An overview of the 4 April 2010 Sierra El Mayor-Cucapah (Baja California) earthquake

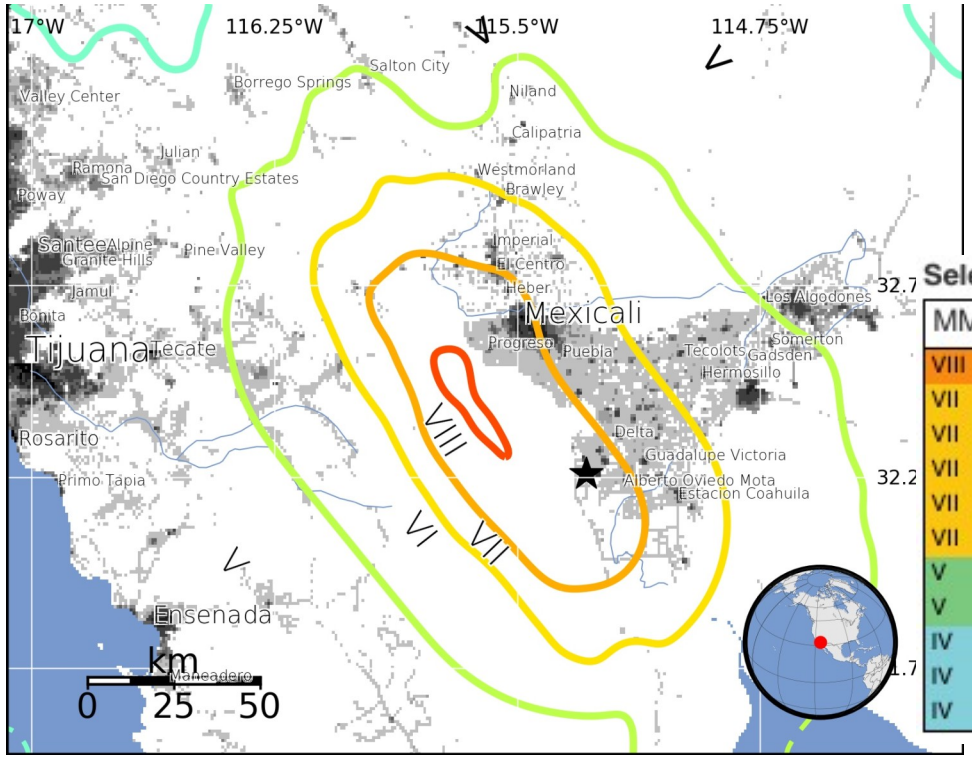
Rich Briggs, Shengji Wei, Eric Fielding, Sebastien Leprince, Anthony Sladen, Risheng Chu, Mark Simons, Jean-Philippe Avouac, Egill Hauksson, Donald V. Helmberger, Rowena Lohman, Ken Hudnut and Sinan Akciz

Caltech , JPL, Cornell, & USGS

USGS
science for a changing world

Initial earthquake information

- Mw 7.2 earthquake Easter (April 4), 2010 at 3:40 PM
- Epicenter located in Mexicali Valley, Baja California
- Widely felt



Mexicali at MMI VII
~600,000 people

Selected Cities Exposed

MMI	City	Pop.
VIII	Progreso	5k
VII	Alberto Oviedo Mota	8k
VII	Mexicali	597k
VII	Calexico	36k
VII	Heber	3k
VII	Seeley	2k
V	San Luis Rio Colorado	139k
V	Tijuana	1,376k
IV	Escondido	137k
IV	Chula Vista	213k
IV	Ensenada	257k

PAGER courtesy of P. Earle, USGS NEIC

Today's talk

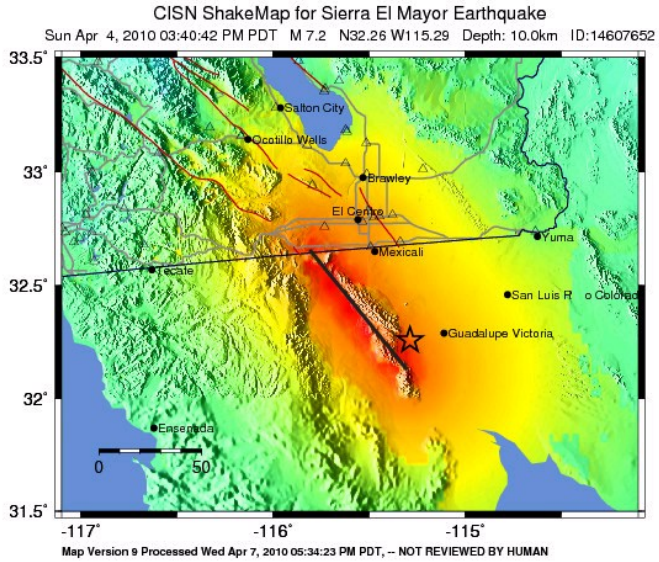
Summarize surface deformation observations (primarily geology, sub-pixel correlation, and InSAR)

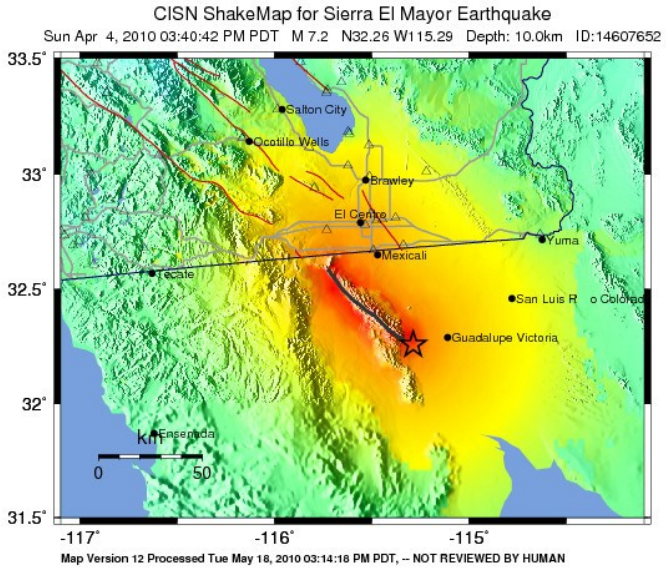
- Large deformation on previously unmapped faults

- Extensive surface disruption in Colorado River Delta

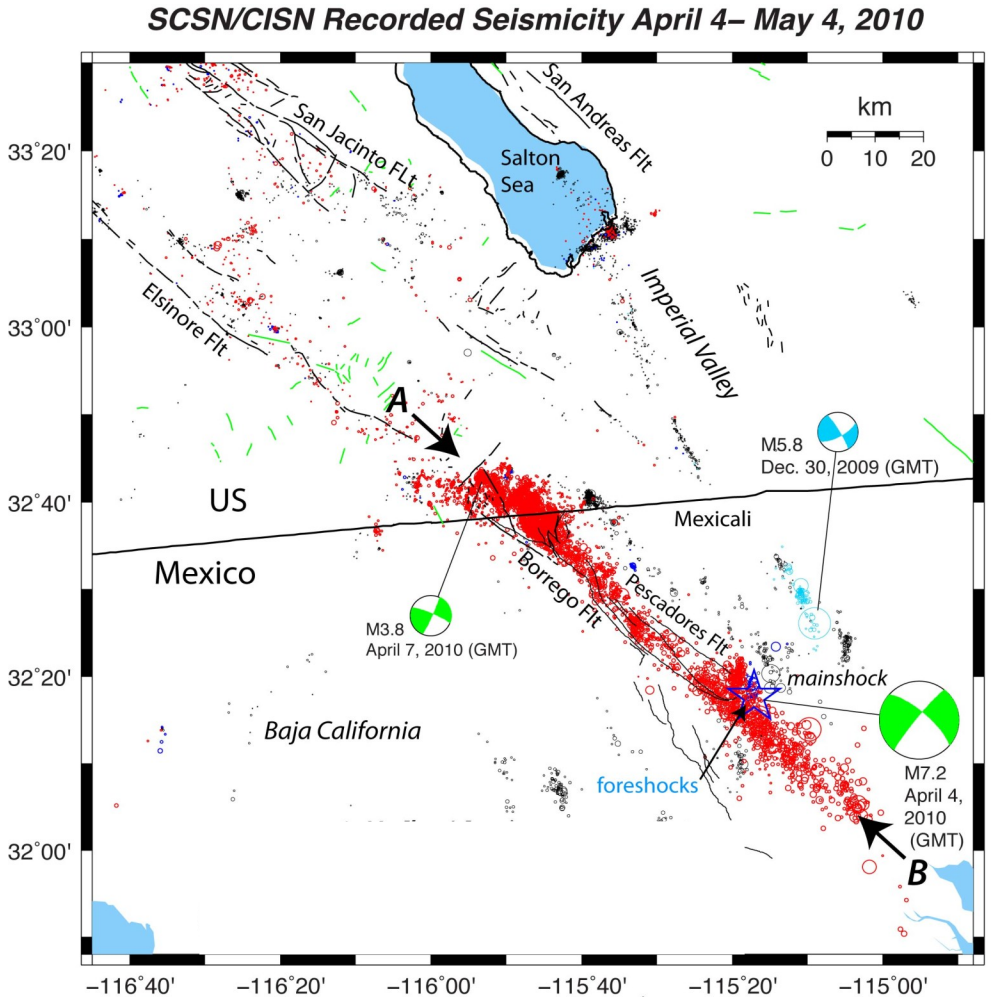
Snapshots of various efforts to model coseismic slip, postseismic effects, stress transfer

Touch on a few unresolved/compelling issues





At the plate boundary scale, this earthquake seems to represent simple accommodation of right-lateral shear



Egill Hauksson

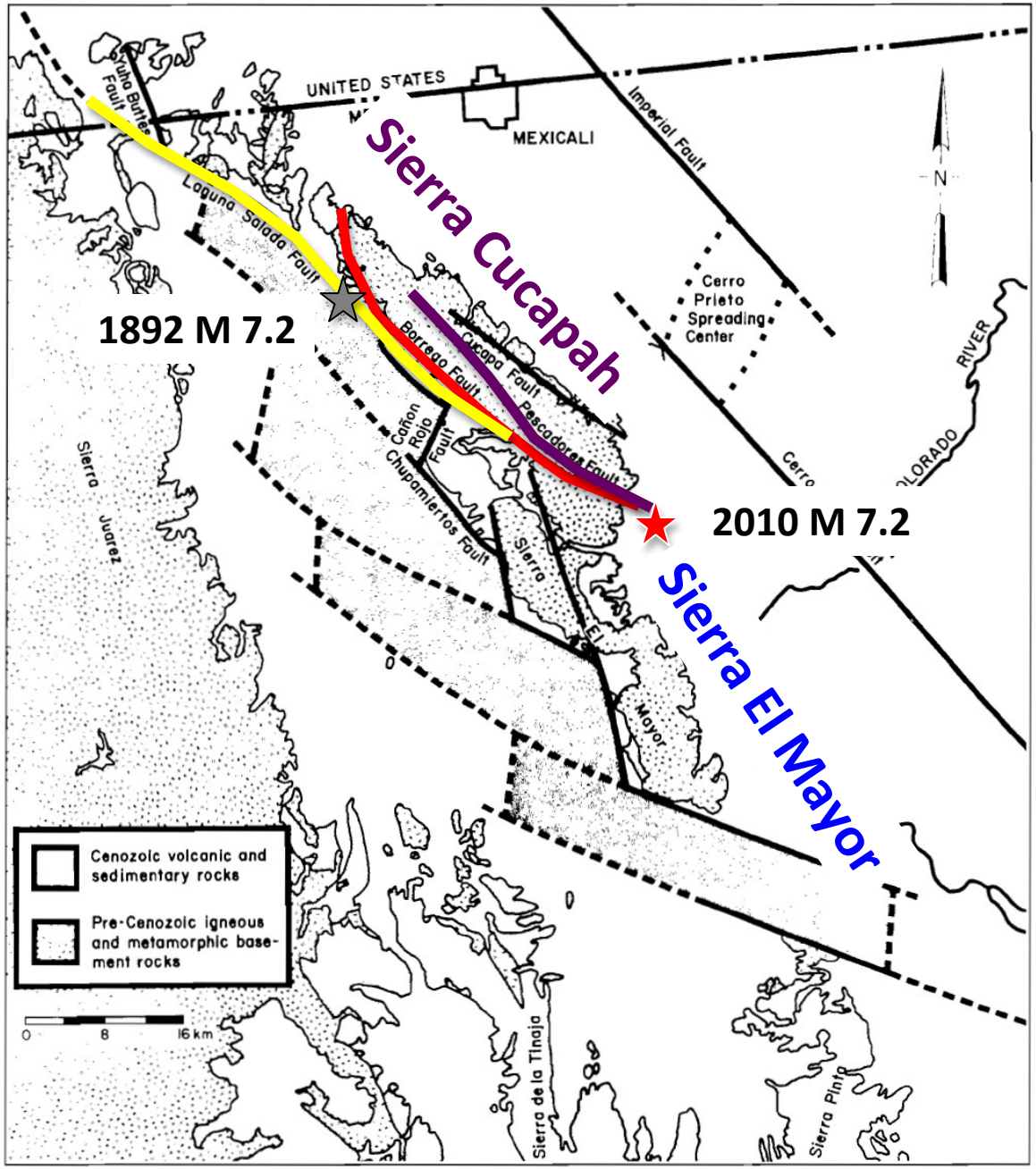
. . .but considerably more complex when viewed in detail

252 Mueller and Rockwell 1995

What is the name of this earthquake again?

