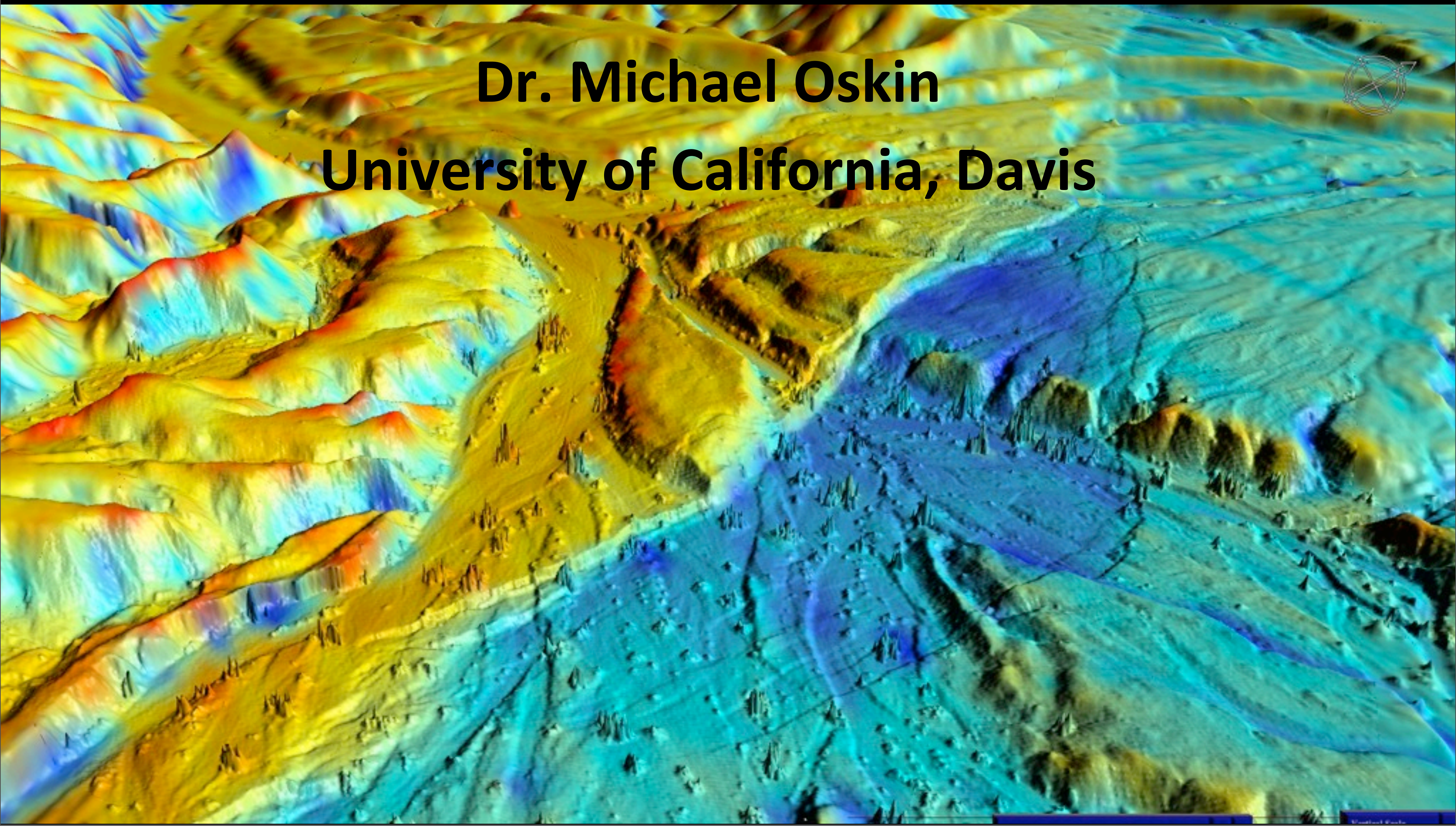
Near-field coseismic deformation from airborne and terrestrial LIDAR of the El Mayor-Cucapah earthquake



Dr. Michael Oskin
University of California, Davis

This is very much a team effort

Airborne LIDAR

- Univ. of California, Davis
- Arizona State University
- CICESE
- NCALM (Univ. Houston)
- OpenTopography
- Colorado School of Mines
- Univ. of California, San Diego
- U.S. Geological Survey
- Caltech

Terrestrial LIDAR

- Univ. of California, Davis
- CICESE
- University of Kansas
- UNAVCO

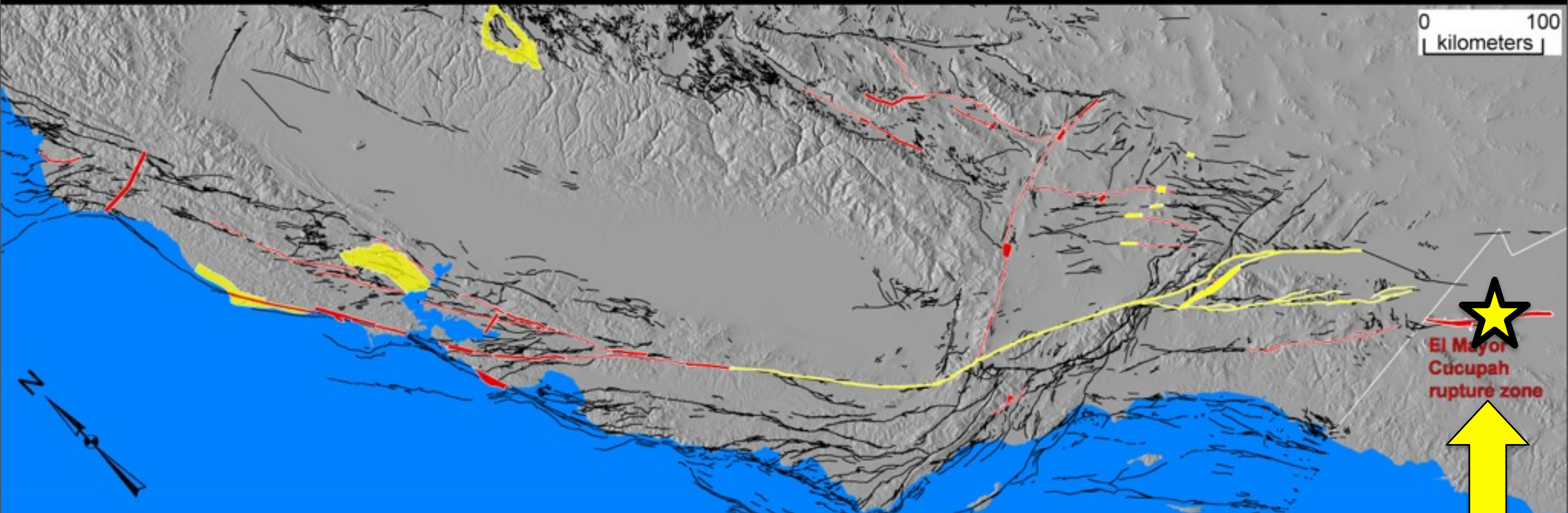
Objectives & Outline

- Airborne LIDAR
  - Fault Mapping
  - Hidden Faults
  - Distributed Deformation

- Terrestrial LIDAR
  - Slip Vectors
  - Slip Uncertainty
  - Scarp Erosion

UC DAVIS KECKCAVES
W.M. Keck Center for Active Visualization in the Earth Sciences

