



Observing multiscale temporal behavior on a megathrust: Transient behavior and the 2012 Mw7.6 seismic event

Rocco Malservisi¹ Susan Schwartz² Nick Voss¹ Marino Protti³ Victor Gonzales³ Timothy H. Dixon¹ Yan Jiang⁴ Andrew V. Newman⁵ Jacob I. Walter⁶ Jacob Richardson¹ Denis Voytenko¹

¹ University of South Florida, Tampa, USA.

² University of California Santa Cruz.

³ Observatorio Vulcanológico y Sismológico de Costa Rica, Universidad Nacional, Costa Rica.

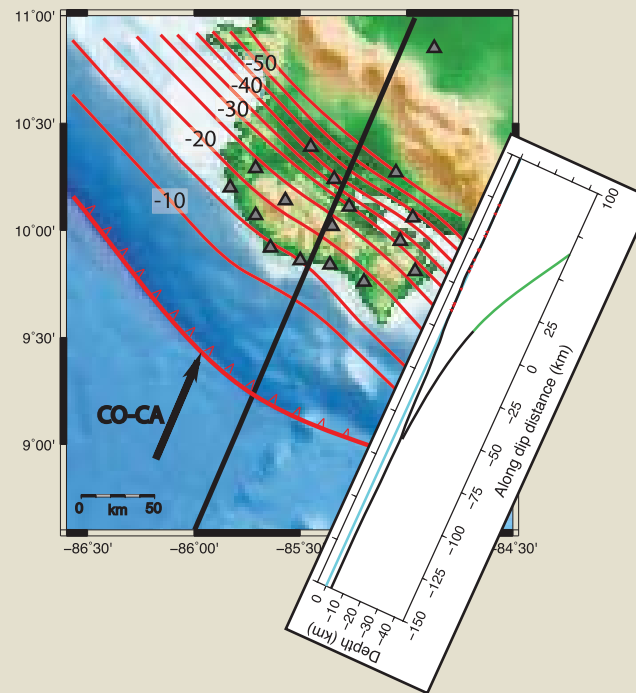
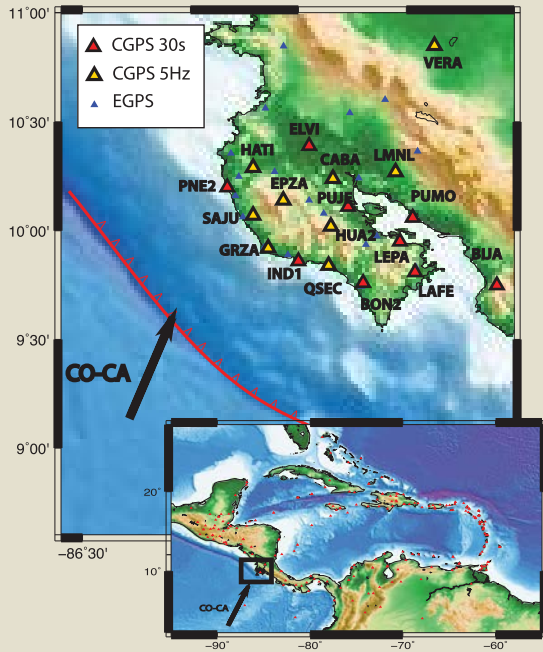
⁴ Pacific Geodetic Center, Canada.

⁵ Georgia Tech, Atlanta, GA, USA.

⁶ University of Texas Austin, USA.

The results presented here have been published on G3 in August 2015.

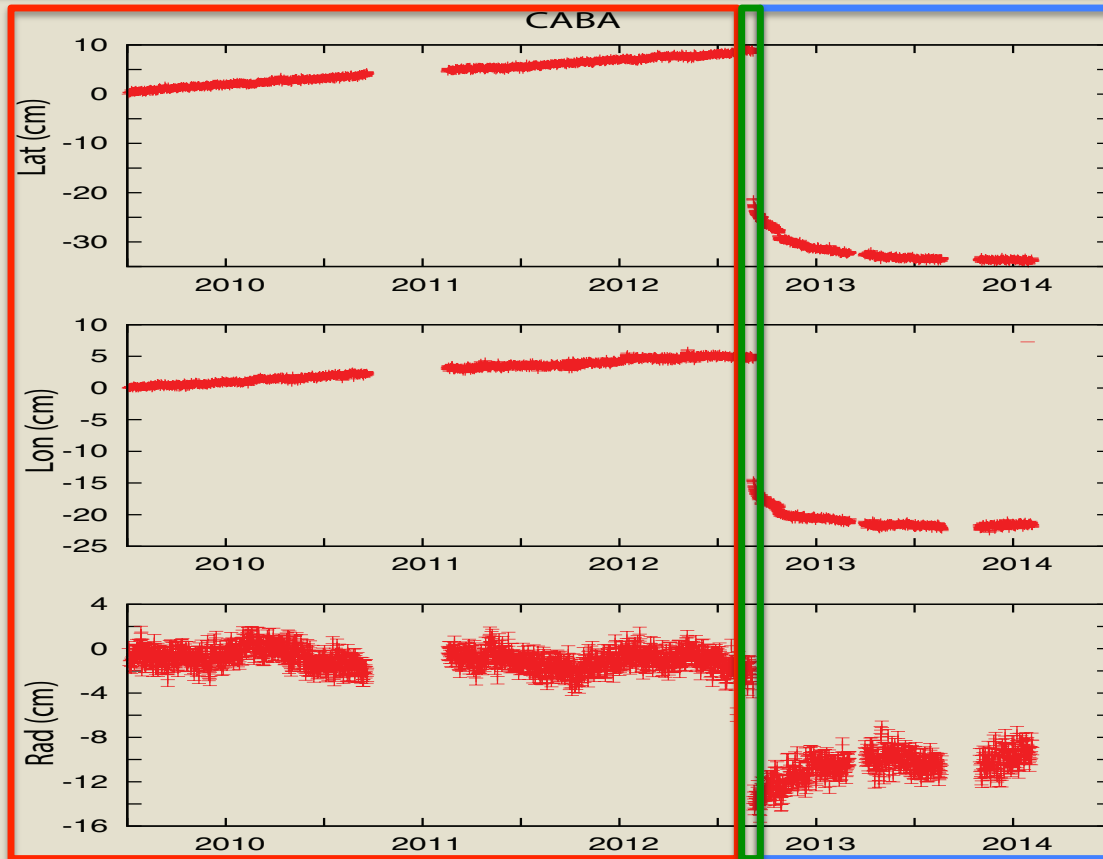
Nicoya Peninsula Costa Rica



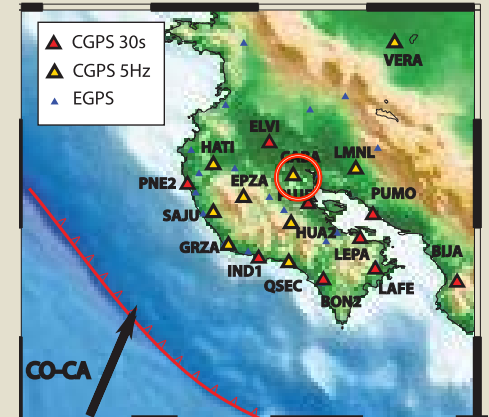
- A network of 18 CGPS and 23 EGPS
- Network installed between 2002 and 2006 to monitor the strain accumulation, slow slip events and eventually observe thrust earthquakes (funded by NSF).
- Different CGPS during the Sept. 5 2012 earthquake recorded the event at high rate.
- **The network is located just above the seismogenic zone (near field)!**

Slab geometry from DeShon et al. 2006

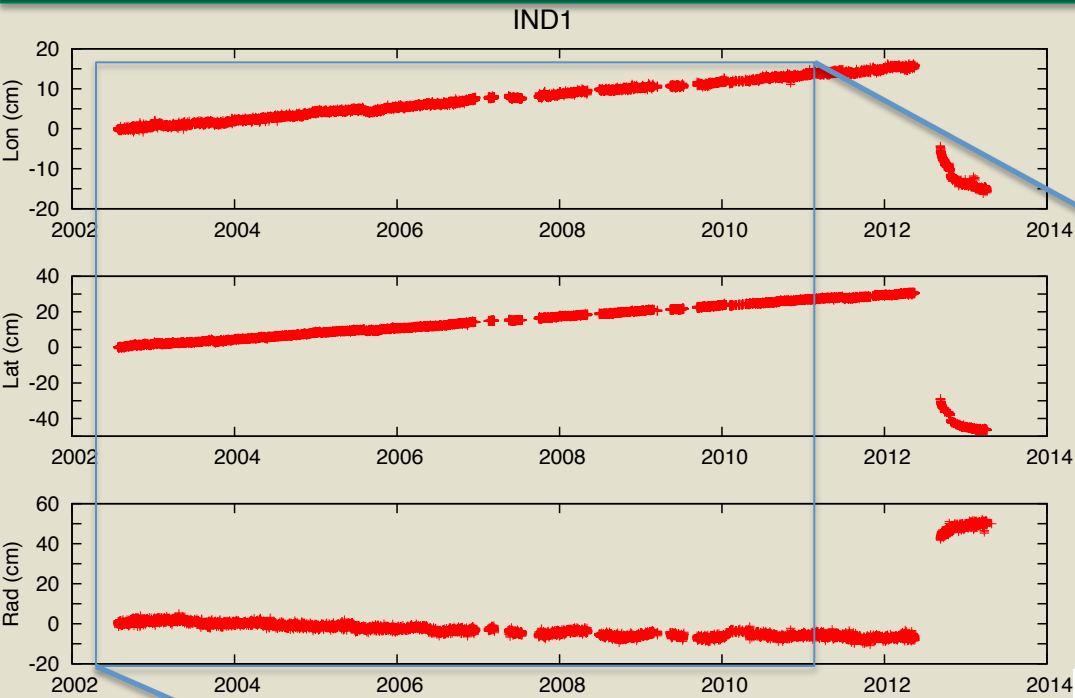
GPS Time Series



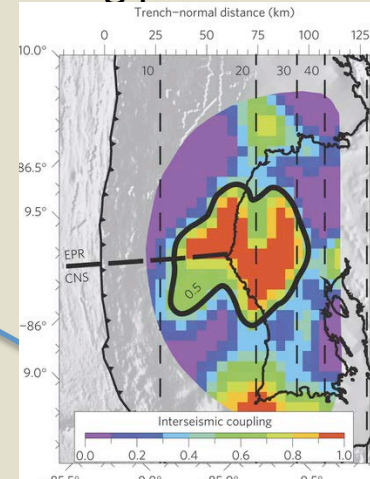
- The CGPS time series shows inter-seismic, co-seismic, and dynamic behavior in the post-seismic



