Earthquake Cycle Monitoring under the Nicoya Peninsula, Costa Rica

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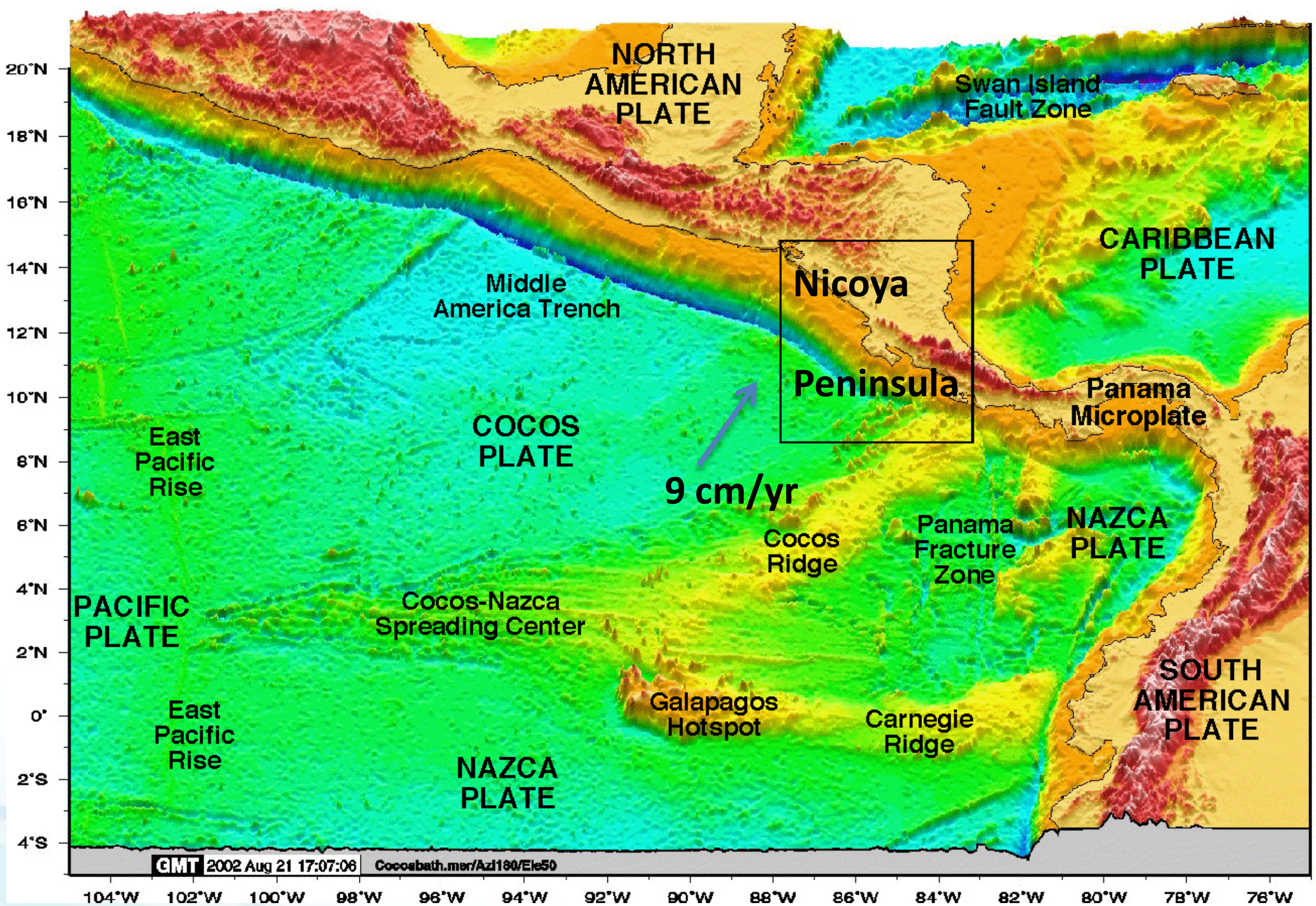
Tectonic Setting of Nicoya