Airborne LiDAR coverage of Pacific-North America Plate-Boundary Zone

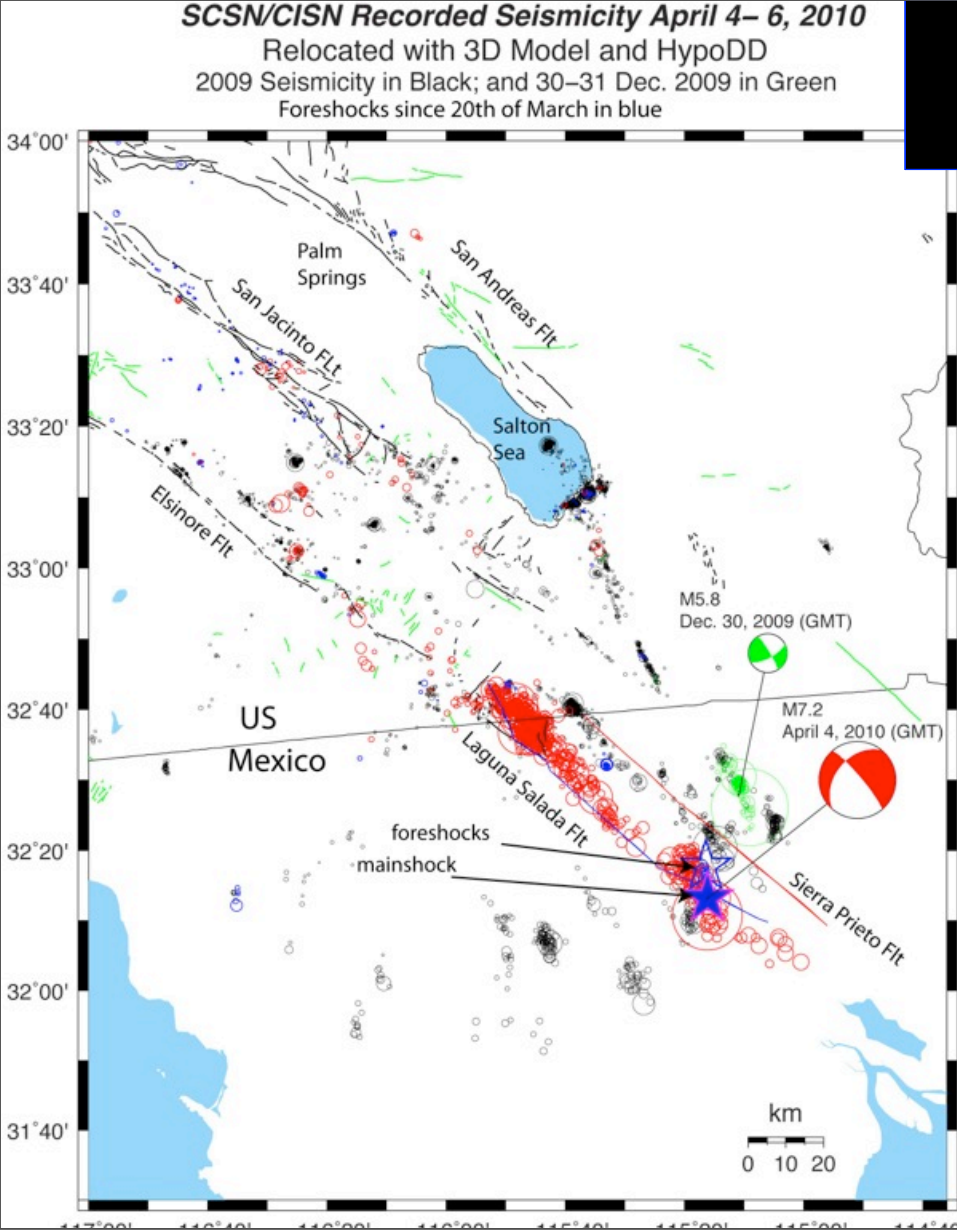


M **7.2** April 4, 2010

EarthScope

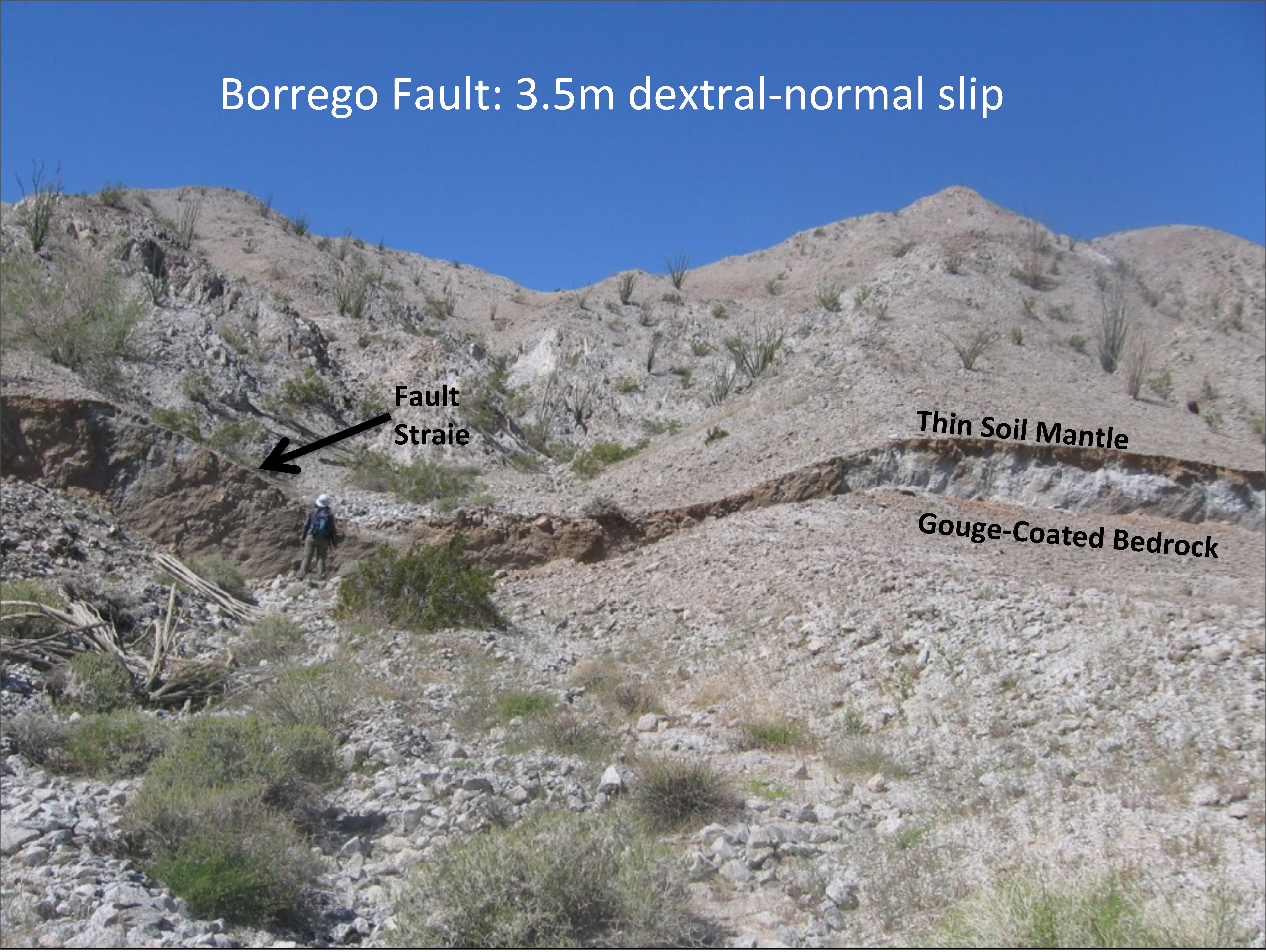
San Andreas Fault (B4) and Other Data Sets

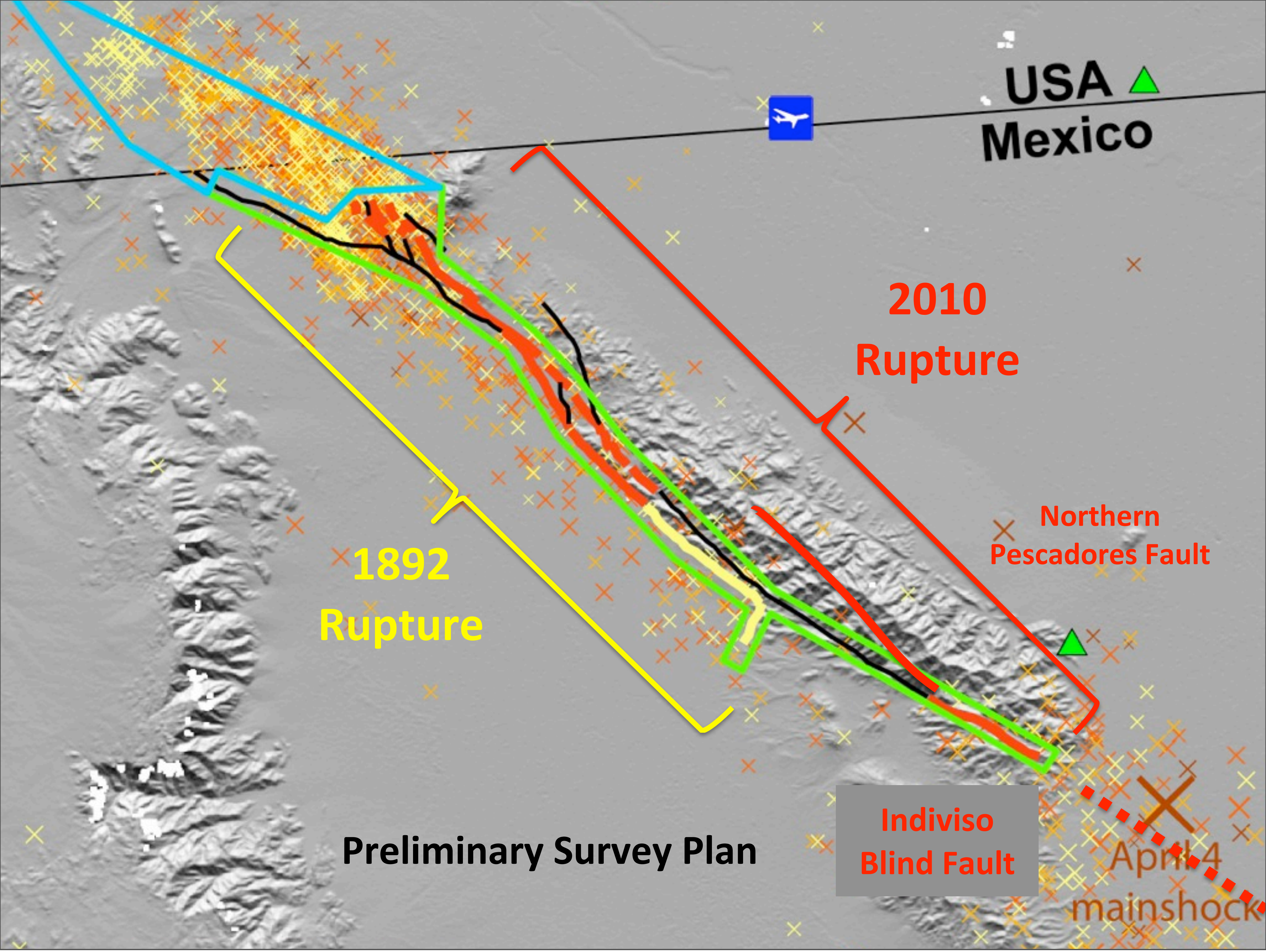
Planning a LIDAR Survey in post-EQ Rapid-Response