Faults:

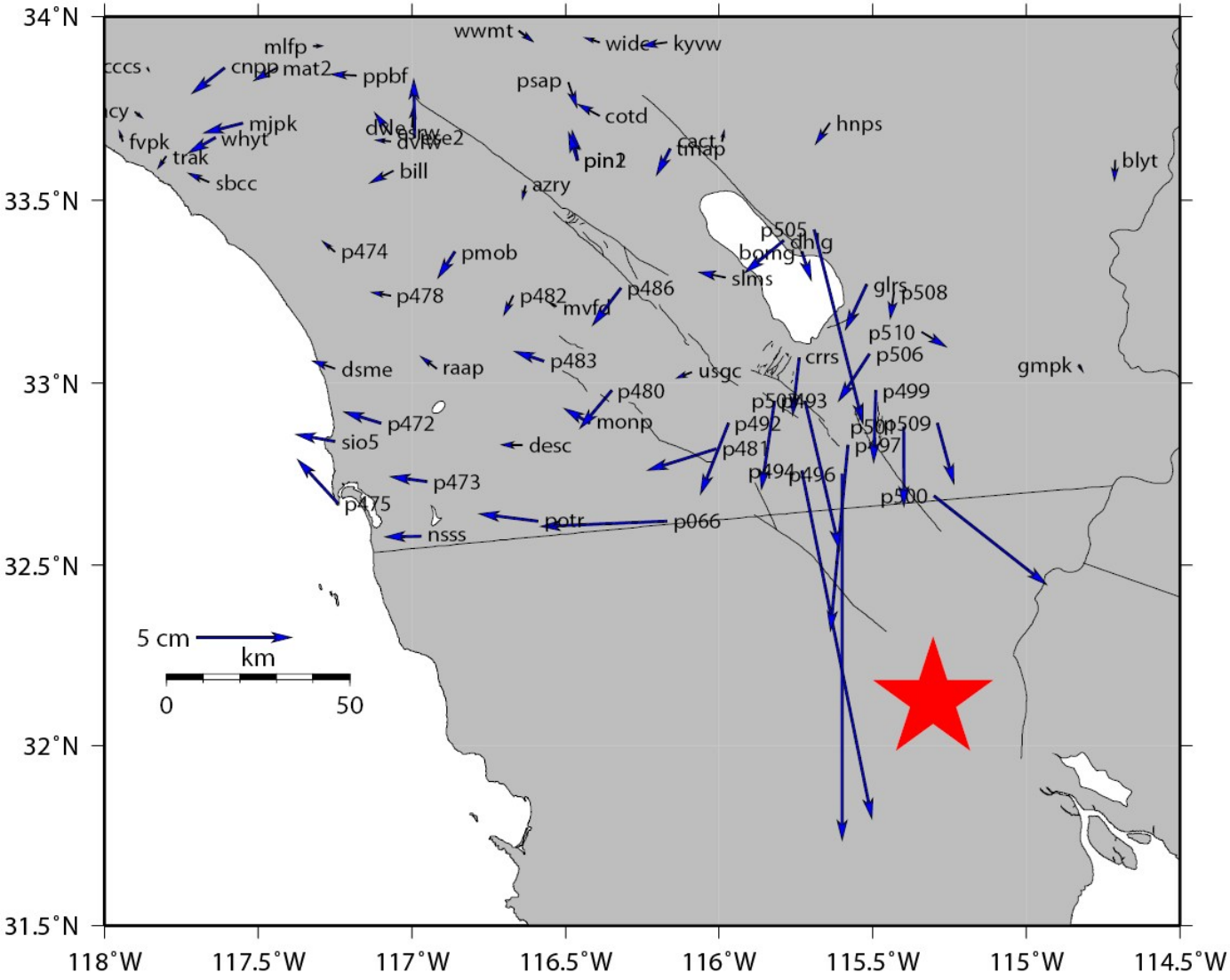
- Laguna Salada
- Borrego
- Pescadores



The Sierra El Mayor-Cucapah Earthquake

Sierra Cucapah Quaternary fault map (pre-2010)

SOPAC's rapid coseismic GPS displacement map

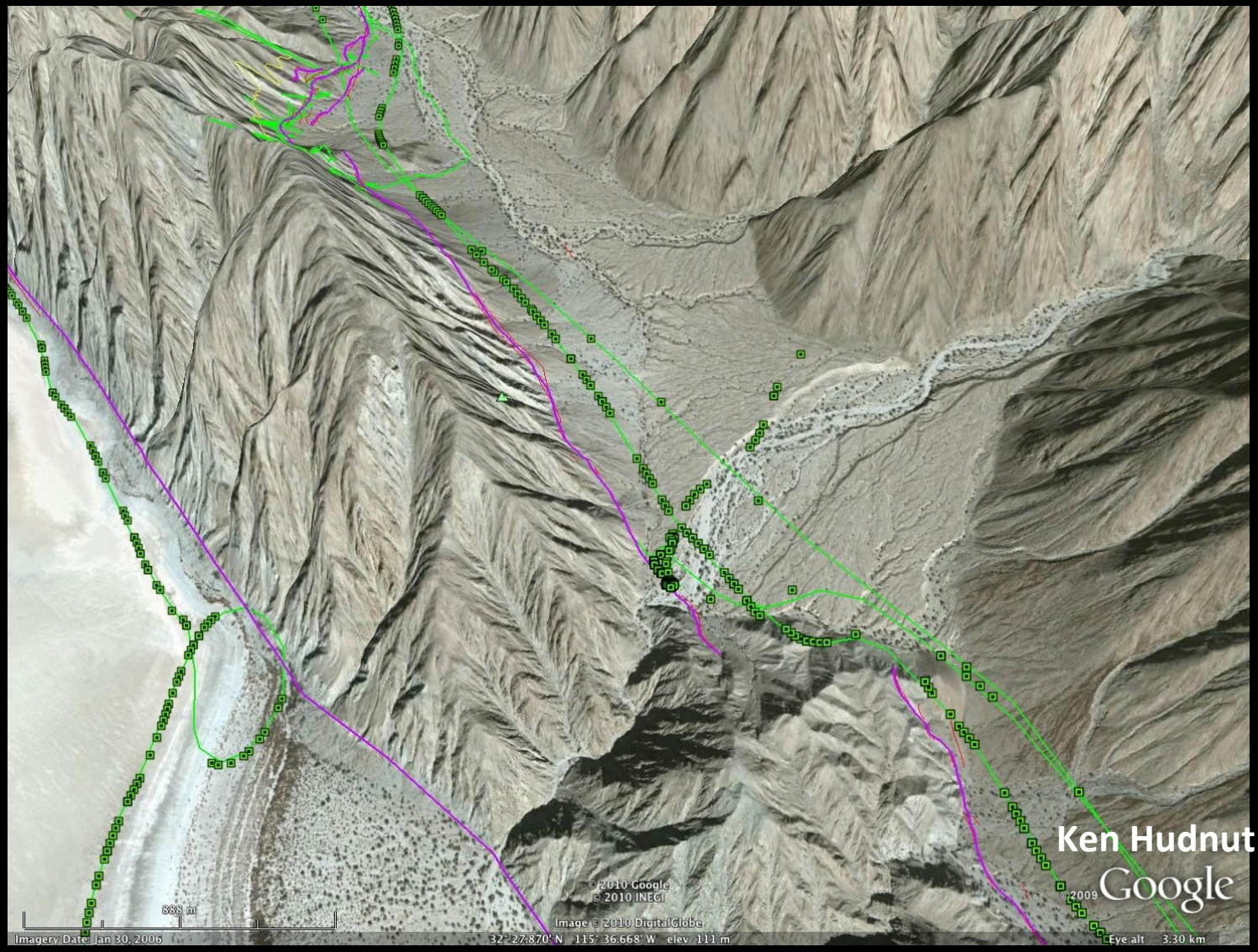


http://supersites.unavco.org/baja.php

Hwy MEX 2D fault crossing

Ken Hudnut (USGS): 1769 air photos (w/ GPS)

Airborne recon photos



Airborne recon 4/6/10 established the rupture involved multiple faults

Ken Hudnut

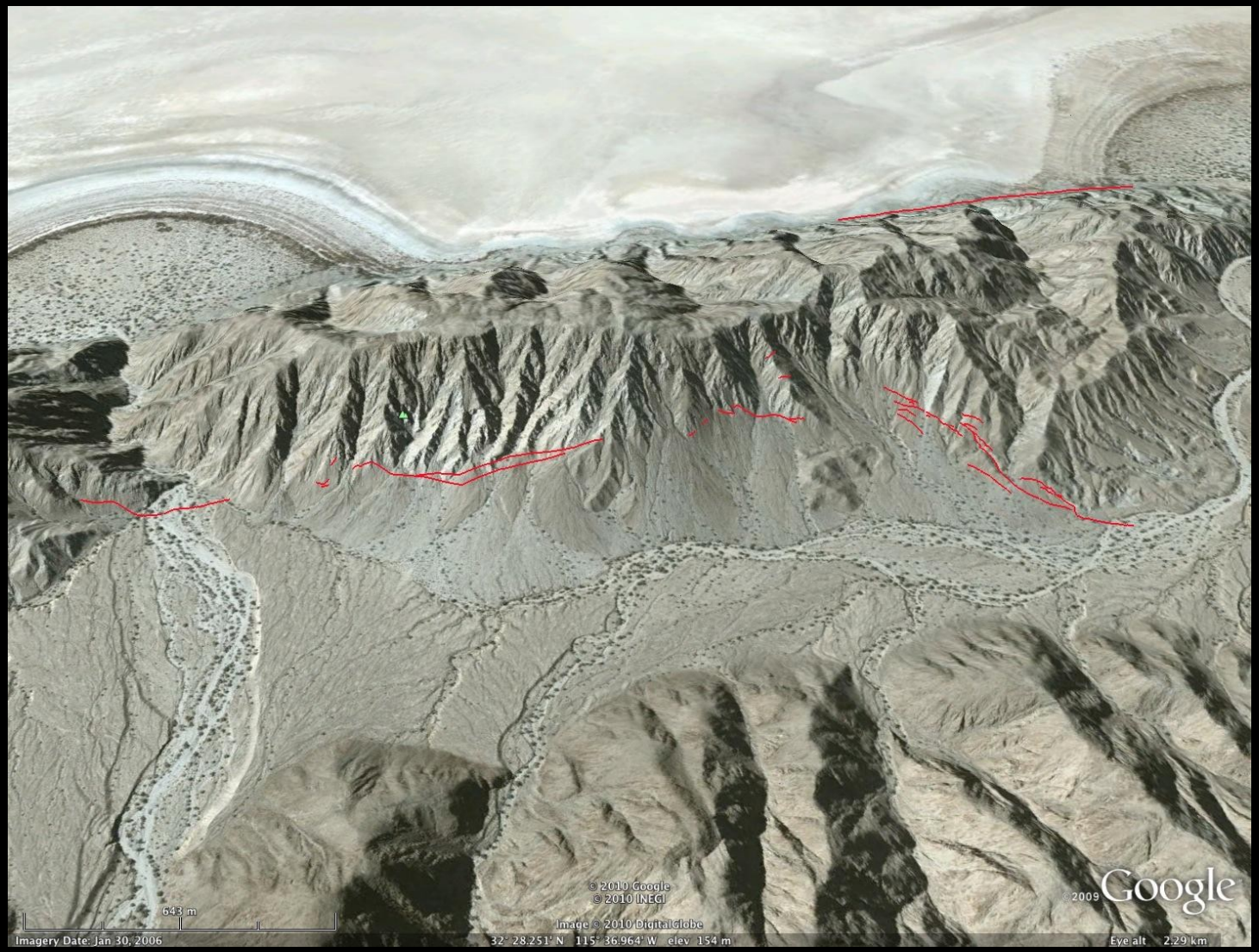
View from the ground

photo by Jim McCrory, Aspen Helicopters

Offsets east-down & right-lateral

Borrego Rupture Mapping Team (John Fletcher, Prof. CICESE, Orlando Teran, Ph.D. Student, CICISE, Ronald Spelz, Ph.D. Post-doc, UABC, Tom Rockwell, Prof. SDSU, Eulalia Marsana, Prof. Univ. of Barcelona, Geoff Faneros, SDSU)

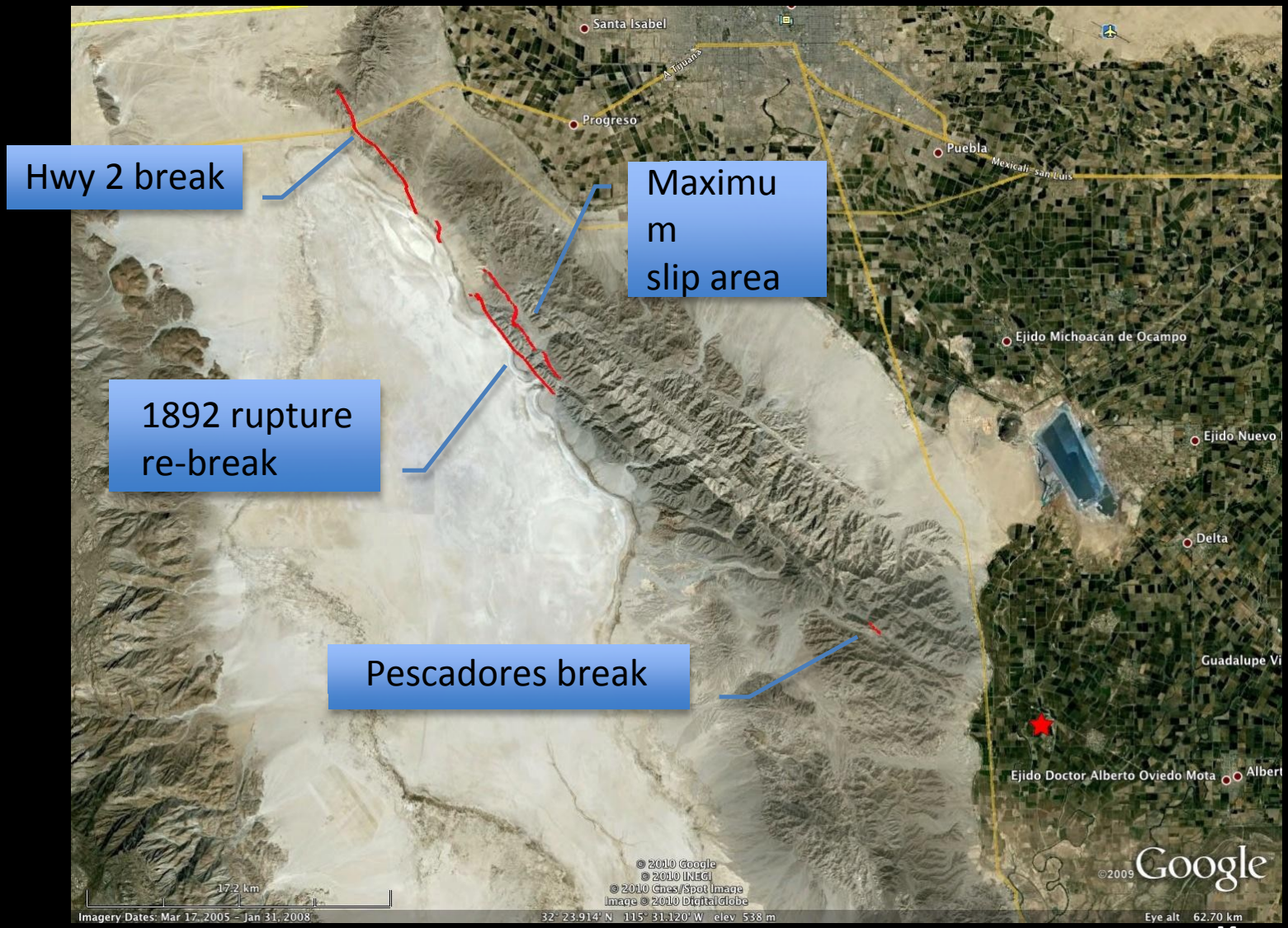
Detailed mapping ongoing



Courtesy Orlando Teran (CICESE)

2010 rupture trace versus previously mapped faults

Recon aerial view of surface faulting 4/6/10



Ken Hudnut

Another way to chase the surface rupture: Sub-pixel offset tracking (aka sub-pixel correlation)

Optical

CALIFORNIA INSTITUTE OF TECHNOLOGY

COSI-Corr Measuring ground deformation using optical satellite and aerial images

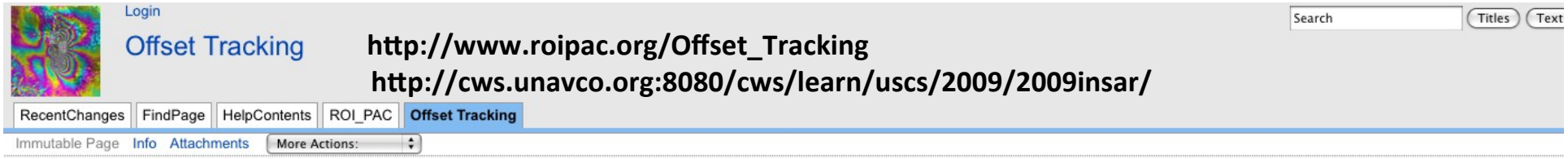
Tectonics Observatory

Funded in part by the National Science Foundation

www.tectonics.caltech.edu/slip_history/spot_coseis/index.html

Sebastien Leprince, Francois Ayoub, Lionel Keene, Jean-Philippe Avouac, Pablo Muse, Sylvain Barbot, Remi Michel, Renaud Binet, Yann Klinger

