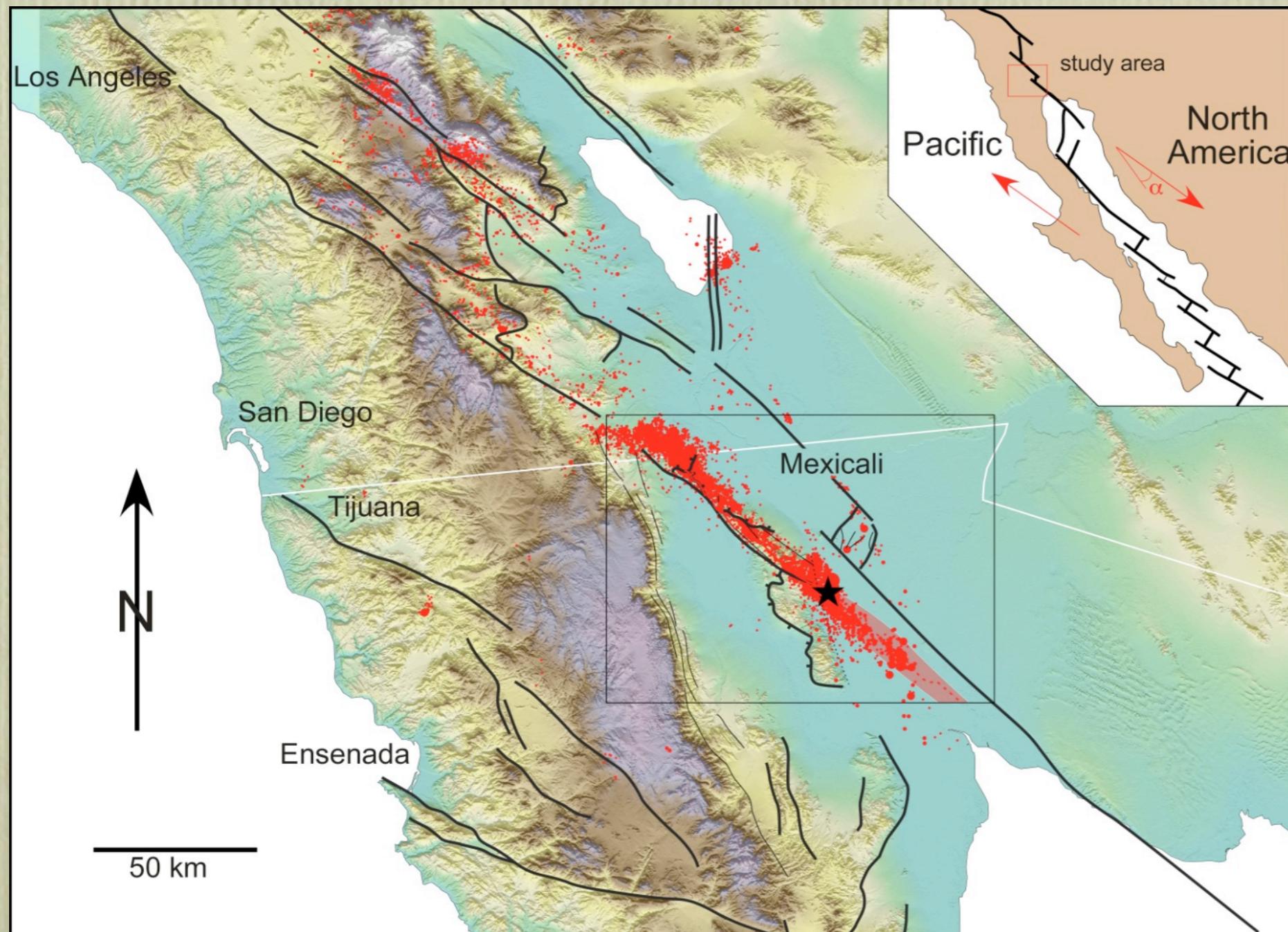


Imaging Recent Complex Earthquake Ruptures with Combined InSAR and Seismic Analysis

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Agram, Mark Simons, Sang-Ho Yun, Walter Szeliga
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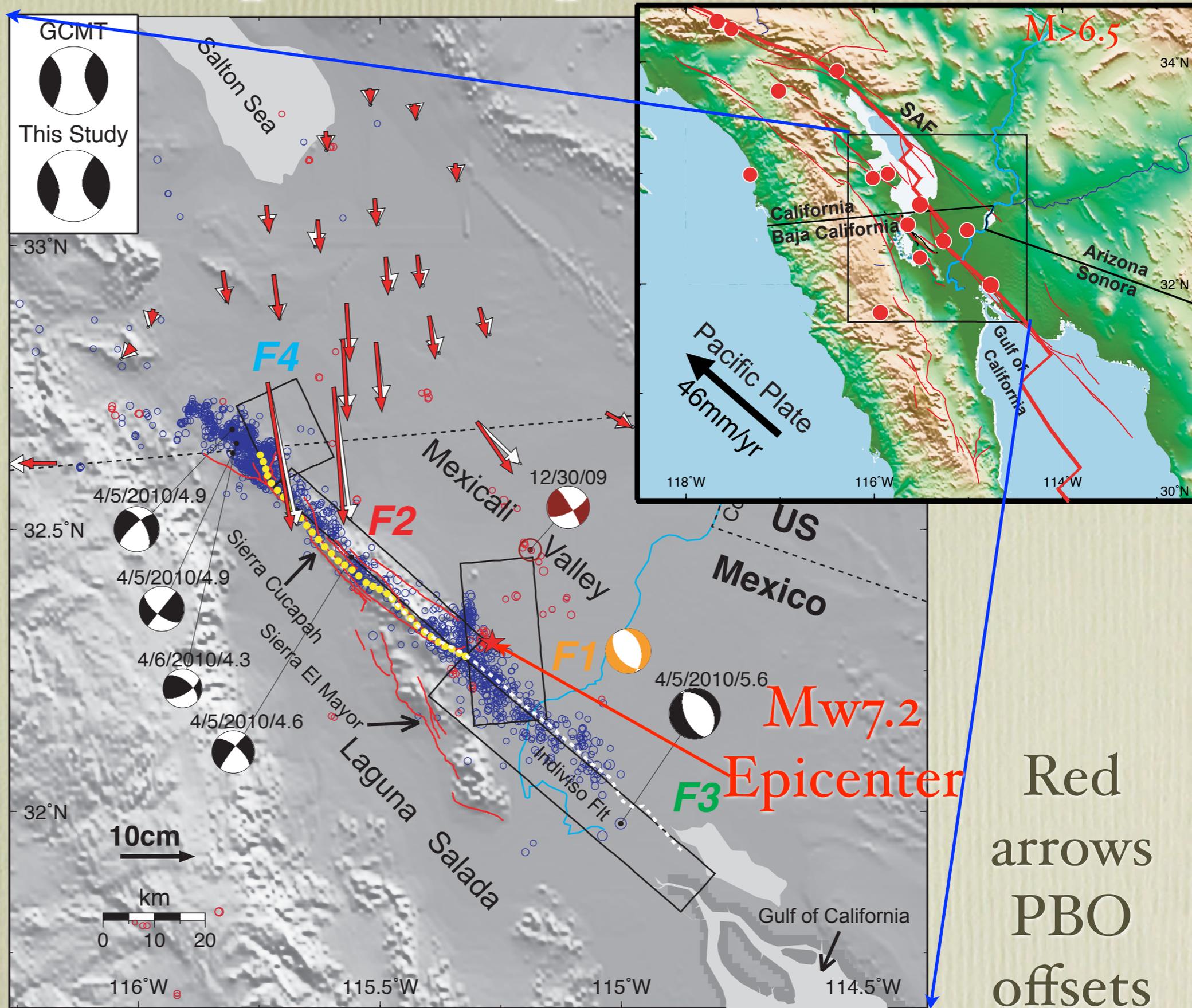
Baja California Earthquake (John Fletcher, CICESE)



- M_w 7.2 earthquake April 4, 2010 3:40 p.m. (local time)
- Epicenter located in Mexicali Valley, Baja California
- Aftershocks extended both to southeast and northwest with many in U.S.
- Main surface rupture extends ~120 km
- Part of plate boundary system of faults