Faulted Highway
(K. Hudnut)

Relocated Seismicity
(E. Hauksson)

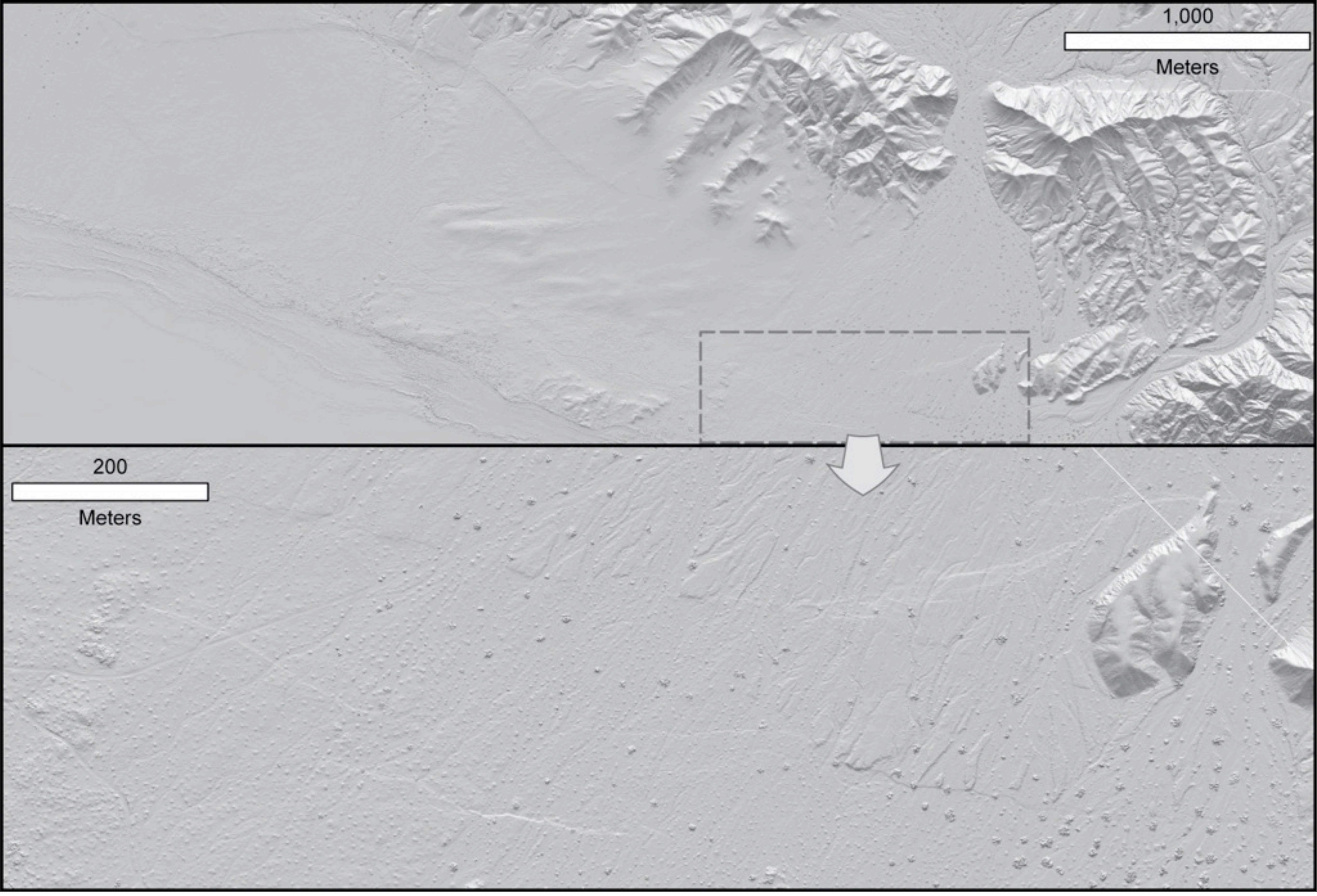

Borrego Fault: 3.5m dextral-normal slip
Fault
Straie
Thin Soil Mantle
Gouge-Coated Bedrock


USA
Mexico
2010
Rupture
Northern
Pescadores Fault
1892
Rupture
Preliminary Survey Plan
Indiviso
Blind Fault
April 4
mainshock