Interseismic

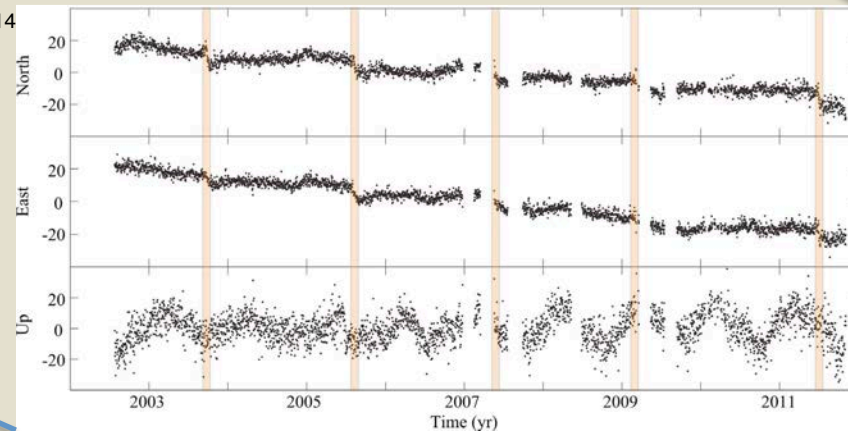


- Analysis of inter-seismic data show Slow Slip Events or locking patches

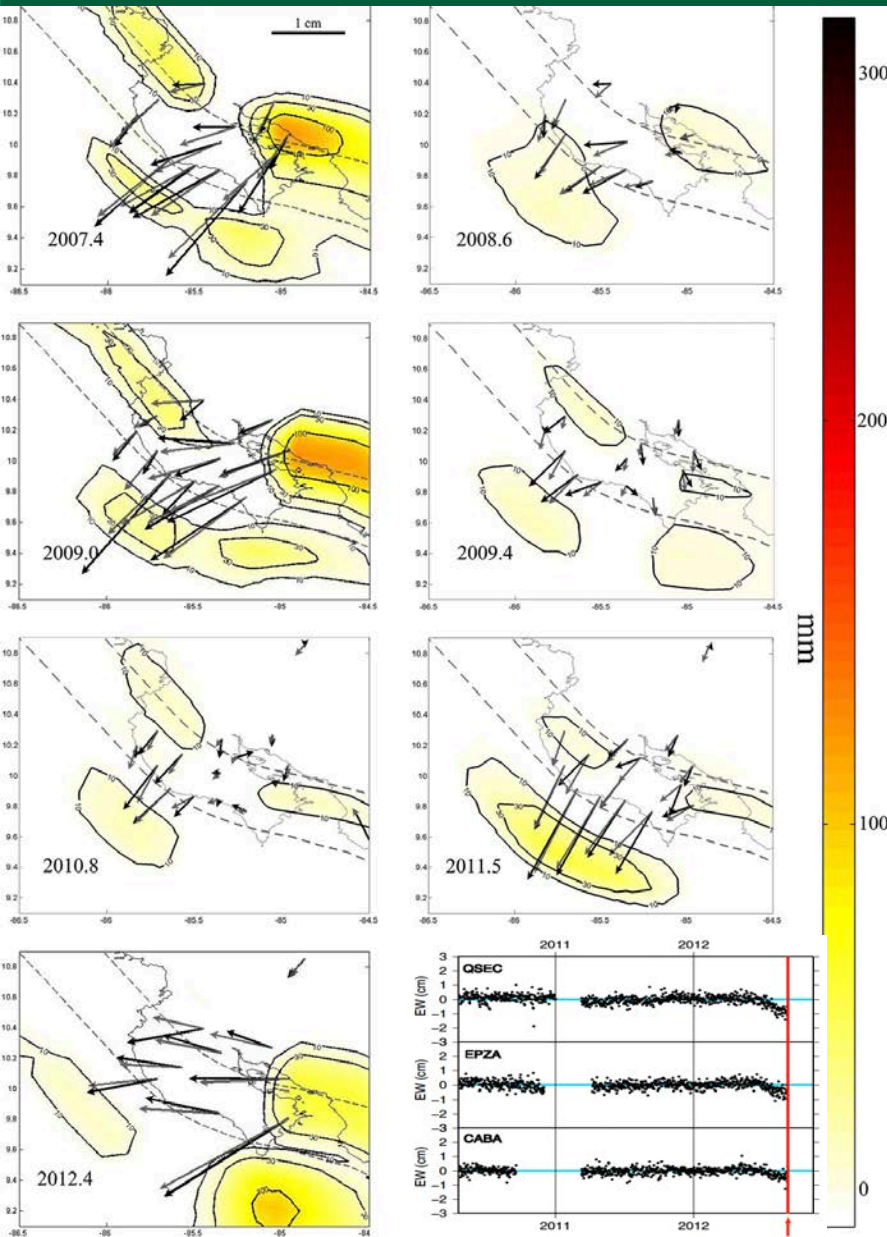


Protti et al 2014

Jiang et al. 2012

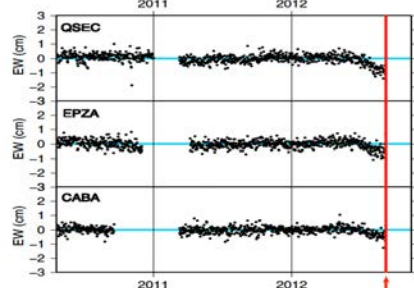
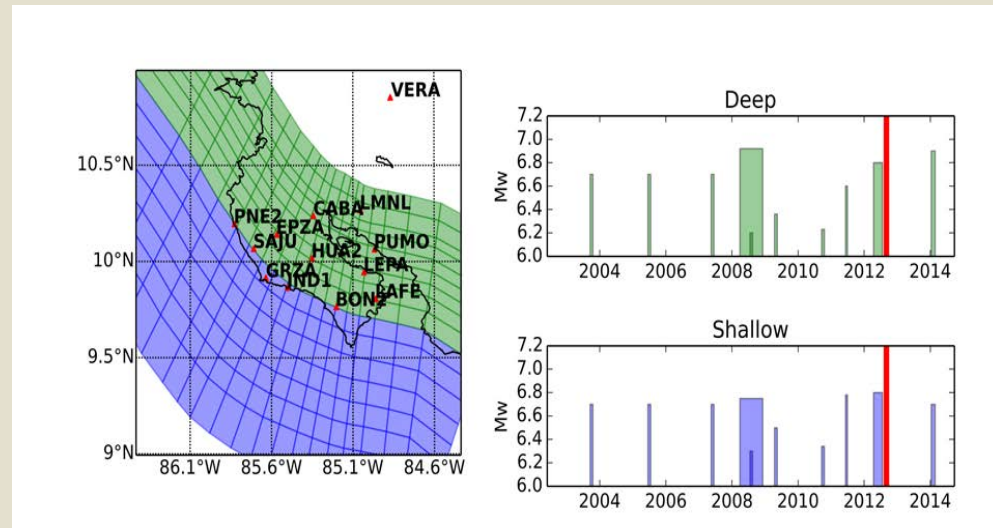


Slow Slip Events

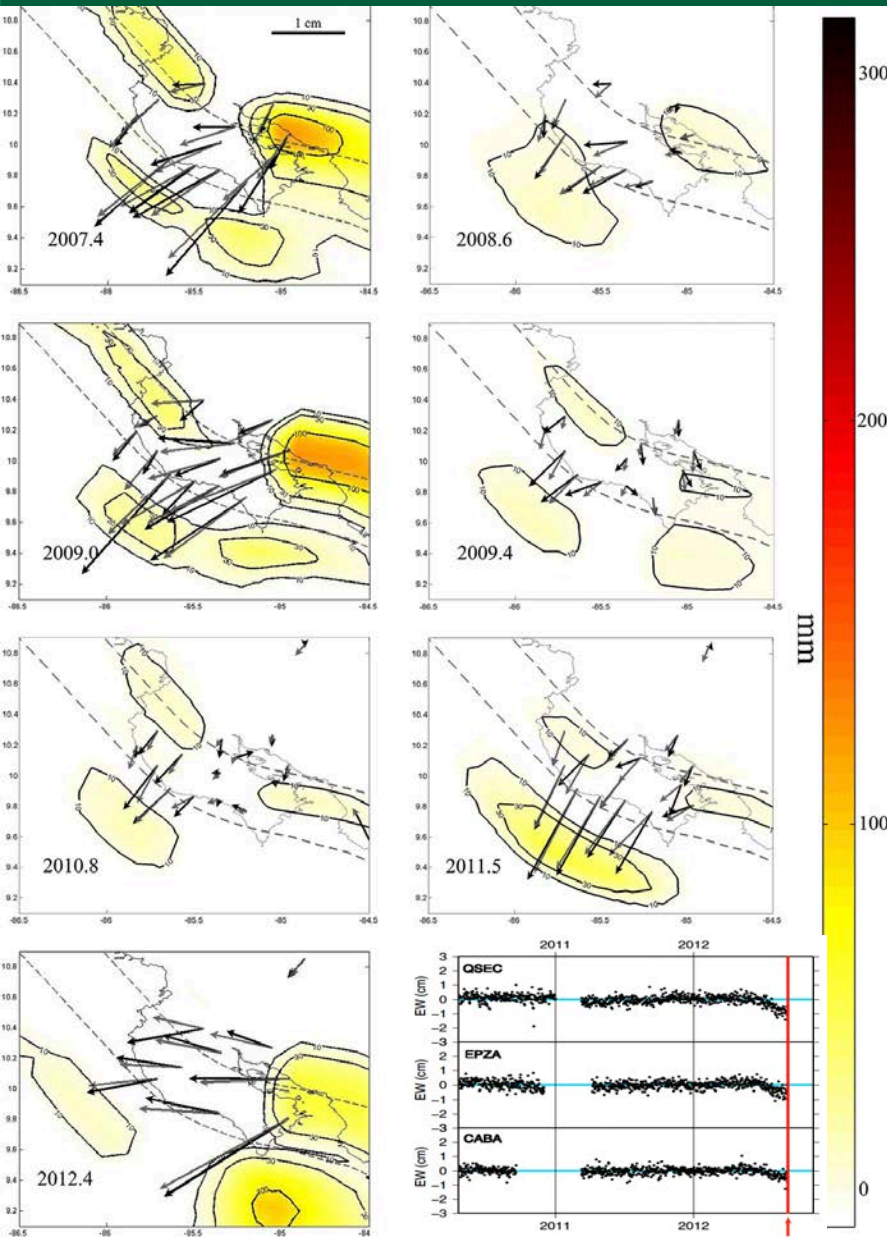


SSE mainly in 2 areas:
 A shallow and a deep one
Importance of near field network