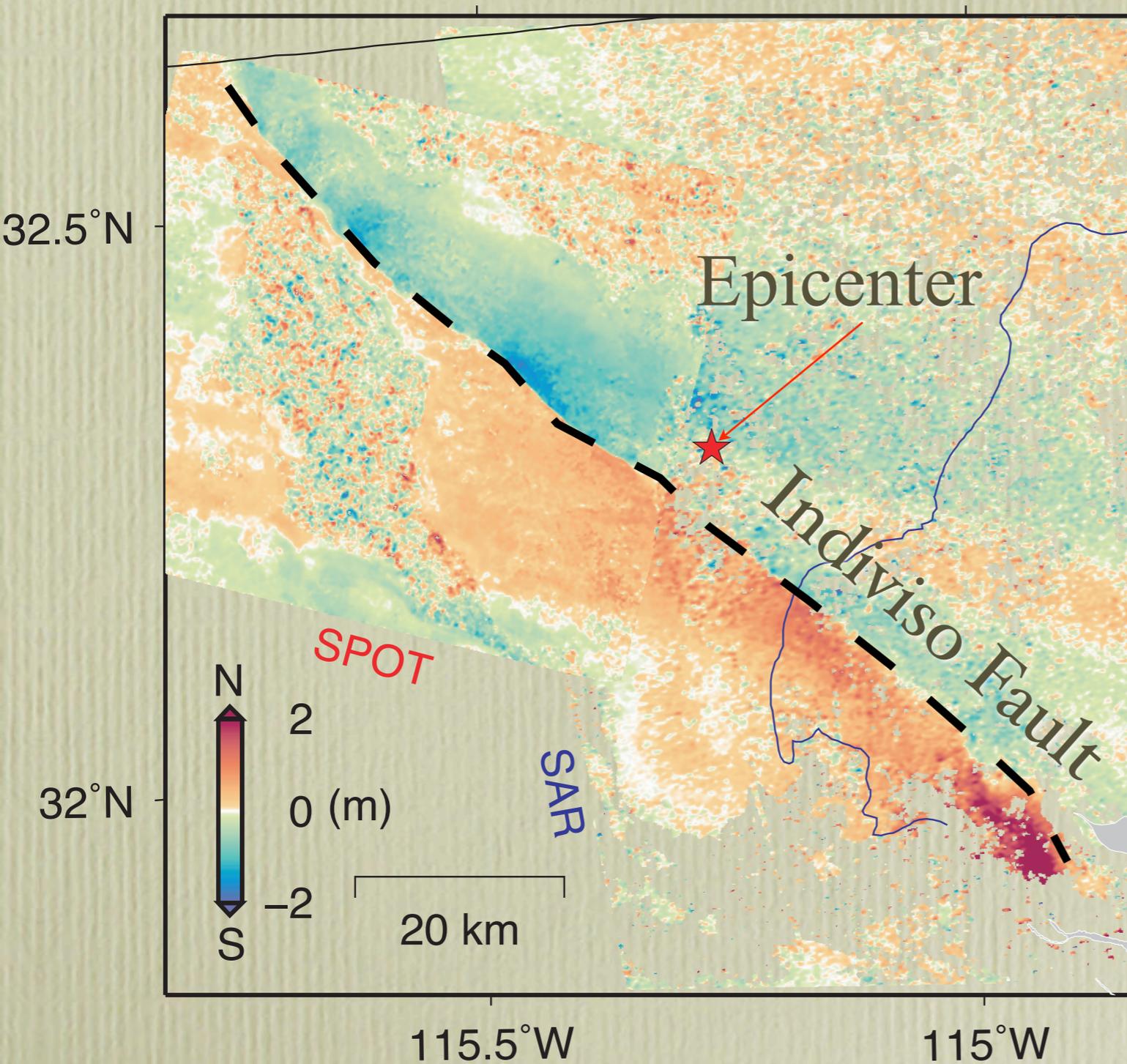
Complex Rupture

- part of plate boundary system
- Quake started with **M6 normal fault F1**
- aftershocks (blue) extended northwest and southeast



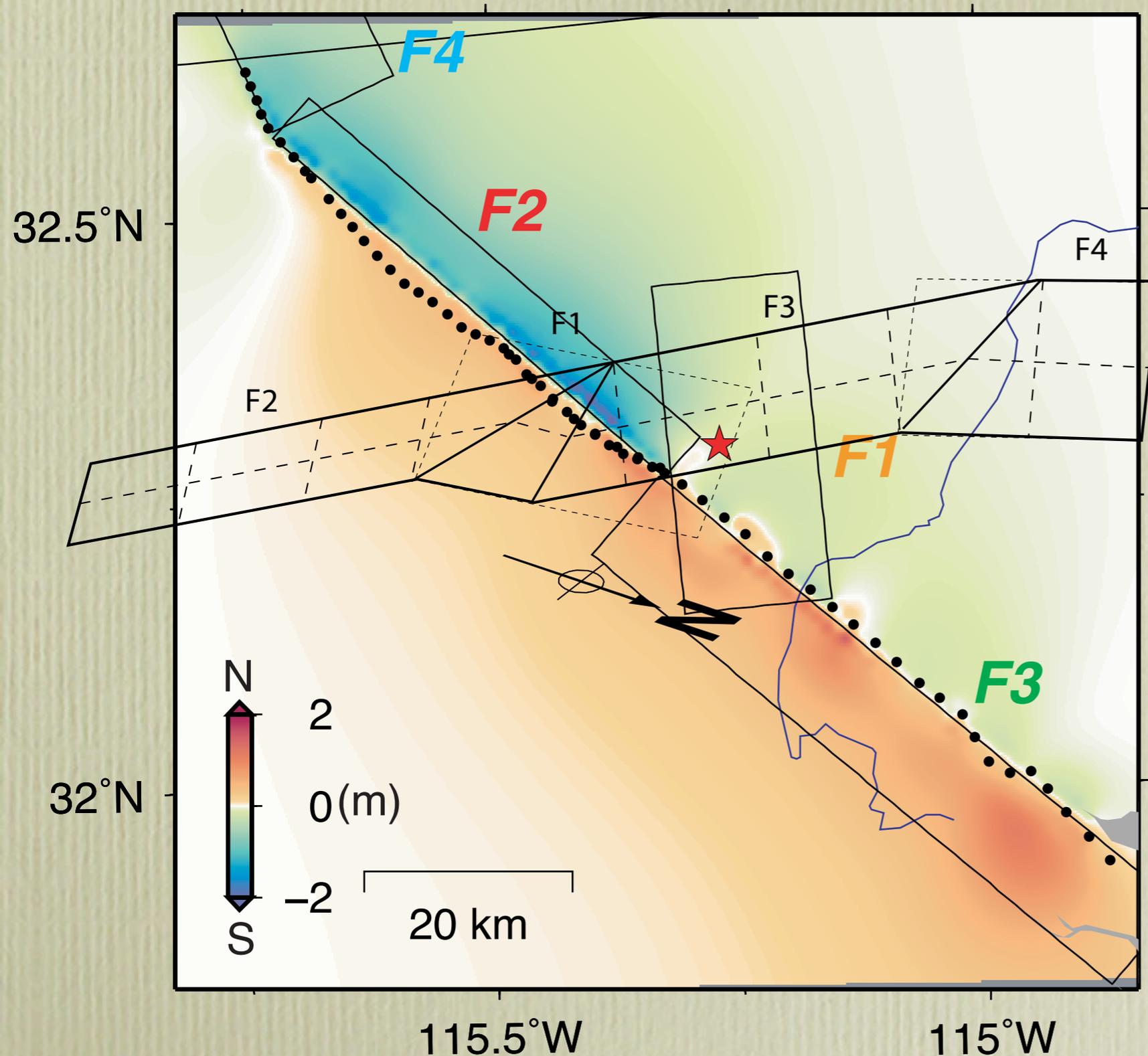
Red arrows
PBO offsets

SPOT & SAR pixel tracking



- Pixel tracking on ALOS SAR shows full length of rupture to SE
- Up to 3 m in along-track direction (~north) beneath Colorado River Delta
- New, previously unmapped “Indiviso Fault” (named by Javier Gonzalez) appears to be major part of plate boundary system