SAR

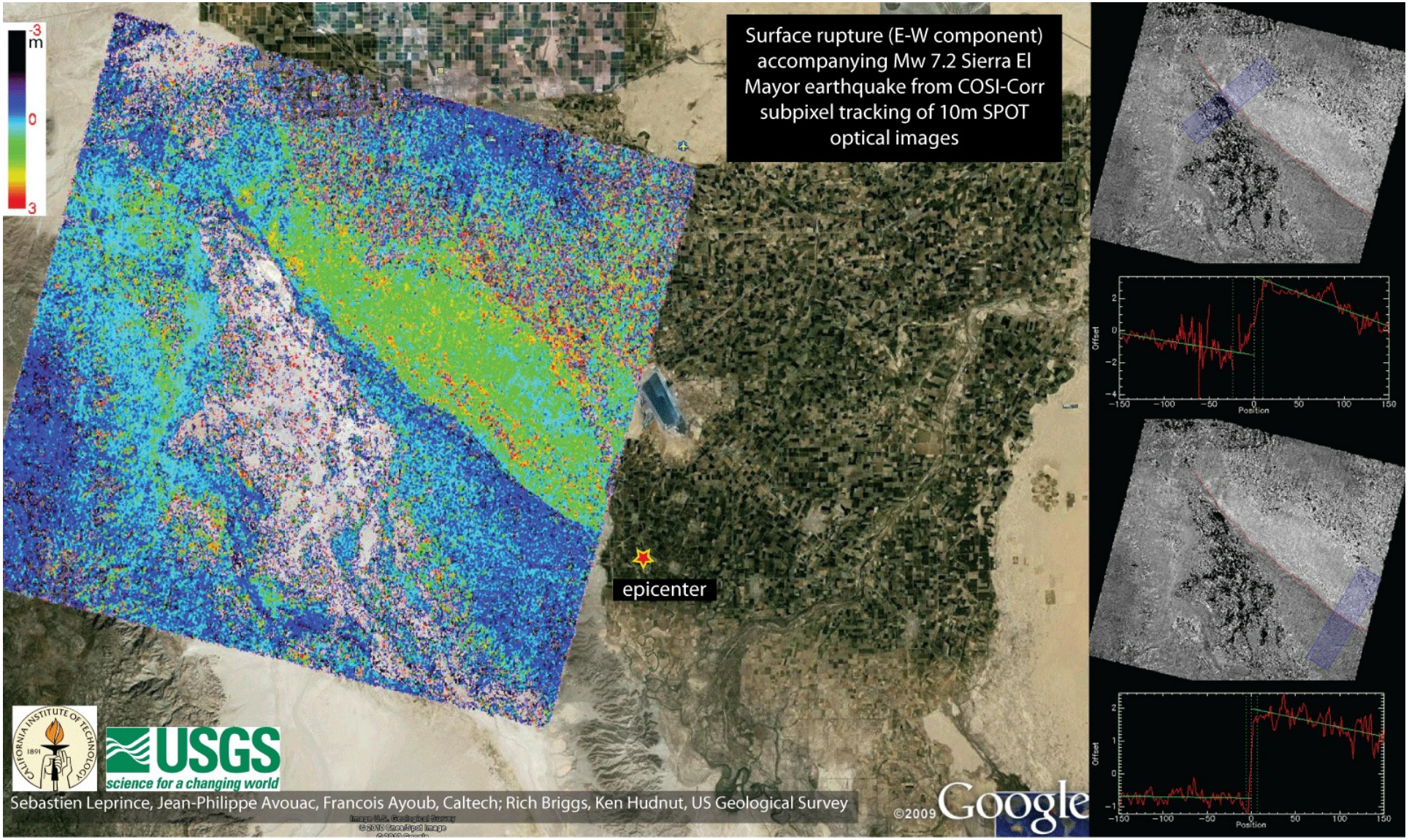


http://www.roipac.org/Offset_Tracking

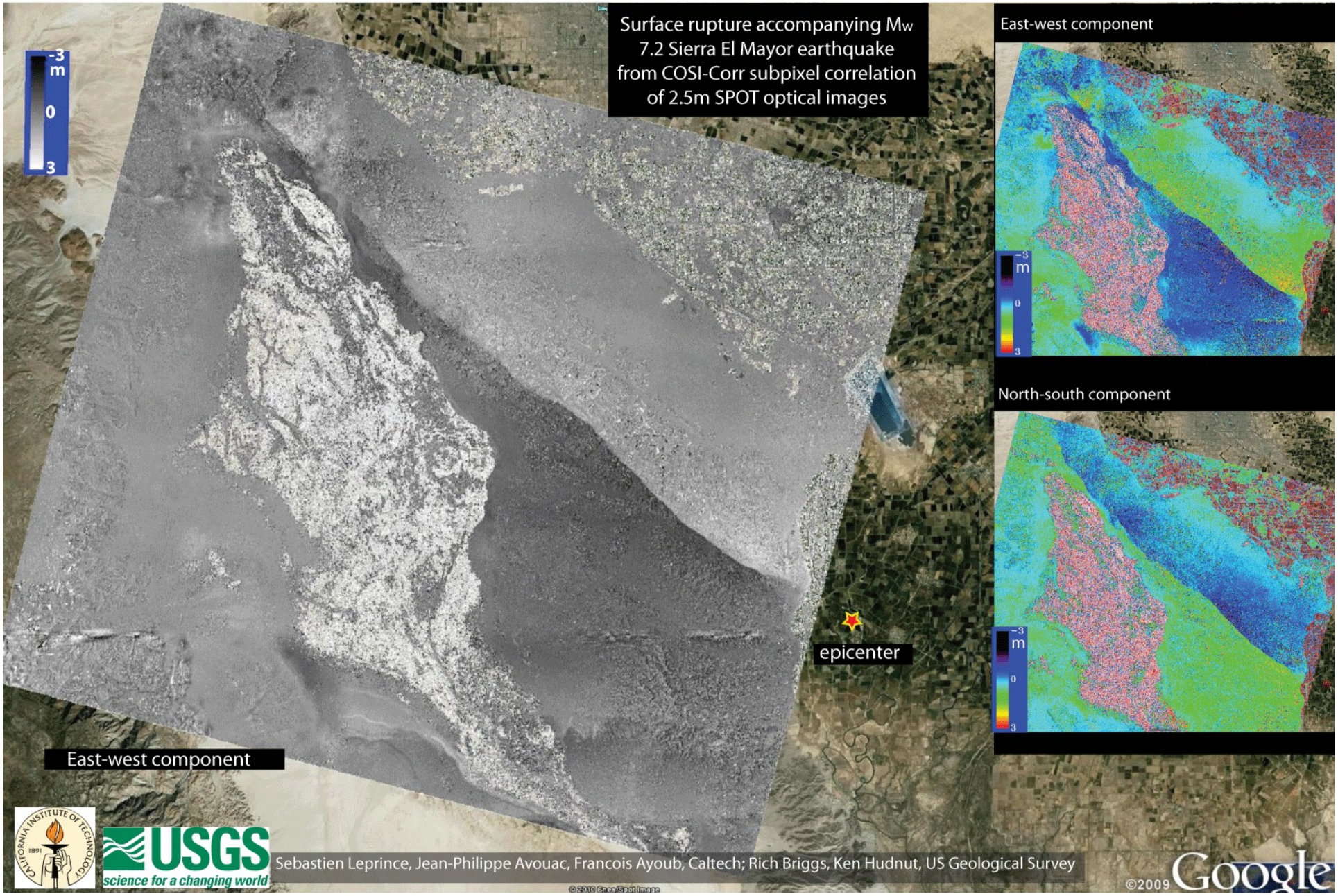
http://cws.unavco.org:8080/cws/learn/uscs/2009/2009insar/

Mark Simons, Andrew Melkonian, Matt Pritchard, Paul Rosen

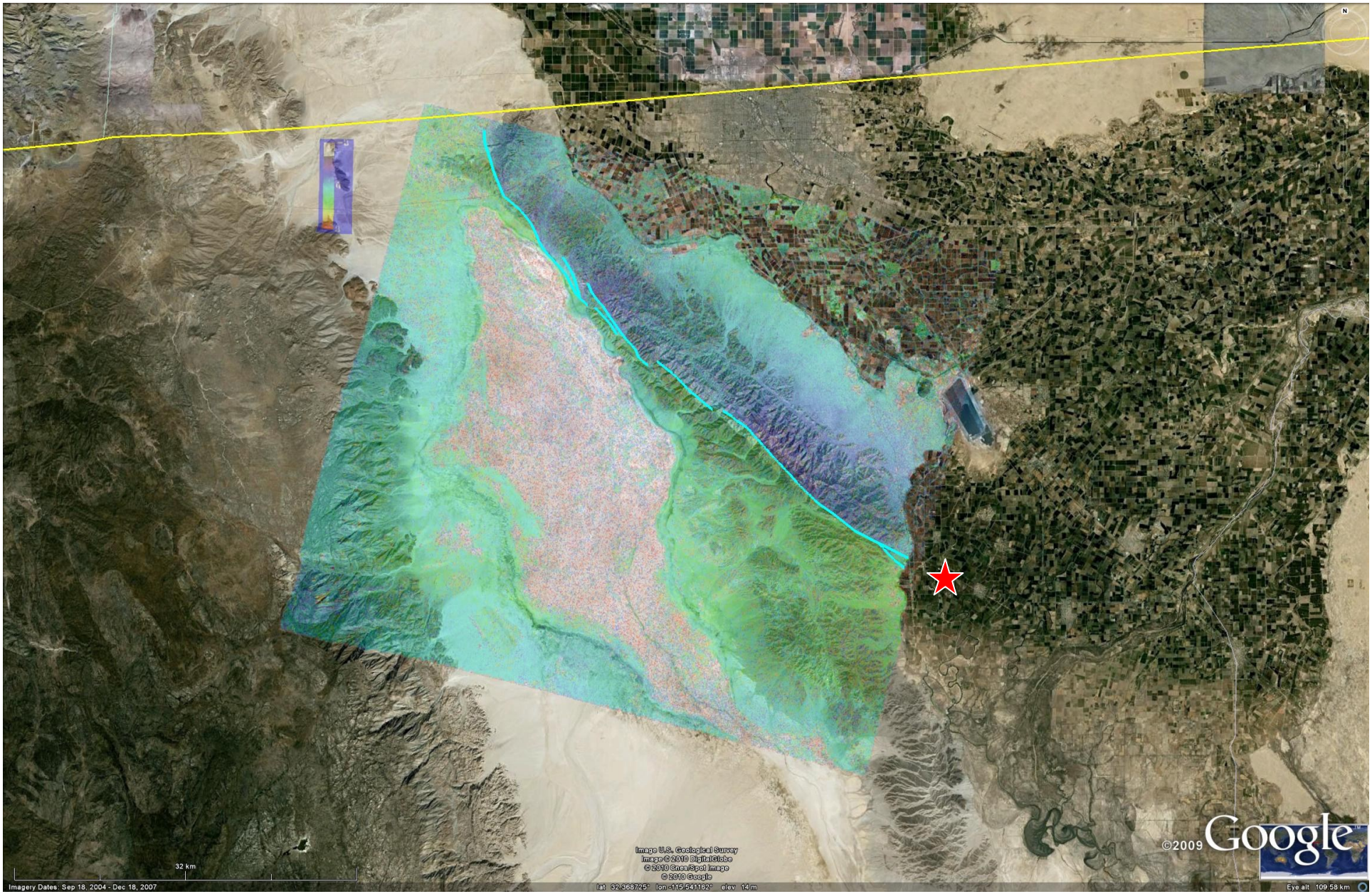
Subpixel correlation of 10m SPOT imagery



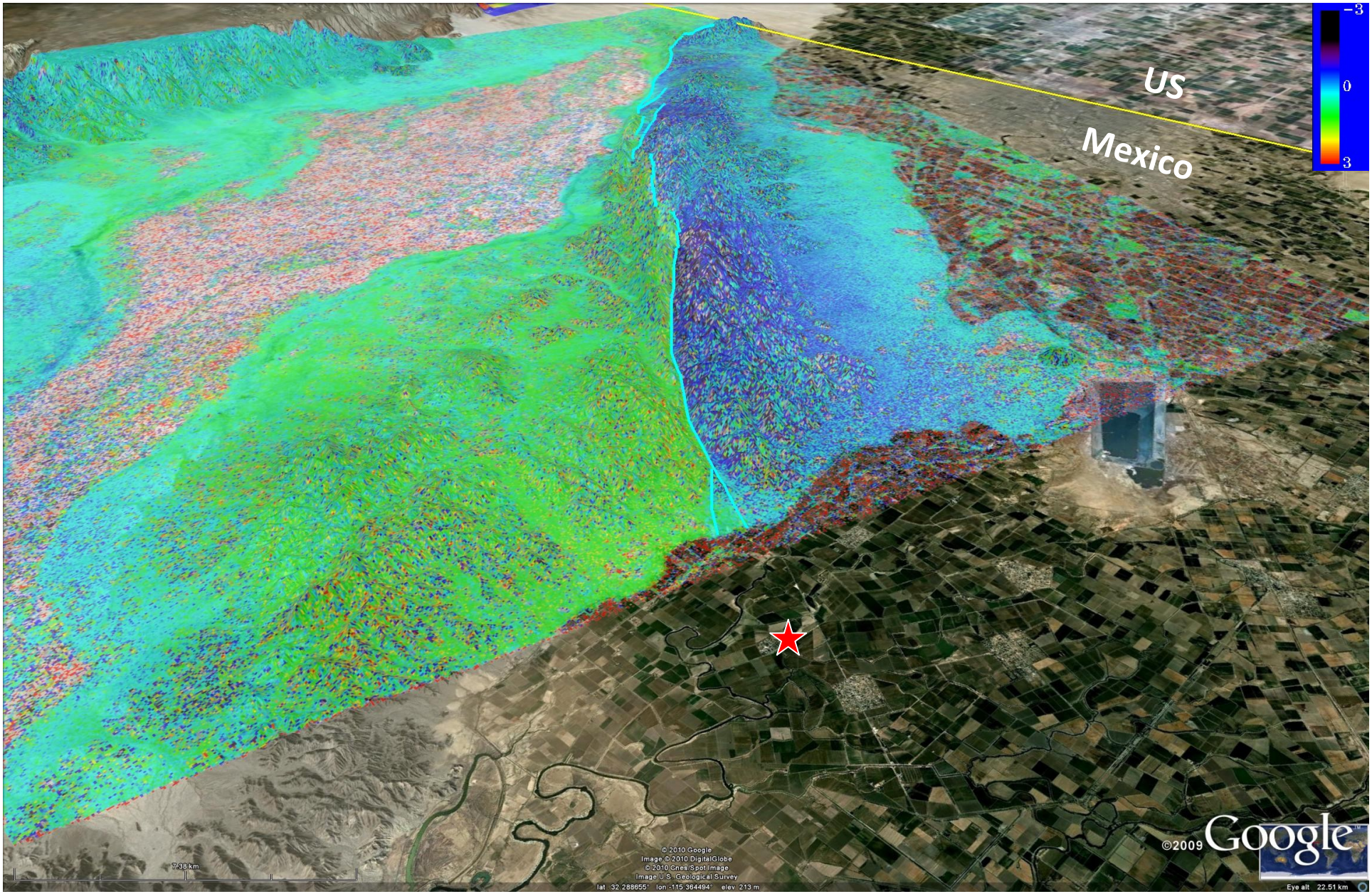
Subpixel correlation of 2.5m SPOT imagery