Modified from Marshall, 2002

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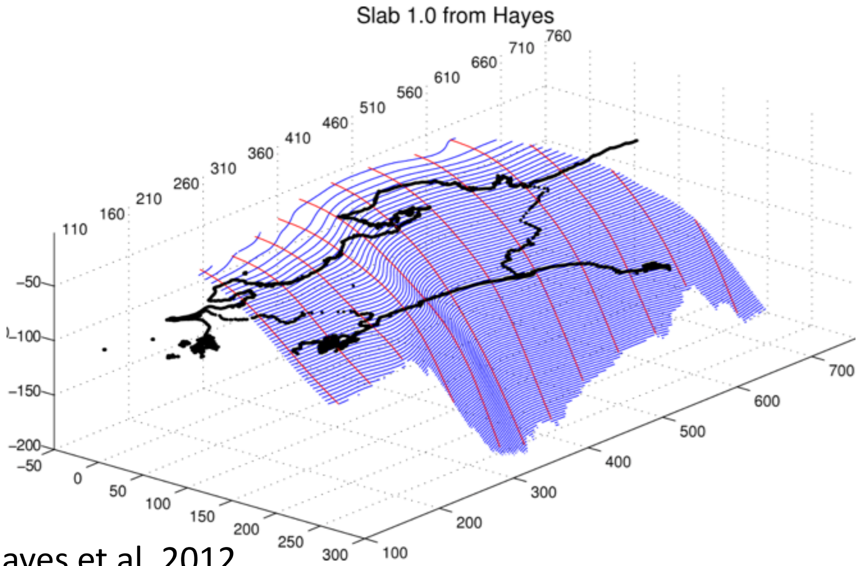
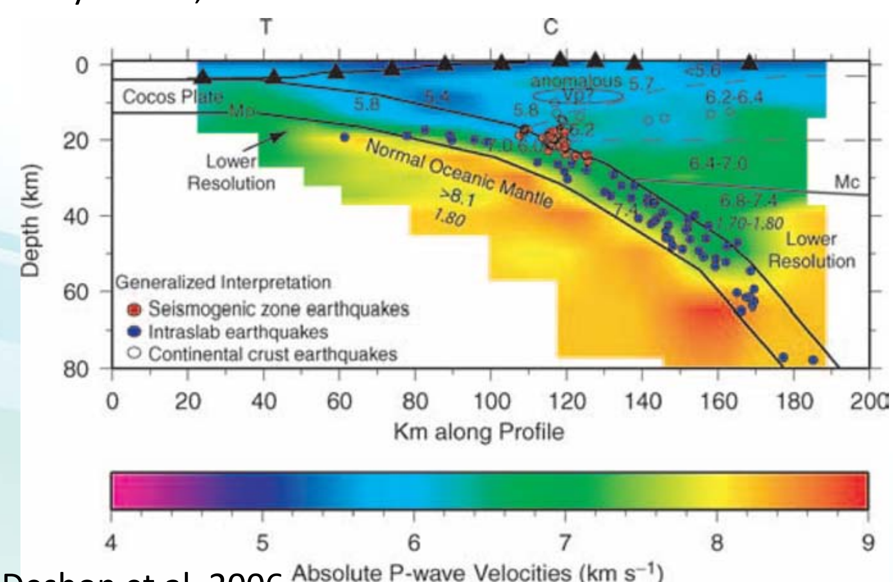
Structure of the Subducting Slab



Hayes et al, 2012



Deshon et al, 2006

- Complex Geometry due to the rougher subducting sea-floor to the south.
- Peninsula's location near the trench (<75 km) allows for great geodetic resolution above the seismogenic zone.

USF/UCSC/GT/OVSICORI Networks

GPS

- 17 Continuous GPS (Most installed beginning in 2005)
- 24 Survey GPS monuments
  - Most were ~3-14 day occupations (yellow)
  - 5 left for long-term postseismic (red)
  - Volcanic and some far-field sites omitted (orange)

Seismic

- Continuous development 2005-present
- 13 Broad-band sensors (white triangles)
- 3 short-period sensors(yellow triangles)