Four Fault Segments Model



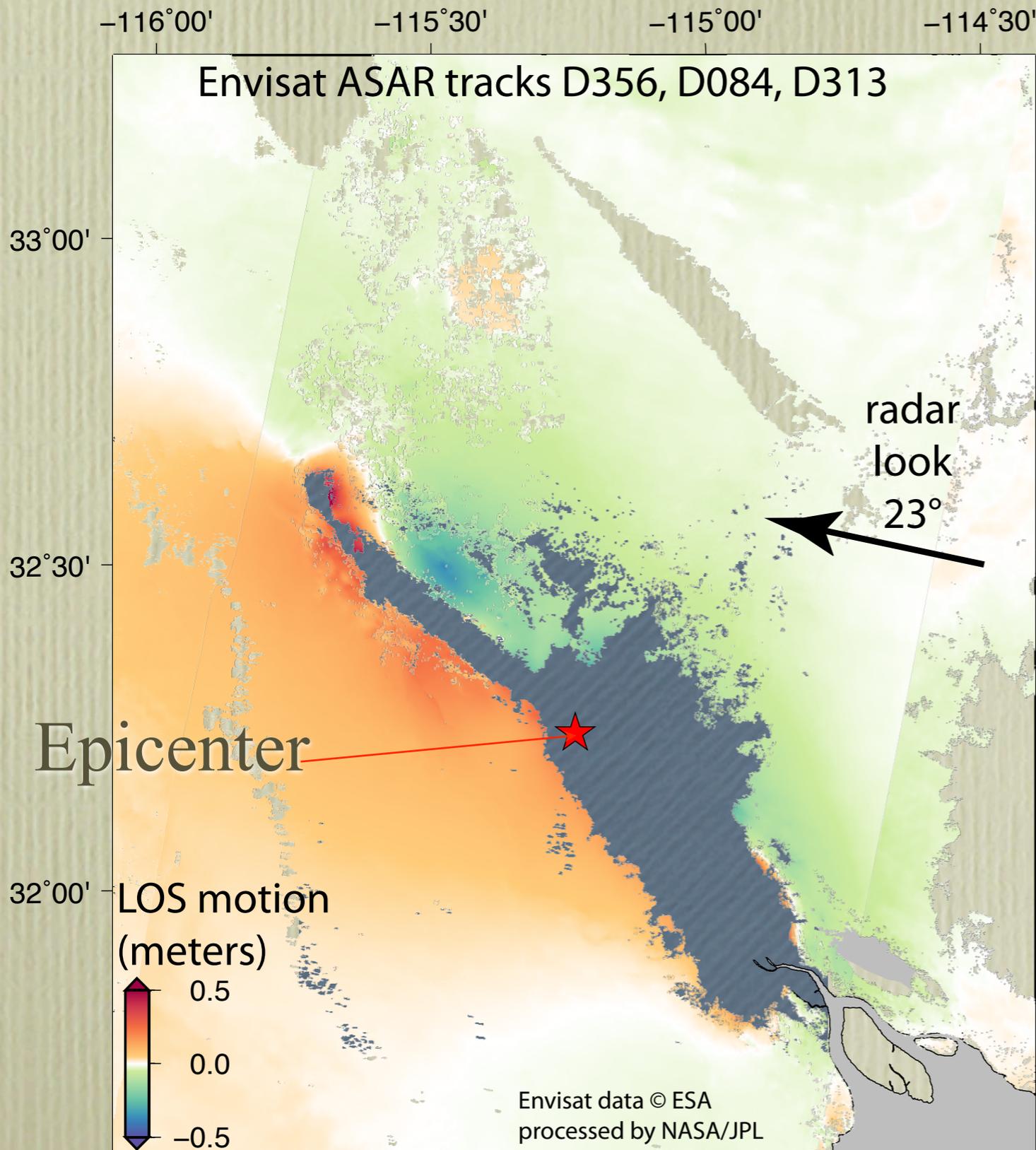
- F1 from nodal plane of first rupture
- F2 dips NE to fit down-to-east motion Sierra Cucapah
- F3 dips SW to fit down-to-west motion and larger north motion west of Indiviso Fault
- F4 dips east under Centinela Peak to fit InSAR
- Final model prediction matches offset data

