Source Parameters for Small Earthquakes along the Middle America Trench – Focus on 2012 Nicoya Earthquake Rupture Zone

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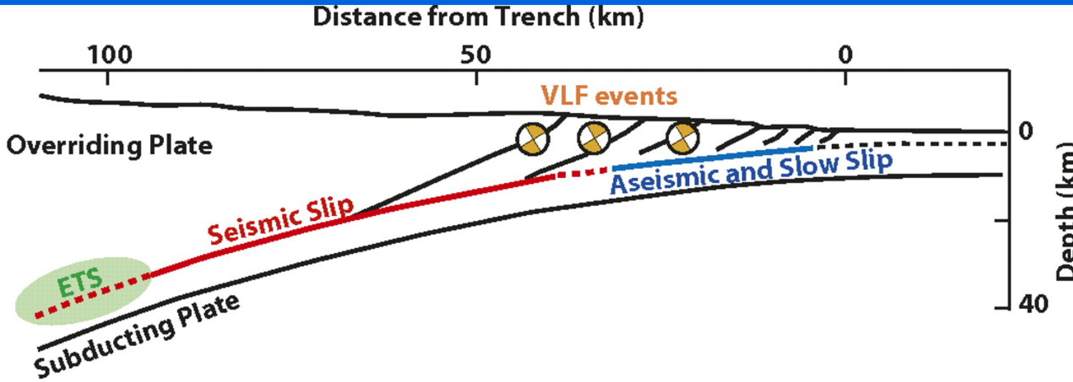
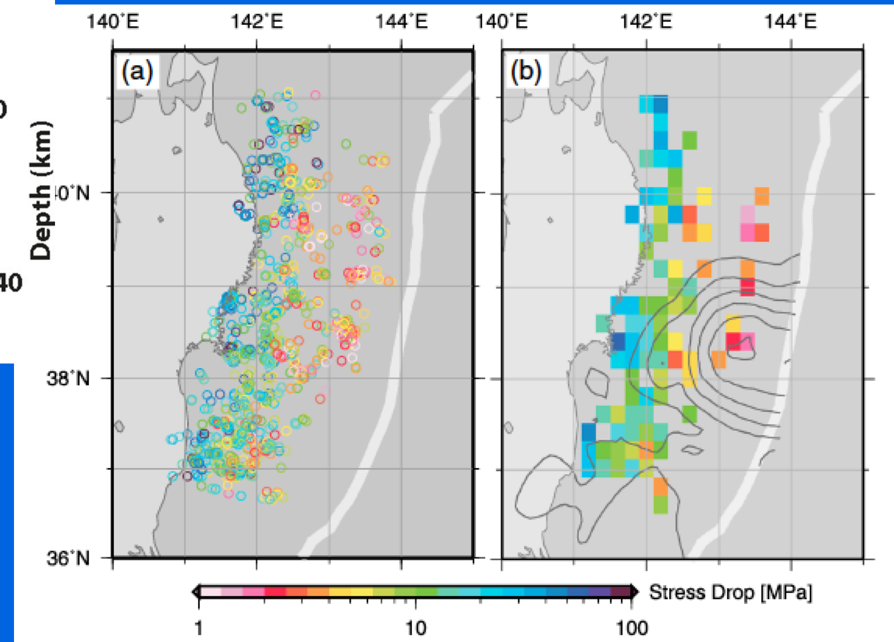
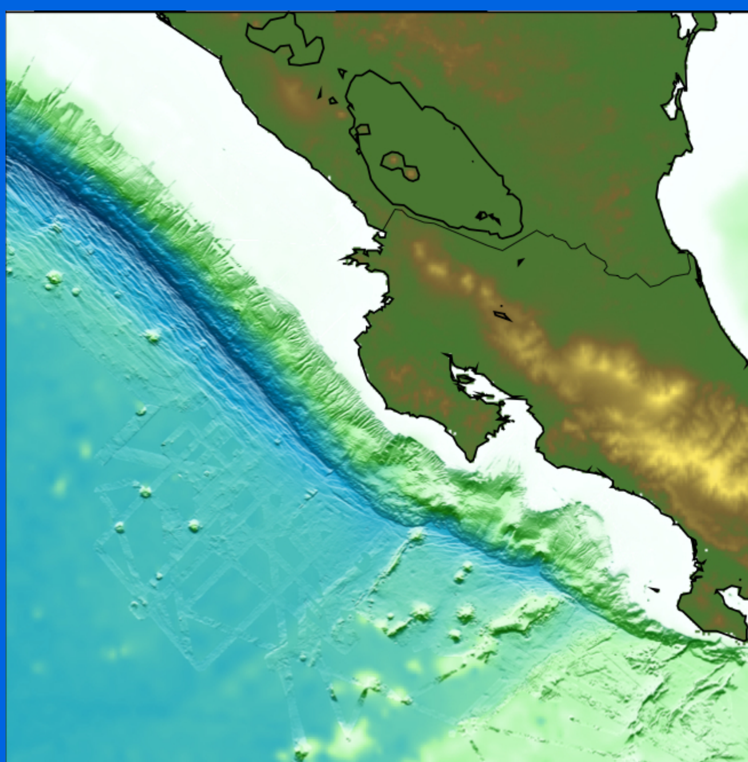
Subduction Zone Heterogeneity



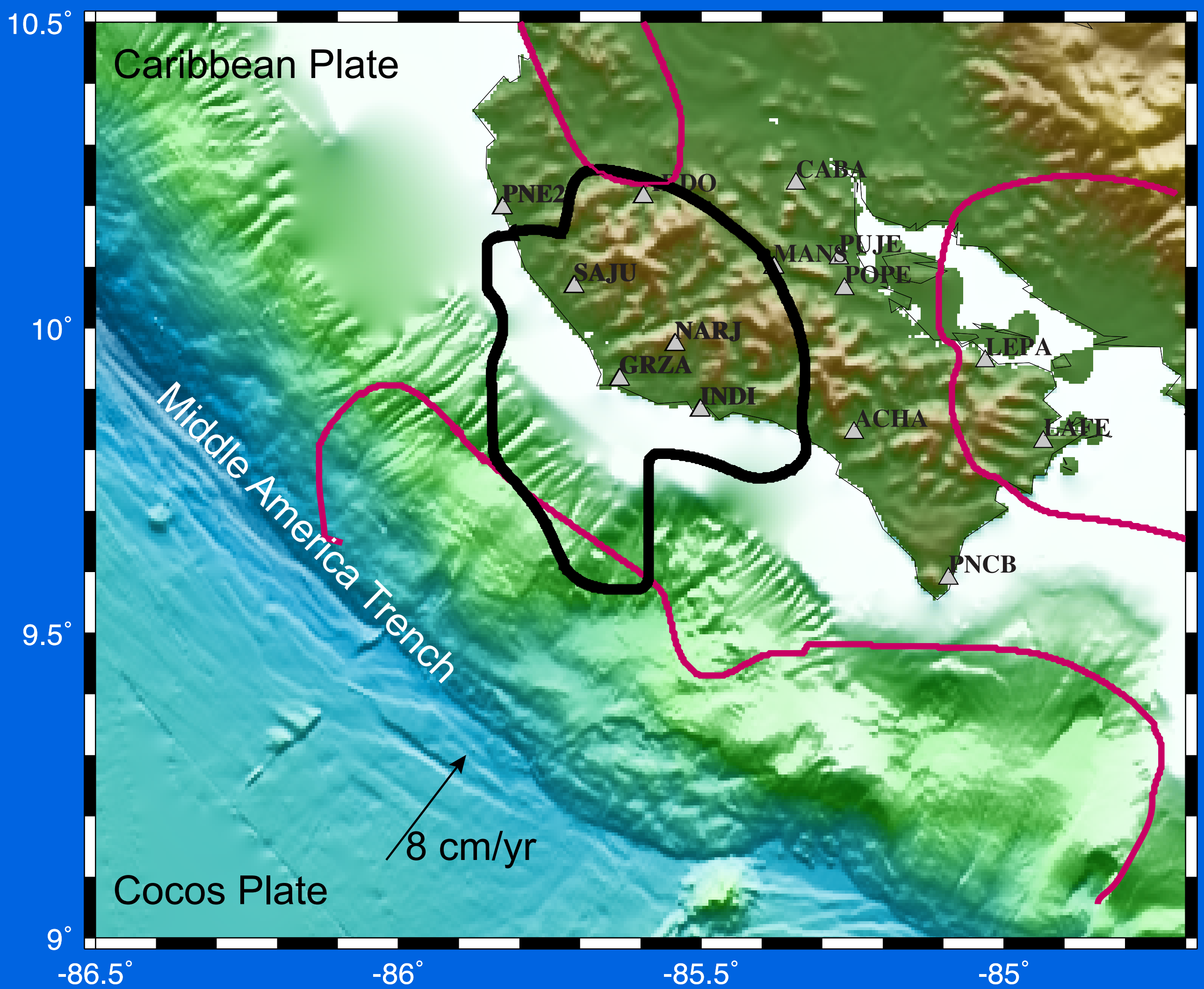


Stress drop for Japan trench earthquakes before 2011 Tohoku (*Uchide et al*, 2014)



How does the observed heterogeneity manifest in the earthquake process?