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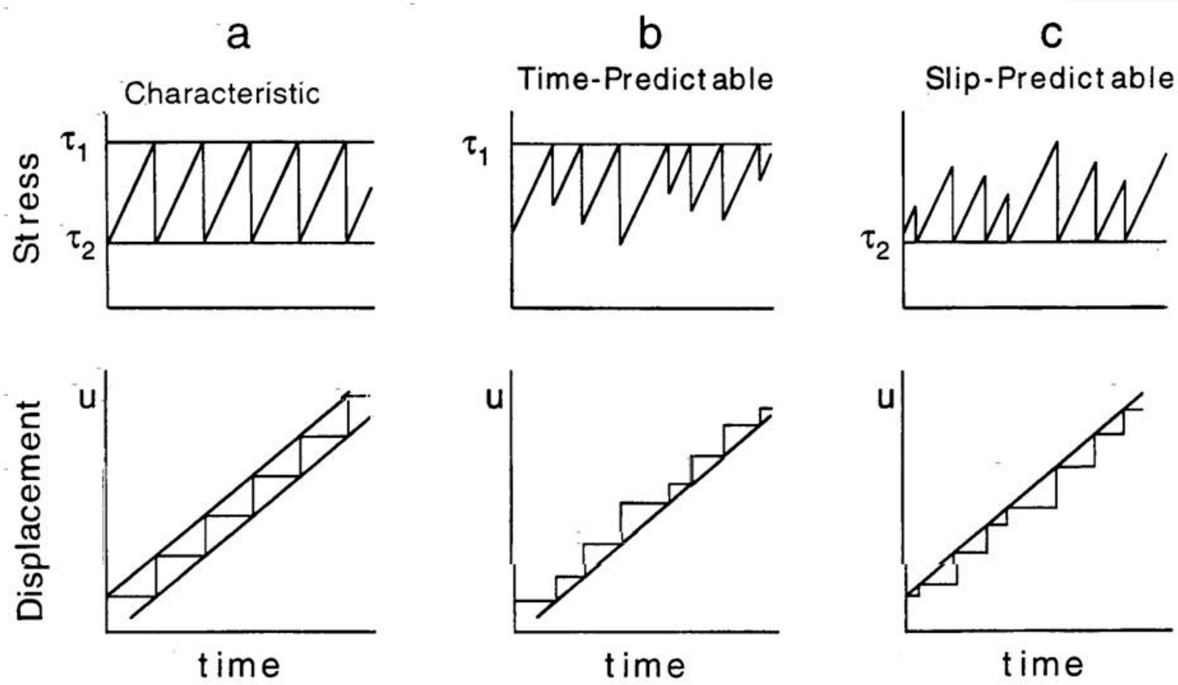
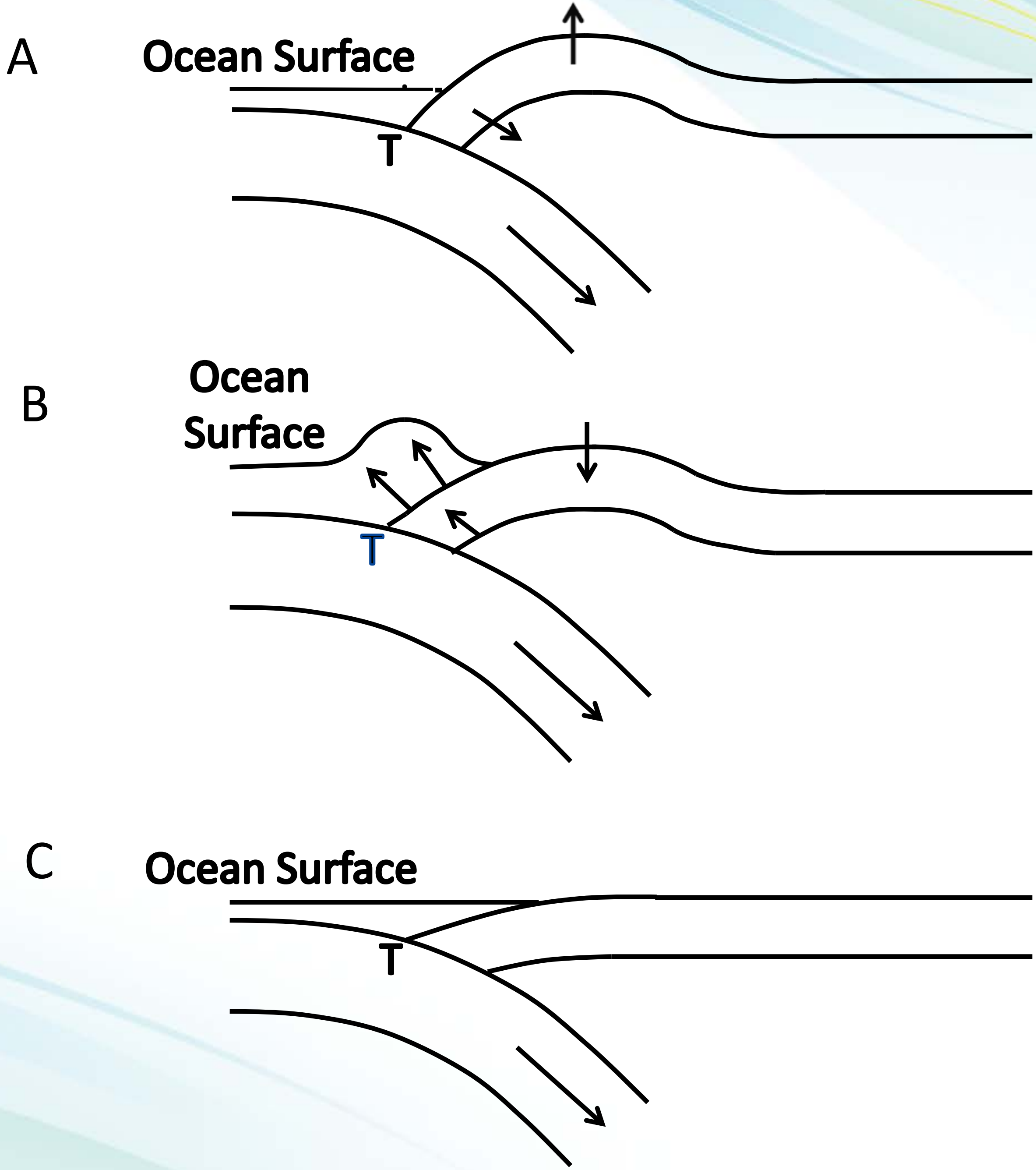
Goals in monitoring the Earthquake Cycle