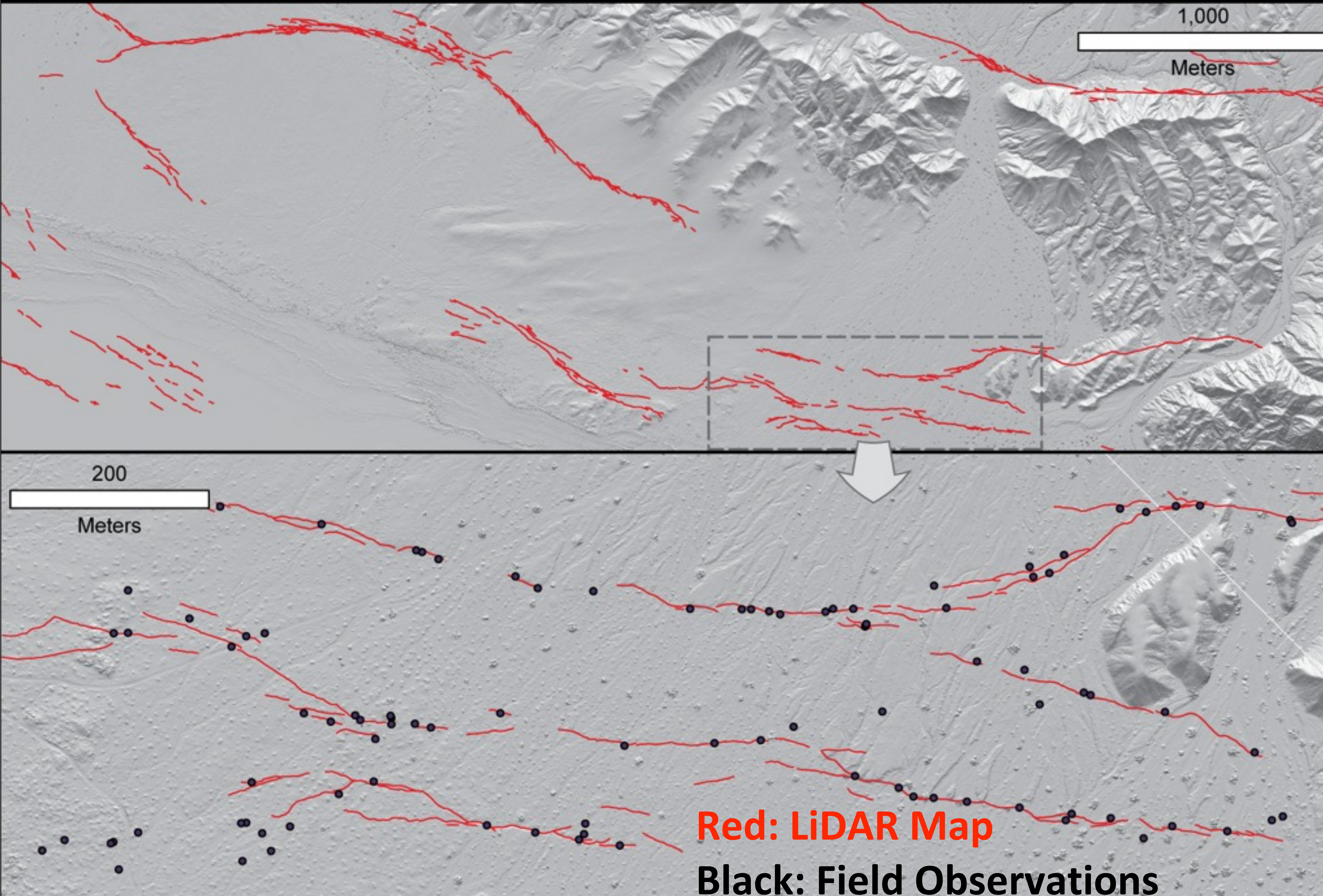
LIDAR Survey August 2010

View of Dust Storm from NCALM Survey Aircraft

Rapid Mapping of Surface Rupture

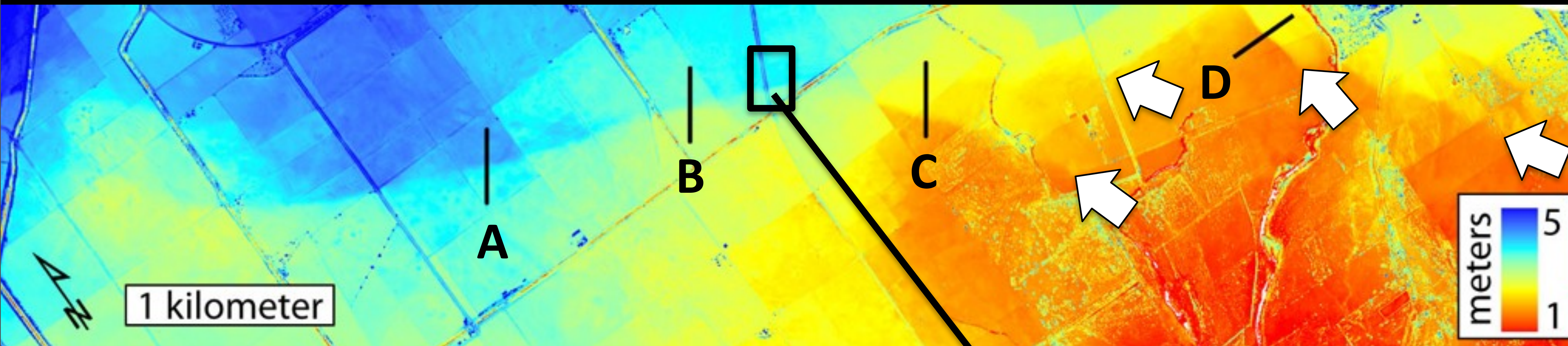


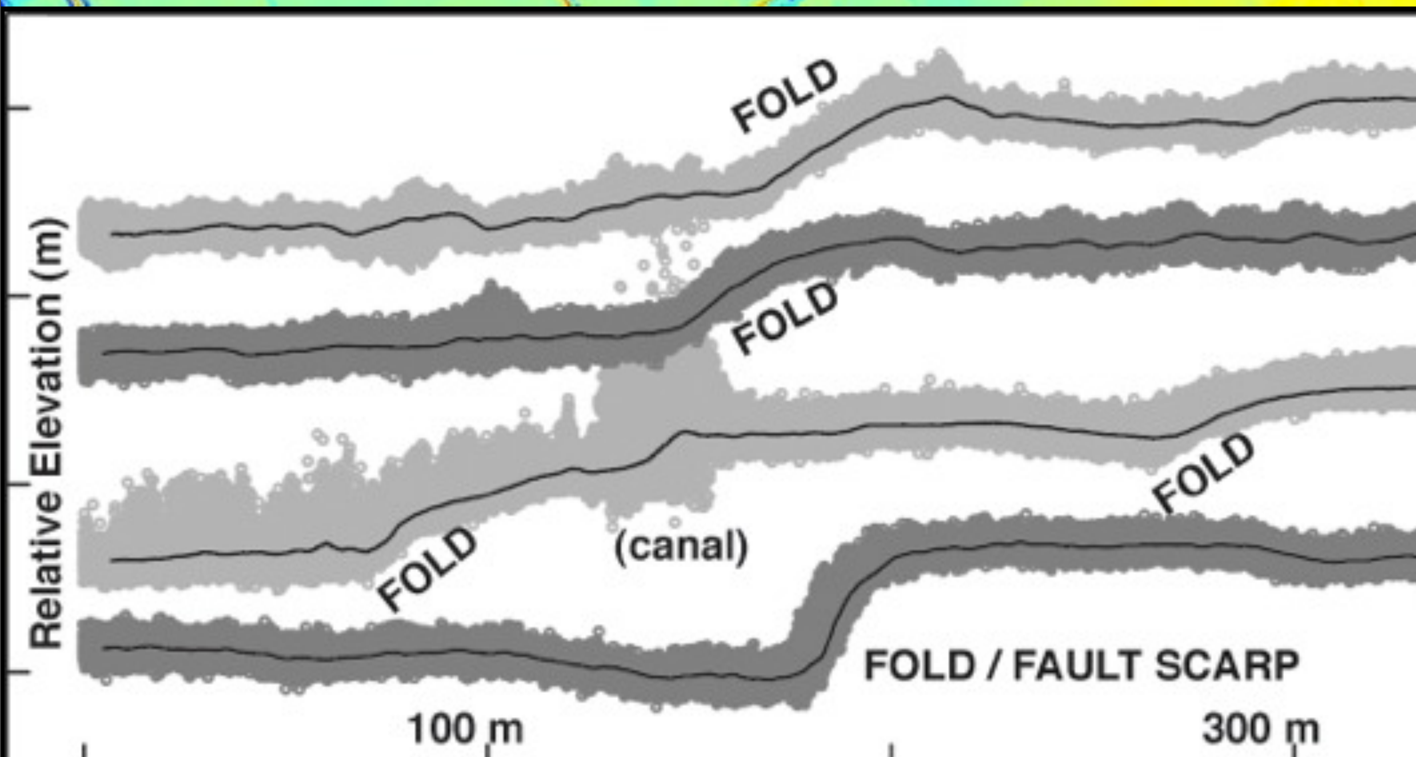
Rapid Mapping of Surface Rupture

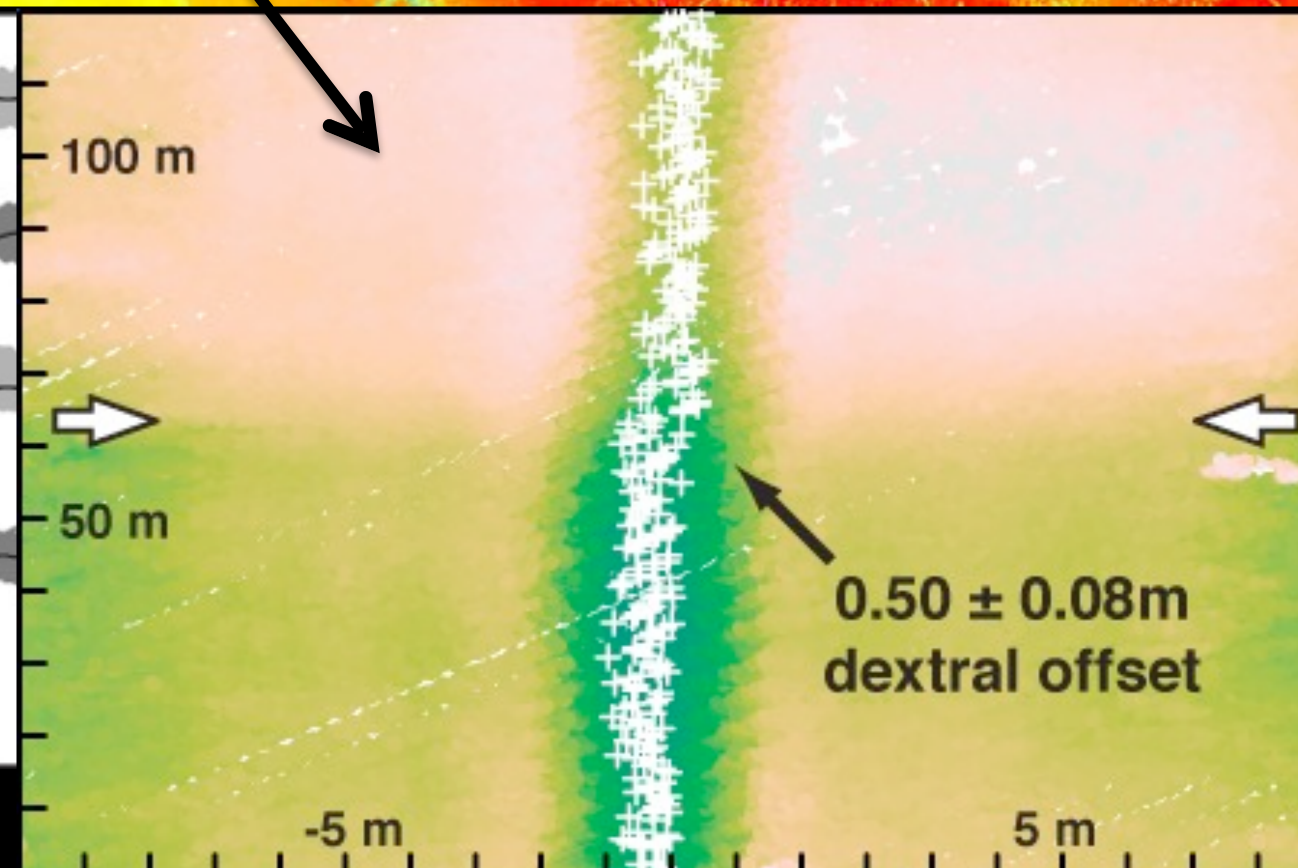


(Blind?) Dextral-Normal Indiviso Fault