Costa Rica – Nicoya Peninsula



Area well instrumented with seismic/geodetic networks, focused area of MARGINS efforts

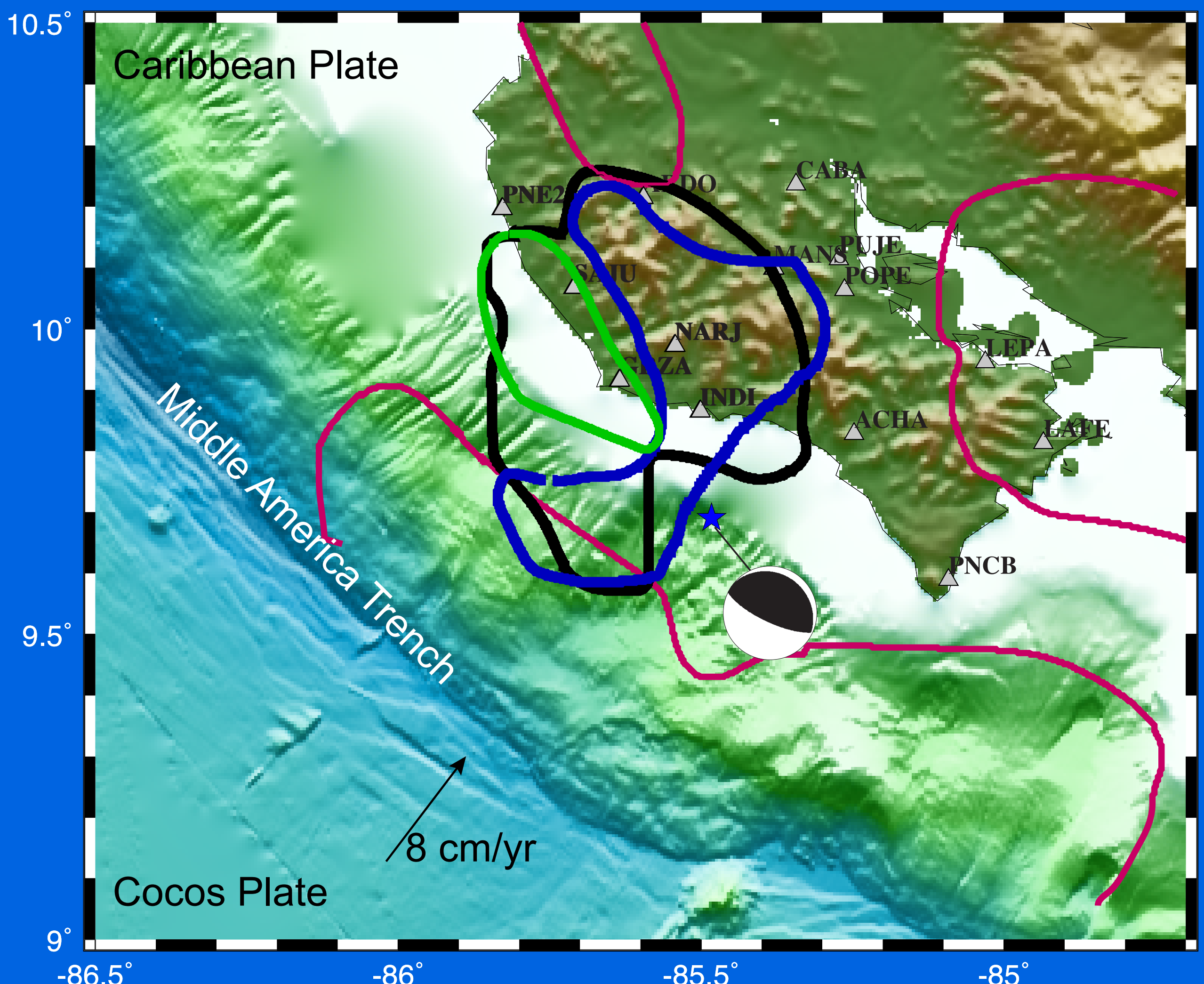
Various slip events observed

Geodetic modeling through early 2012 suggested a strongly locked portion of the seismogenic zone, between regions of SSE

Feng et al, 2012 – outline of >50% geodetic locking

SSE locations in past decade with cumulative slip > 1m, Dixon et al., 2014

Costa Rica – Nicoya Peninsula



5 September 2012 M_w 7.6 earthquake on plate boundary fault ruptured a portion of the previously defined locked zone

Questions:

- What is nature of "no-slip" zone within locked patch
- Are fault properties different where different slip modes occur?
- Hazard implications

Main 2012 rupture area, (Yue et al., 2013) Locked region, no slip in 2012 (Protti et al., 2014)

Nicoya Earthquake Dataset

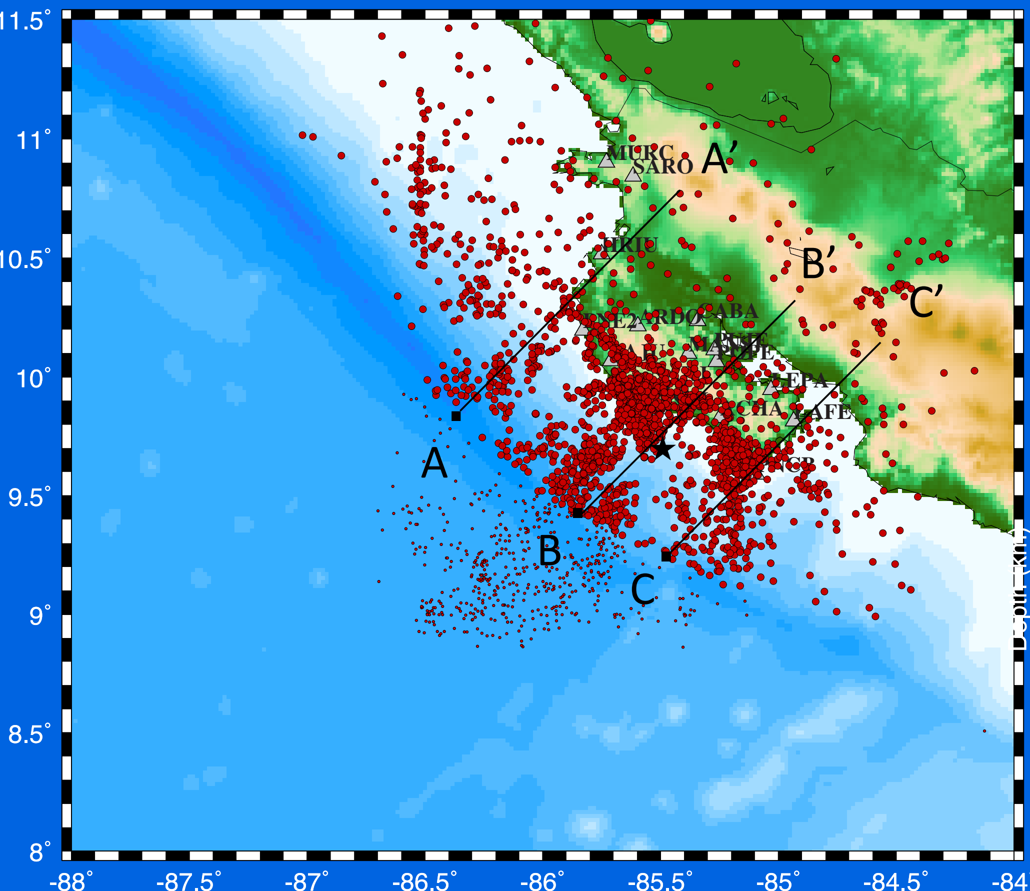
Time periods:

2012 aftershocks: September 5 – December 29, 2012 (n=2717 events landward of trench, M 0.4-5.7)

Earlier events: 09 December 1999 –18 March 18 2001 (n=70 events, M 1.8-3.7)

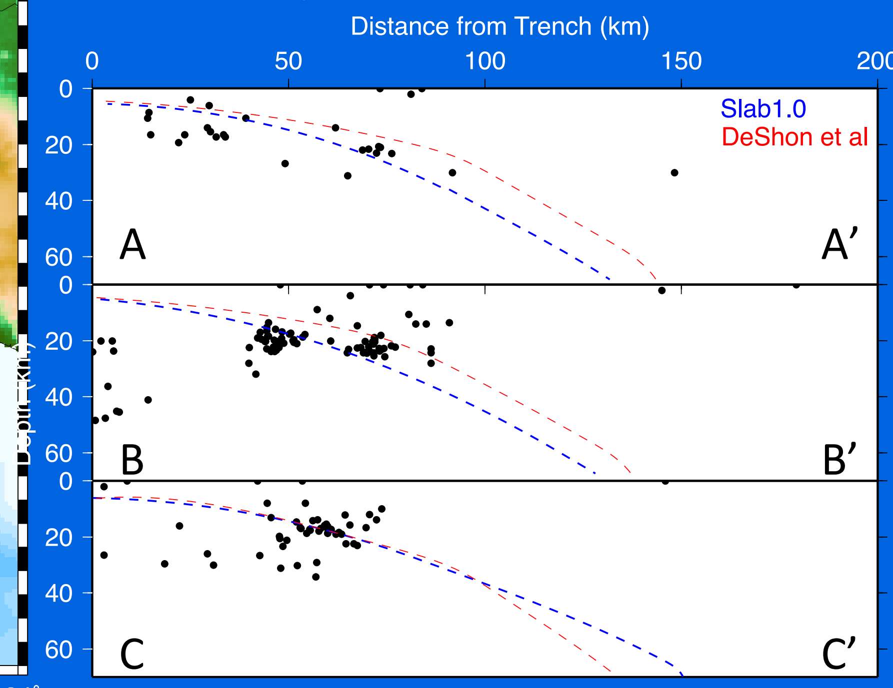
Stations used:

Mix of 3 component BB and SP land, OBS (for 1999-2001 period only)

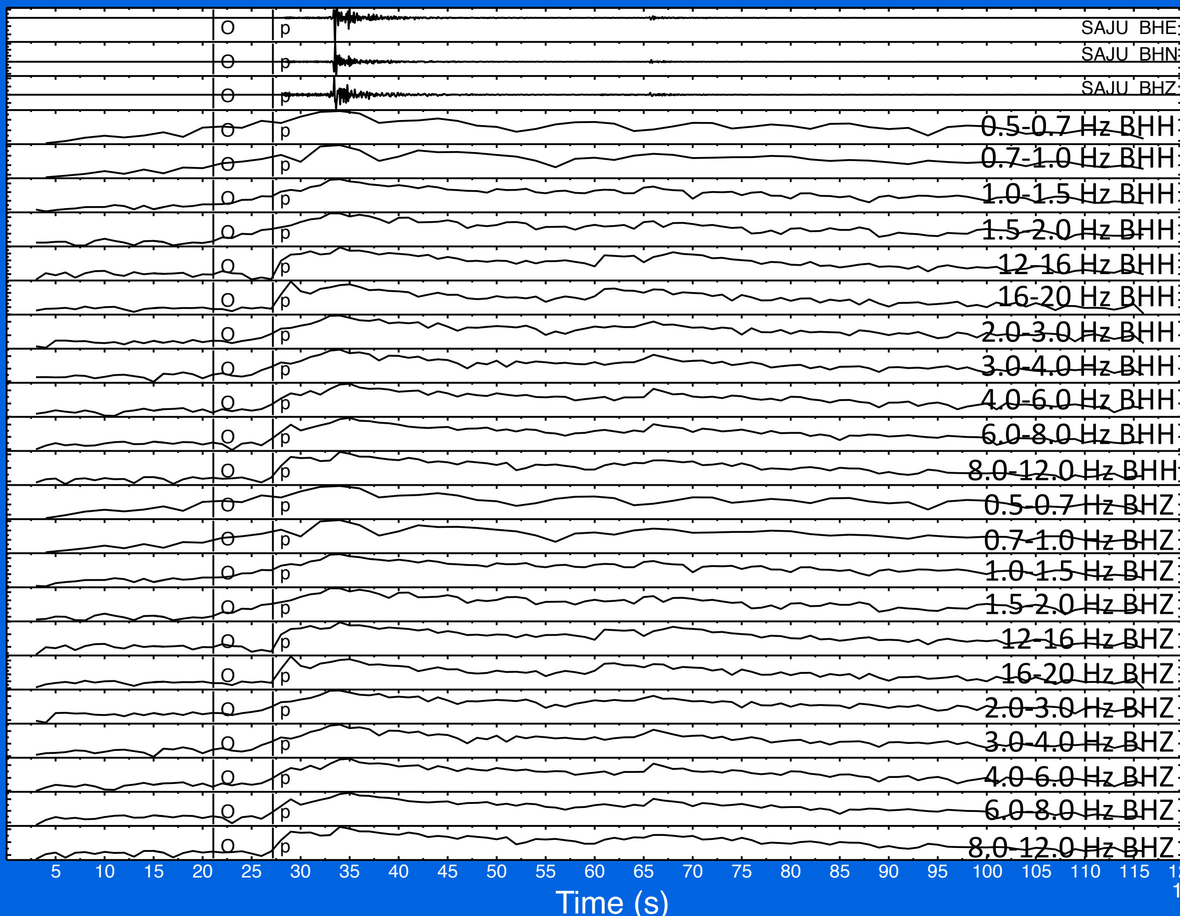


Catalog hypocenters based on regional velocity models (DeShon et al., 2006)

Dataset culled based compatibility with independently determined slab position, available focal mechanisms



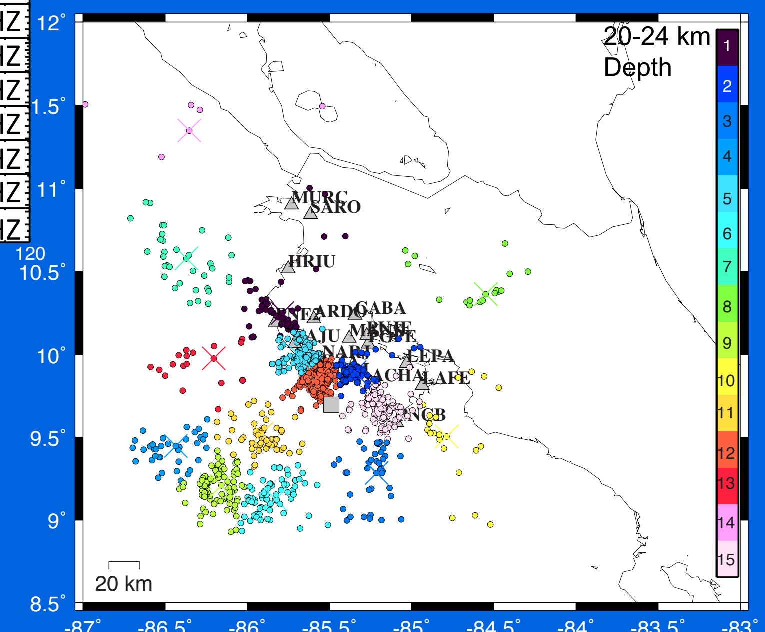
Methods – Event clustering and envelopes