Almost periodic with a periodicity of ~20 months

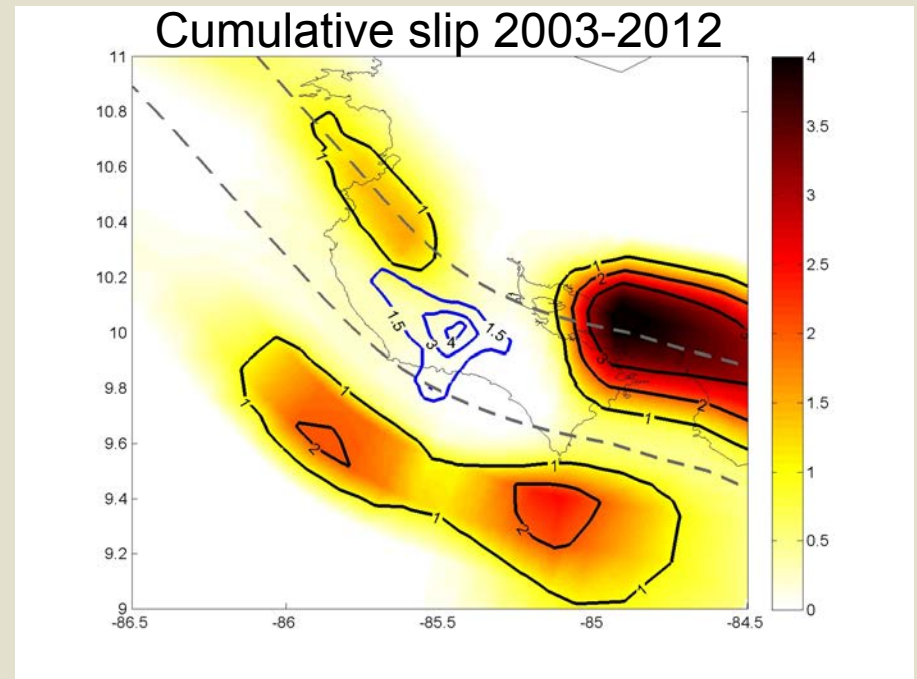


Slow Slip Events



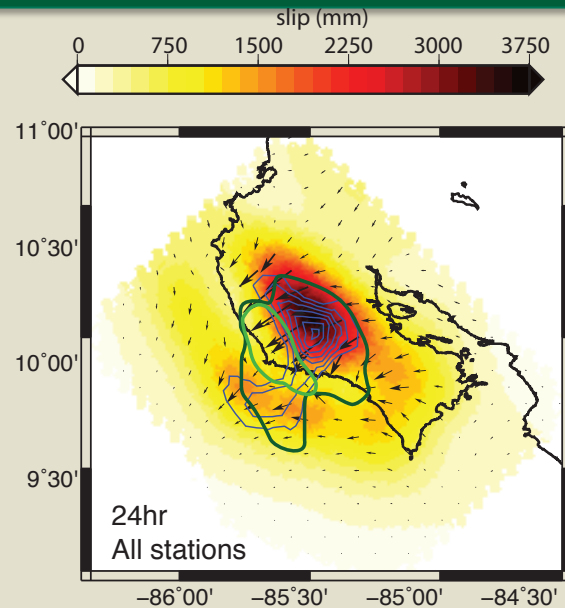
SSE mainly in 2 areas:
A shallow and a deep one
Importance of near field network

Significant amount of slip deficit released at shallow depth by SSE

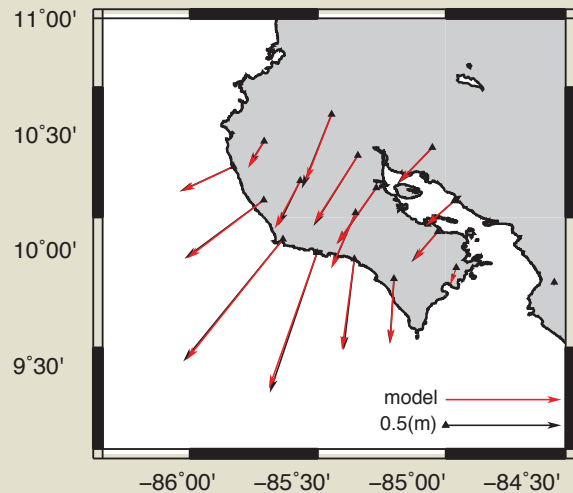


Dixon et al 2014

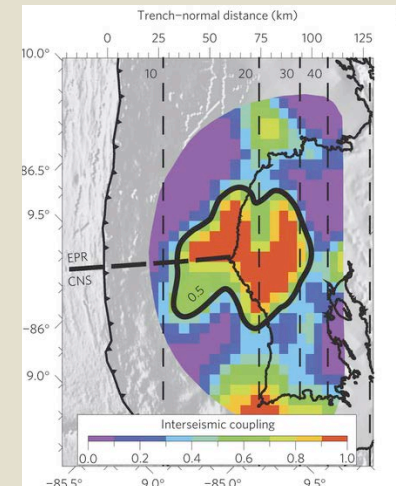
Co-seismic September 5th 2012



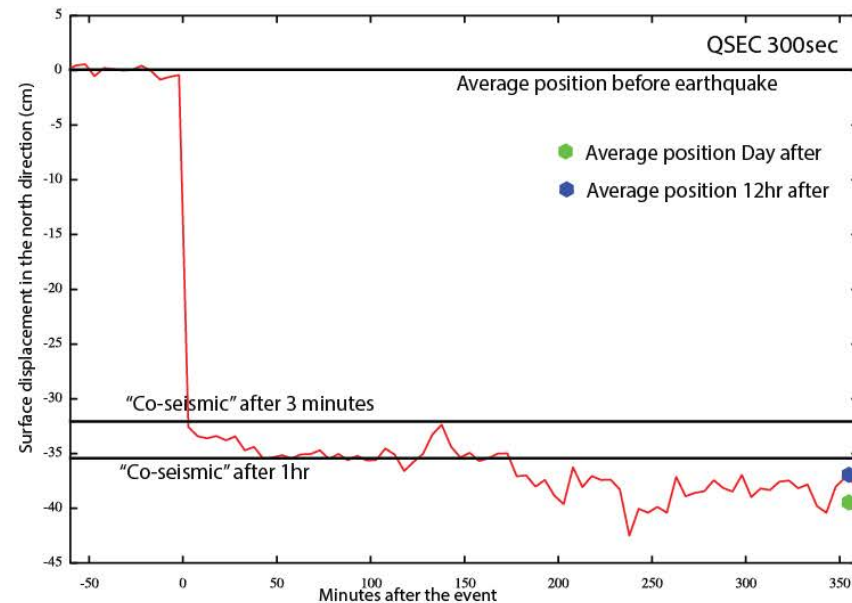
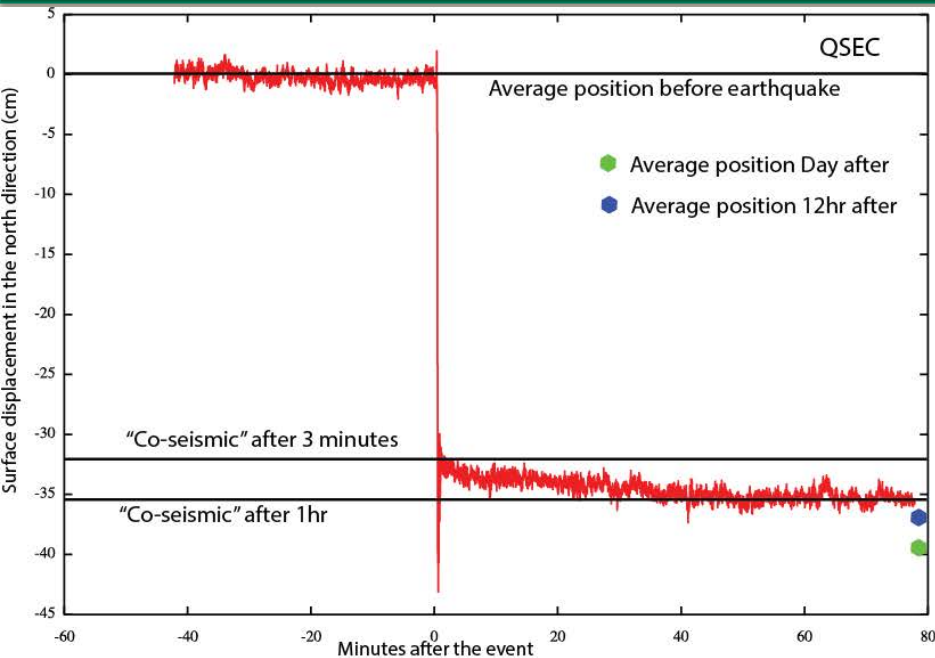
- Co-seismic deformation computed as the average position a few days before the event (or for EGPS using the projected position before the event) and the position of the first available day after the event.
- Blue line coseismic from seismic data contours every 500 mm (Yue et al. 2013).
- **Significantly more slip (1.5m vs. 1.1m) offshore in the geodetic inversion than seismic inversion. M7.7 vs M7.6.**