Generalized surface trace from 2.5m SPOT imagery



View to NW along rupture trace



View to NW along generalized rupture trace


photo courtesy of Prof. John Fletcher, CICESE

27-28 April 2010

John Fletcher, Orlando Teran, Geoff Faneros, Tom Rockwell, Joann Stock, Kate Scharer, Sinan Akciz, Javier Gonzalez, Janet Harvey, John Galetzka, Amy Galetzka, Vanessa Andrews, Alison Piasecki, Erika Swanson, Steve Skinner, Eulalia Masana, Maria, Wally and Ken Hudnut

CICESE, Caltech, SDSU, App State, UCI, USGS

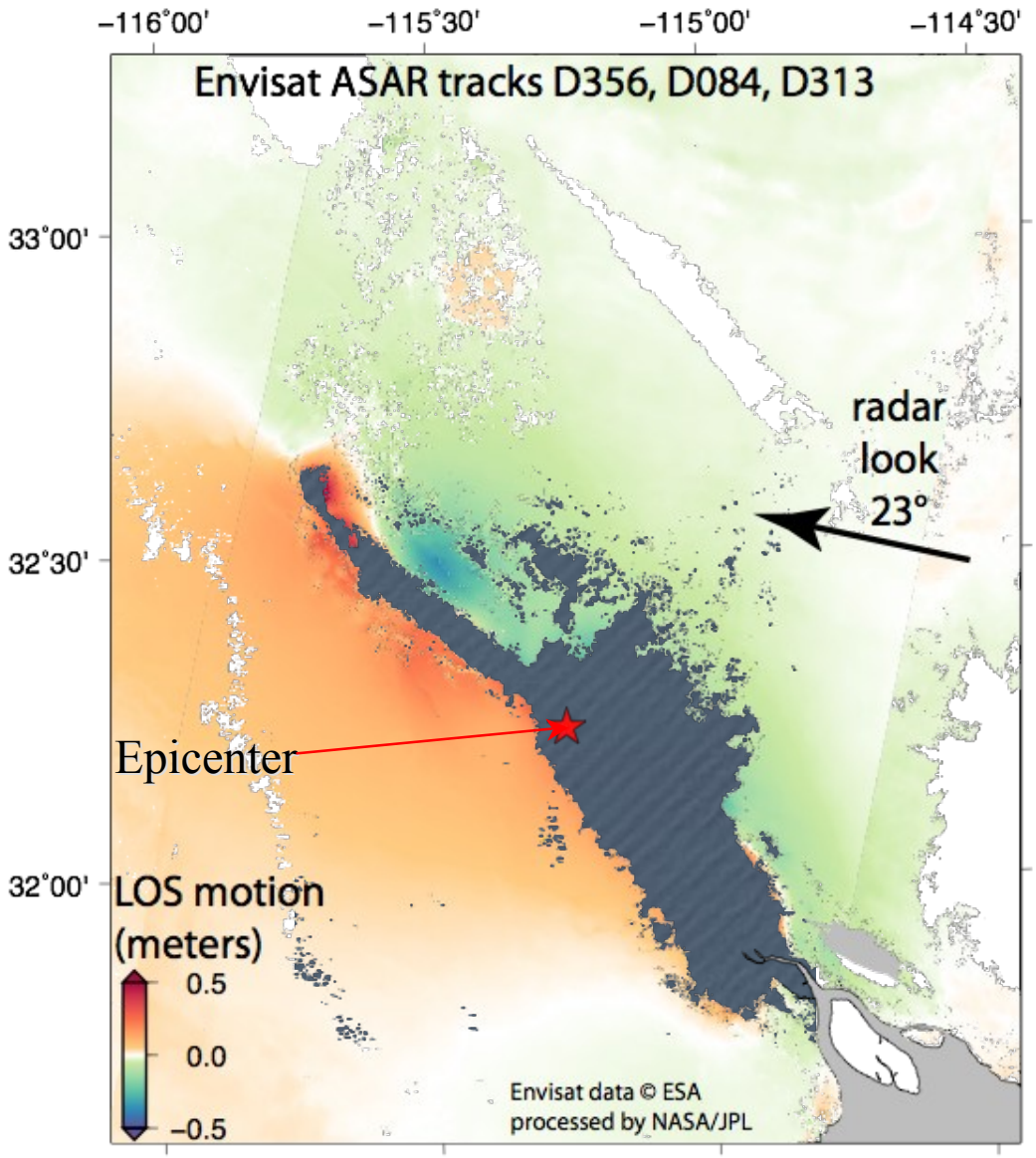
20 people

Six 4 x 4's plus a quad ATV

2 x 19+ hr. days

+ extra days for some

InSAR revealed a substantially larger deformation signal

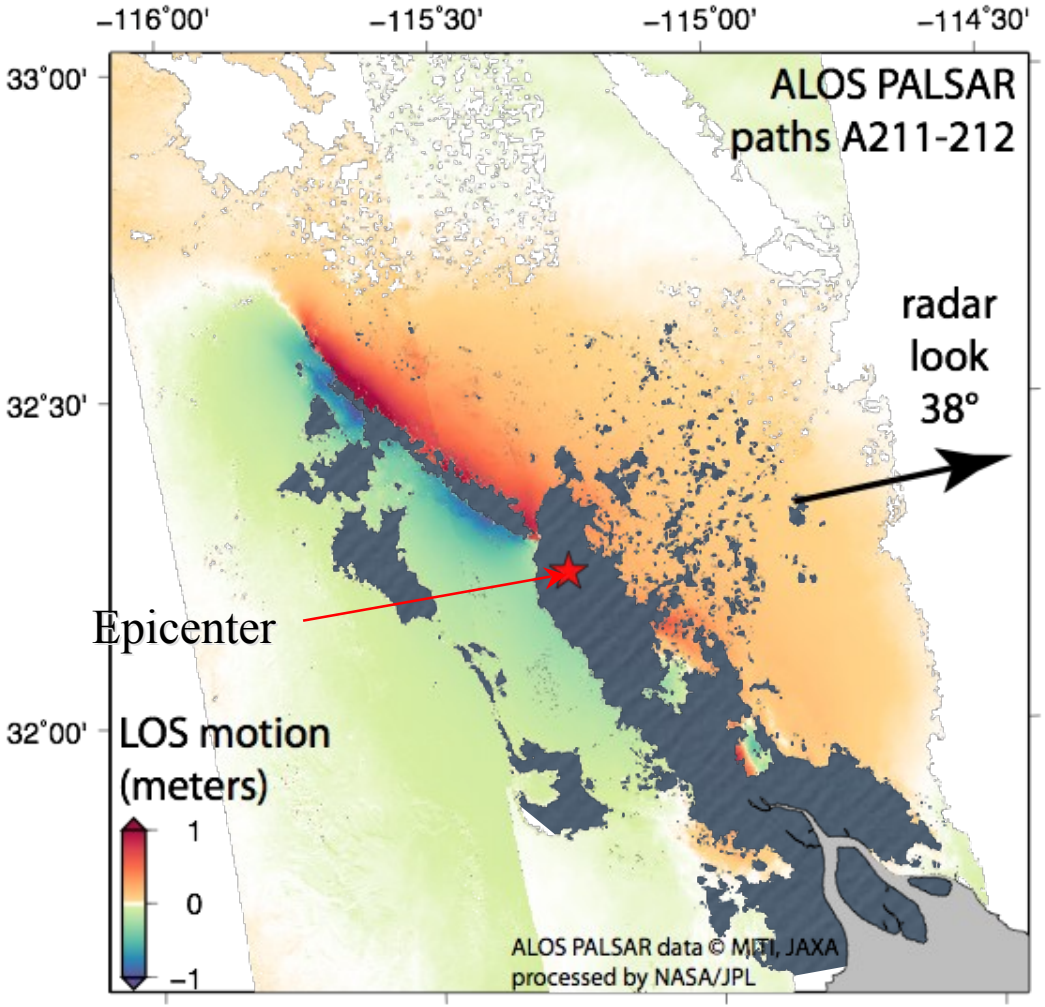


Envisat (5.6 cm) descending shows right-lateral fault slip extended about 120 km, stronger normal slip at north end

Large area of decorrelation (gray) in Colorado River Delta due to widespread disruption of surface by liquefaction, lateral spreading and fault slip

Eric Fielding

ALOS InSAR

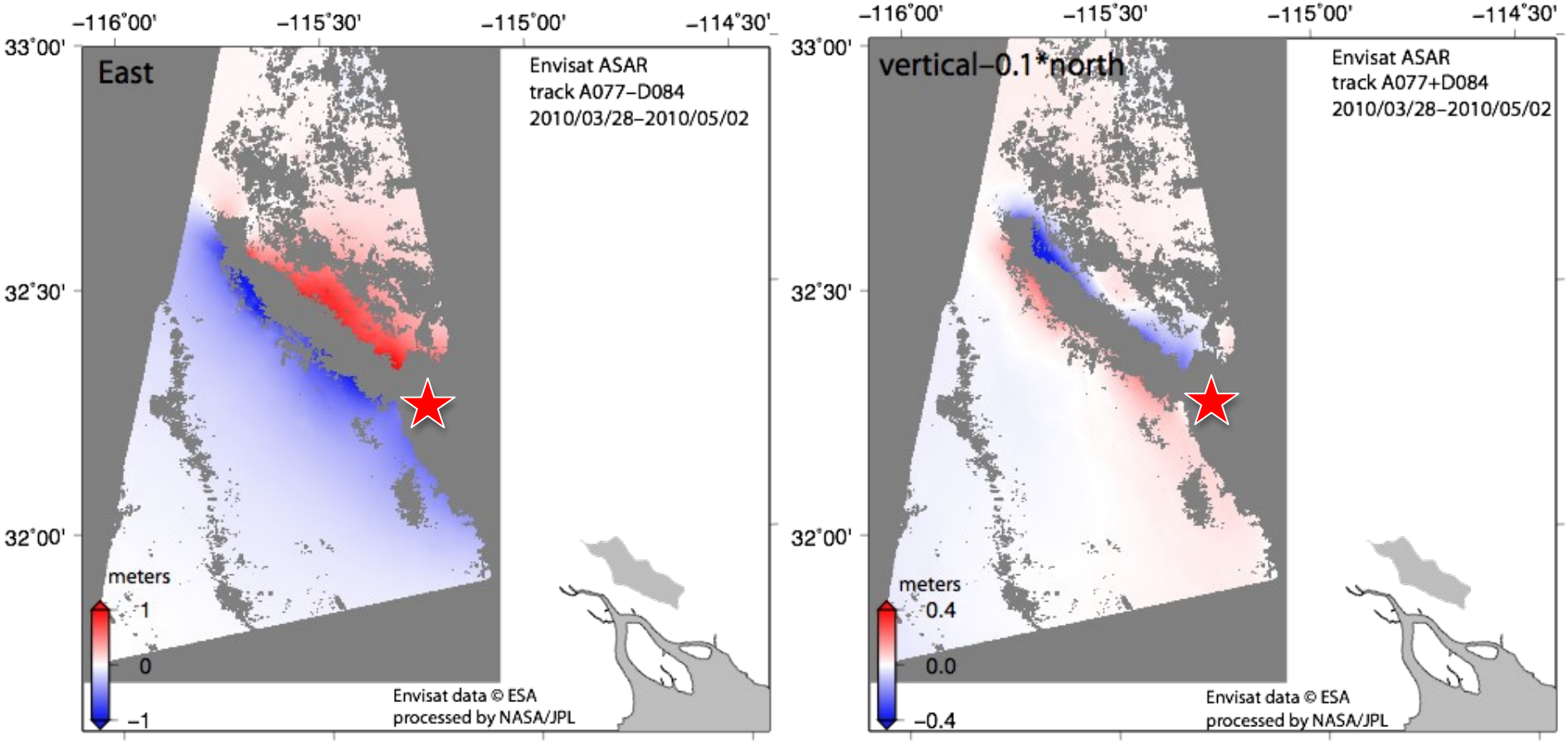


ALOS (23.5 cm) ascending shows oblique slip NW, down to the west block at SE end

Area of decorrelation (gray) somewhat smaller with longer radar wavelength

Eric Fielding

Envisat InSAR combo



- Ascending and descending combined to separate East (primarily strike slip) from Vertical–0.1*North (primarily normal slip)
- Largest vertical (&south) motion northern part of rupture

Eric Fielding

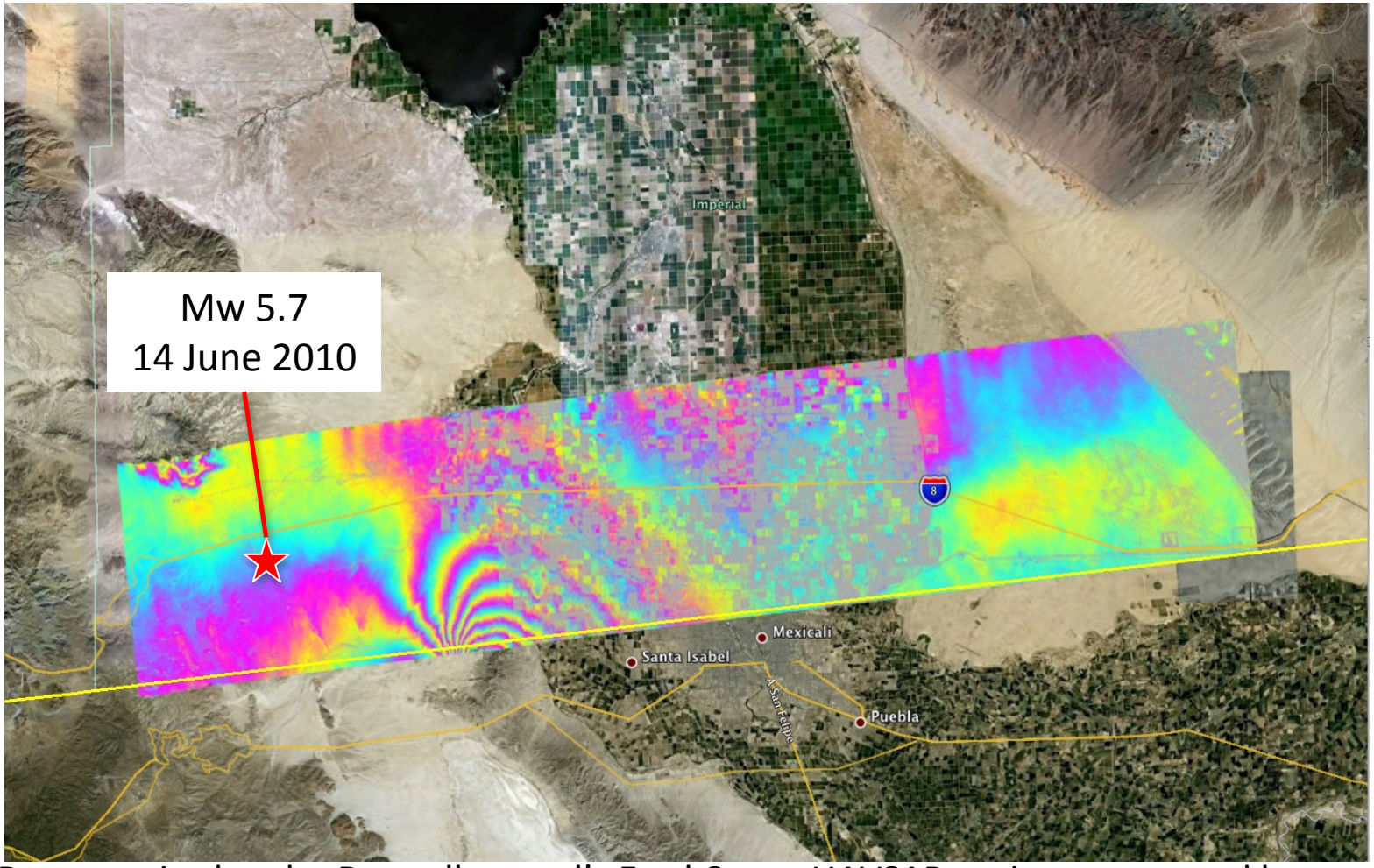
UAVSAR interferogram

- First earthquake deformation captured by the UAVSAR system using data acquired on October 21, 2009 and April 13, 2010.