Which one is it?

(Lay and Wallace, 1995)



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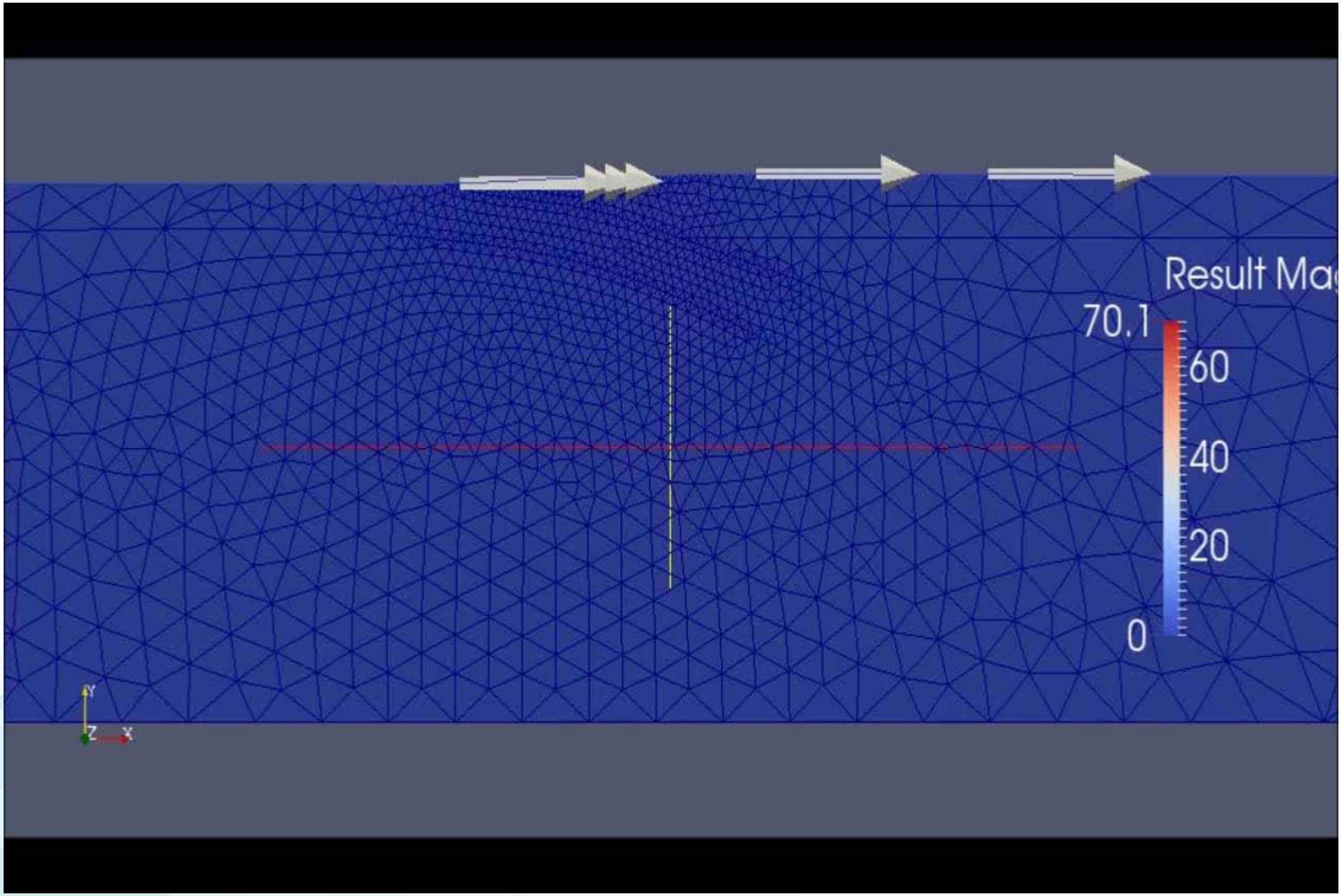
Earthquake Cycle Animations