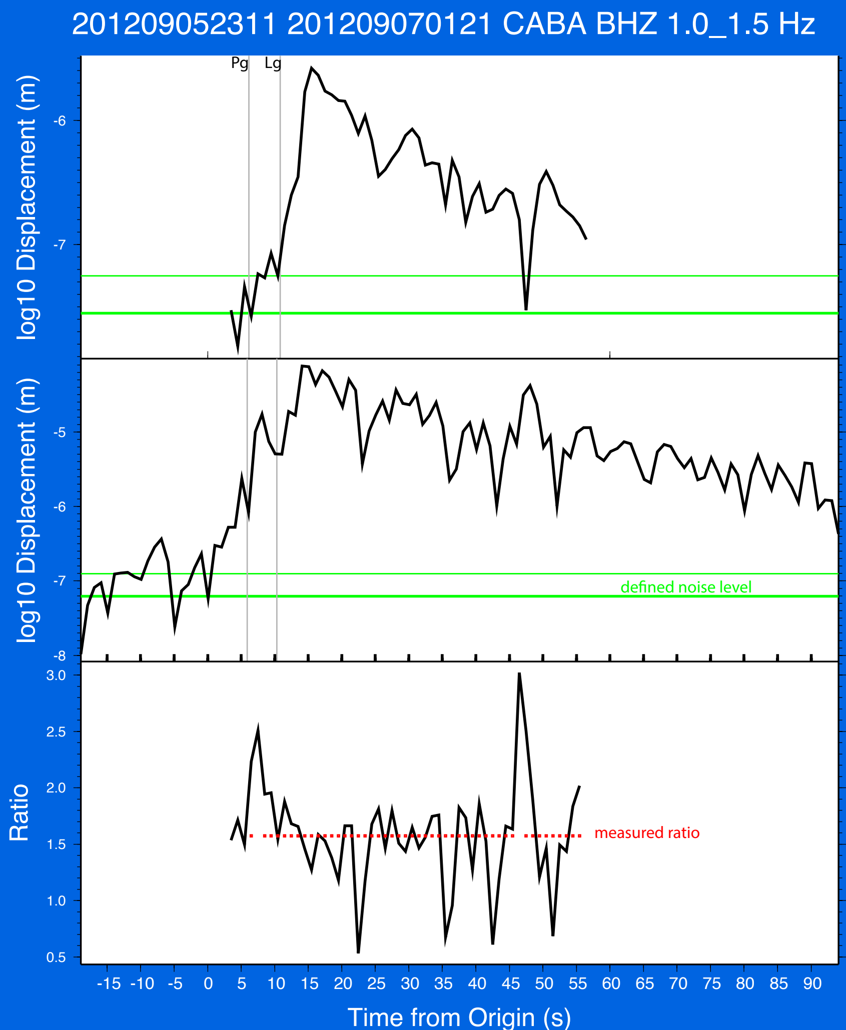
For each event within a cluster, use vertical component and combine horizontal components, compute envelopes at specific narrow frequency bands for vertical component and combined horizontal components

Determine event clusters within narrow depth bins with at least 3 events per cluster

Reduces differences in path between event pairs and stations

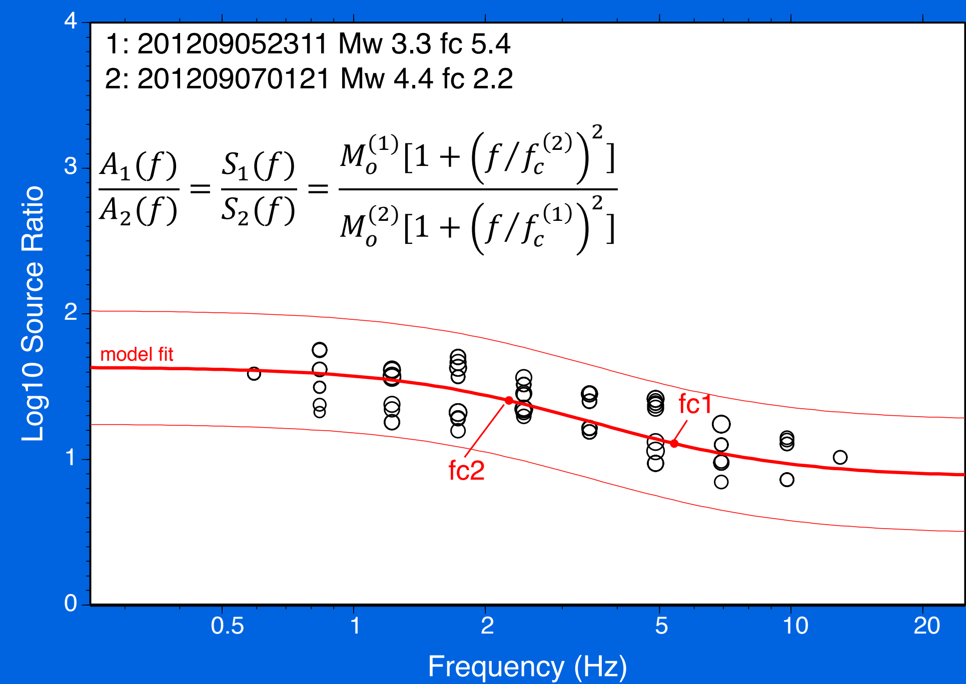


Methods – Amplitude Measurements and Spectral Ratios



For event pairs, difference envelope amplitudes where amplitudes are greater than pre-event noise level

Fit an ω^2 Brune source model to the ratios, finding M_o and f_c for each event pair



Compute stress drop ($\Delta\sigma$) using M_o and f_c, and

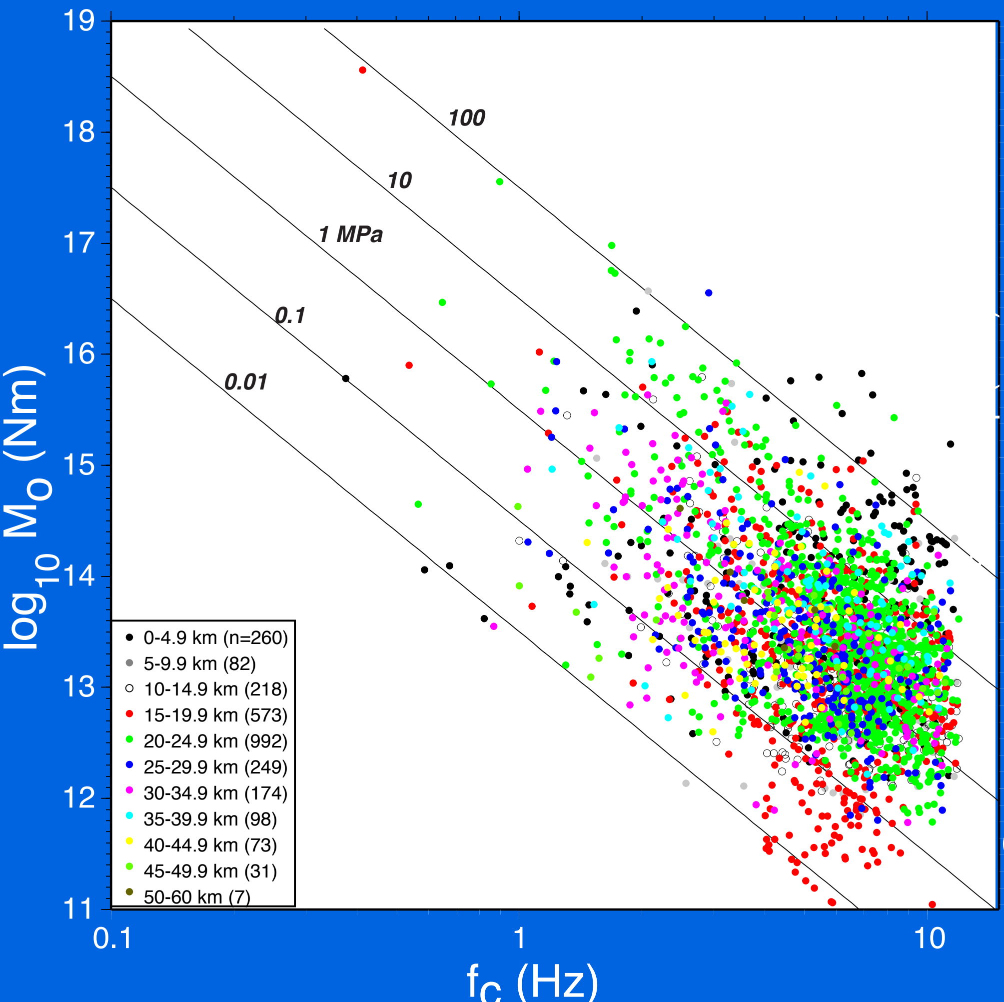
$$f_c = cv\left(\frac{\Delta\sigma}{M_0}\right)^{\frac{1}{3}}$$