11.8 cm fringes

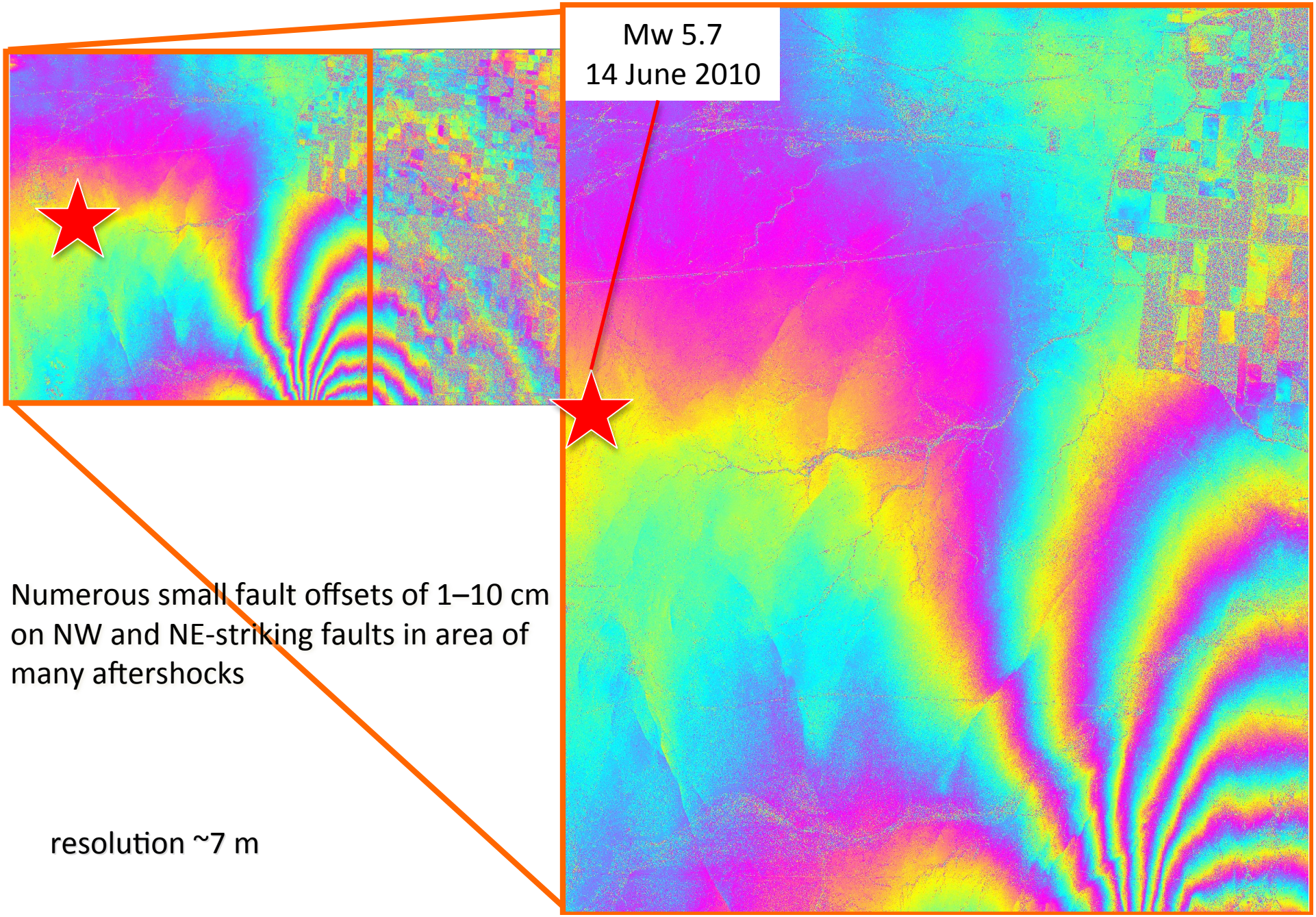
radar look

Signal: up to 80 cm to the south and down



Data acquired under Donnellan et al's EarthScope UAVSAR project, processed by Scott Hensley and the UAVSAR team

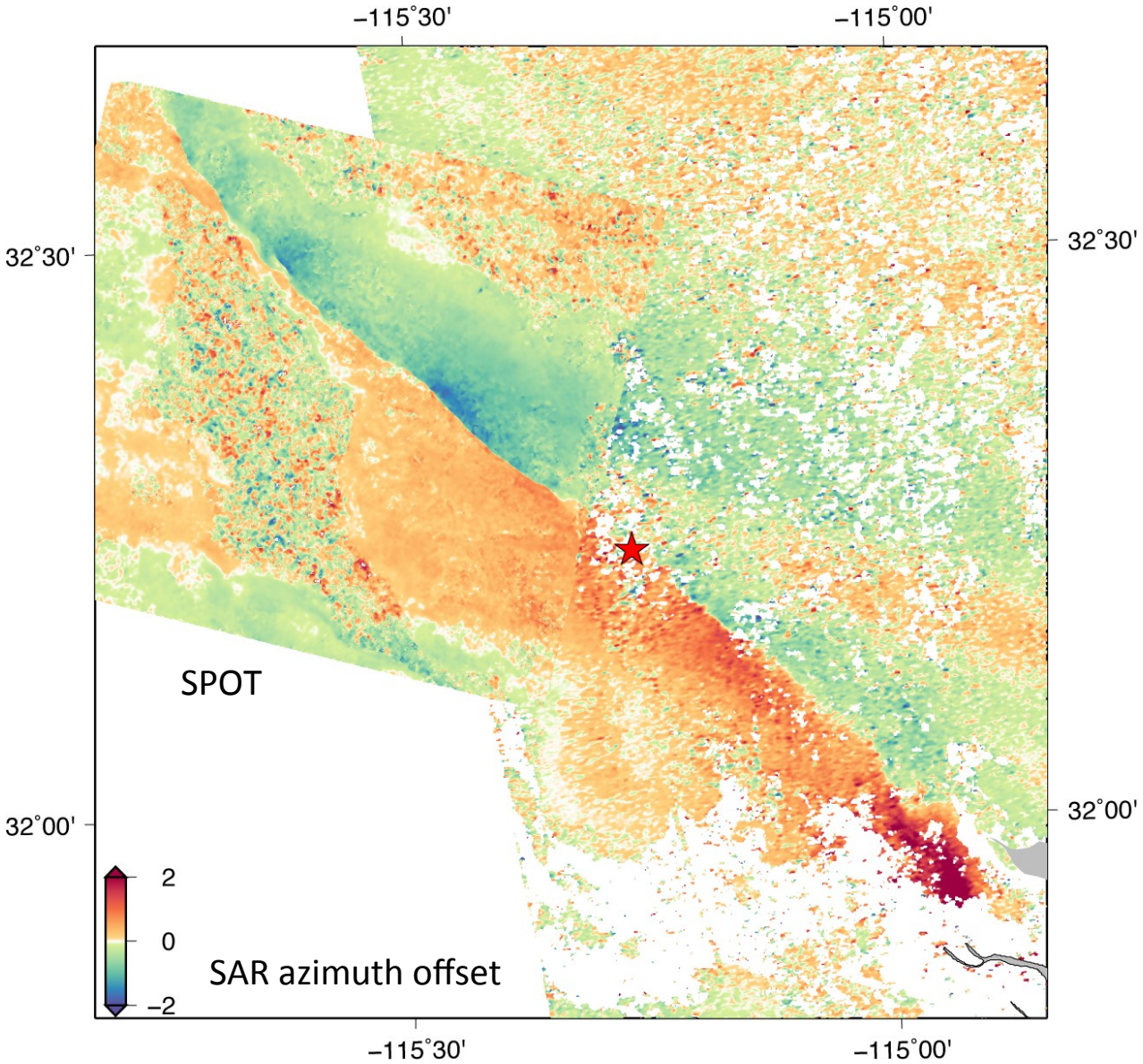
UAVSAR details and (approx.) Mw 5.7 aftershock location



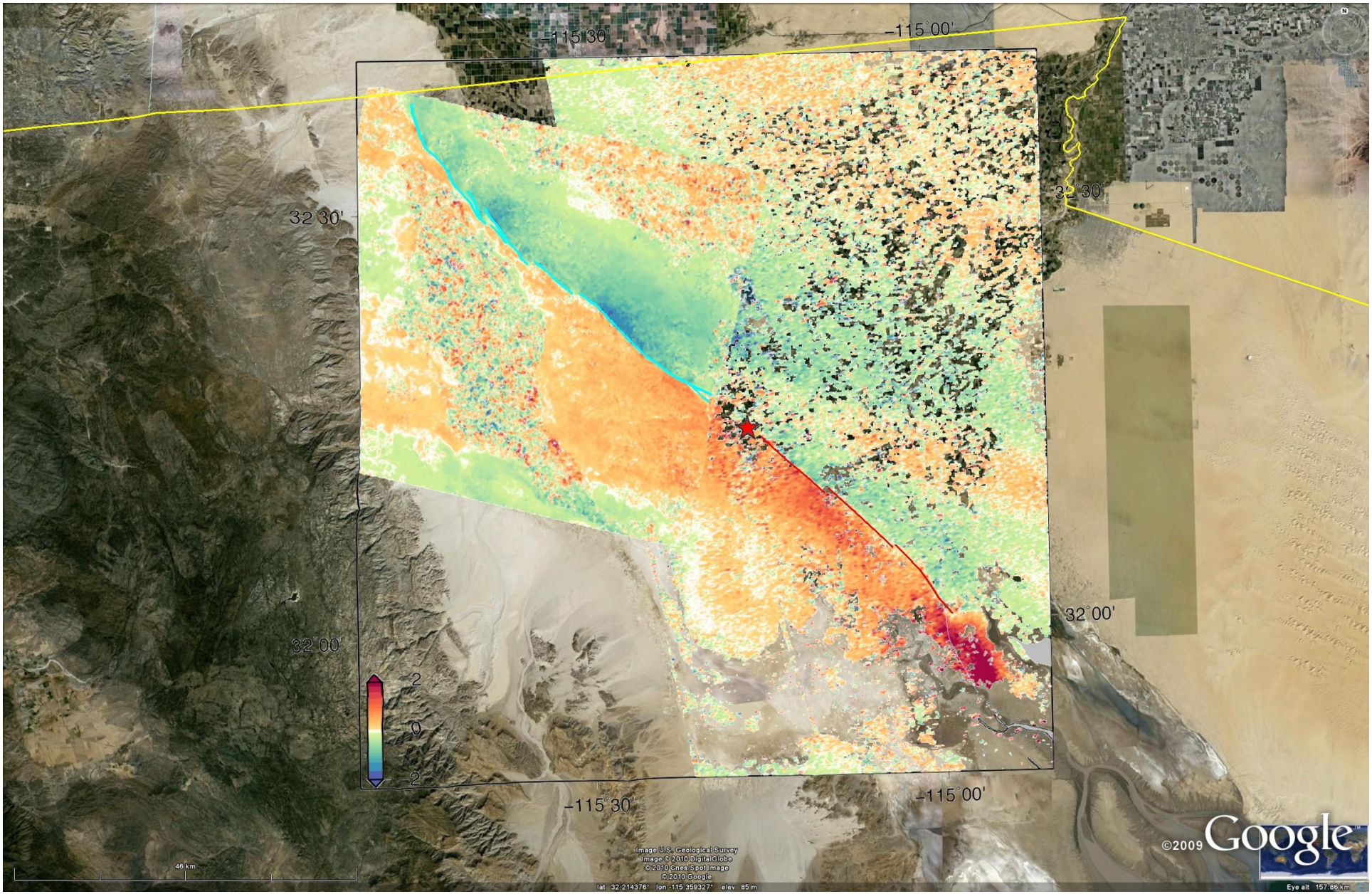
Numerous small fault offsets of 1–10 cm on NW and NE-striking faults in area of many aftershocks

resolution ~7 m

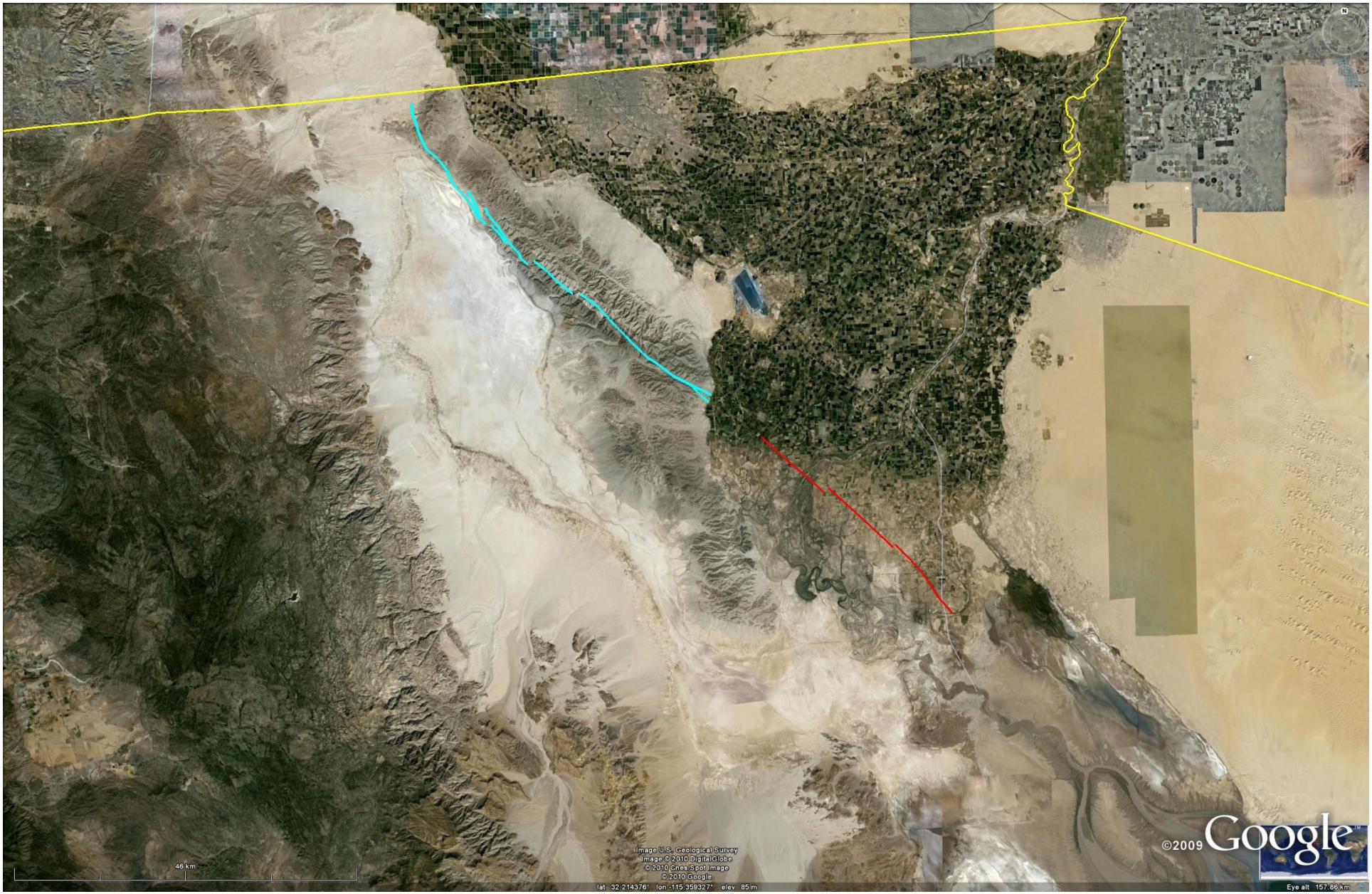
Integrated view of rupture from SPOT and SAR pixel tracking