Fine scale features of the Earthquake cycle

- Pre-Seismic
  - Slow Slip events, slow earthquakes with M>5.0 that take place over weeks to months
  - Variance in locking both spatially and temporally
  - Continuous observation is critical
- Co-Seismic
  - Earthquake behavior on different time scales
  - High Rate GPS
- Post-Seismic
  - After-Slip vs Relaxation of the Mantle?

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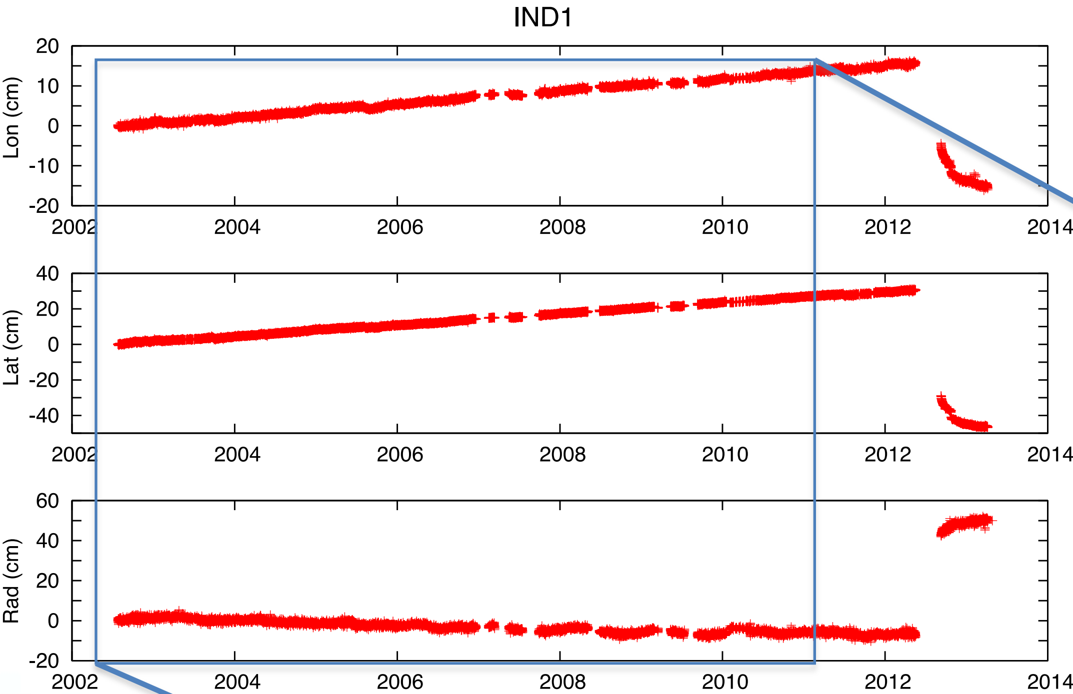
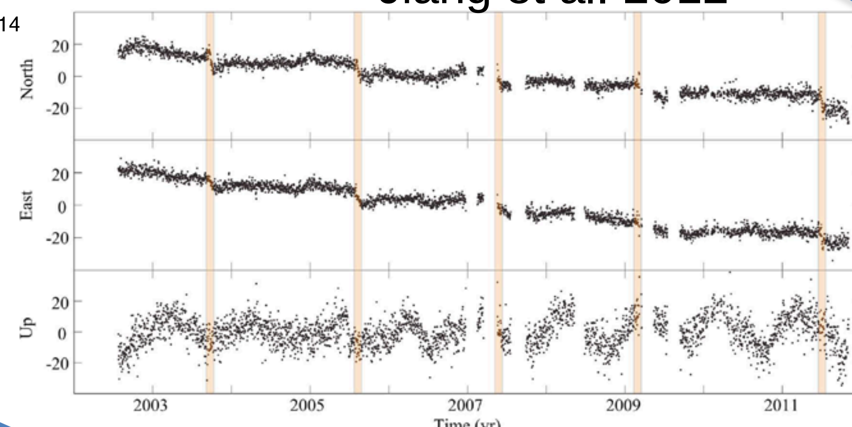
The Pre-Seismic