c constant related to phase type, geometry
v source medium velocity

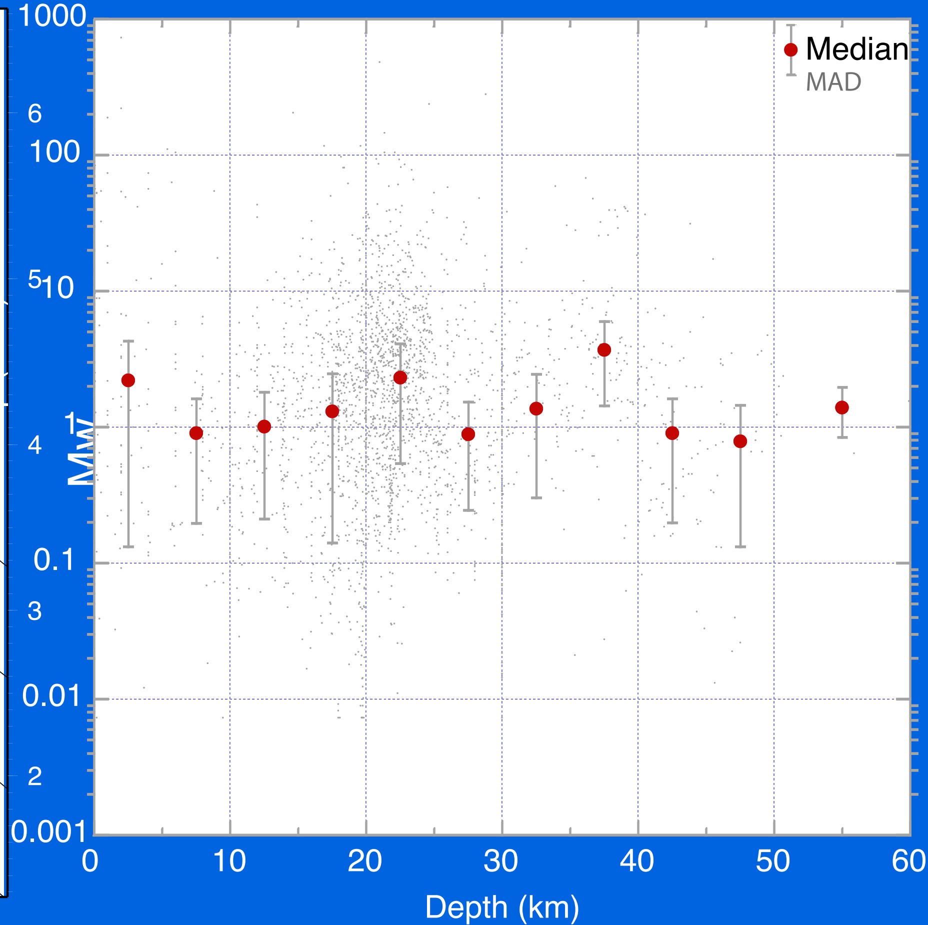
Method modified from *Fisk and Phillips*, BSSA, 2013

Results

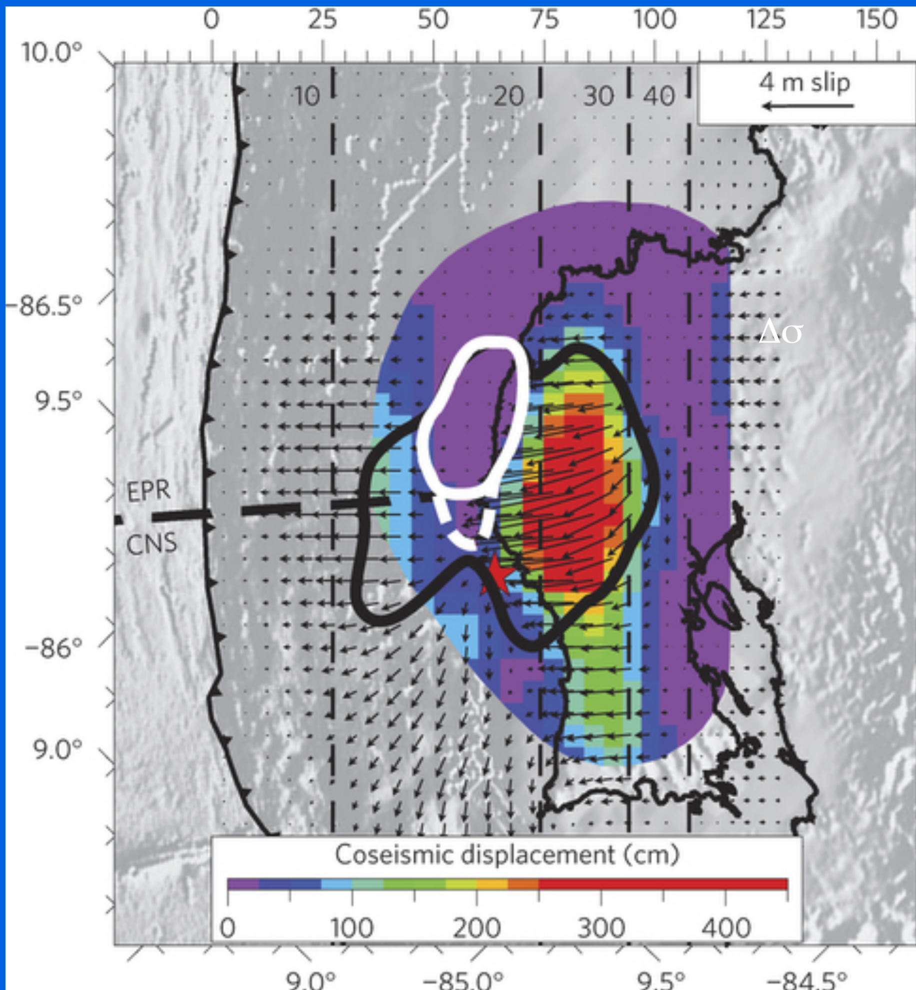
- Majority of events (landward of trench) within expected range of Δσ
  - Median 1.6 MPa



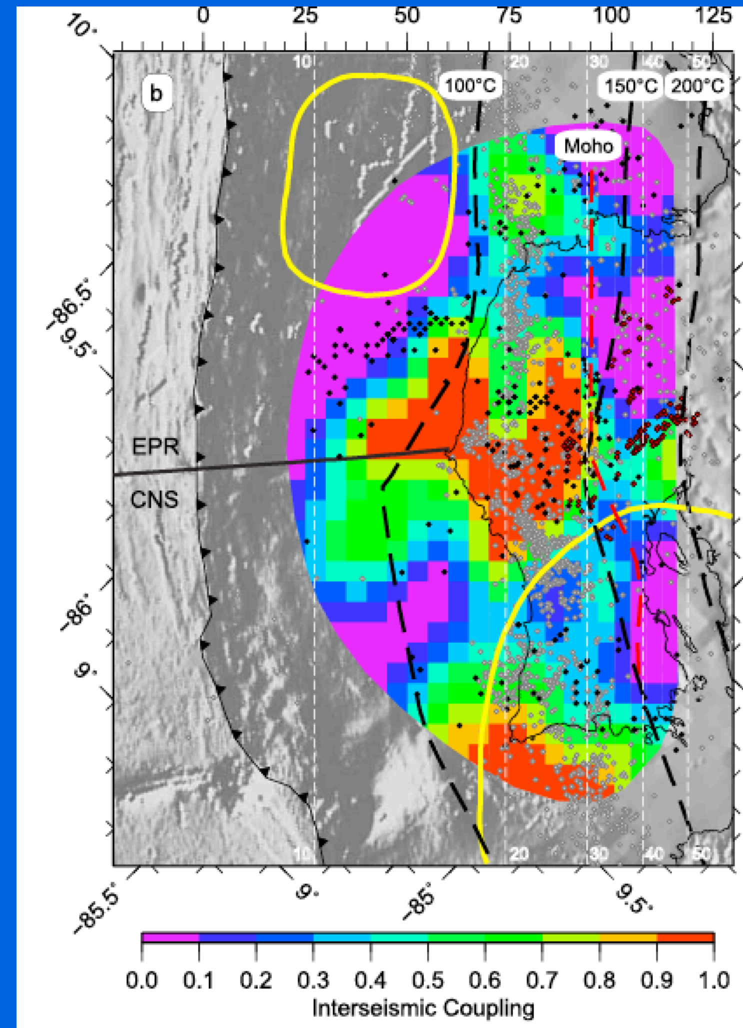
- No significant depth variation for Δσ
  - Contrast with NE Japan