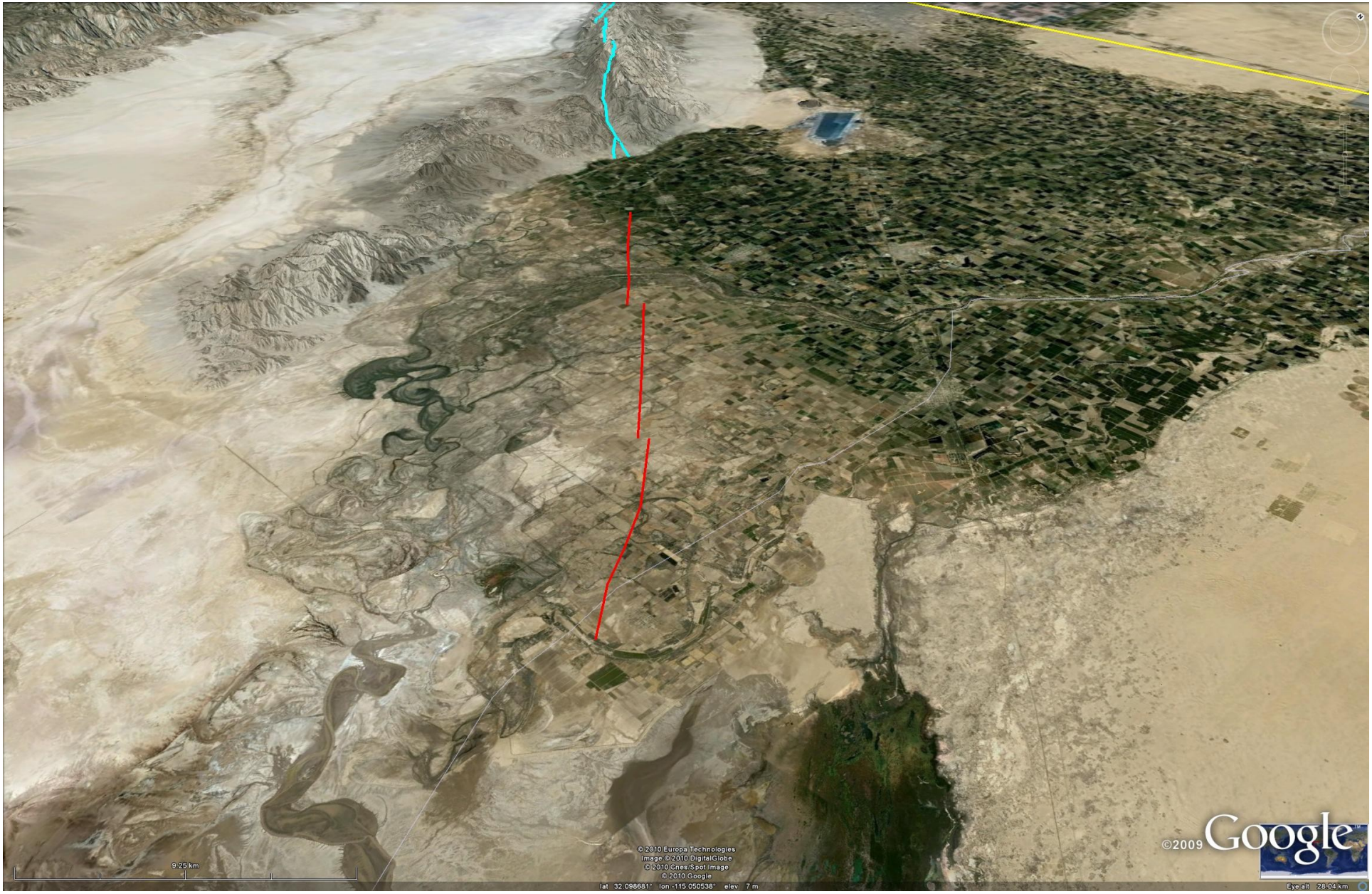
Zone of liquefaction masks primary tectonic surface deformation



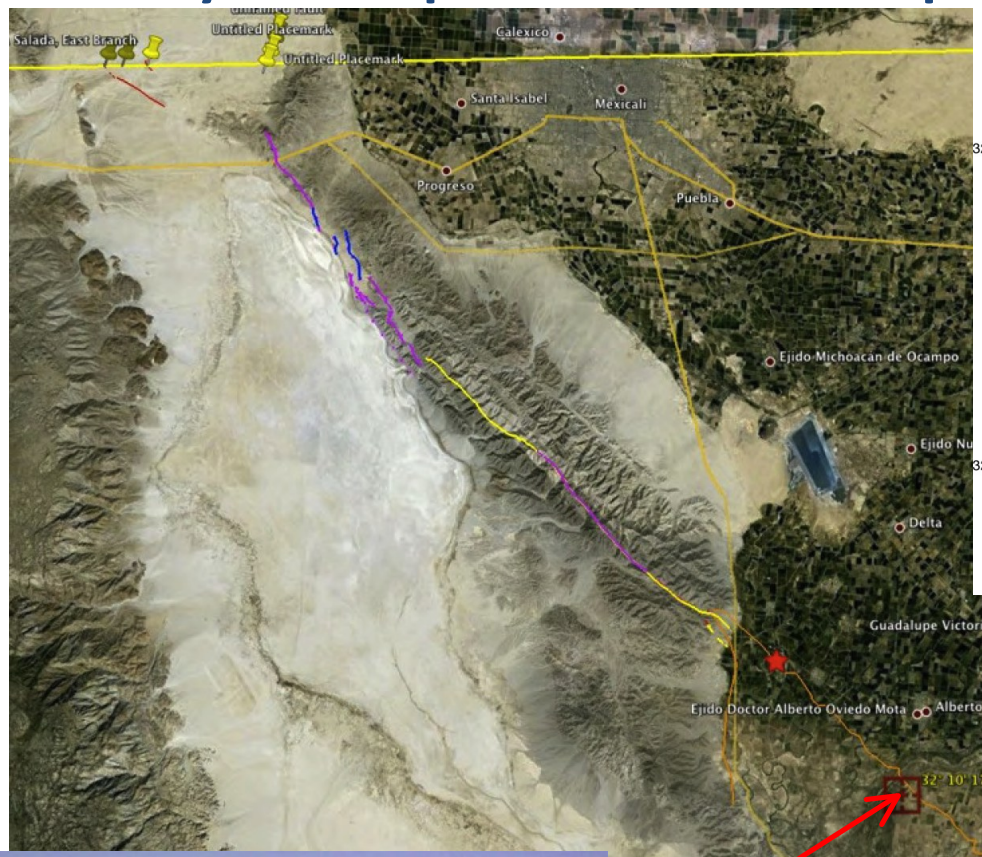
Generalized fault traces from pixel tracking

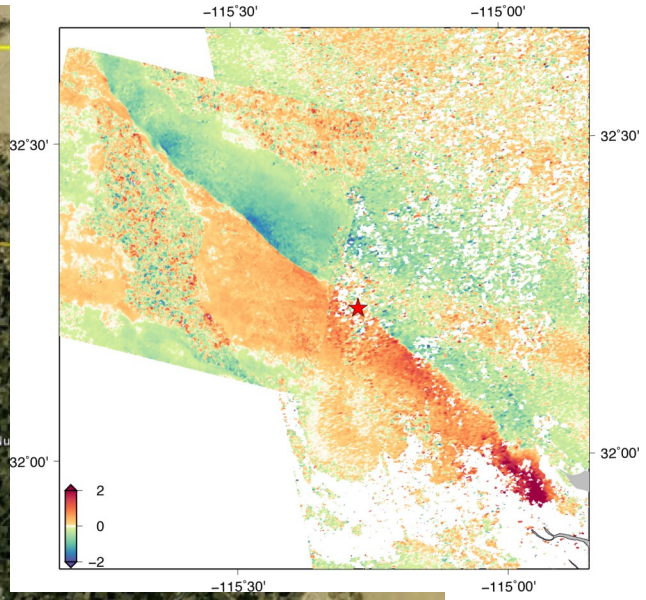


Predicted fault trace across the Mexicali Valley



The Sierra El-Mayor Cucapah Indiviso Earthquake?



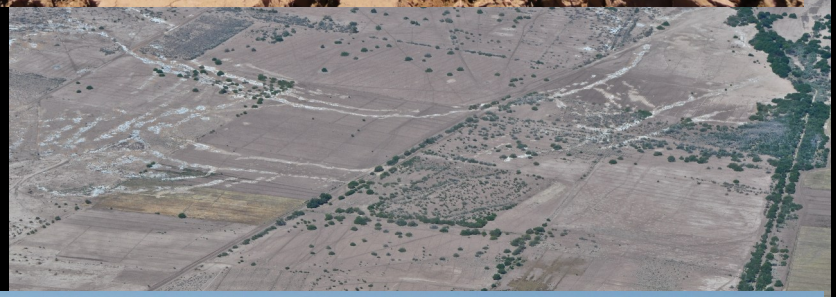


Indiviso fault

2010 – same agricultural impacts as 1940, 1979 & 1987!

Fault Ground Rupture (tectonic)
Liquefaction (shaking induced)
Lateral Spreading (shaking induced)

Levee & field repairs (laser leveling costs $60 to $350 per acre)



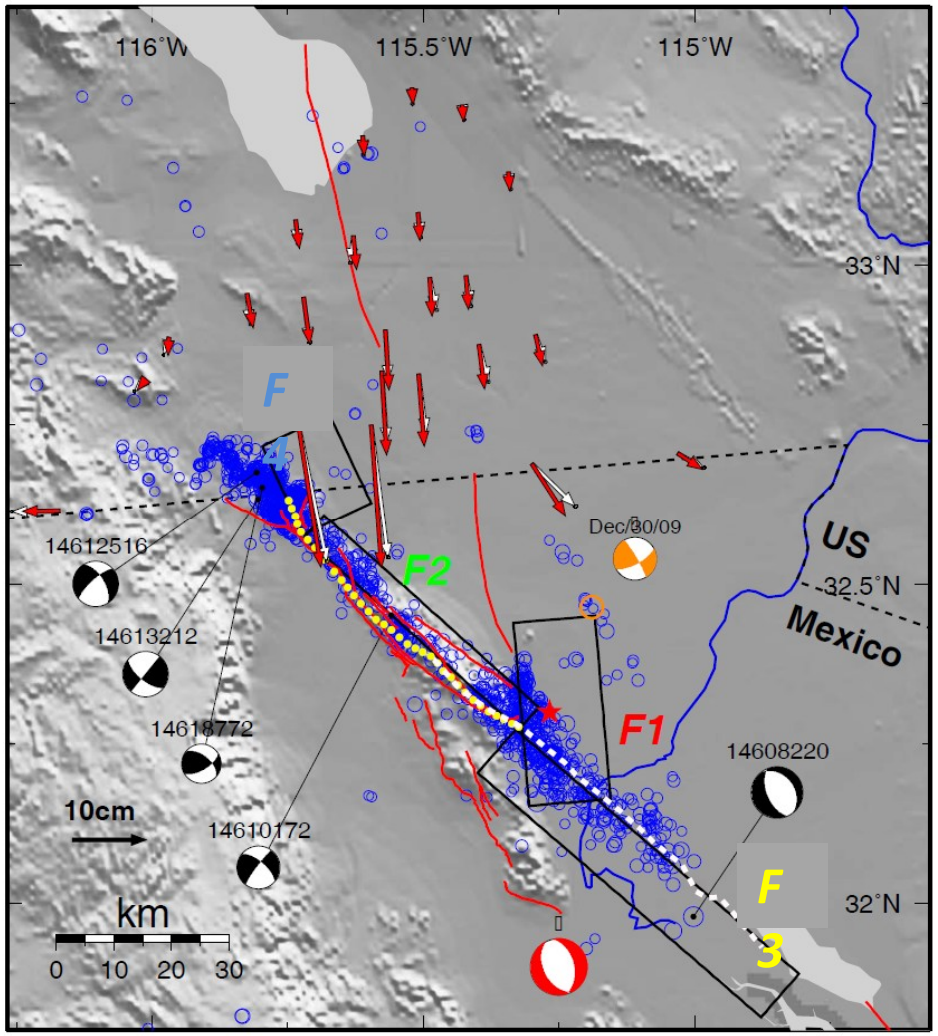
Widespread severe damage to agriculture

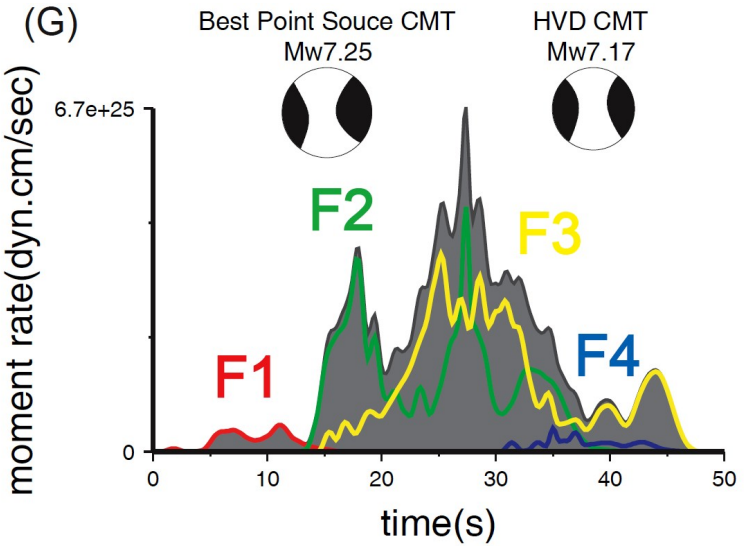
Damage to agriculture will be long term and expensive

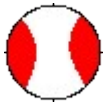
Heidi Stenner & Betsy Mathieson

How many growing seasons will be affected?