Right: Interseismic coupling from Protti et al. 2014 Nature Geosciences
Left: Green lines left (dark >50% Light ~100%)

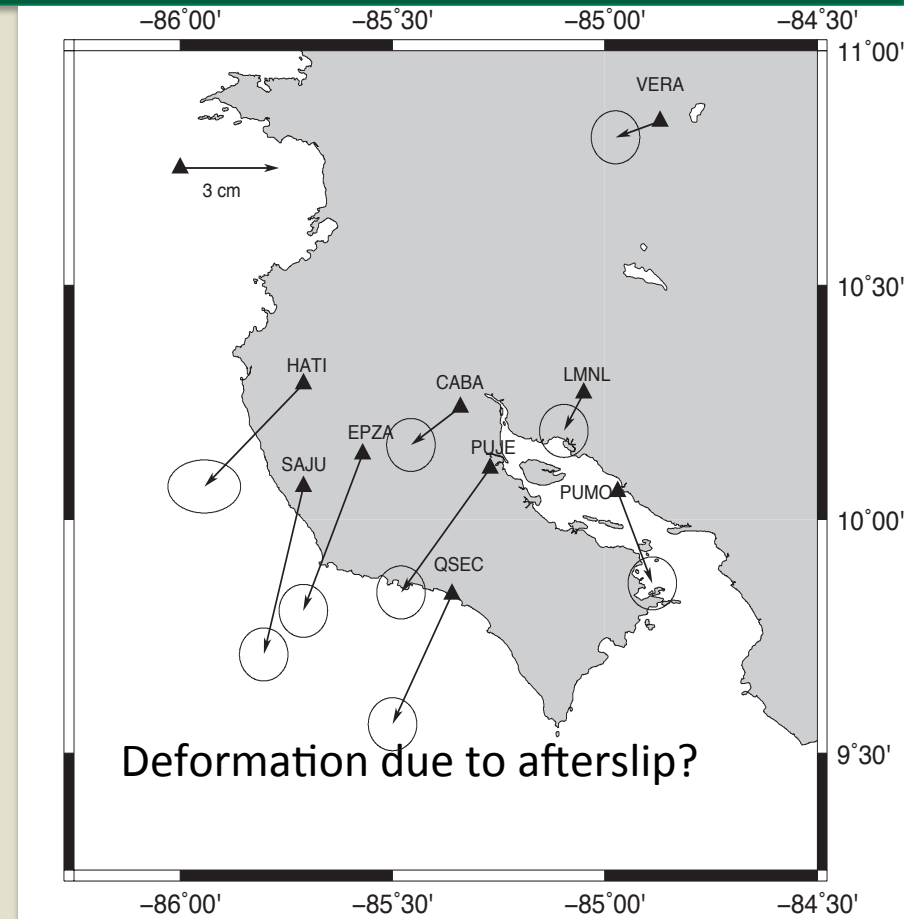
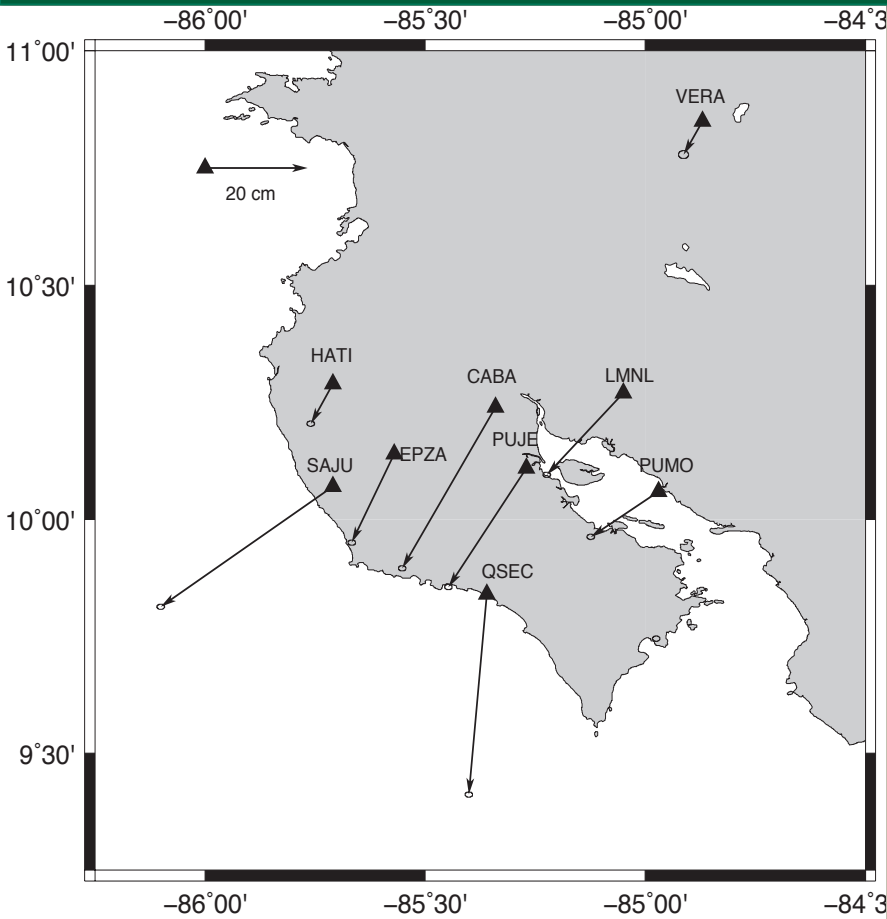


“Co-seismic” changes with time



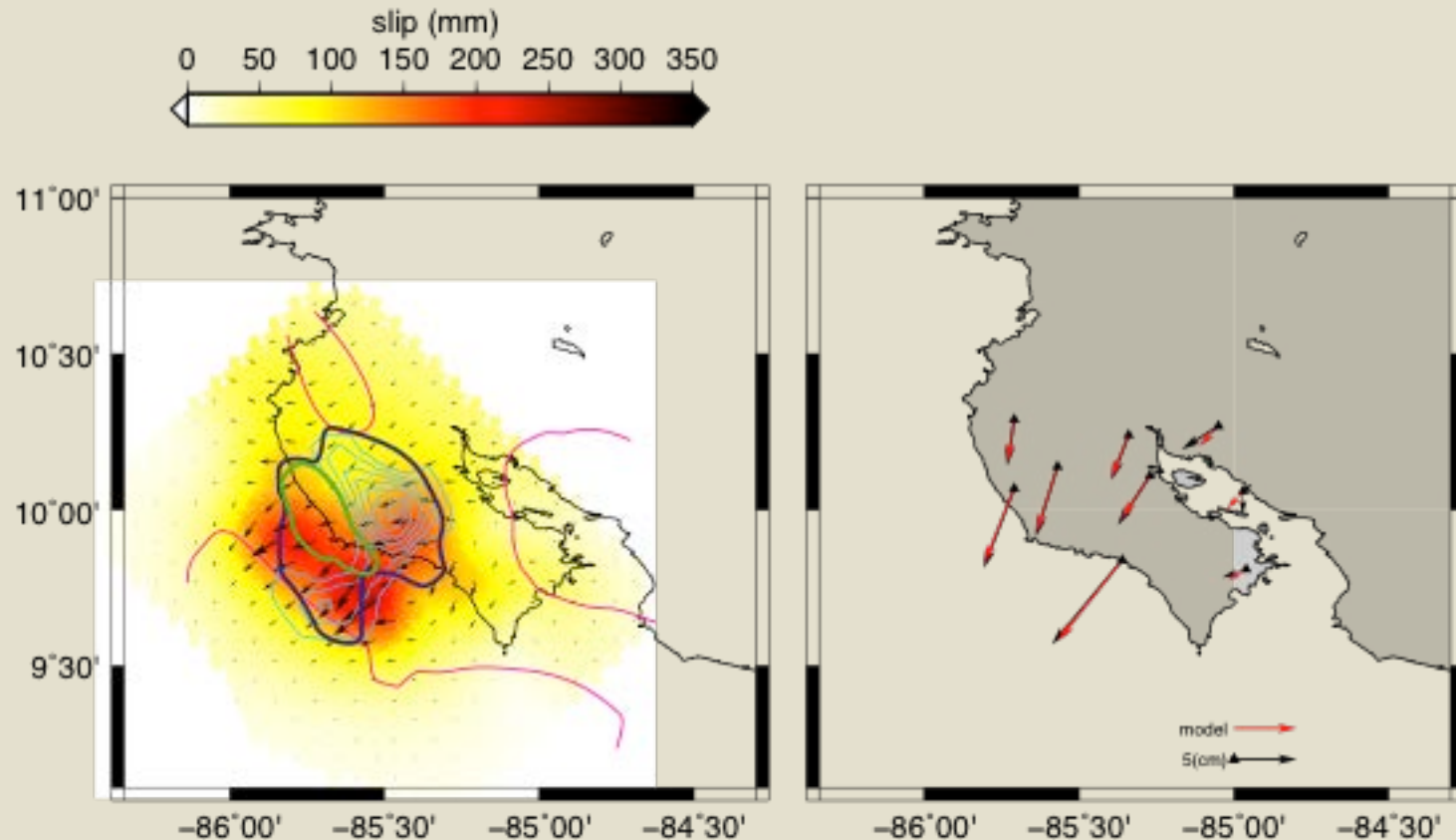
- Co-seismic deformation computed as the difference from the average position before and after the event is dependent on time since the earthquake.
- Co-seismic deformation computed using 3 vs. 60 minutes after are smaller than the value 12 hours after the event (or the day after the event, i.e. the classical value for co-seismic).