Comparisons with Plate Coupling and Coseismic Slip



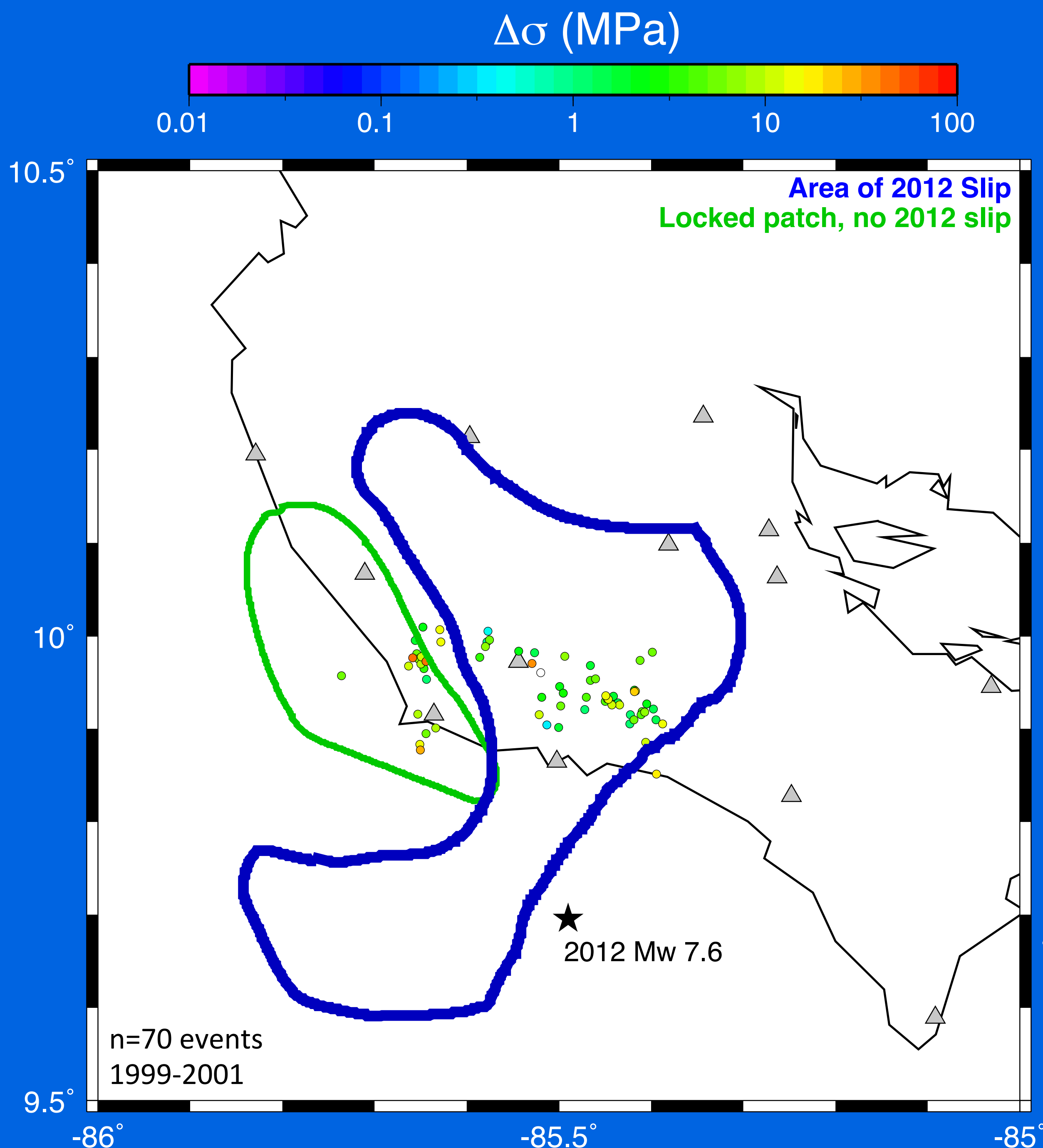
Protti et al., 2014



Within 2012 M_w 7.6 event region, detailed geodetic models suggest significant variation in geodetic coupling that links partially to area of coseismic slip during the 2012 event