Envisat InSAR

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

Envisat data from Supersite and WInSAR

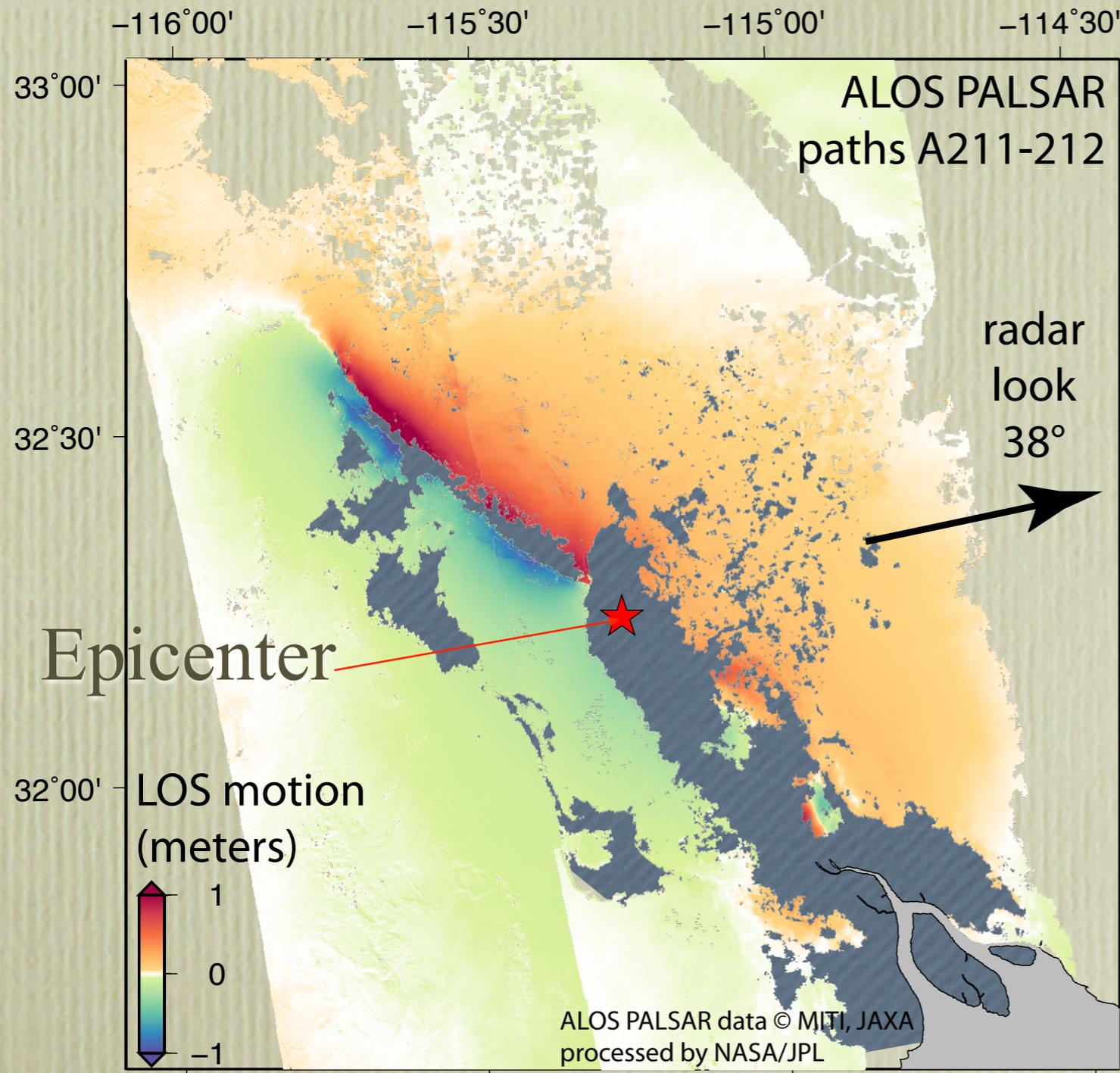


ALOS InSAR

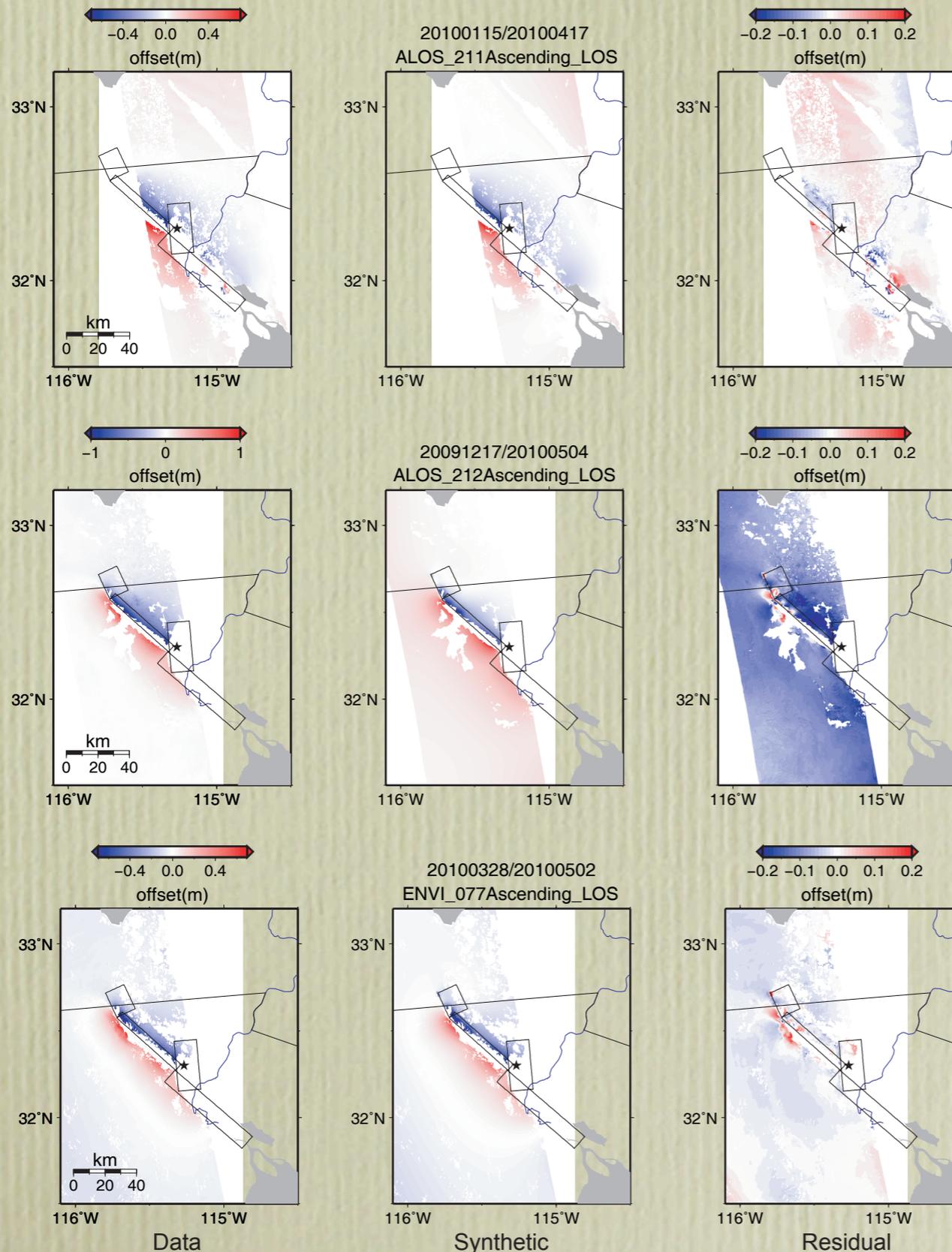
ALOS (23.5 cm) ascending shows oblique slip NW, down to the west block at SE end

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

ALOS data from ASF US Gov. Research Consortium WInSAR project

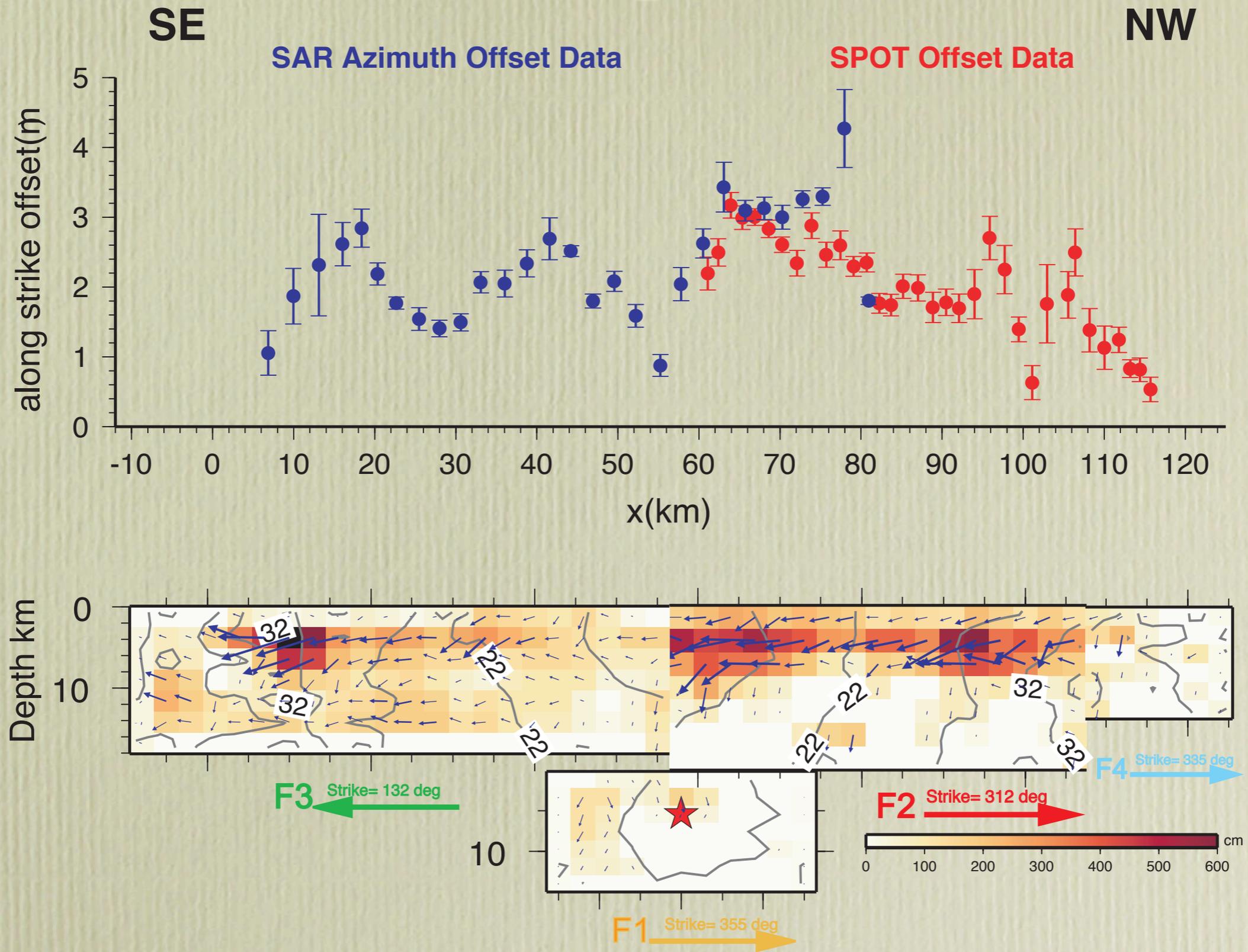


Joint Geodetic-Seismic Inversion



- Fit to InSAR (Envisat, ALOS: 5 Asc, 4 Desc), PBO GPS, pixel offsets from profiles
- Teleseismic waveforms
- Fault slip evolution model 3 x 3 km subfaults
- Simulated annealing modified Chen Ji code

Kinematic Fault Slip Evolution Model



Wei, S., Fielding, E.J., Leprince, S., Sladen, A., Avouac, J.-P., Helmberger, D.V., Hauksson, E., Chu, R., Simons, M., Hudnut, K.W., Herring, T. & Briggs, R.W., 2011. Superficial simplicity of the 2010 El Mayor-Cucapah earthquake of Baja California in Mexico, *Nature Geosci*, 4, 615-618.