“Early Afterslip”



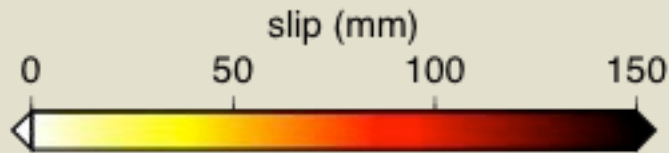
- (left) Co-seismic measured from before the event to 3 minutes after the event.
- (right) “Co-seismic” measured from 3 minutes after the event to the next day.

Early afterslip

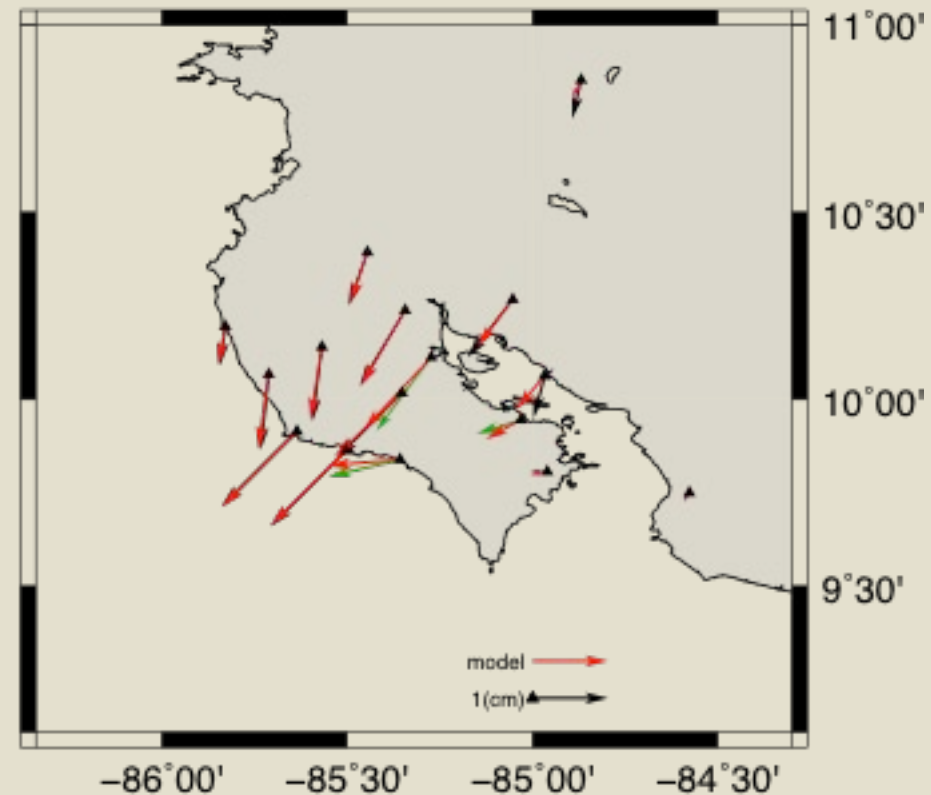
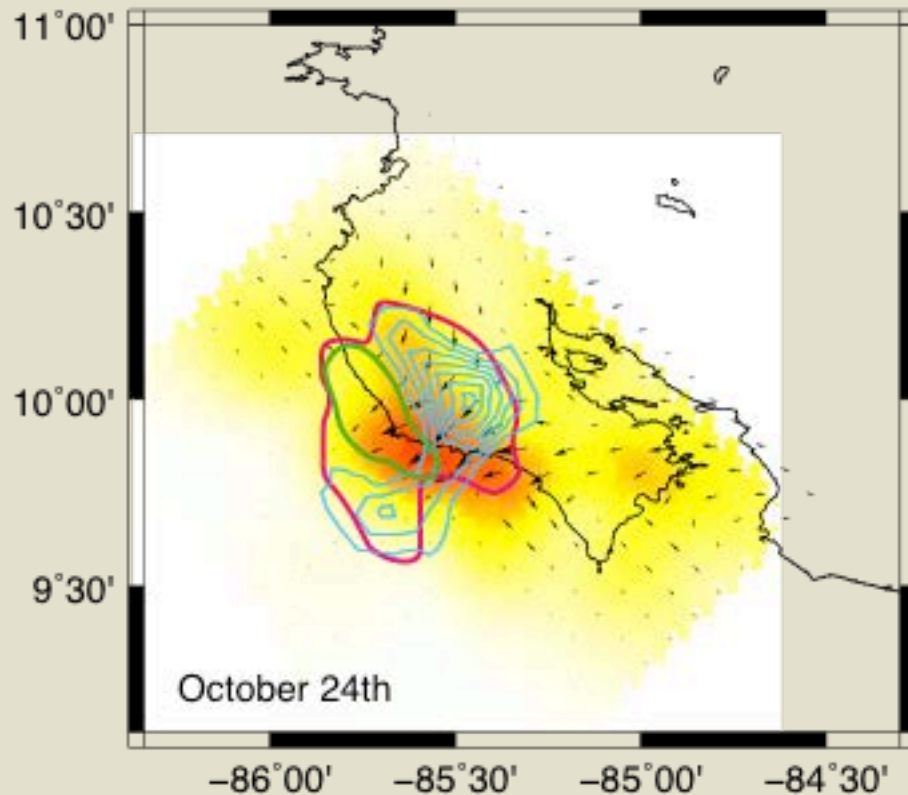


- Inverted postseismic afterslip in the first 300s
- Comparison with area of cumulative SSE slip (red line 1m of slip) and coseismic slip from seismic data Yue et al. 2013 (blue line) and interseismic locked region

Aftershock October 24th

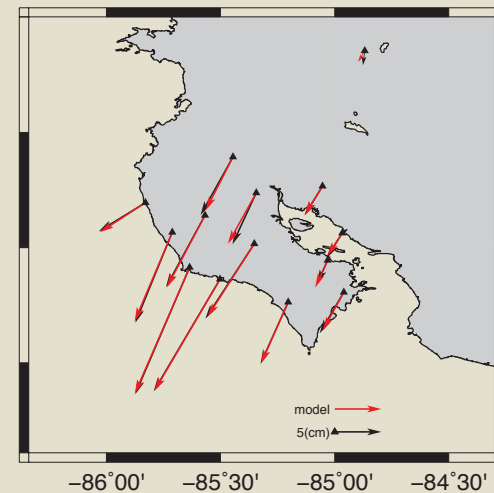
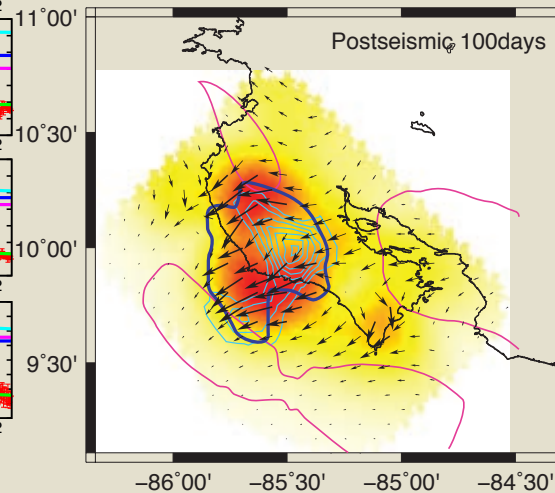
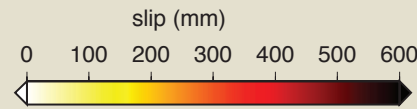
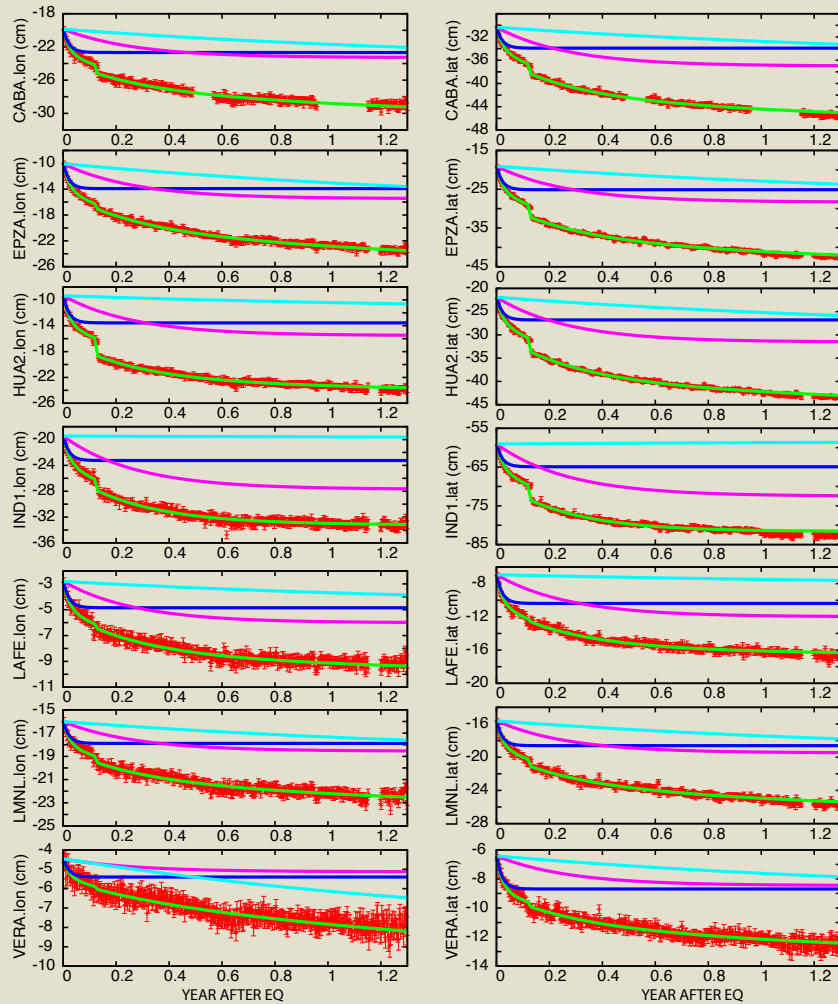