- questions/concerns about updip locked patch that did not slip in 2012

Before 2012



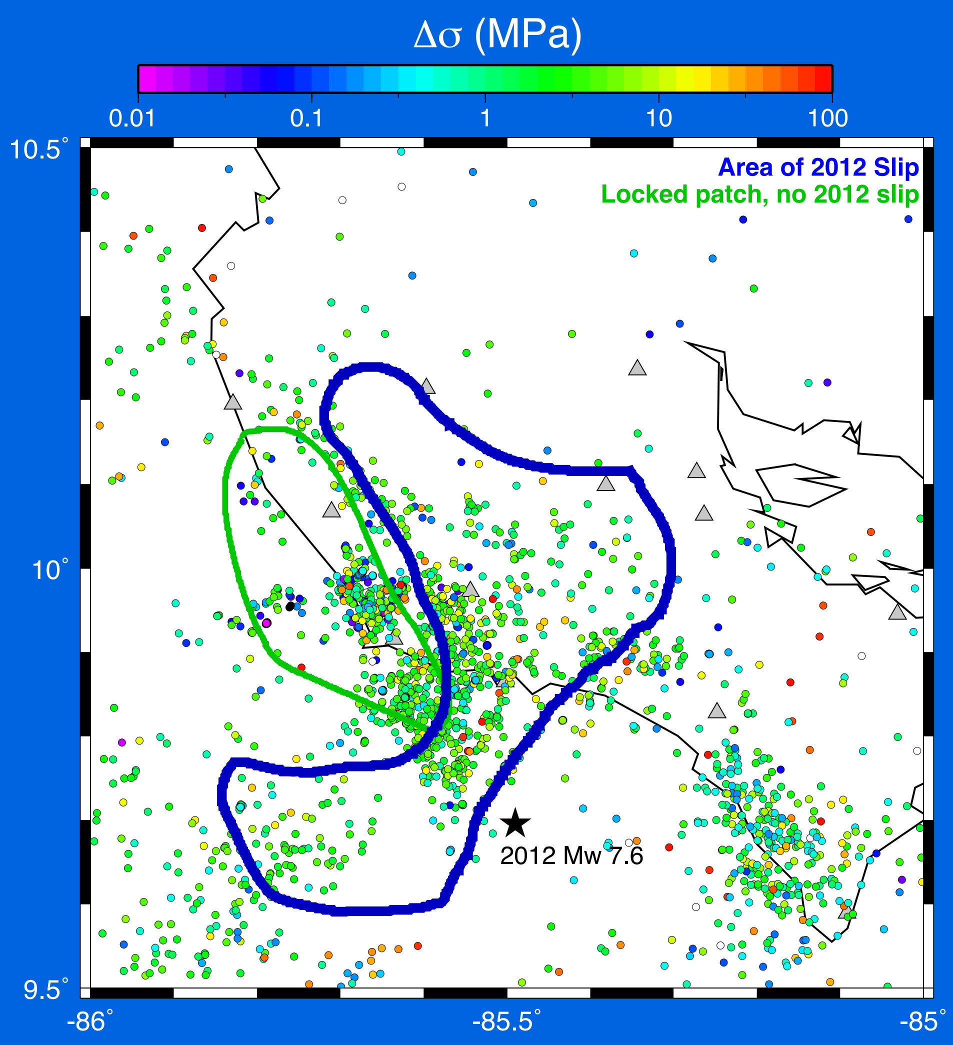
Median Δσ= 5.3 MPa

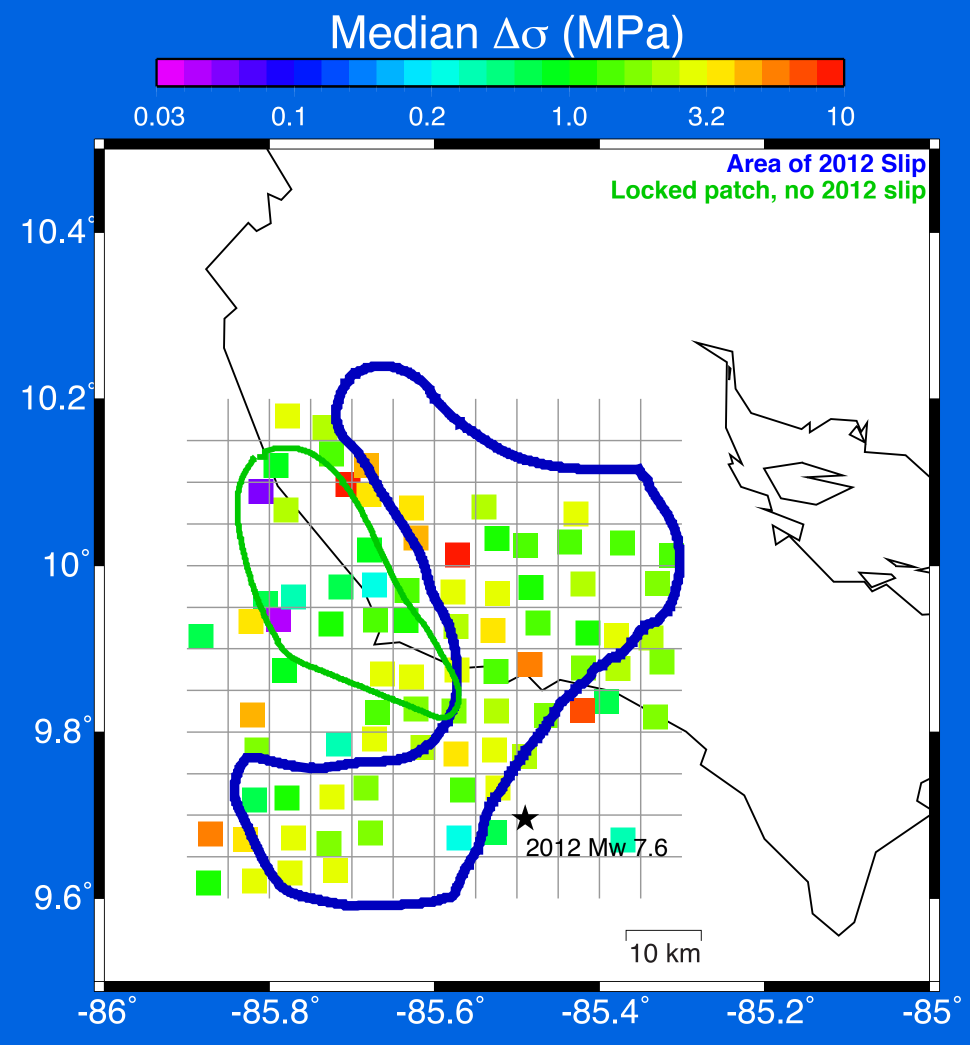
Within slip zone:
median Δσ=4.2 MPa
(n=42)

Within “locked, no-slip” zone:
median Δσ=7.2 MPa
(n=17)

Higher stress drop within area that did not slip in 2012 – rupture barrier?
similar to 2011 Tohoku

Comparisons with Plate Coupling and Coseismic Slip: Focus on Aftershocks

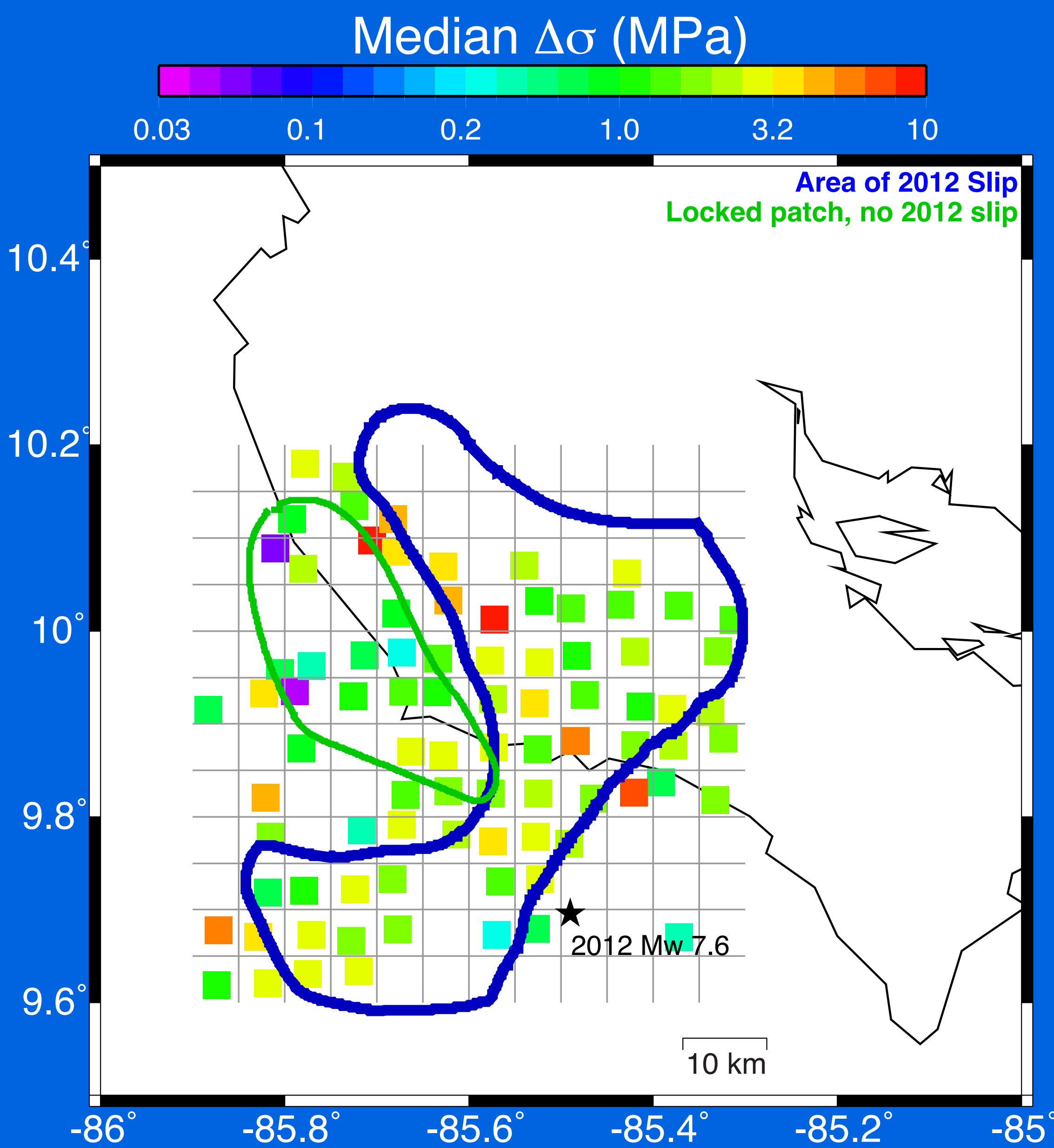




Within rupture zone:
median $\Delta\sigma$=2.4 MPa (n=621)

In no-slip zone:
median $\Delta\sigma$=1.3 MPa (n=629)