LiDAR reveals linear fold scarps across Colorado River delta







~50 cm of tectonic warping distributed over 20 to 50 meters

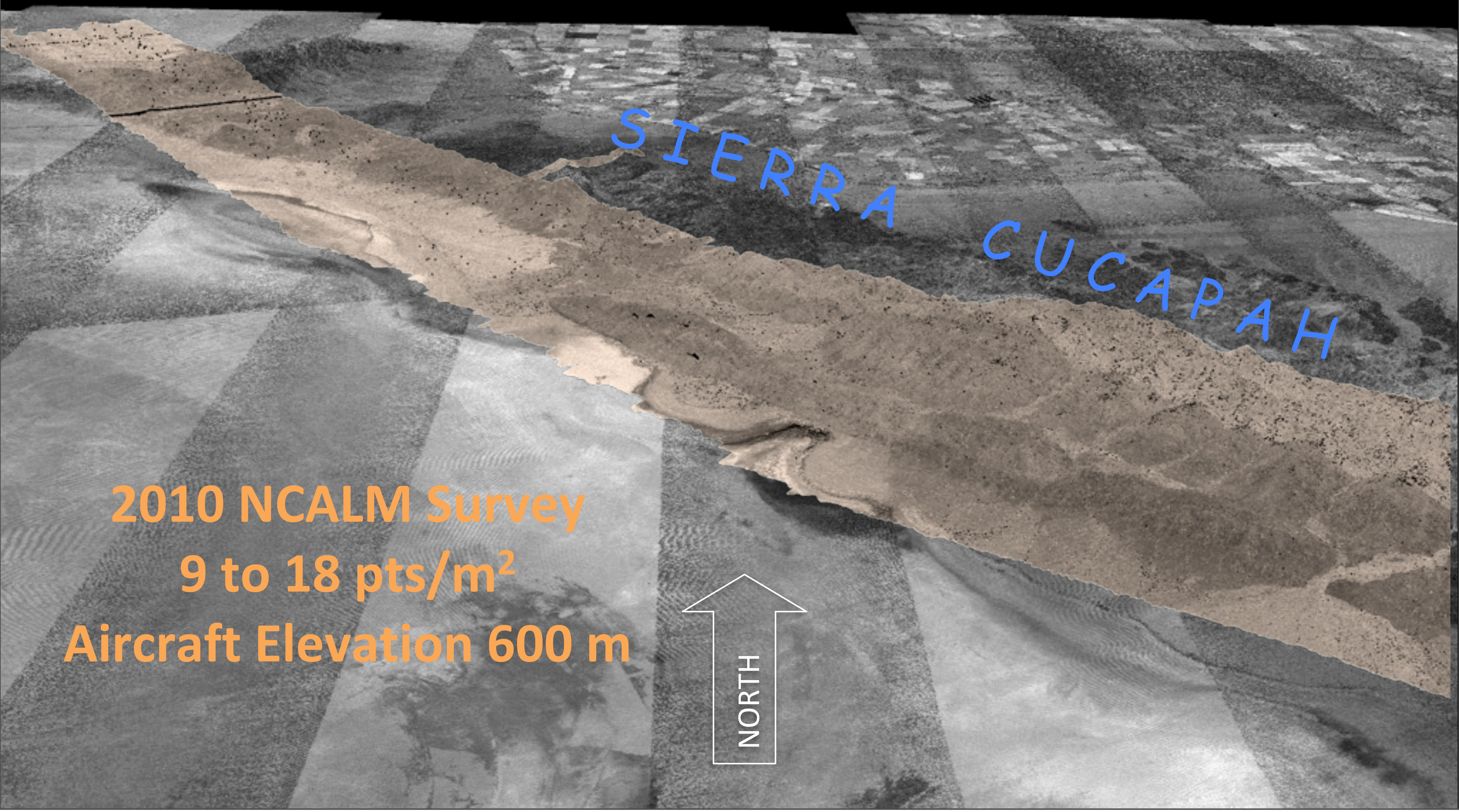
Dextral warping of canal

Warped Irrigation Canal, Indiviso Fault

Photos from Kevin Brown, UCSD

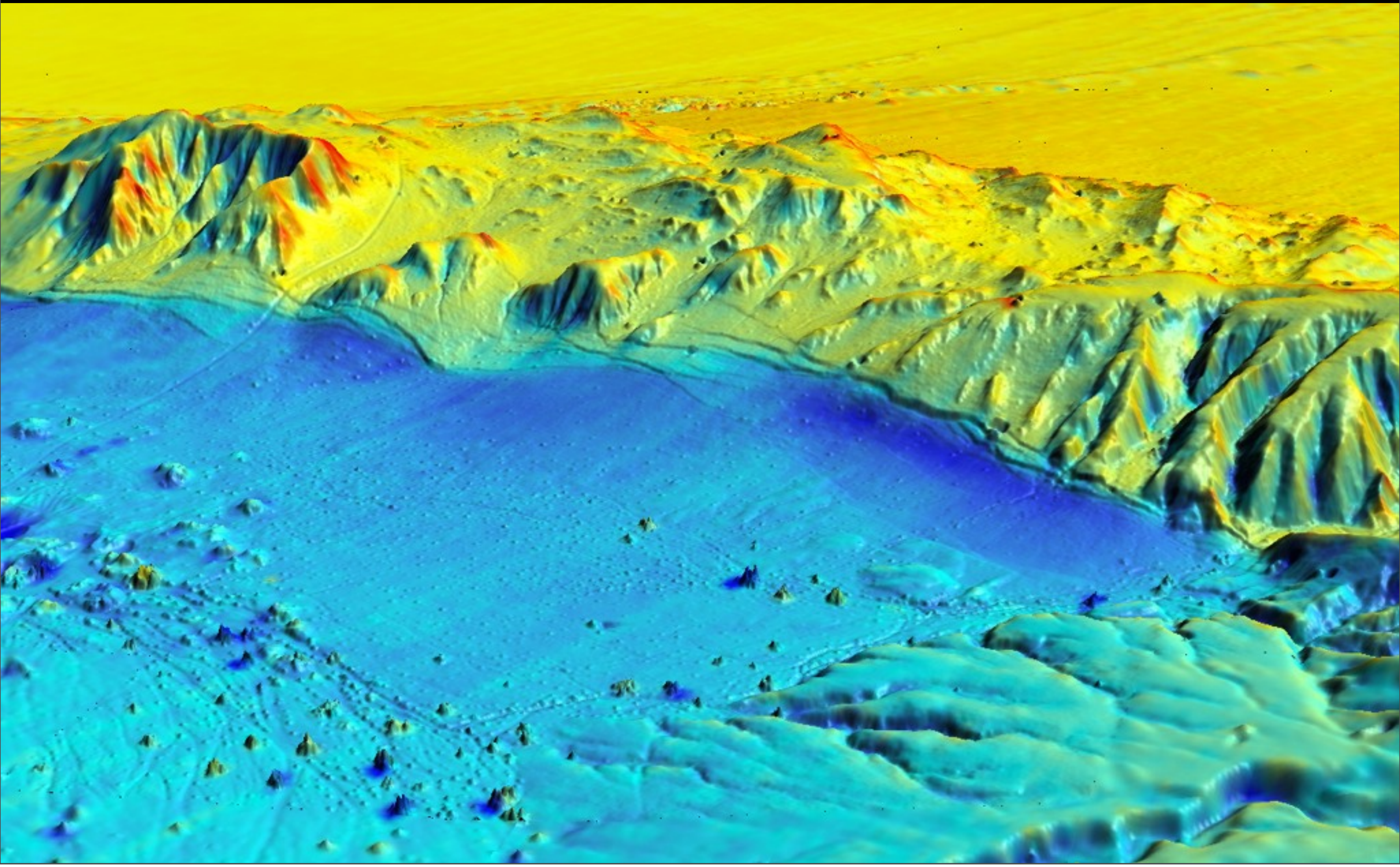
2006 INEGI Regional LiDAR Survey

0.013 pts/m², Aircraft Elevation 6000 m