Mw 6.6

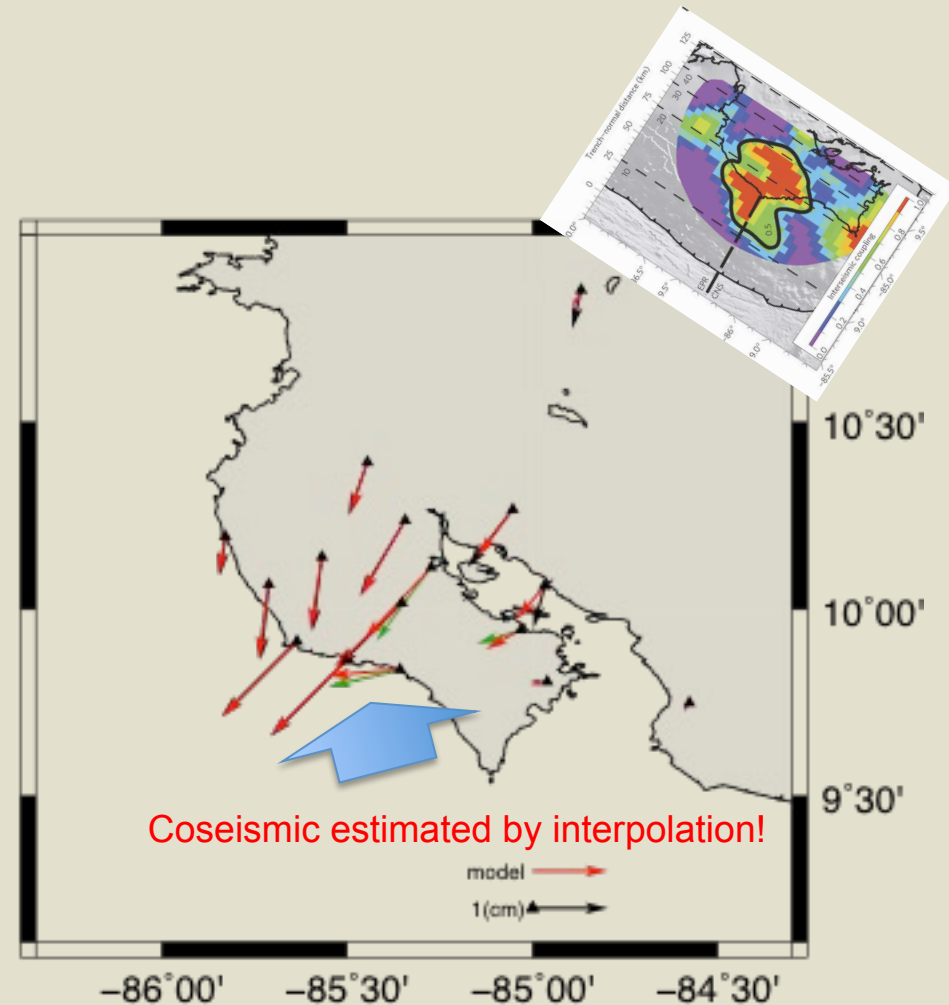
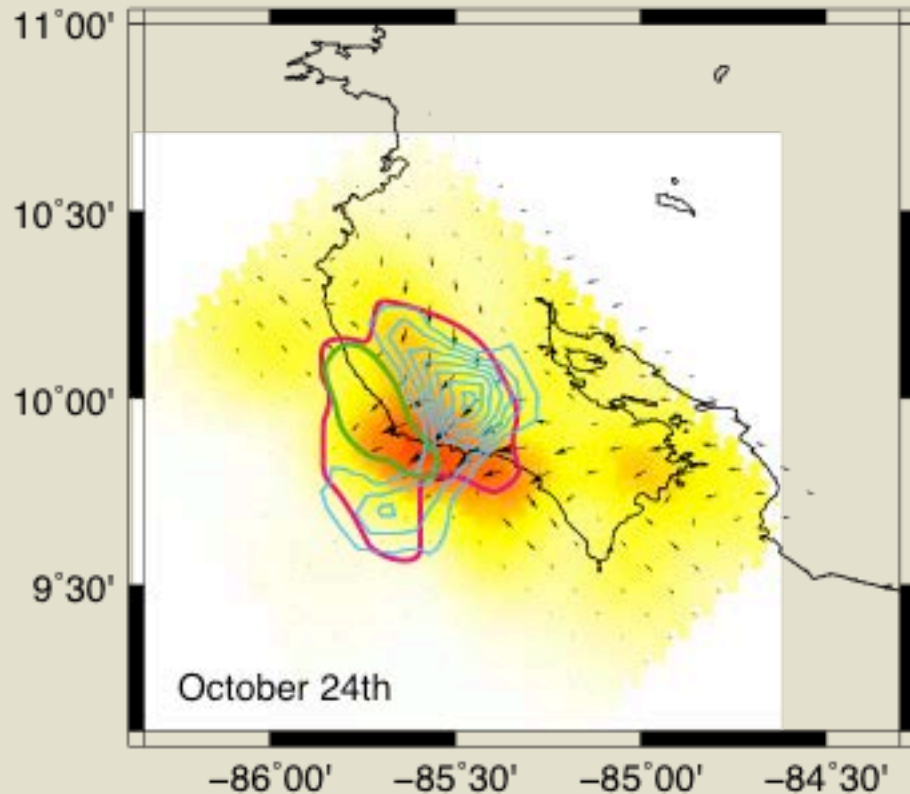
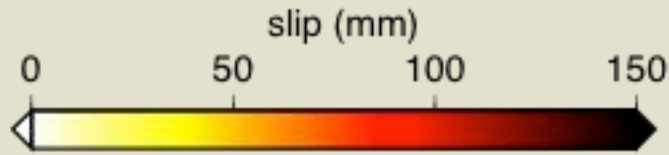


Post-seismic

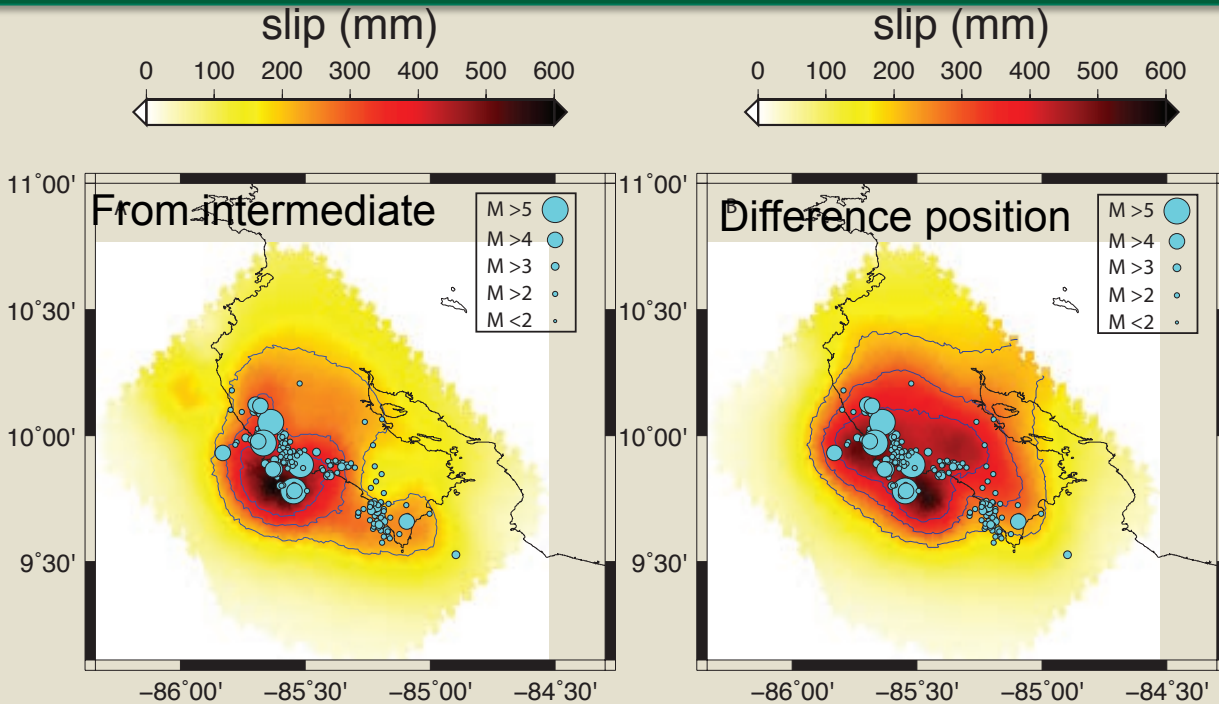
- Strong Post-seismic signal is seen in the entire network.
- An exponential decay fits the data.
- Need three relaxation times to fit the data: a fast one (~7 days) (mixed, poroelastic and other) intermediate (~70 days) (likely afterslip) slow (>420 days) (viscoelastic).