Wei et al. rupture model: Geometry and source-time





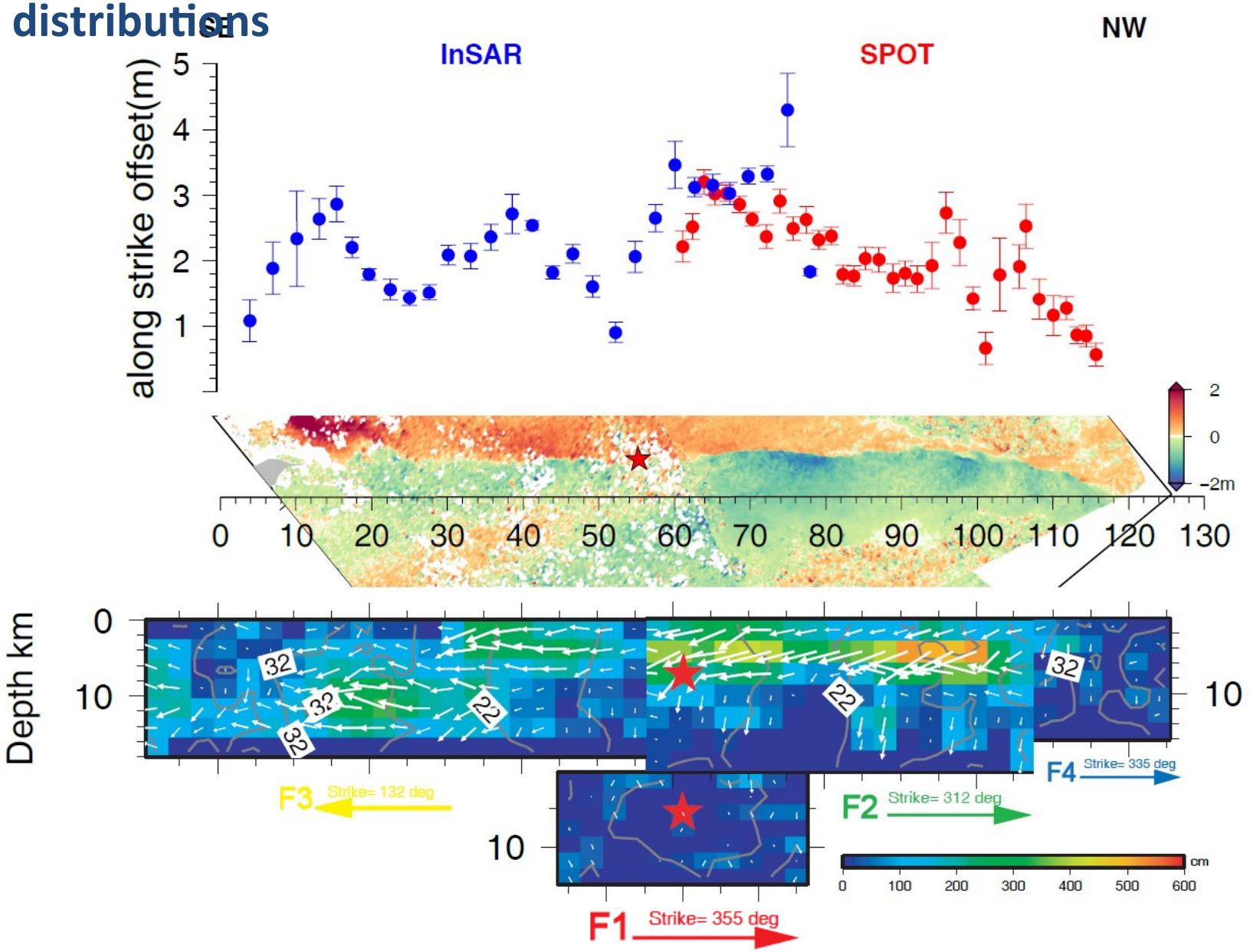


Mw7.2

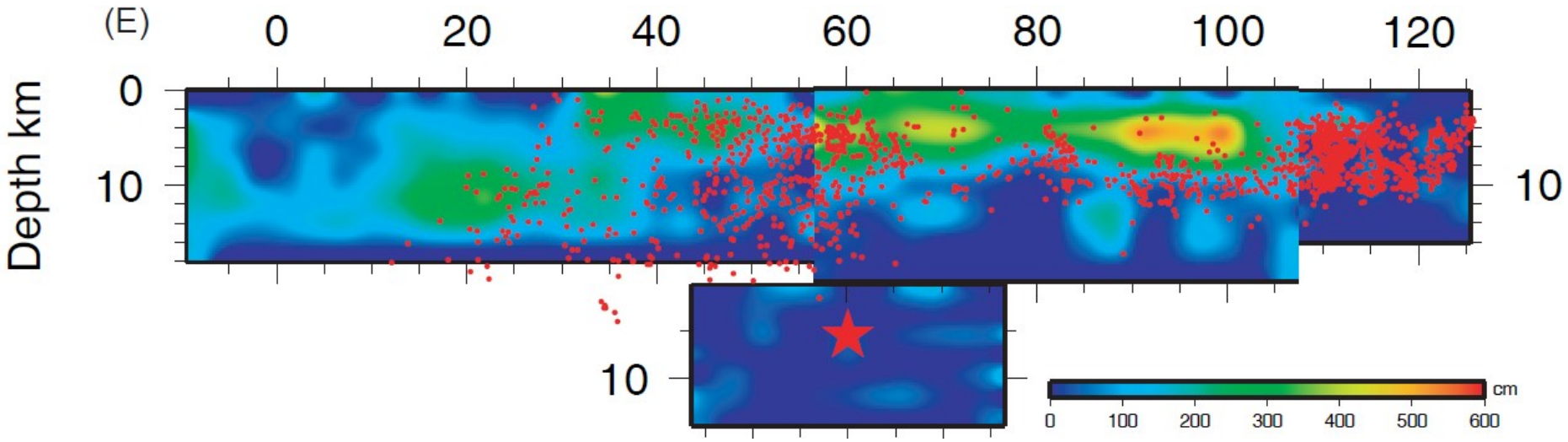
Harvard CMT

Fault model is well constrained from the optical offsets (measured on SPOT images) and the SAR azimuth offsets (measured on ALOS images).

Wei et al. rupture model: Surface slip and fault slip distributions



Wei et al. rupture model: Comparison between coseismic slip distribution and aftershocks

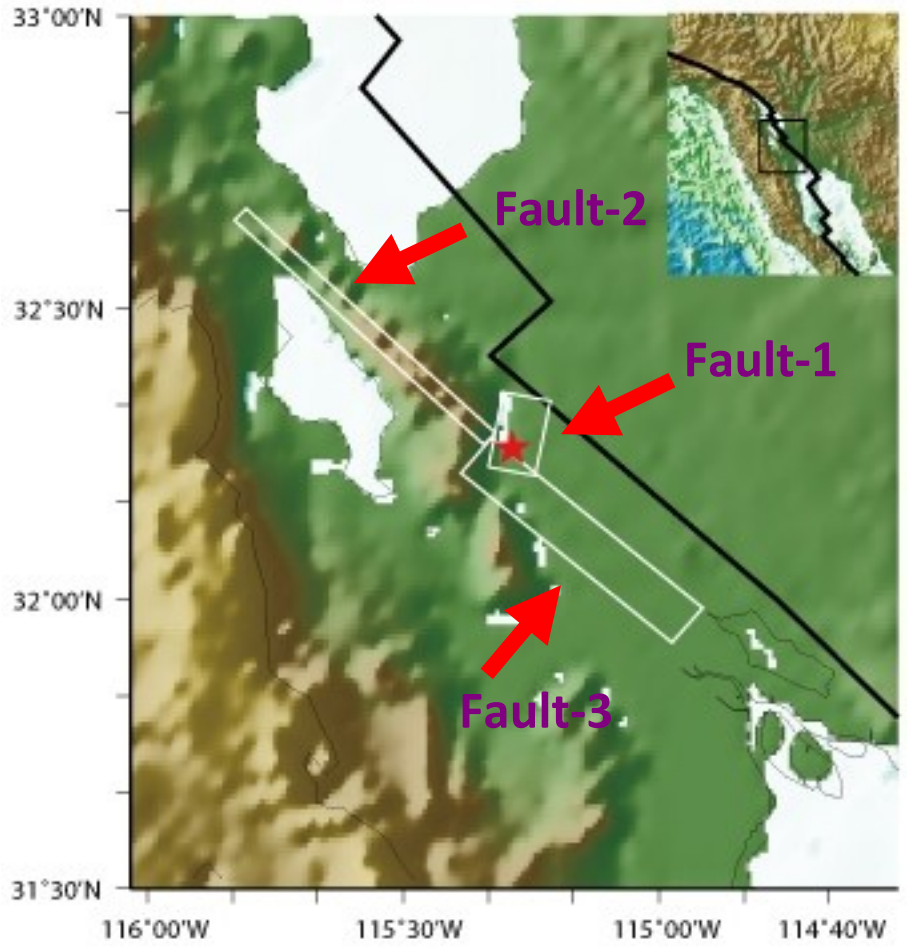


M>2.5 aftershocks

Anti-correlation between slip distribution and aftershock location

Zhao et al. rupture model: Fault geometry

Preferred Three-segment Fault Model			
	Strike	Dip	Rake
Fault-1	11	57	240
Fault-2	312	75	236
Fault-3	132	68	236

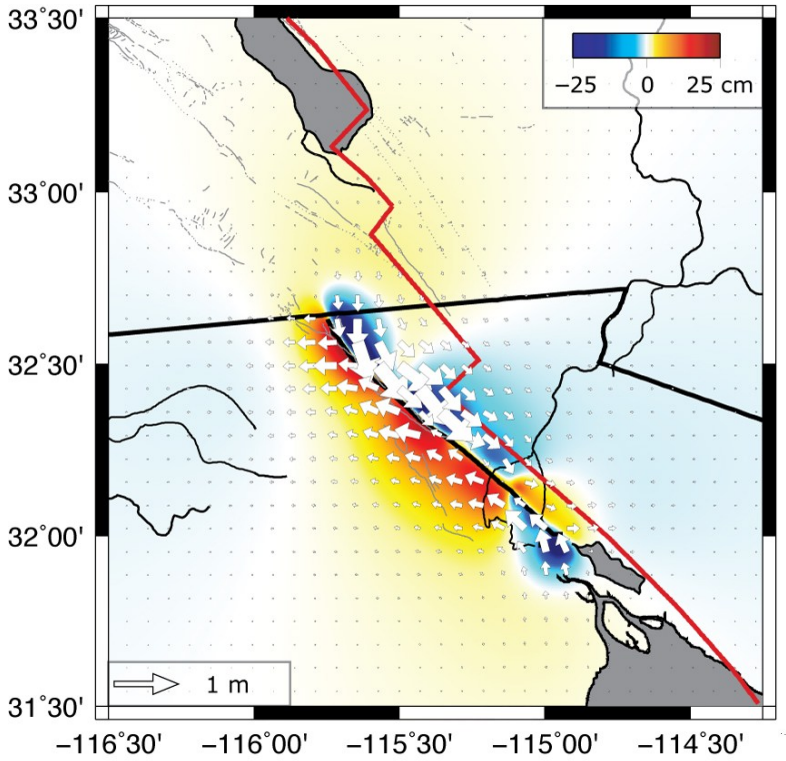


Xu Zhao, Guangfu Shao, Chen Ji, Kristine Larson,
Ken Hudnut, Tom Herring

Zhao et al. rupture model: Slip distribution

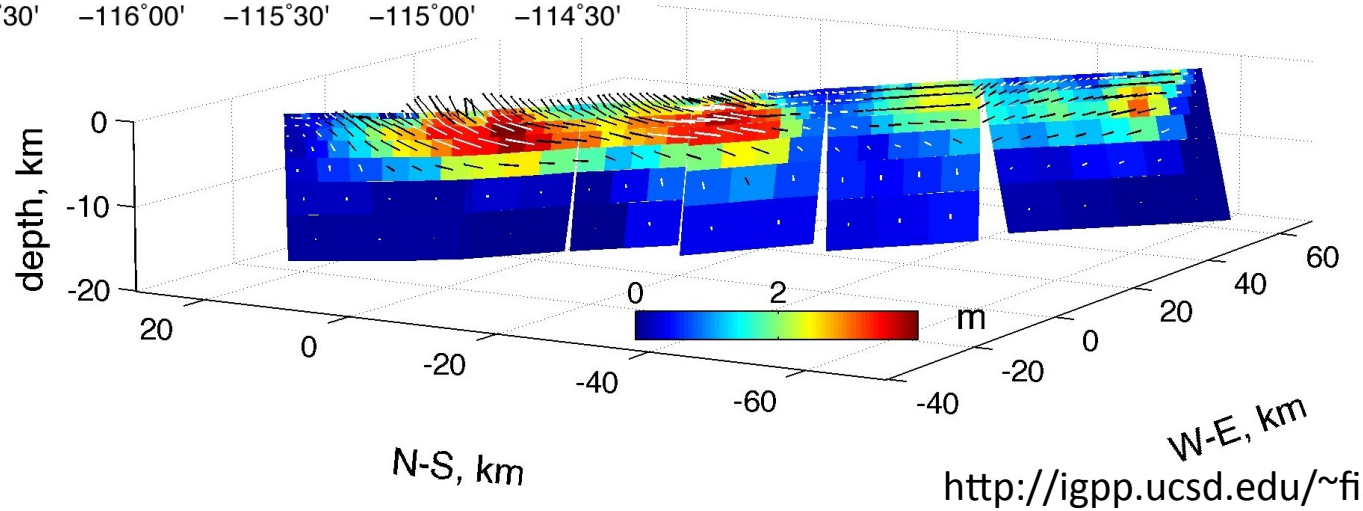
Zhao et al.