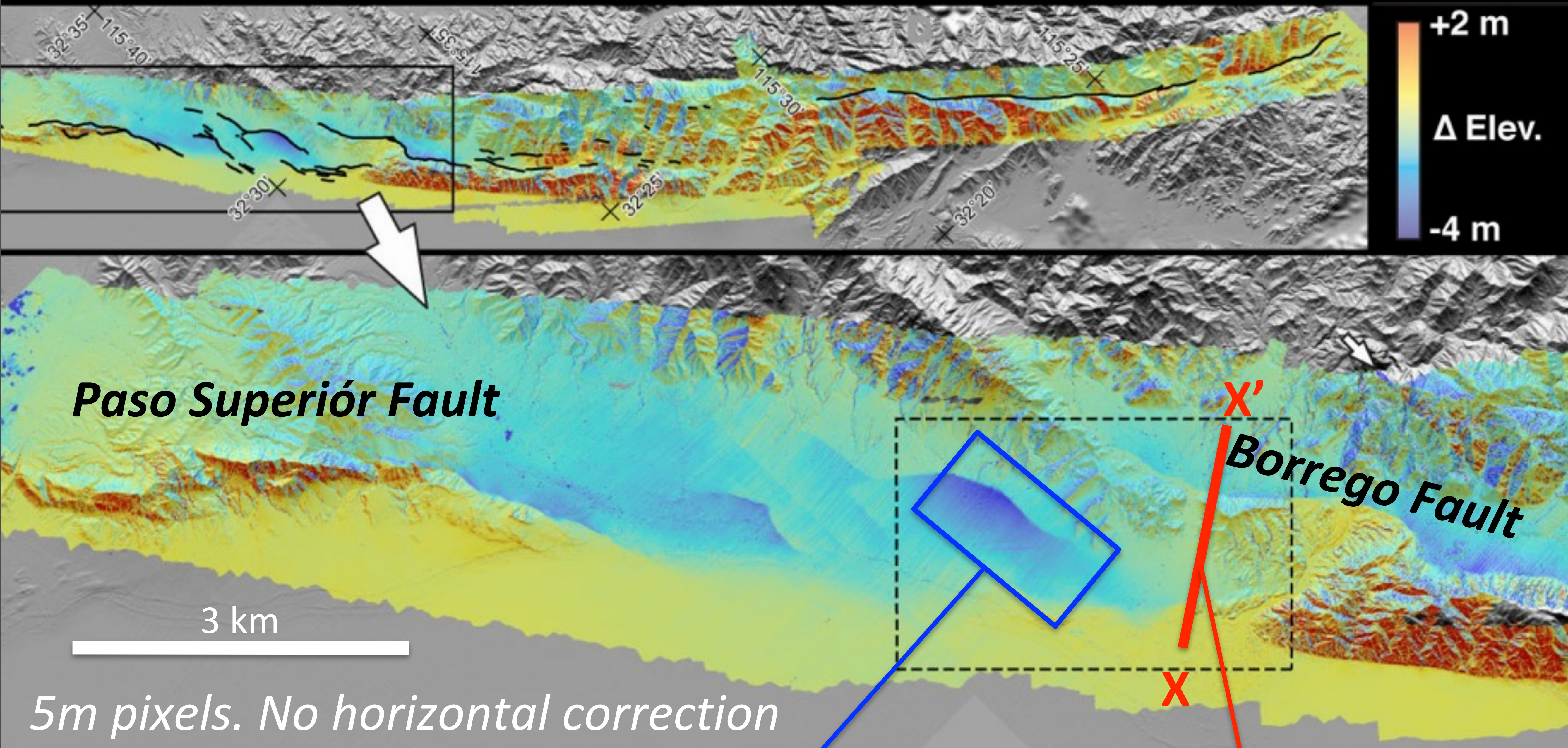


Paso Superior Fault

2.5x Vertical Exaggeration



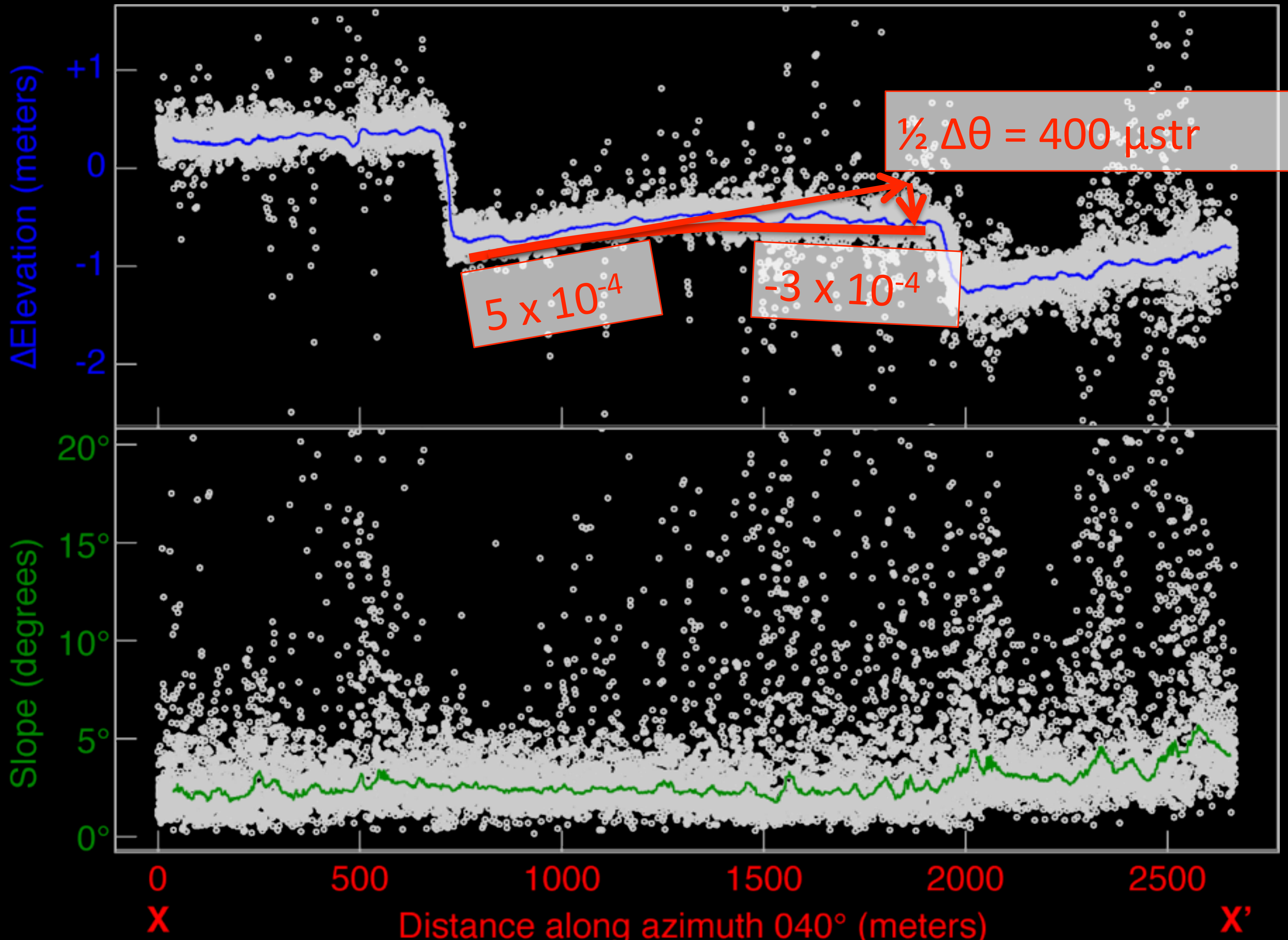
Differential LiDAR of Sierra Cucapah



Serial profiles with NE- and SW-dipping faults

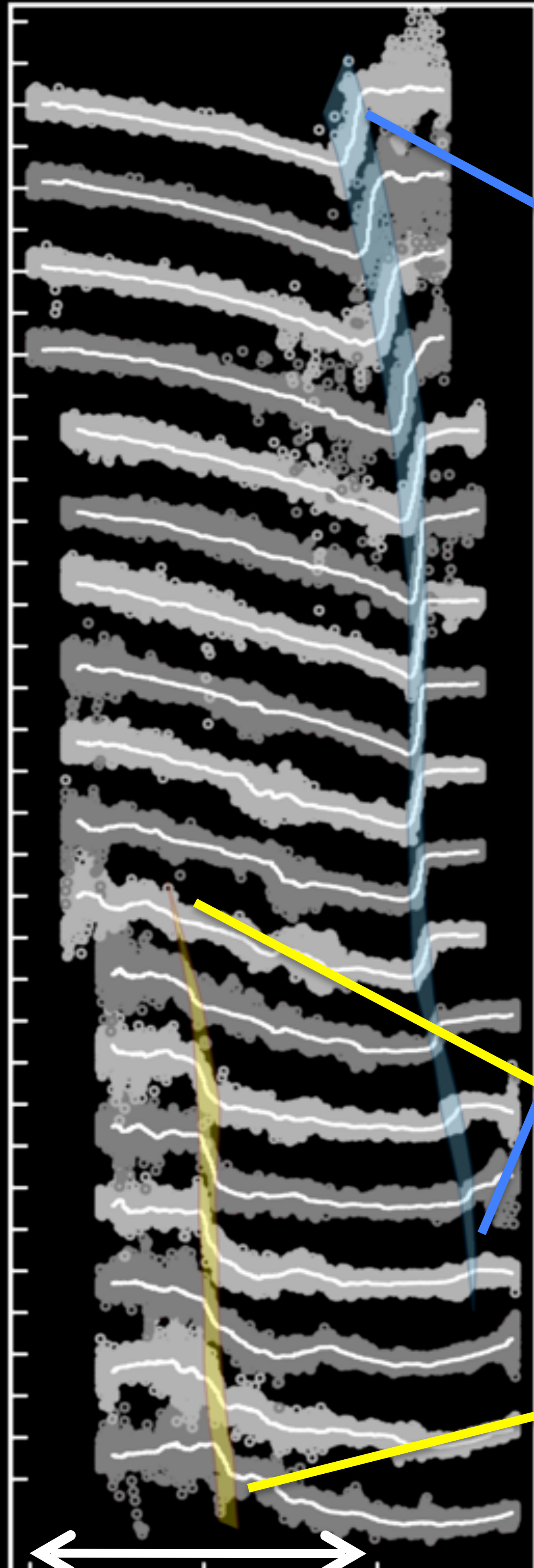
Cross-Section with two NE-dipping faults

ΔElevation and Slope along X-X’