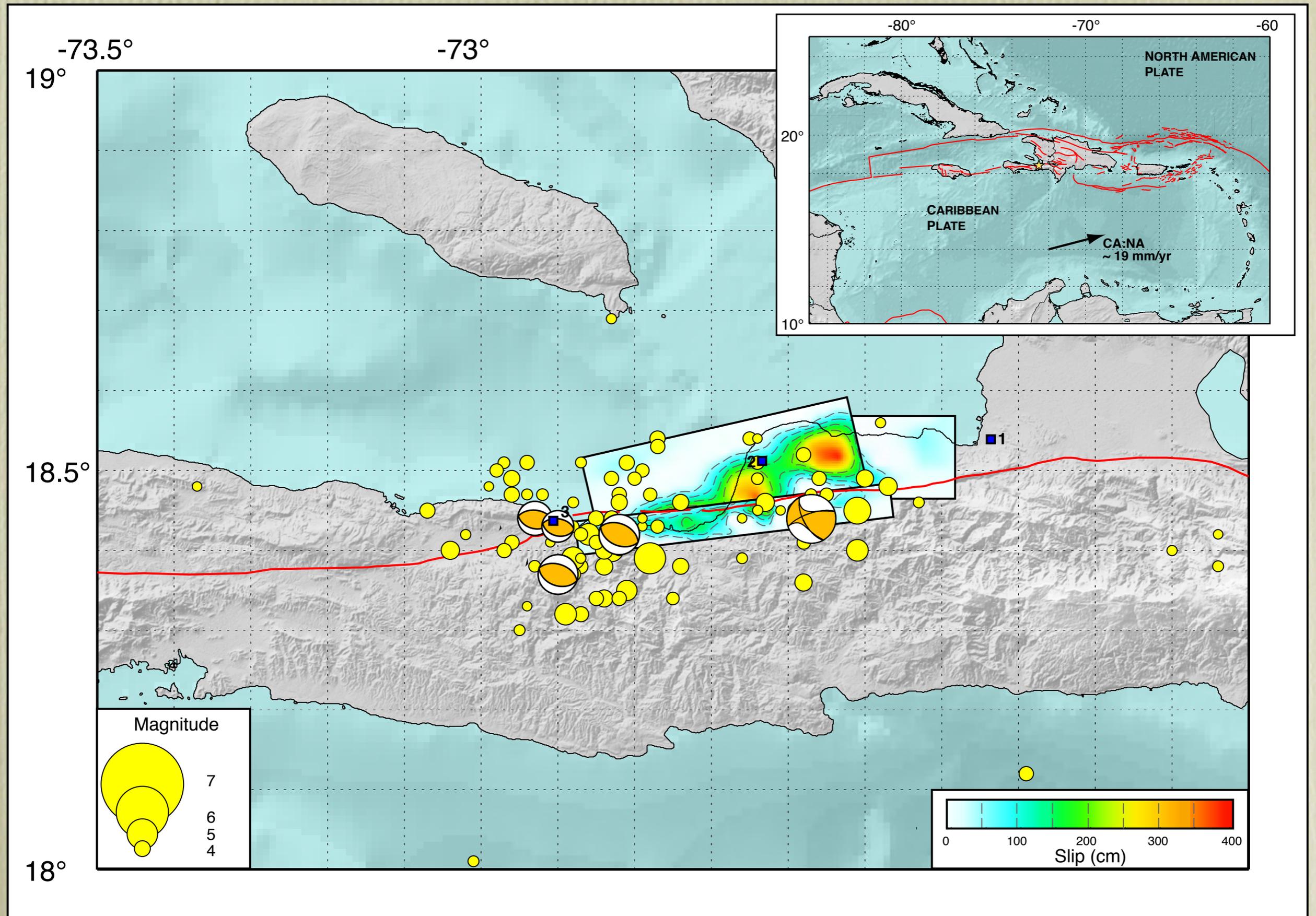
Conclusions

- Main fault ruptures extended about 120 km
- New Indiviso Fault runs beneath Colorado River Delta, may have blocks with tilts in different directions
- Near-linear surface trace over extensional jog at depth near epicenter—M6.3 event started M7.2
- Complex ruptures in many places may indicate low maturity of the fault system, more like Landers than San Andreas earthquakes
- Zone between Elsinore Fault and Laguna Salada Fault had deep slip in June–July, including M5.7

January 2010 Haiti Earthquake

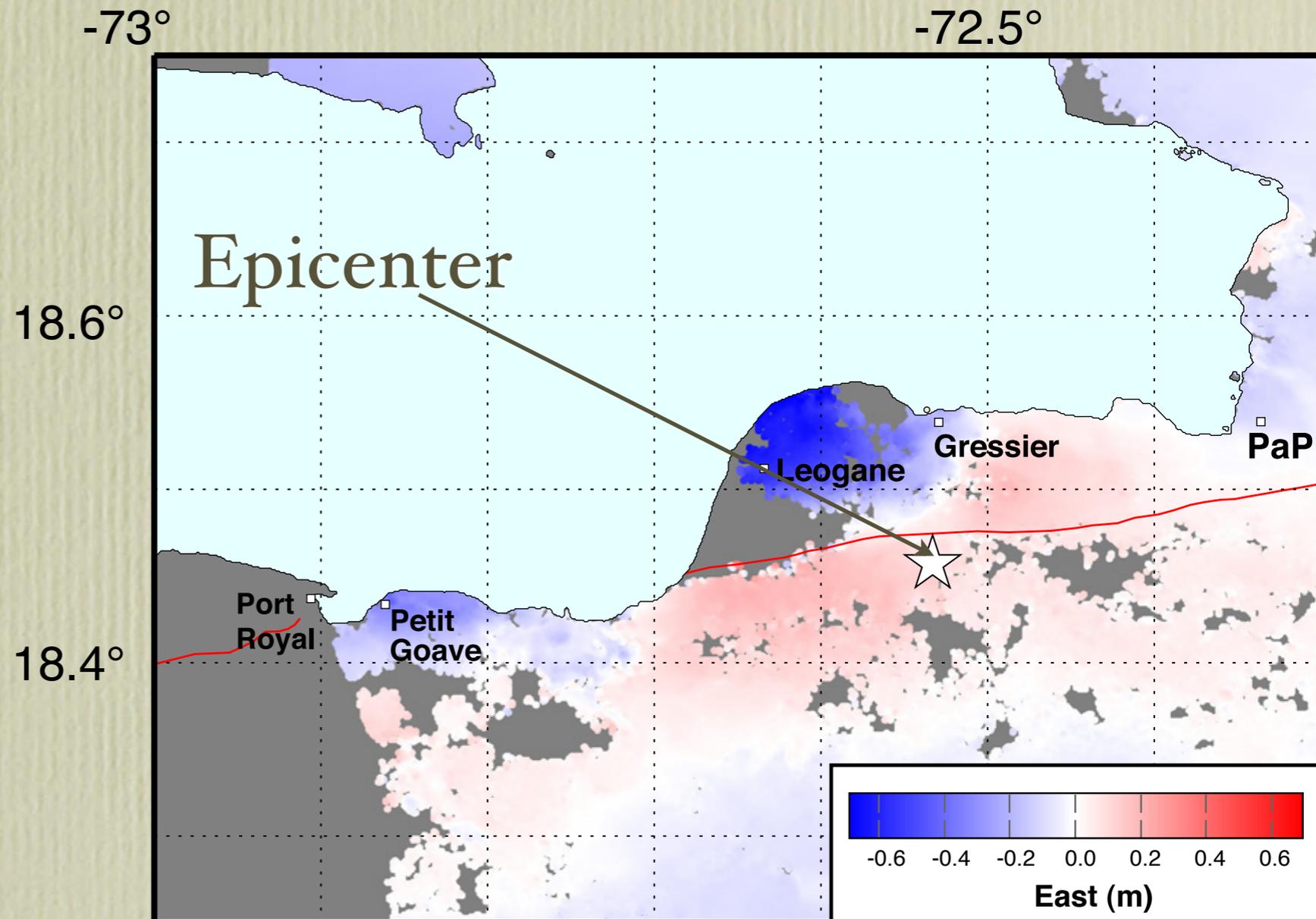
- January 12, 2010 at 4:53 PM local time
- M_w 7.0
- oblique strike-slip mechanism, but significant non-double-couple component
- epicenter 25 km southwest of Port-au-Prince
- more than 100,000 fatalities

Haiti earthquake & aftershocks



SAR interferometry–East

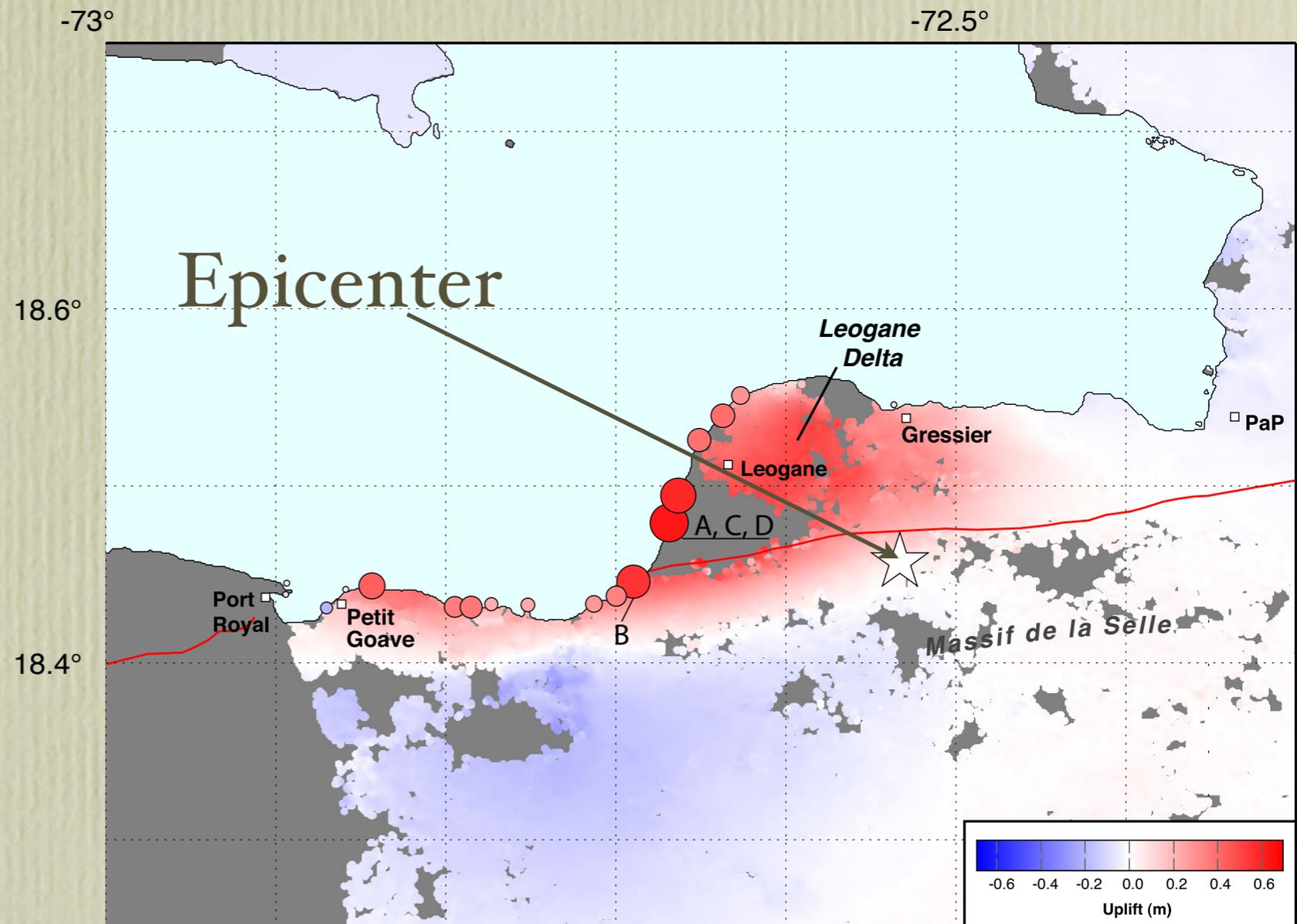
- difference of two ALOS PALSAR look directions gives estimate of east motion
- nearly all of 12 Jan. rupture west of epicenter, so fault zone near Port-au-Prince unruptured
- rupture appears different from previously mapped Enriquillo fault zone (red line)