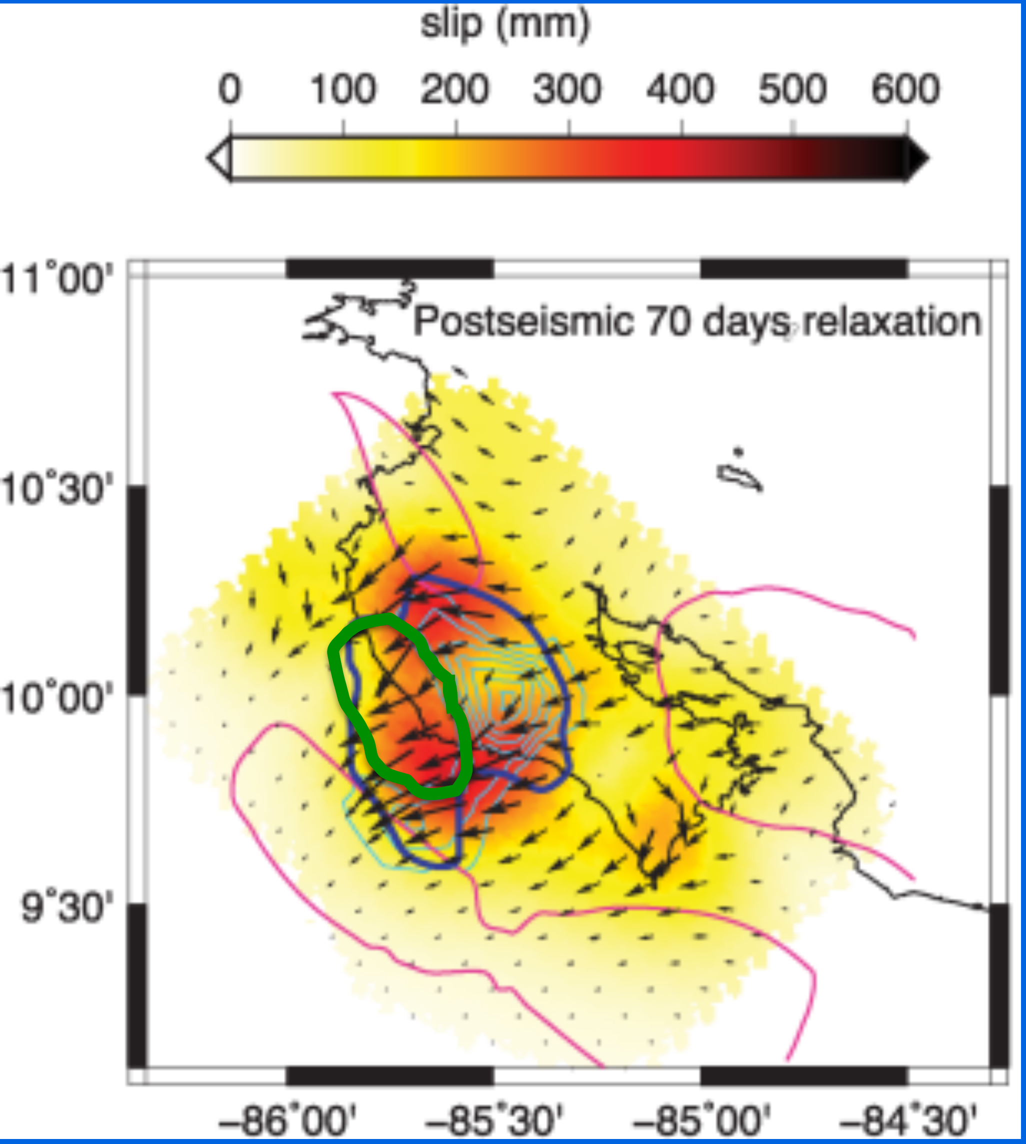
Comparisons with Plate Coupling and Coseismic Slip: Aftershocks



After 2012 earthquake, lower stress drop for aftershocks in "no-slip" zone than for aftershocks in the rupture area.

Why?

Aftershocks and afterslip



Significant levels of afterslip in region that was defined as locked, but did not slip coseismically.

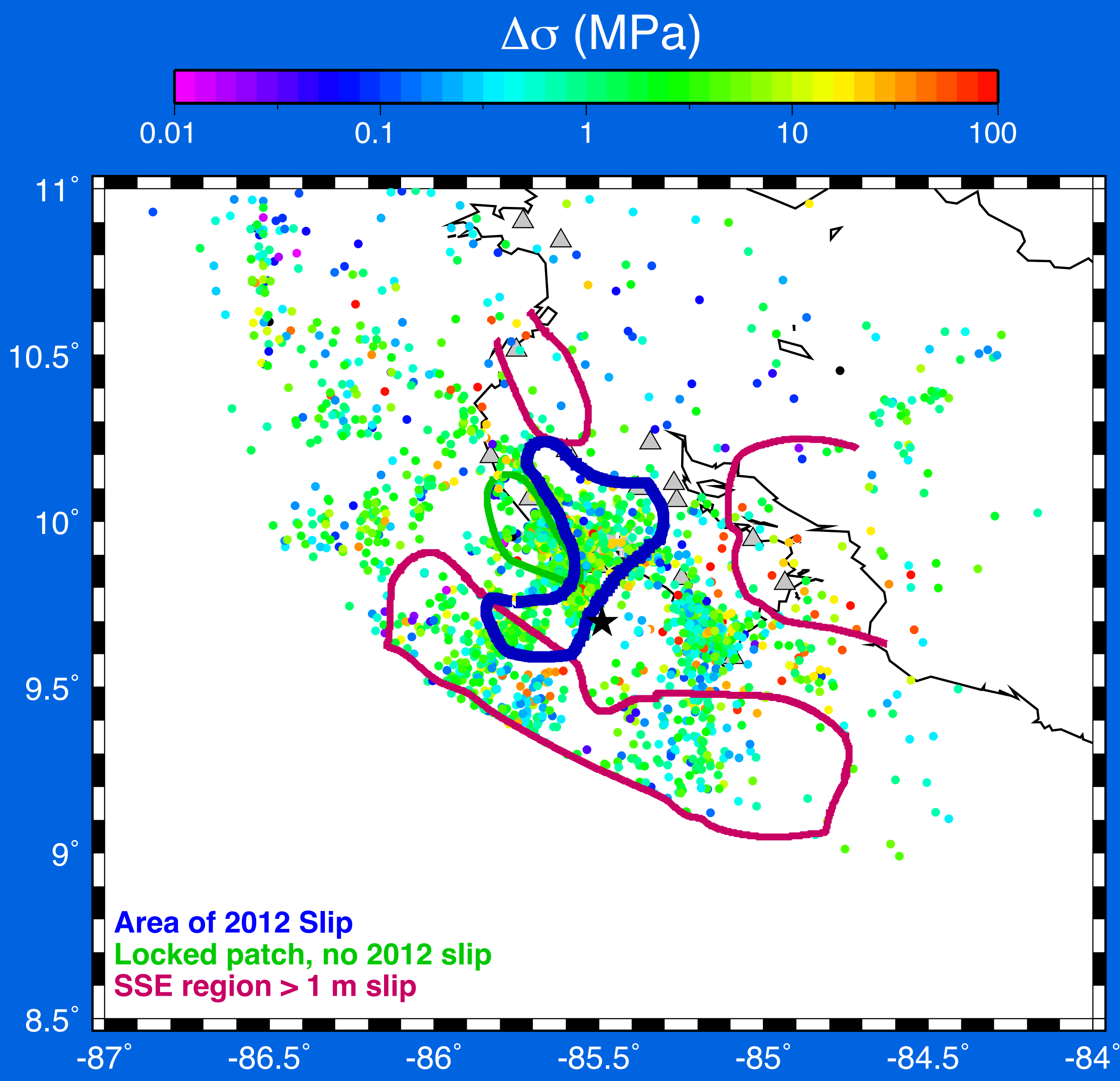
Afterslip area corresponds of lower stress drop aftershocks occurring during the afterslip period.

Conditions needed for afterslip similar to those to produce low stress drop events?

Why the change from pre-2012 high stress drop events to low stress drop and afterslip after the mainshock?

Afterslip map: Malservsi et al, 2015

Comparison with SSE



Focus on shallow/near trench SSE region

Median Δσ = 1.4 MPa (n=407)

Similar Δσ as found in the afterslip region

- Are conditions required to produce both SSE and afterslip similar?

Some Complexity Required!

- Spatial and temporal variations in $\Delta\sigma$ within the area of the 2012 M_w 7.6 earthquake
  - Within previously defined locked patch and using events ~10 years prior, find higher $\Delta\sigma$ events in portion of the fault that did not rupture in 2012, acting as a barrier to 2012 rupture
  - All aftershocks had lower $\Delta\sigma$ than before, with ~2x lower $\Delta\sigma$ in the portion of fault with no coseismic slip, but significant afterslip
  - Similarly low $\Delta\sigma$ in shallow SSE zone as in area of significant afterslip

- Provides new observations to link to models of fault locking, rate & state friction
  - Small earthquakes used as probe for fault zone properties and identifying heterogeneity