Strain Between Faults

Swath Profiles 100 m apart



West-Dipping Fault

½ (2.6 m / 1.3 km) = 1000 μstr

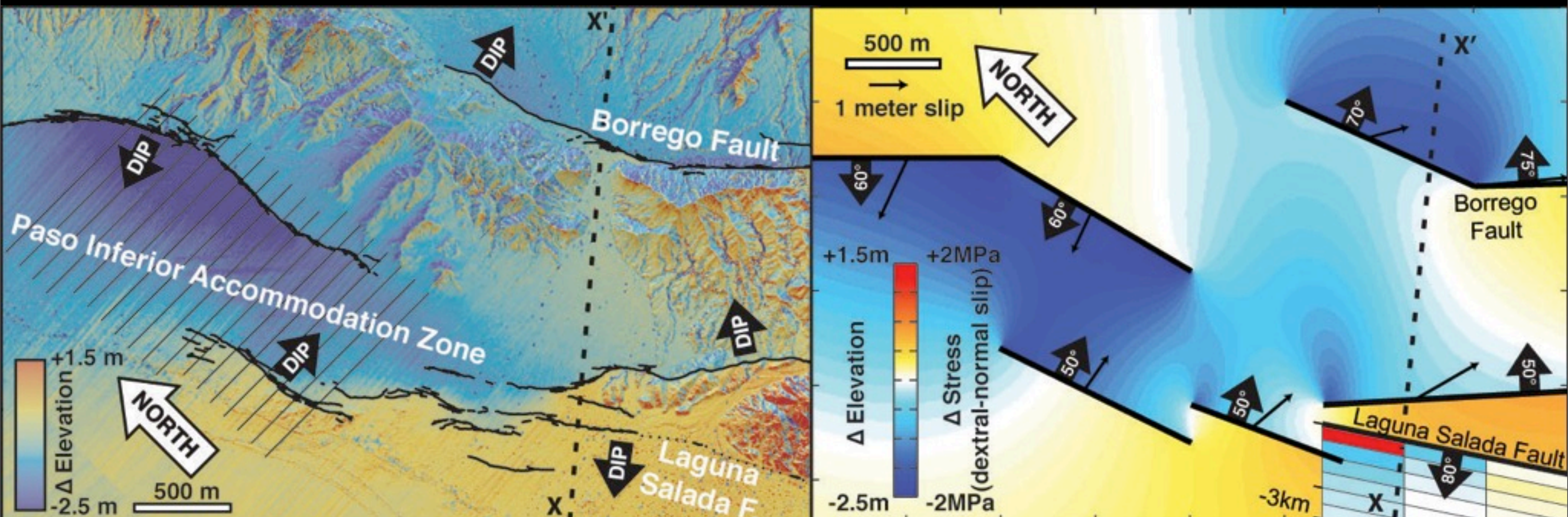
Fault Tip-Line Strains

East-Dipping Fault

½ (1.0 m / 1.0 km) = 500 μstr

Differential LIDAR of Paso Inferior AZ

Comparison to Elastic Dislocation Model

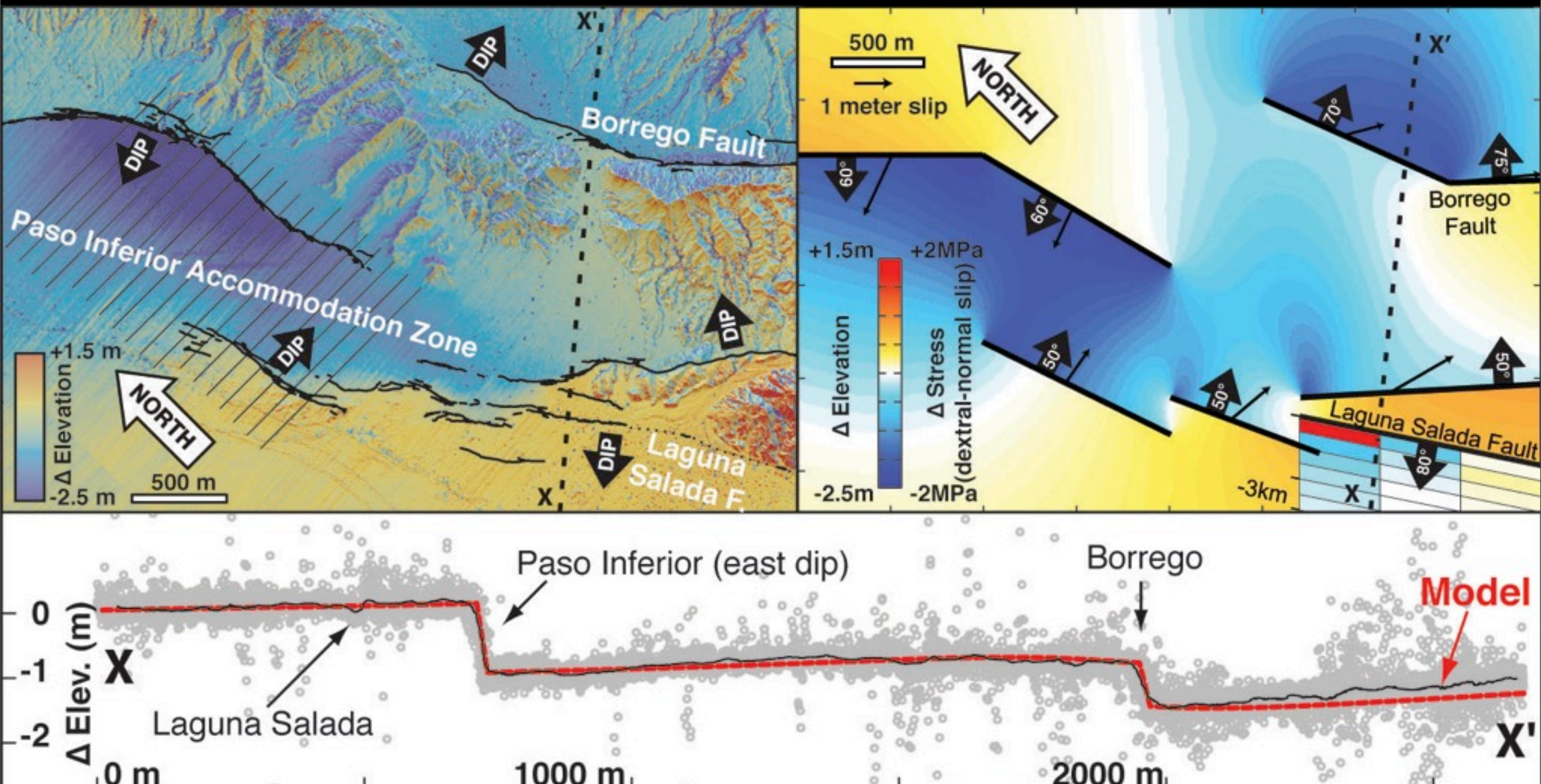


Data: Post-EQ – Pre-EQ Elevation
No horizontal correction

Model: Rectangular Dislocations
Slip based on field measurements
Stress based on G = 8 GPa
Δelevation shown