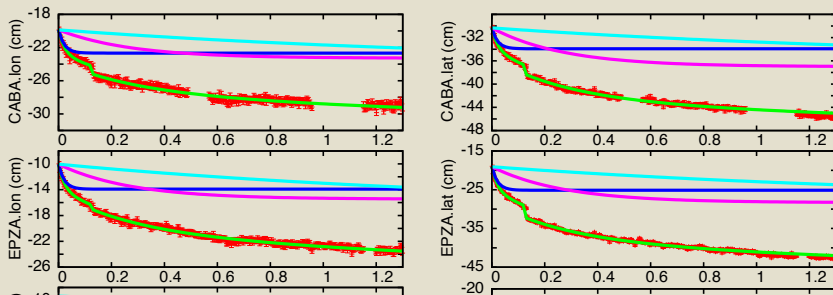
Aftershock October 24th



9 days Post-seismic and seismicity



9 days slip on the fault assuming all deformation due to fault motion:
From 70 days relaxation fit (left)
Difference from position day 1 and day 9
Fault interface aftershock



Seismicity fits better with relaxation model

Diffuse deformation on right suggests the total deformation at surface not limited to strain release only on fault plane

Total slip

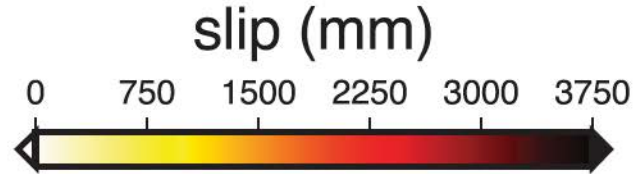
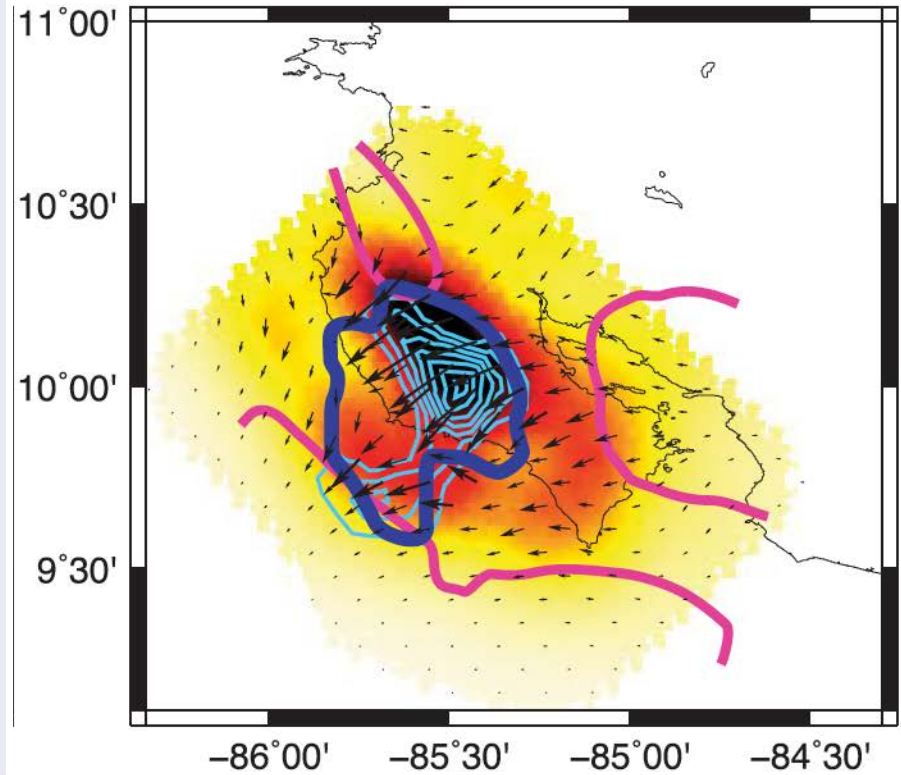
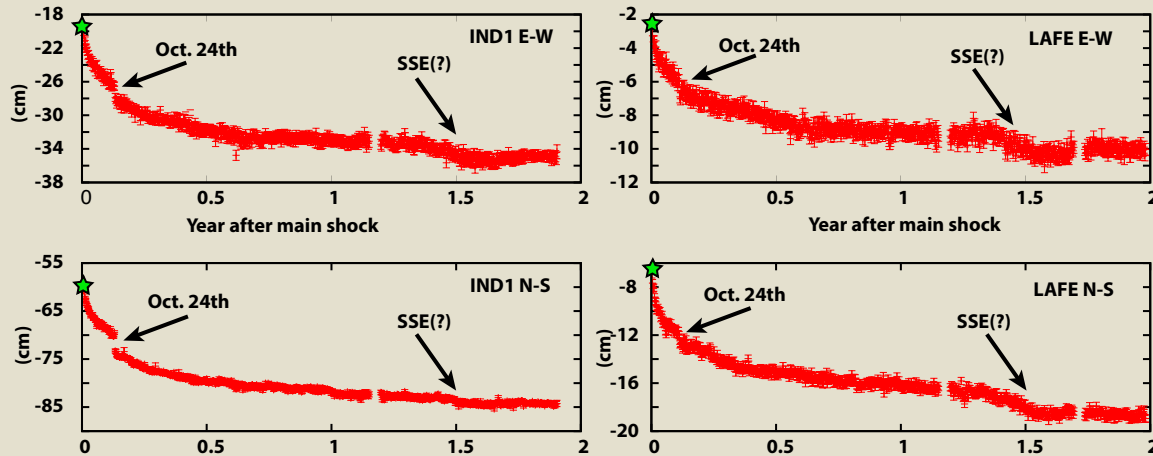


Table 2. Corresponding Seismic Moment From Geodetically Inverted Fault Slip Compared With the Seismic Moment From Global CMT

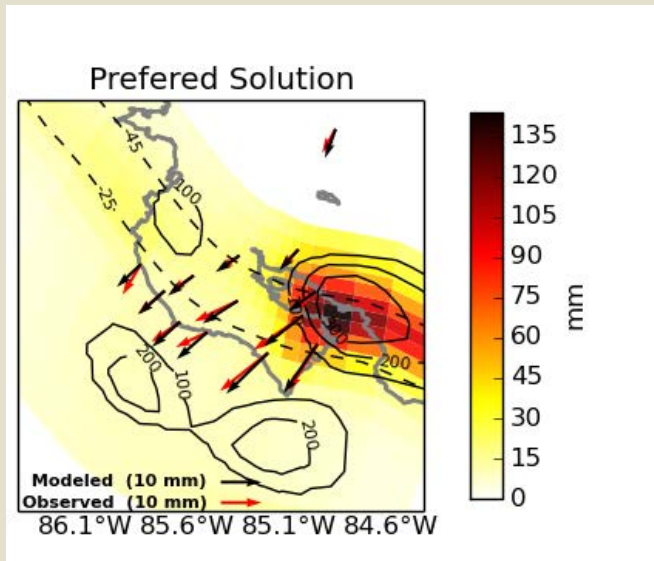
Event	Geodetic Moment (N m)	Corresponding M_w
24 h "coseismic"	3.7×10^{20}	7.7
Early-afterslip 300 s–3 h	3.9×10^{19}	6.9
Coseismic 300 s	3.3×10^{20}	7.6
24 October aftershock	8.5×10^{18}	6.6
Afterslip ($\tau = 70$ days)	6.9×10^{19}	7.2
CMT 5 September	3.1×10^{20}	7.6
CMT 24 October	5.3×10^{18}	6.5
10 days aftershock seismic moment	5.65×10^{17}	



SSE 2014

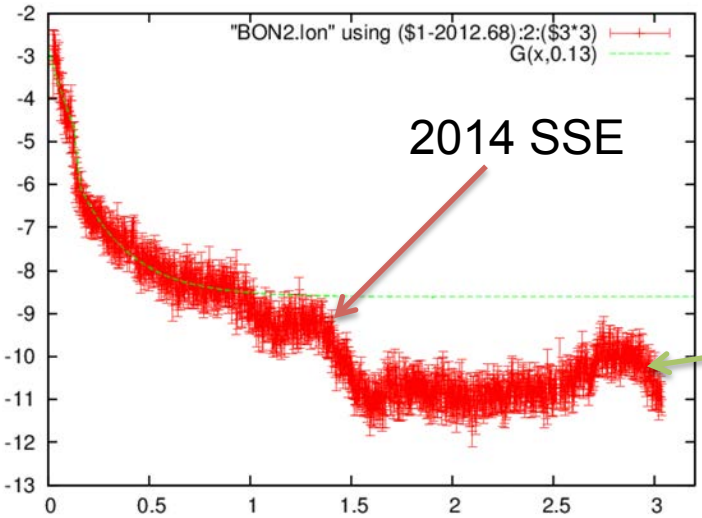
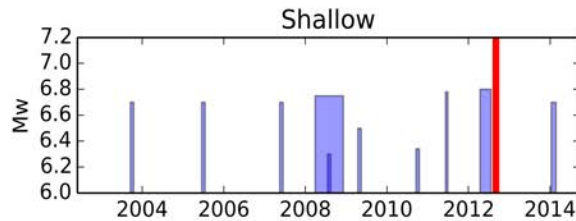
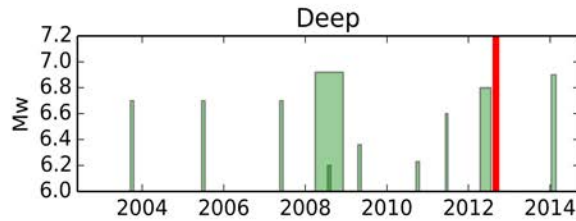
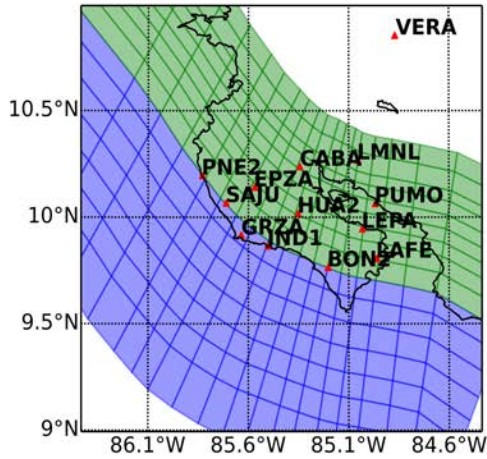


A slow slip event happened “regularly” in 2014 following the normal periodicity as if it was not affected by the main event.



2014 event presents slip only on the deep patch. It seems that the 2012 earthquake did not affect the deep SSE but affected significantly the shallower one.

A new one?



Starting new event?

Too early to say come to Nick Voss talk at AGU

Conclusions

The position of the geodetic network of Nicoya provides invaluable data to understand the mechanical behavior of the subduction mega-thrust. **NEAR FIELD STRAIN OBSERVATIONS ARE IMPORTANT!**

Coseismic surface displacement takes a few hours to get to the “static” deformation measured as average position of the next day (**EARLY AFTERSLIP**).