ALOS data from JAXA via GEO Supersite
and ASF US Gov. Research Consortium

SAR interferometry—vertical

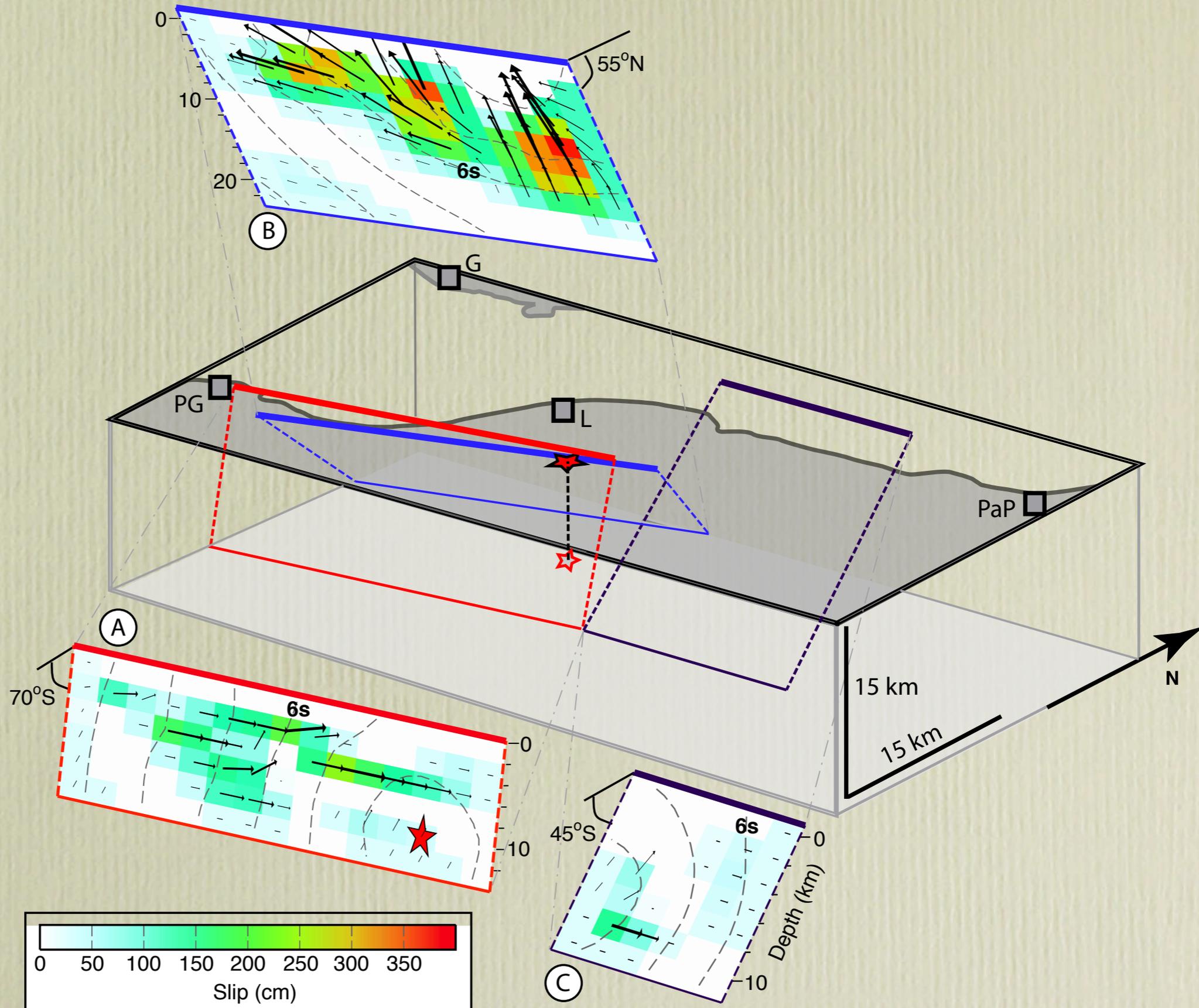
- combination of two radar look directions gives estimate of uplift (with a little south)
- uplift extends across Enriquillo fault zone, strongest south of Léogâne
- InSAR confirmed by coral uplift (circles)
- fault geometry complex, with thrust faults overprinting strike-slip



Hayes, G.P., Briggs, R.W., Sladen, A., Fielding, E.J., Prentice, C., Hudnut, K., Mann, P., Taylor, F.W., Crone, A.J., Gold, R., Ito, T. & Simons, M., 2010. Complex rupture during the 12 January 2010 Haiti earthquake, *Nature Geosci*, doi:10.1038/ngeo1977.