Fialko and Barbot model: Slip distribution, surface displacements



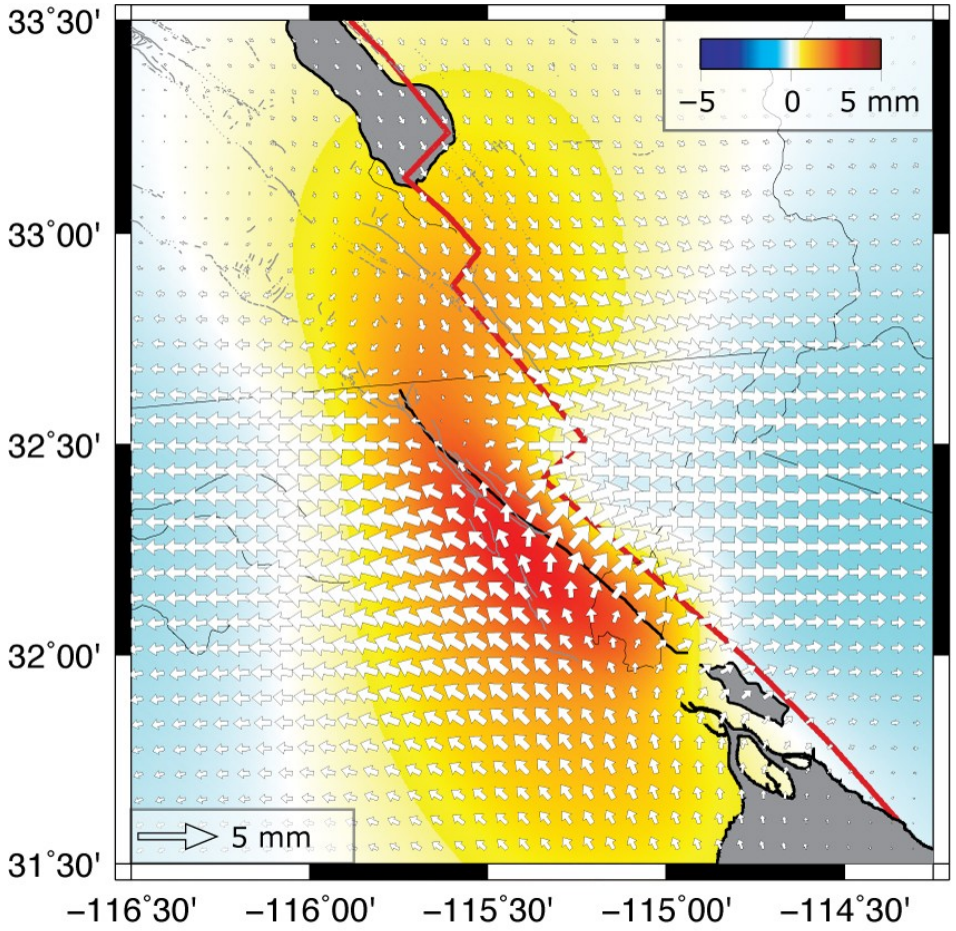
Coseismic surface displacements using the slip model of Y. Fialko inferred from inversion of InSAR and GPS data.

http://www.its.caltech.edu/~sbarbot/elmayor.html



http://igpp.ucsd.edu/~fialko/baja.html

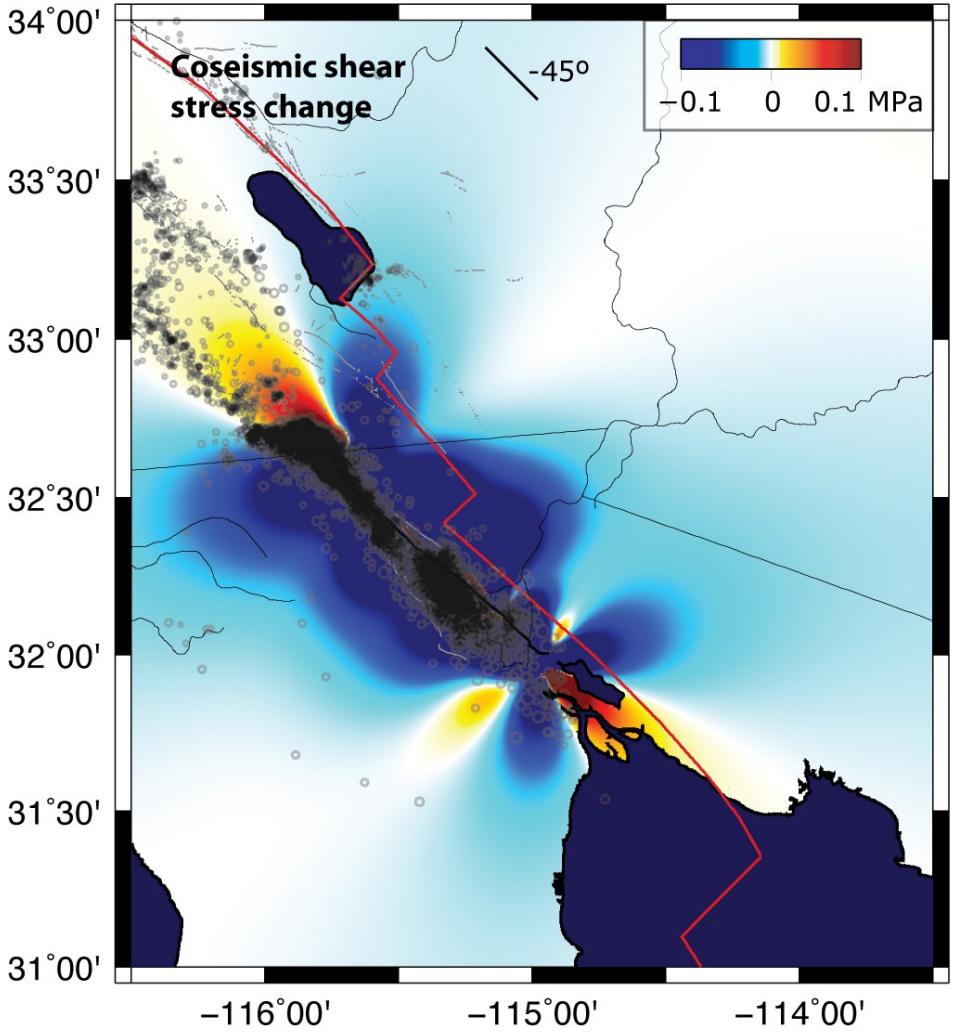
Fialko and Barbot model: Postseismic deformation (0.1 relaxation times)



The lithosphere model includes a weak horizon between 25 and 30 km depth at the bottom of the lower crust and a viscous substrate below 50 km depth in the upper mantle. The map view corresponds to cumulative surface displacements after 0.1 relaxation times. The expected postseismic deformation is significant around the Salton Sea area and may greatly affect the seismic hazard in this area.

http://www.its.caltech.edu/~sbarbot/elmayor.html

Fialko and Barbot model: Static stress change

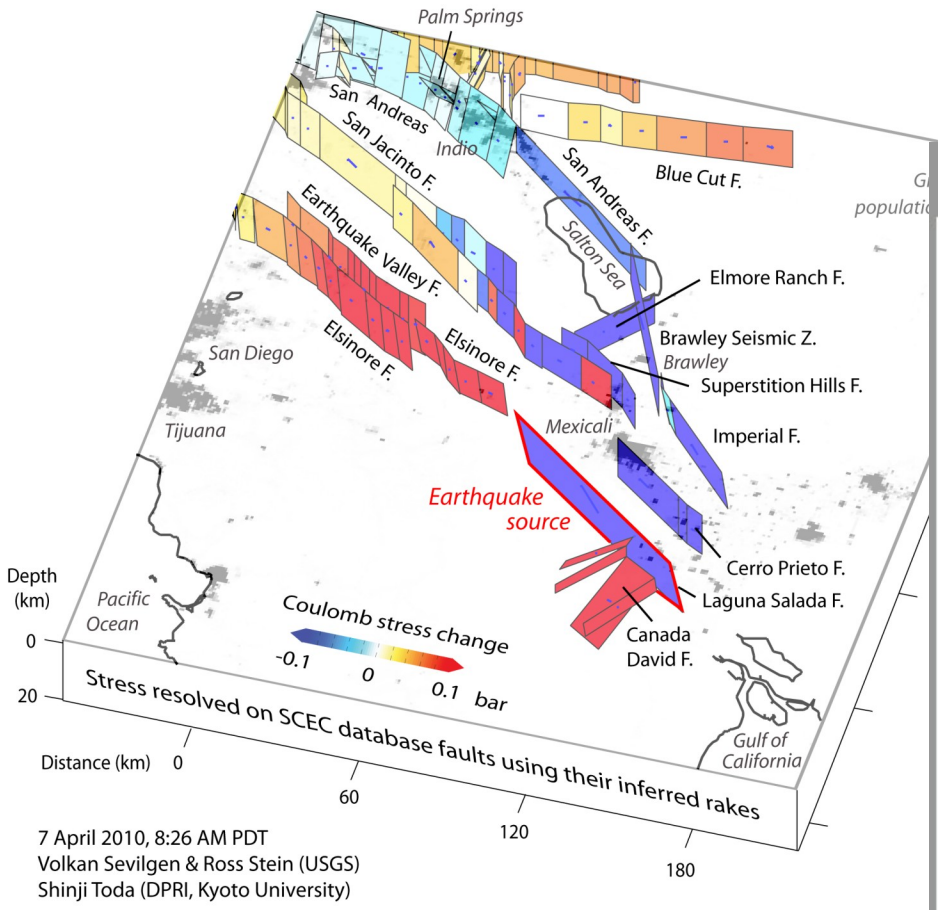


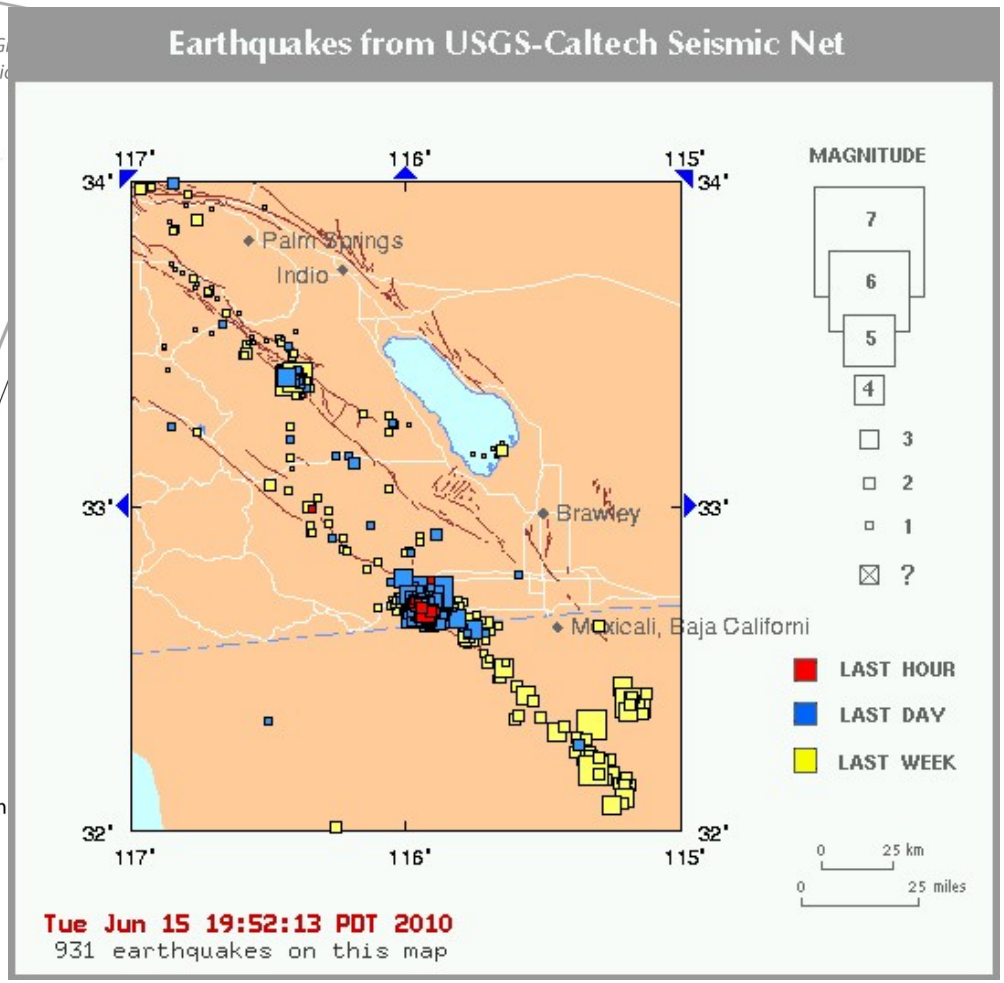
Coseismic stress change projected along the strike direction of a hypothetical vertical fault striking -45 degrees north, similar to active faults in the Salton Sea area.

The coseismic stress calculation indicates that the El Mayor earthquake added right-lateral shear stress on the Elsinore and the Coyote Creek faults but unloaded the San Andreas fault around the Salton Sea area.

http://www.its.caltech.edu/~sbarbot/elmayor.html

Mw 5.7 aftershock (14 June) at south end of Elsinore fault





Summary

•Several meters of surface slip extends along multiple faults 60 km NW of epicenter. Sub-pixel tracking key to guiding field efforts.

•Several meters of far field deformation extends 50 km SE of epicenter, and coincides with zone of extensive liquefaction at surface. Unraveling primary tectonic and secondary shaking signals will be challenging.

•Deformation SE of epicenter is apparently coseismic. Source is complicated because of delay between onset and energetic sub-events. Seismology key because InSAR repeat passes too infrequent.

•Disruption to agriculture, especially to irrigation water systems has been estimated at $91M north of border; US Presidential Major Disaster Declaration. South of border, damage is extensive throughout Colorado River Delta region. Wheat crop endangered (>$18 M lost of $165M crop). B.C. agriculture yields $9.3B/yr.

John Fletcher

Concluding thoughts

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Welcome to GEO's Baja California (Sierra El Mayor), Mexico, Event Website

GROUP ON EARTH OBSERVATIONS

esa

JAXA

Sections

SAR, Creep, Visible, GPS, Strain , Earthquakes, Links

http://supersites.unavco.org/baja.php

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welcome to the scsn

M_w 7.2 Sierra El Mayor Earthquake

(Northern Baja California Earthquake)

http://www.scsn.org

2010.04.04 - El Mayor - Cucapah Earthquake

View Edit Tags

Tags: baja california el mayor - cucapah laguna salada mexico sierra el mayor

The magnitude 7.2 El Mayor - Cucapah earthquake of Sunday April 4th 2010, occurred in northern Baja California, approximately 40 miles south of the Mexico-USA border at shallow depth along the principal plate boundary between the North American and Pacific plates. This is an area with a high level of historical seismicity, and also it has recently been seismically active, though this is the largest event to strike in this area since 1892. The 4 April earthquake appears to have been larger than the M 6.9 earthquake in 1940 or any of the early 20th century events (e.g., 1915 and 1934) in this region of northern Baja California. See full summary by USGS.

From Greg Beroza:

As of 8:15pm PDT on Monday, April 5th, 2010, the earthquake has been christened the Sierra El Mayor earthquake. SCEC geologists and geodesists are in the field now, to be followed tomorrow (Tuesday, April 6th) by seismologists. Surface rupture appears to extend across Highway 2, south of the border. Ken Hudnut is

LiDAR data for N. Baja, Mexico in Google Earth: pre-M 7.2 El Mayor - Cucapah earthquake

SHARE

Posted on Tue, May 04, 2010 by C. Crosby in 2010 Baja EQ • Data • Google Earth

Thanks to a close collaboration with OpenTopography colleague Alejandro Hinojosa at CICESE in Ensenada, Mexico, we have obtained 5 meter resolution LiDAR topography data for the epicentral region of the Sunday, April 4th 2010 magnitude 7.2 El Mayor - Cucapah earthquake in northern Baja, Mexico. These data, which cover an area of over 2,000 square kilometers southwest of Mexicali, were acquired in 2006 by the Instituto Nacional de Estadistica y Geografia (INEGI), a Mexican government agency. We've been told that these data were collected from an elevation of 6000 m with GSD of 10 to 12 meters.