Differential LIDAR of Paso Inferior AZ

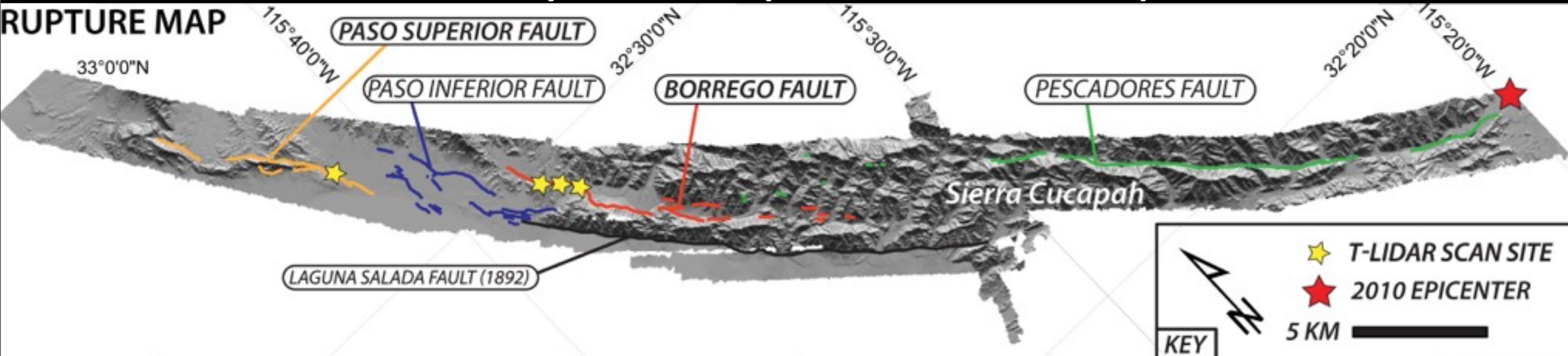
Comparison to Elastic Dislocation Model

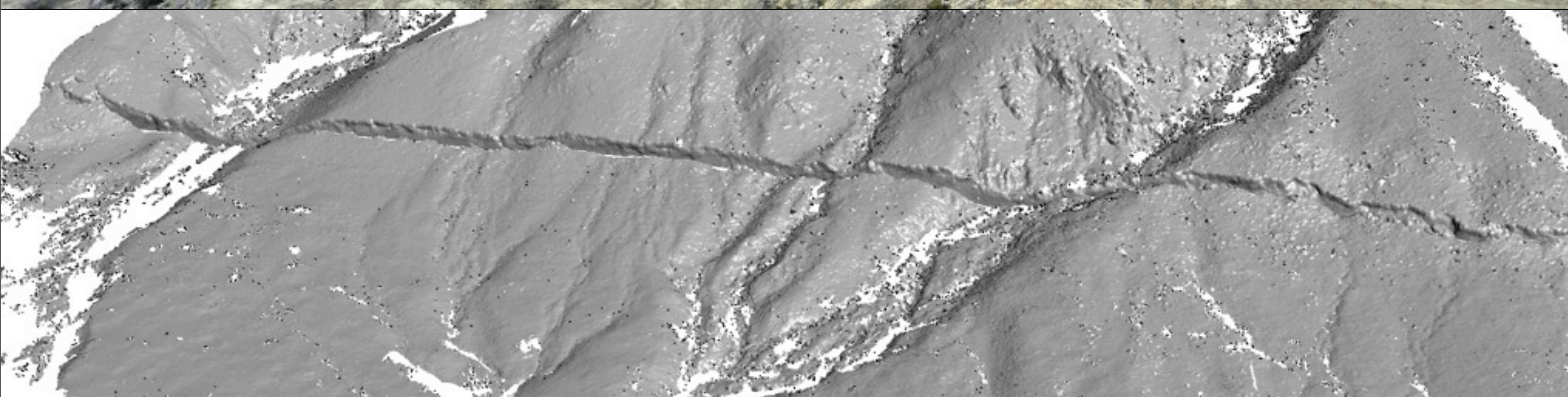


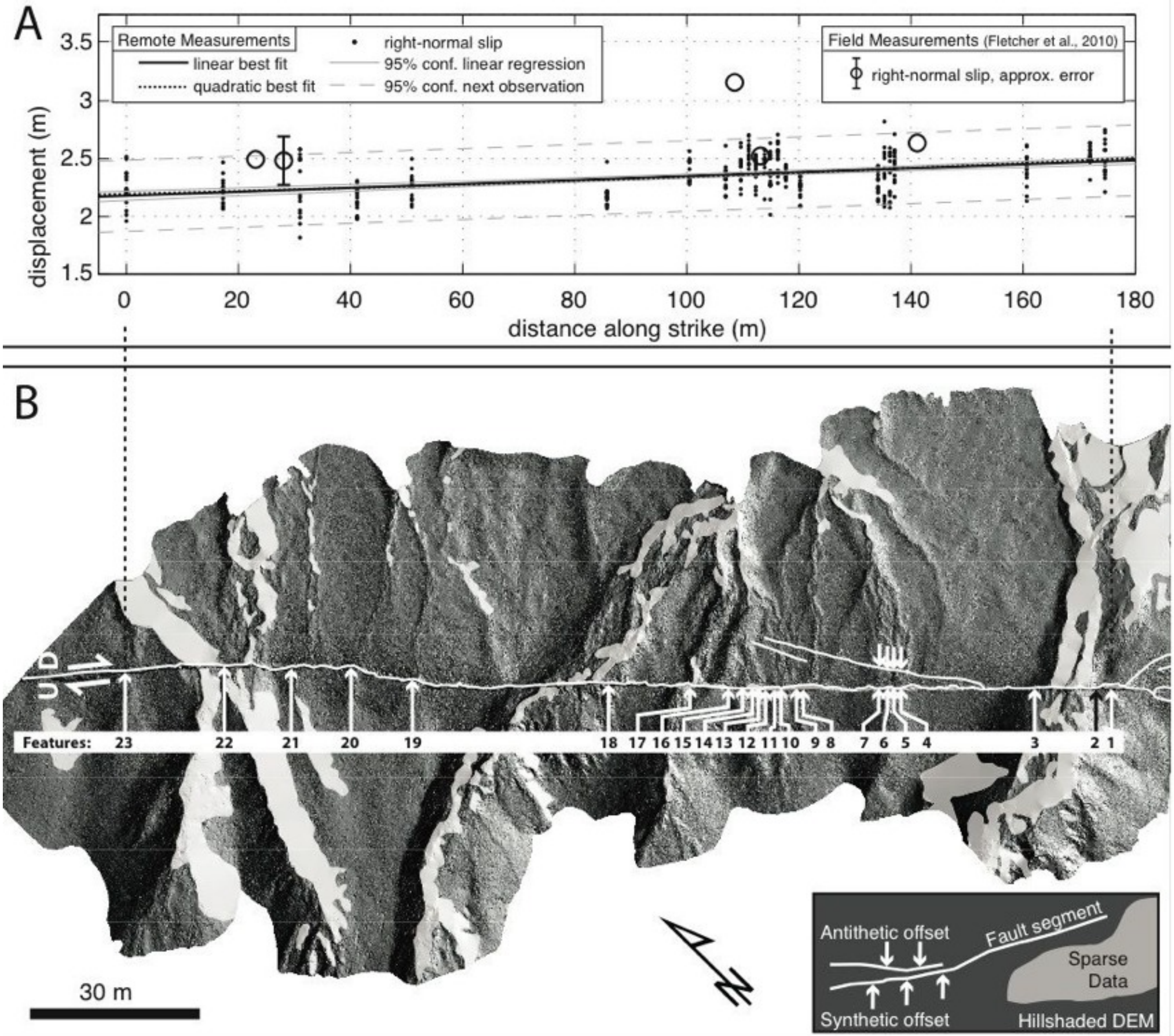
Conclusions (Airborne)

- Post-Earthquake LIDAR enables rapid and uniform mapping of the surface rupture
- LIDAR reveals new structures (e.g. Indiviso fault)
- Differential [lower resolution] LIDAR illuminates near-field strains exceeding 1000μstr (10^{-3})
- Strains appear to be generated elastically due to fault slip, with strains near yield point of rocks
- High shallow stresses unlikely to persist, likely relaxed via distributed postseismic yielding.

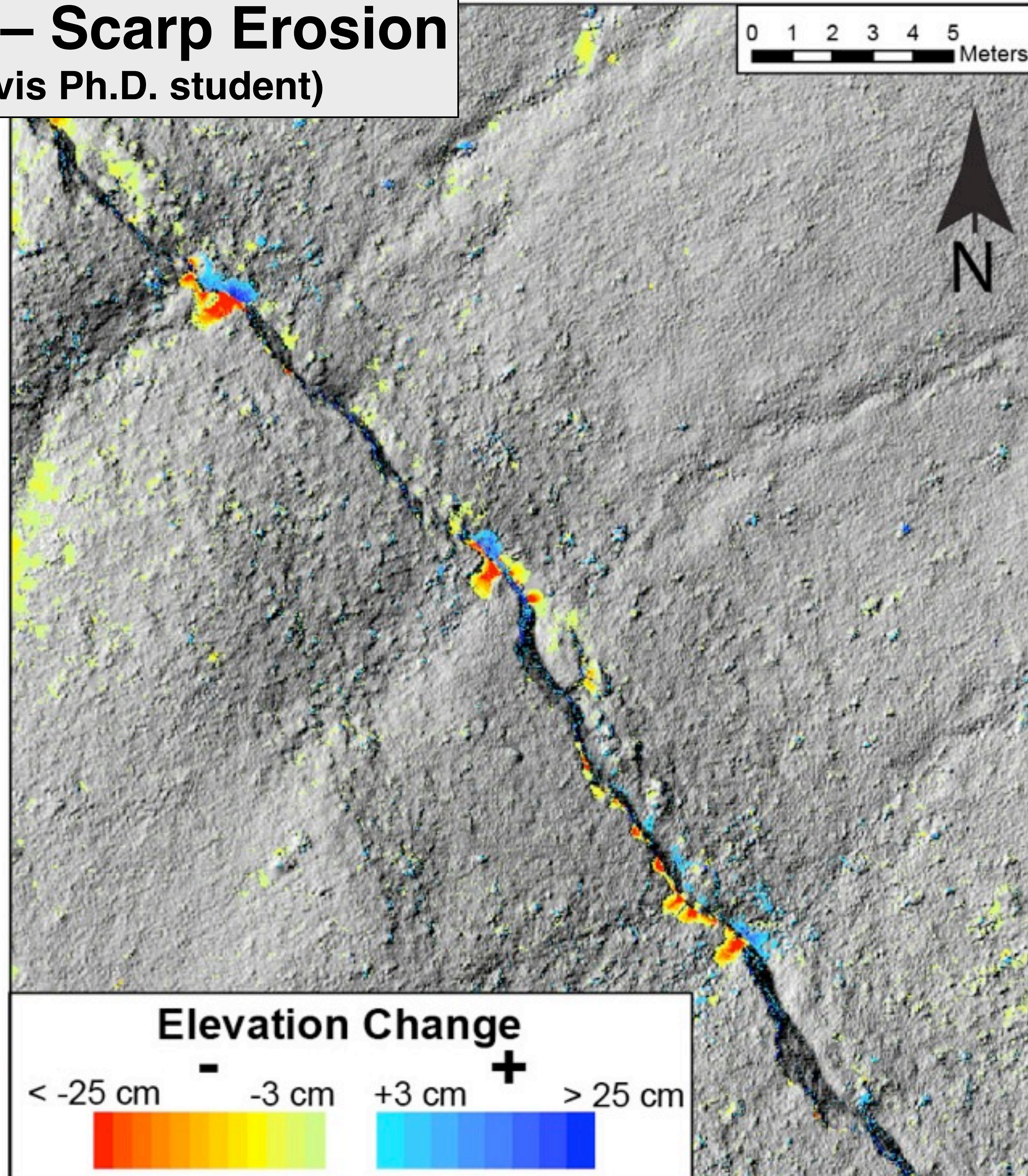
Terrestrial Laser Scanning (T-LIDAR) of the El Mayor-Cucapah Surface Rupture






A
Remote Measurements
linear best fit
quadratic best fit
right-normal slip
95% conf. linear regression
95% conf. next observation
Field Measurements (Fletcher et al., 2010)
right-normal slip, approx. error
displacement (m)
distance along strike (m)
B
U D
Features: 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
N
30 m
Antithetic offset
Fault segment
Sparse Data
Synthetic offset
Hillshaded DEM

Change Detection – Scarp Erosion
Austin Elliott (UC Davis Ph.D. student)



Conclusions (TLS)

- Epistemic (interpretive) slip measurement uncertainty higher than typically reported.
- Noisy slip functions may reflect this epistemic uncertainty, NOT off-fault deformation.
- Slip gradient strains of ~10^{-3} on Borrego fault consistent with differential LIDAR.
- Scarp erosion and infill of fissures sufficient to create paleoseismic record of earthquake within year.
- Sediment flux of 0.01-0.02 m^2/yr across resistant bedrock and uphill-facing conglomerate scarps