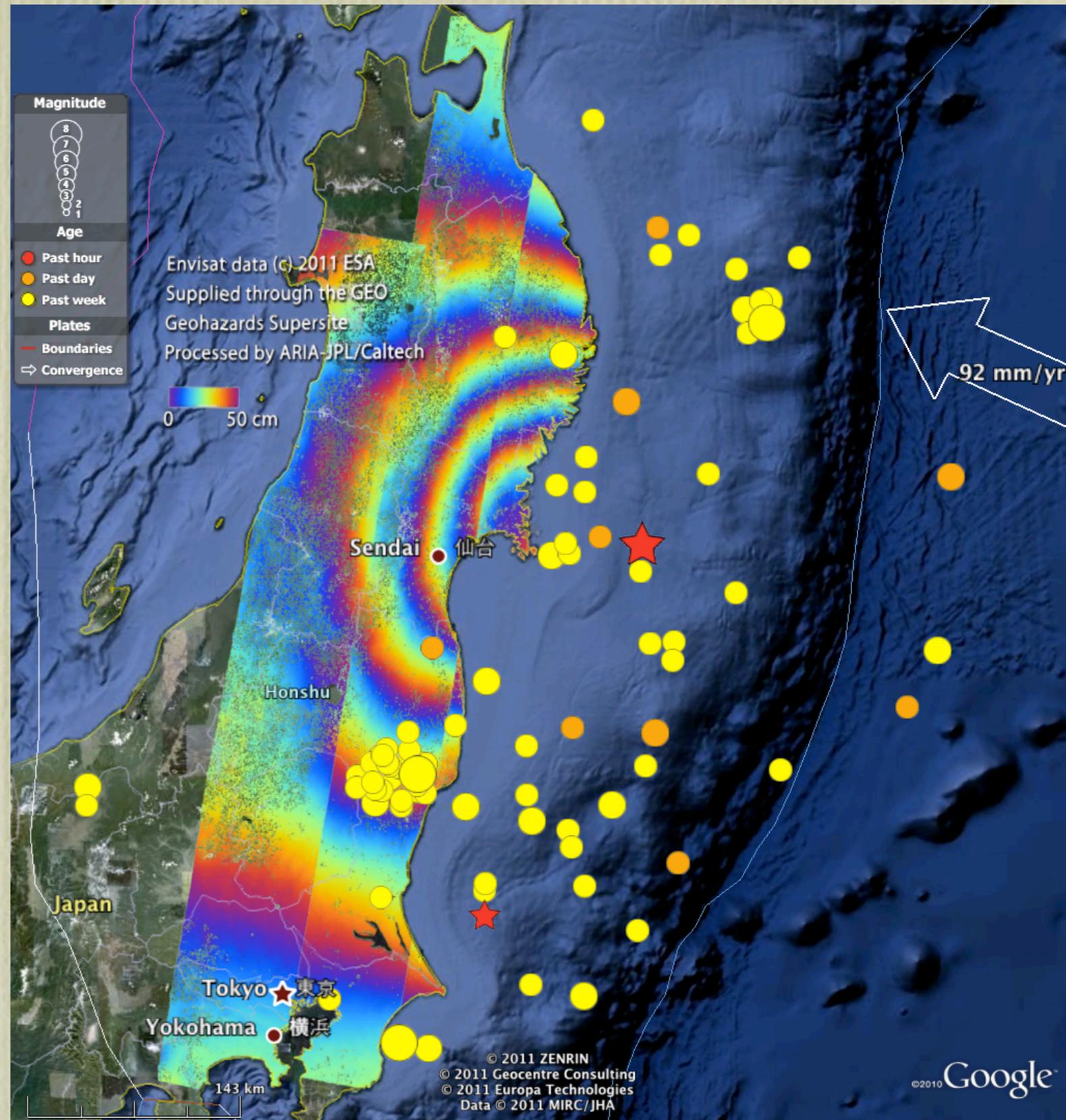
Fault Slip Evolution Model

- At least two and probably three faults ruptured
- Started on Enriquillo Fault
- Majority of slip on north-dipping Léogâne Fault
- Moment release over 15 sec



2011 Tohoku-oki earthquake

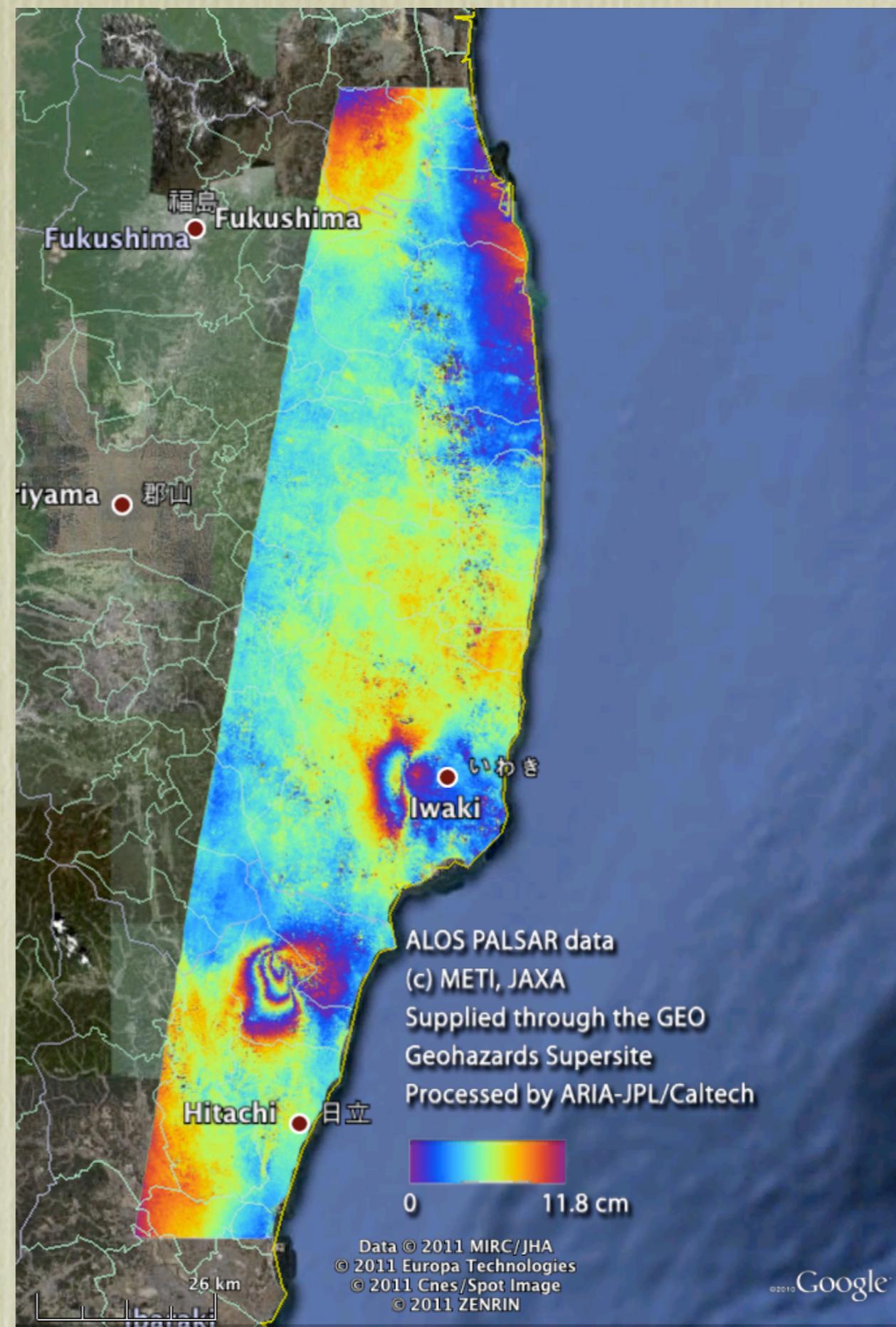
- Mw 9.1 largest in Japan probably for 1000 years
- Extensive destruction due to large tsunami
- >20,000 killed
- Many shallow aftershocks north of Tokyo
- Mosaic of Envisat rewrapped with 50 cm color cycles



Envisat from GEO Supersite

Tohoku-oki aftershocks

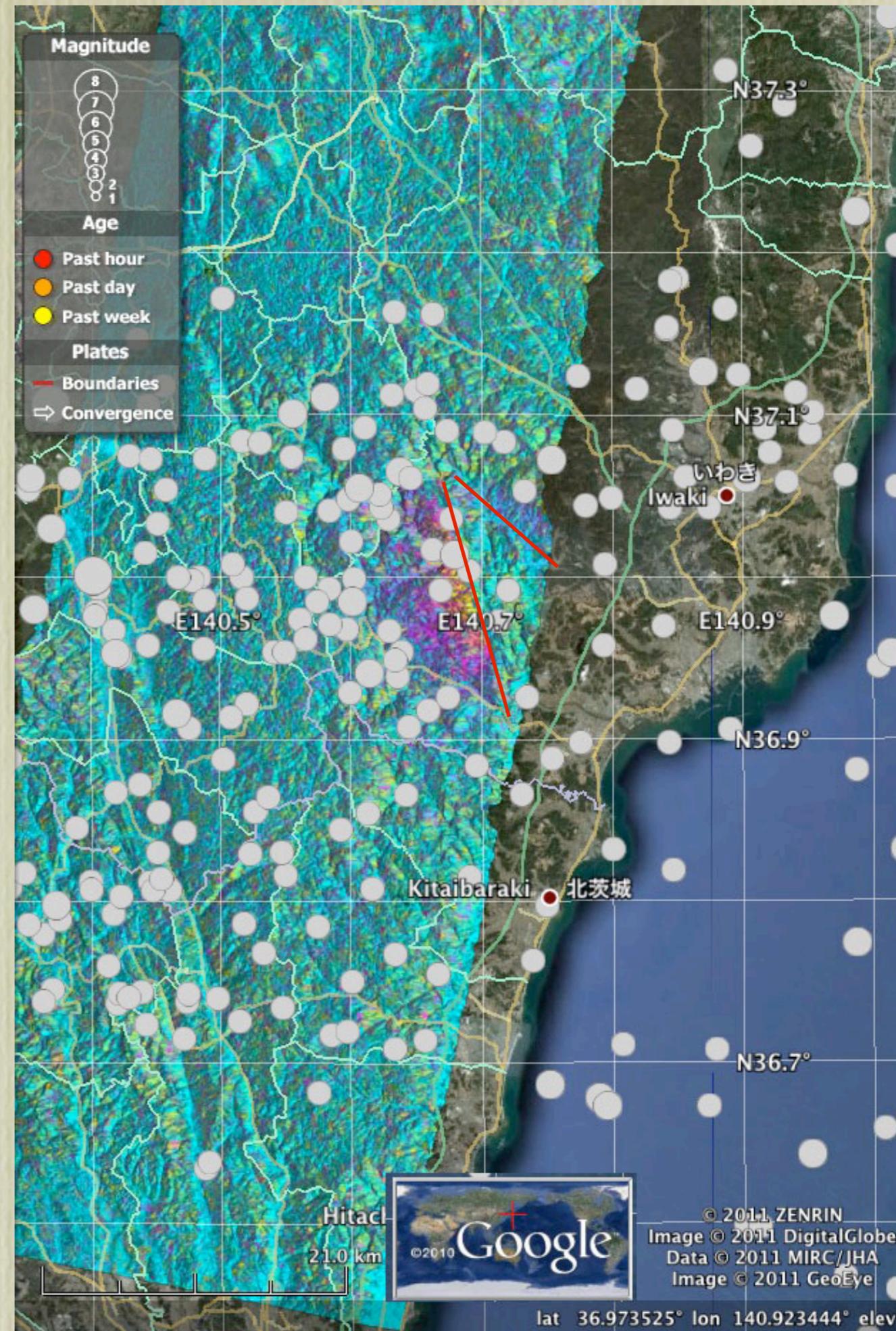
- Shallow aftershocks March 2011 up to M 6.1
- Normal fault mechanisms due to stress change of main quake
- ALOS 2010/11/20–2011/04/07
- remove long-wavelength deformation from M9 and M7.9 quakes



