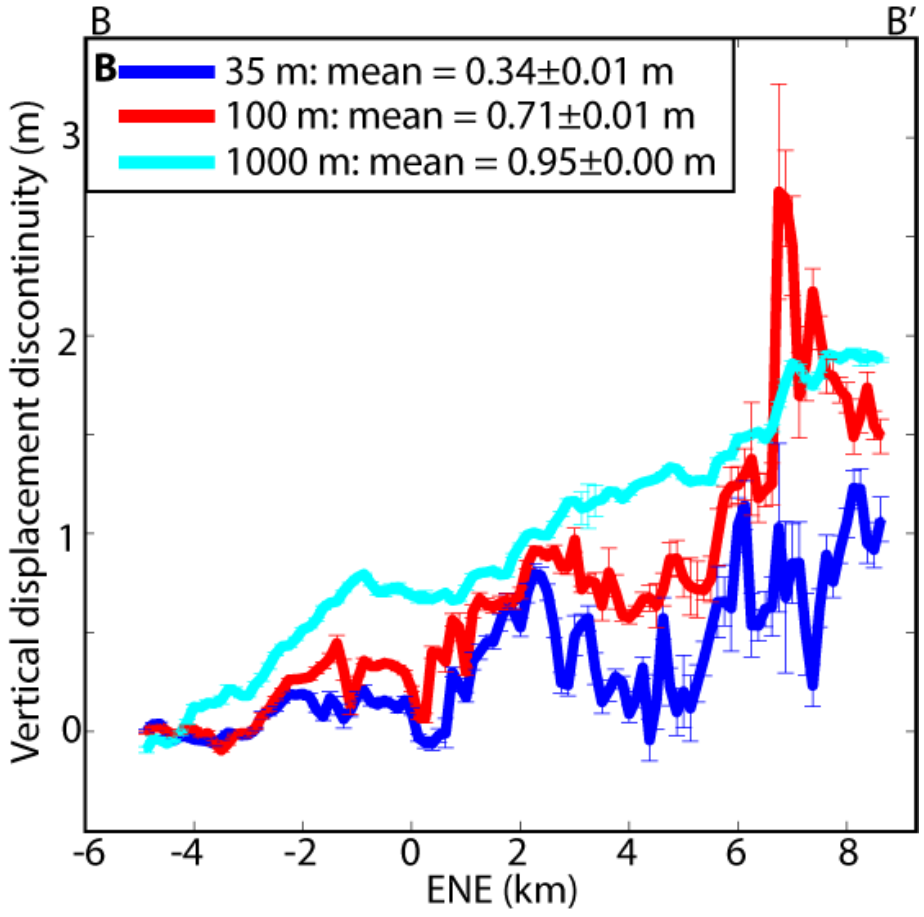
- Lidar-to-lidar differencing
  - Pre-earthquake data imagery along many active fault zone
  - Faster acquisition of the post-earthquake imagery allows for a better distinction between the co- and post-seismic surface deformation
- Hybrid lidar-photogrammetry differencing
  - Smaller research groups can acquire the required imagery
  - Photogrammetry datasets must have high location accuracy
  - Technical issues in differencing two data types

Thank you!

Off-fault deformation







Off fault deformation:

Strike-slip: 36 ± 29%

Vertical: 62 ± 32%