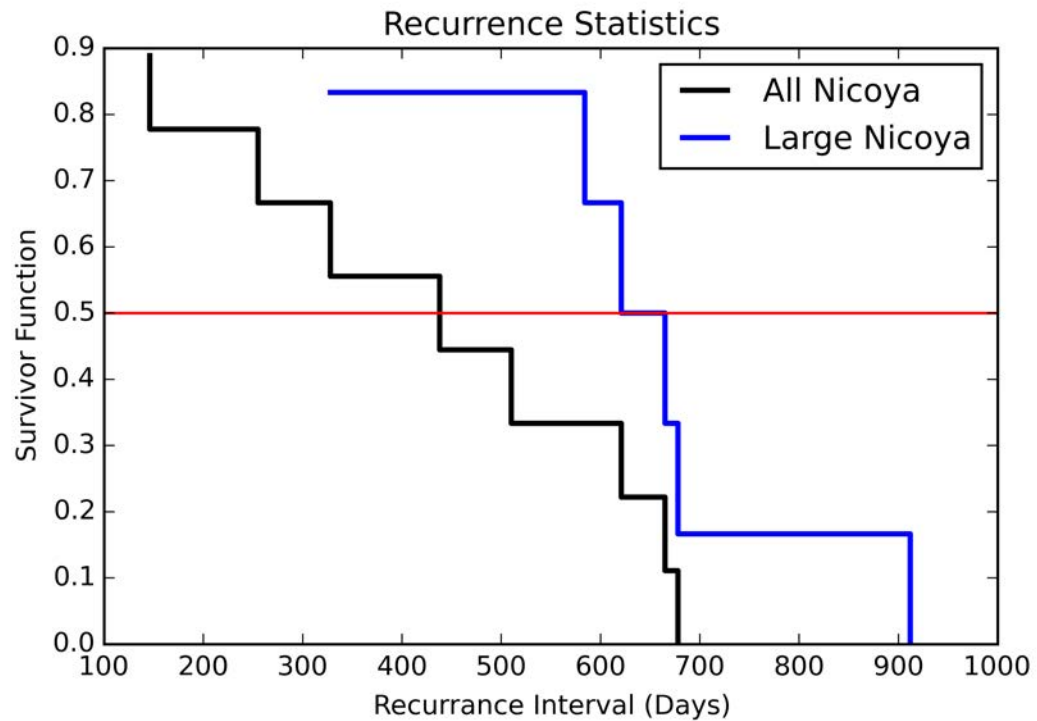
Strong post-seismic deformation evident in the full network with 3 relaxation times.

Cumulative slip on fault interface after the event releases a significant amount of strain from interseismic locking.

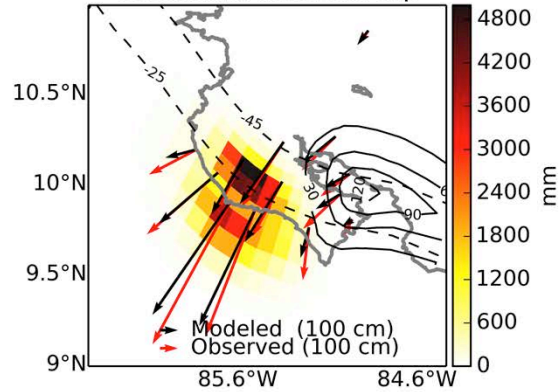
Cumulative afterslip and main slip seems to be spatially limited by areas of SSE

The temporal evolution of the slip on the fault underneath Nicoya suggests the presence of different patches activated by different slip mechanisms.

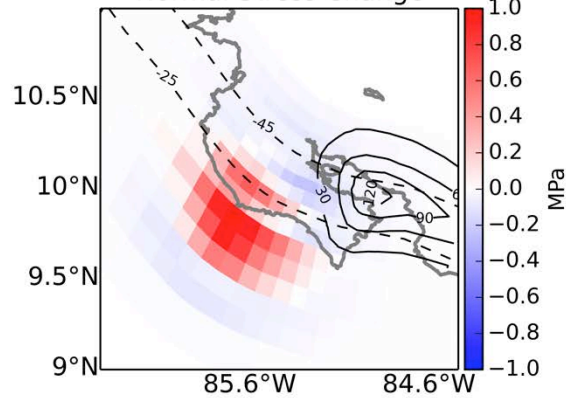
Deep SSEs in Nicoya do not seem to be strongly affected by the main event. Shallow SSEs seem to be affected.



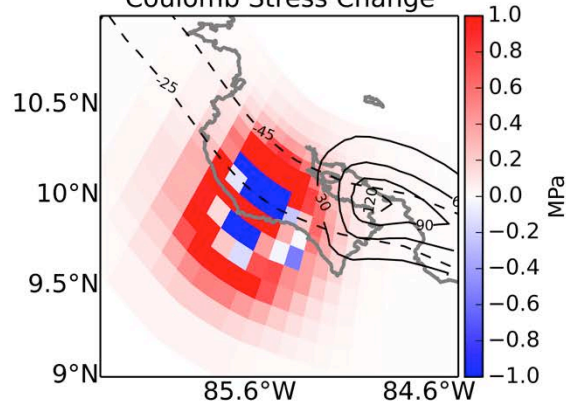
Coseismic and Afterslip



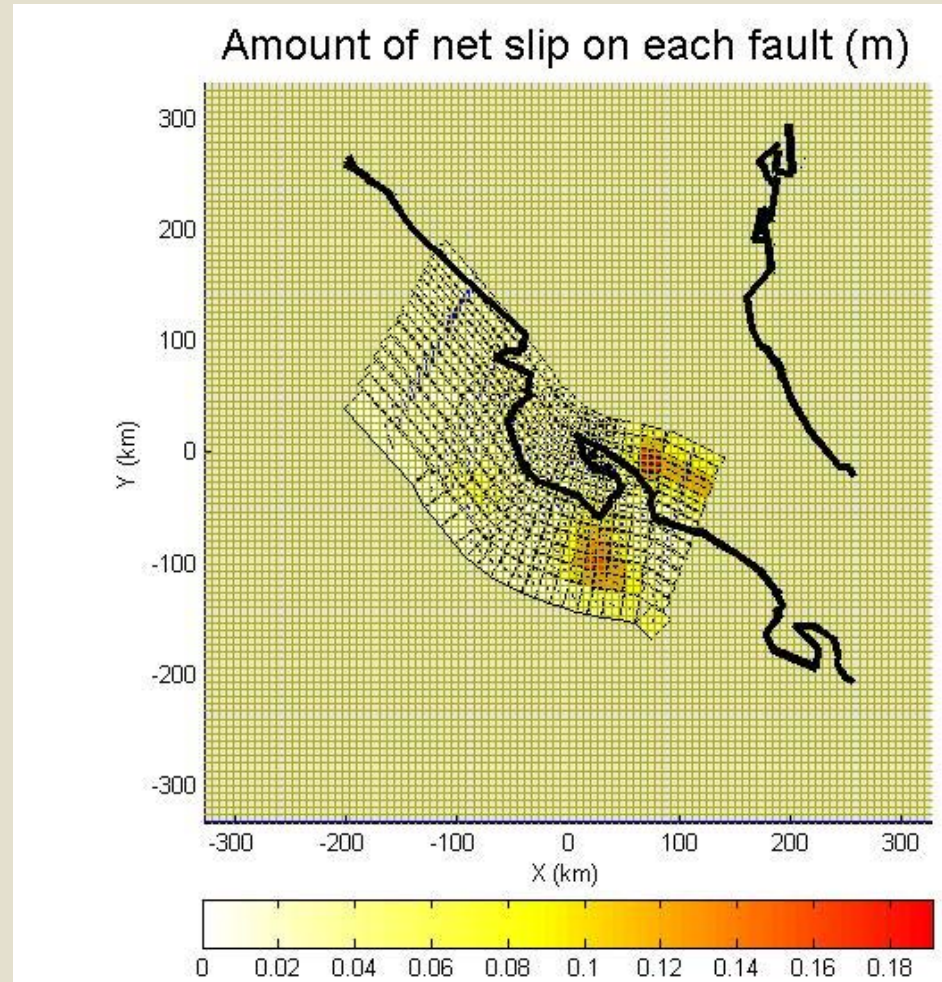
Normal Stress Change



Coulomb Stress Change

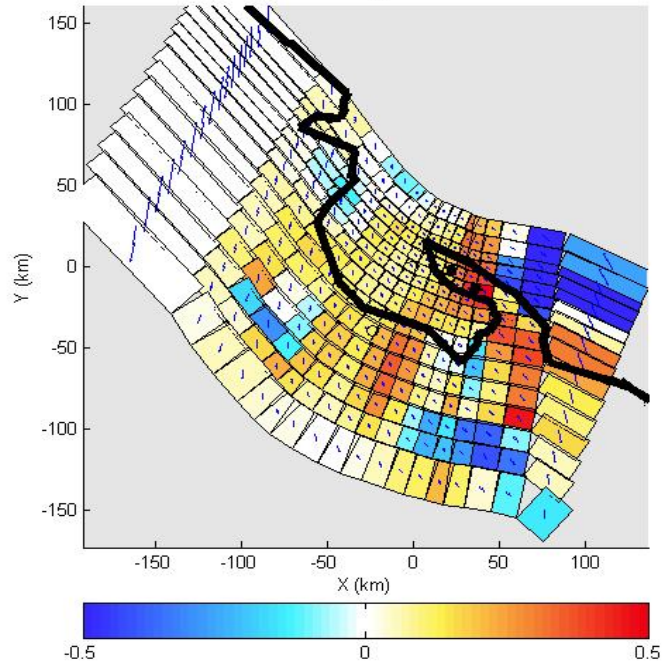


2012 SSE (happening during main shock)



2012 Slow Slip Event

Coulomb stress change for specified rake 128 deg. (bar)



Amount of net slip on each fault (m)