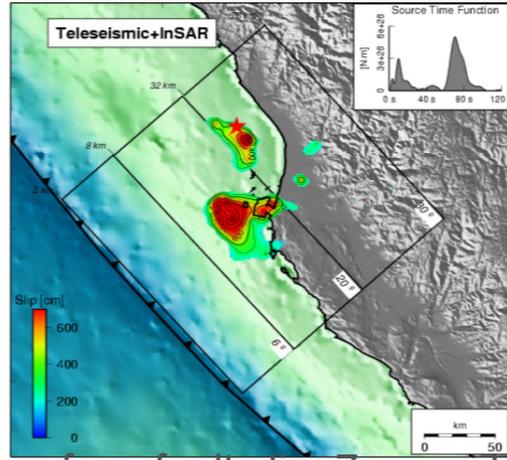
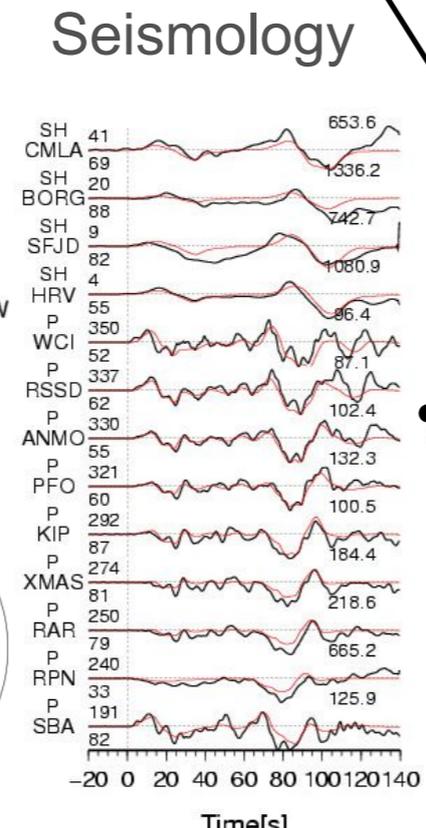
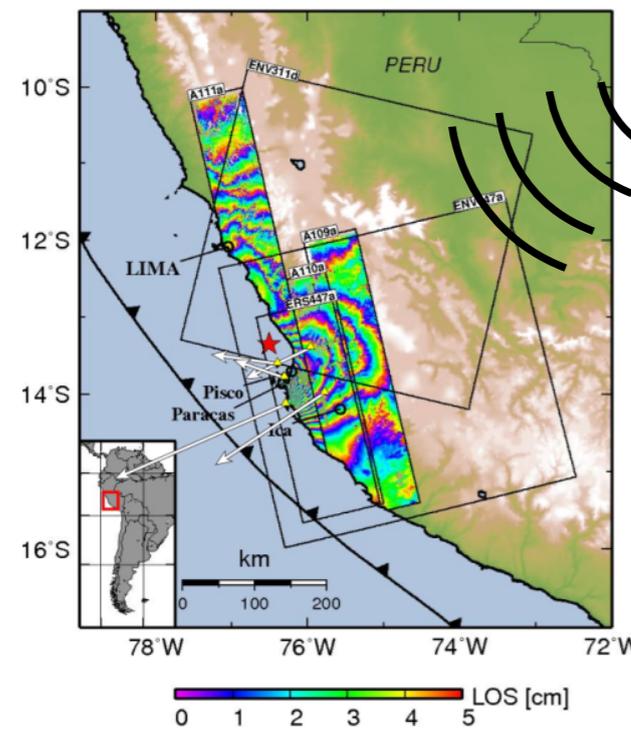
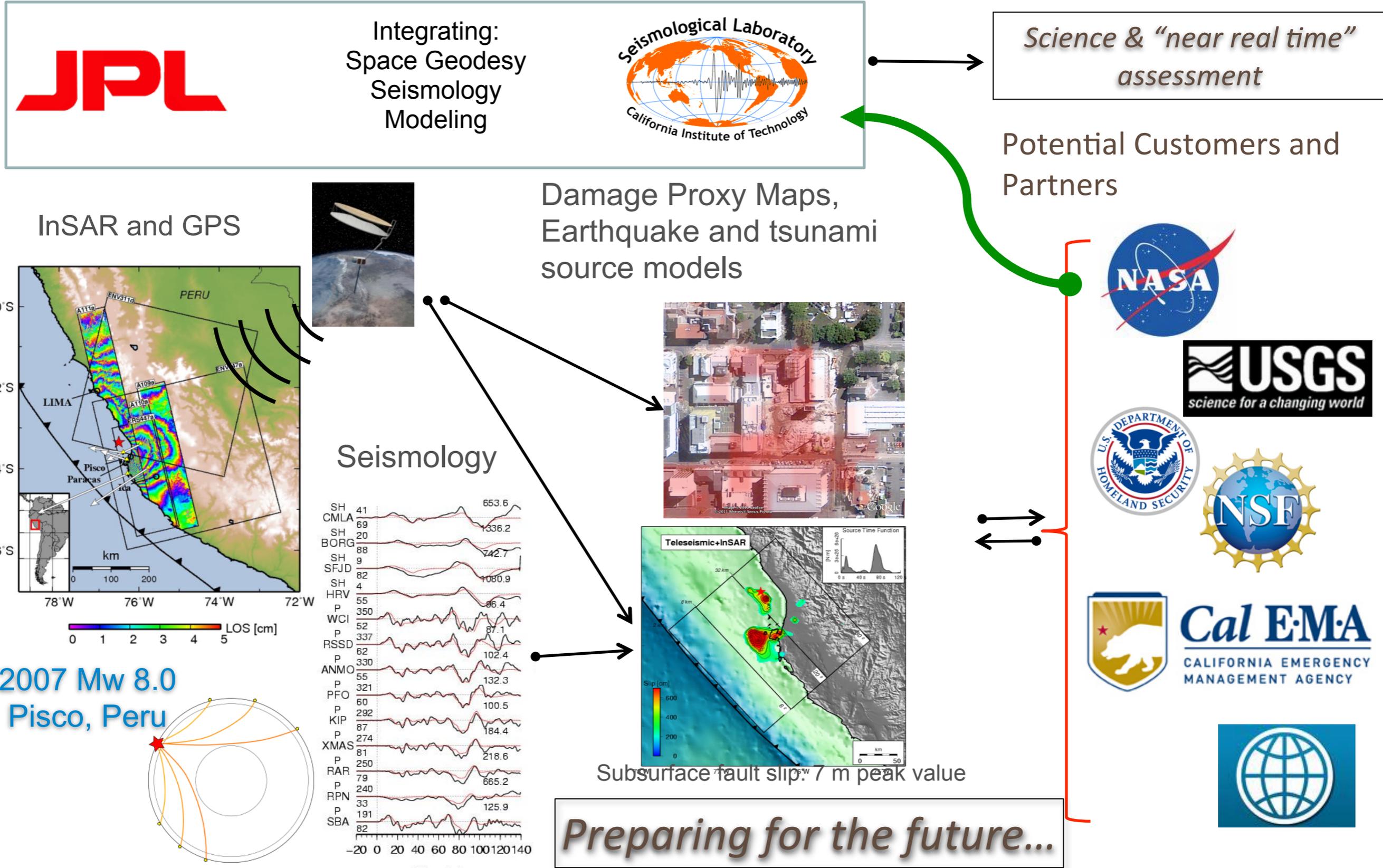
ALOS data from GEO Supersite

Tohoku-oki aftershocks

- Mw 6.6 shallow aftershock on April 11
- TerraSAR-X InSAR not coherent
- TSX pixel offset tracking effective
- total deformation in range 3 m
- two faults ruptured



The Advanced Rapid Imaging & Analysis (ARIA) Center for Natural Hazards



Preparing for the future...