- Analysis of inter-seismic data show Slow Slip Events

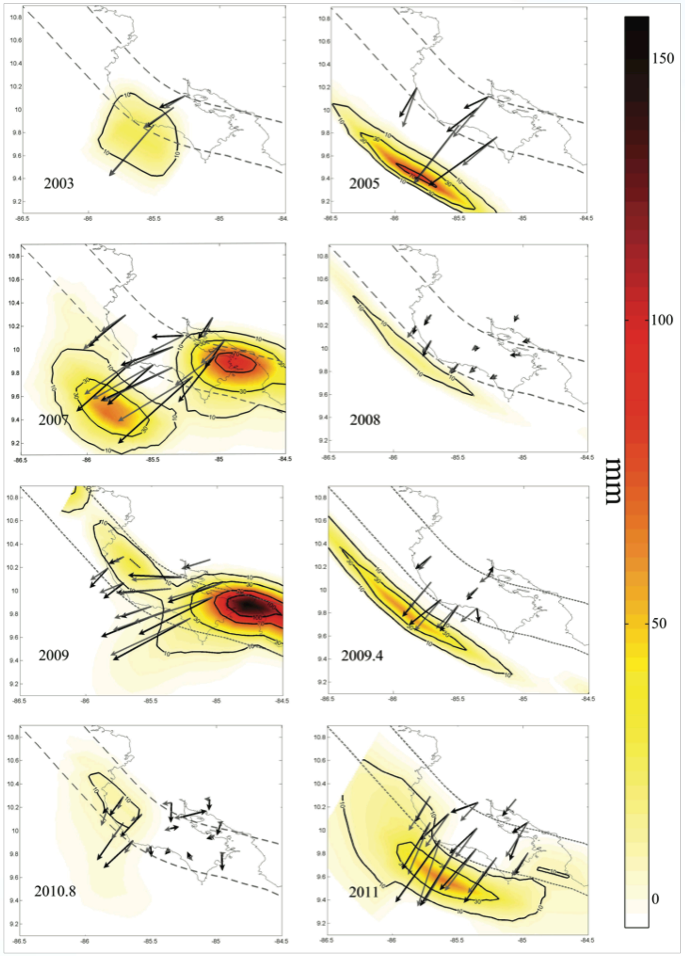
Jiang et al. 2012



Using Geodetic Data to Image Slip Distribution

- Identify SSE

- Invert for slip on a fault with predefined geometry using Okada (1992) analytical solution for dislocation in a elastic half space



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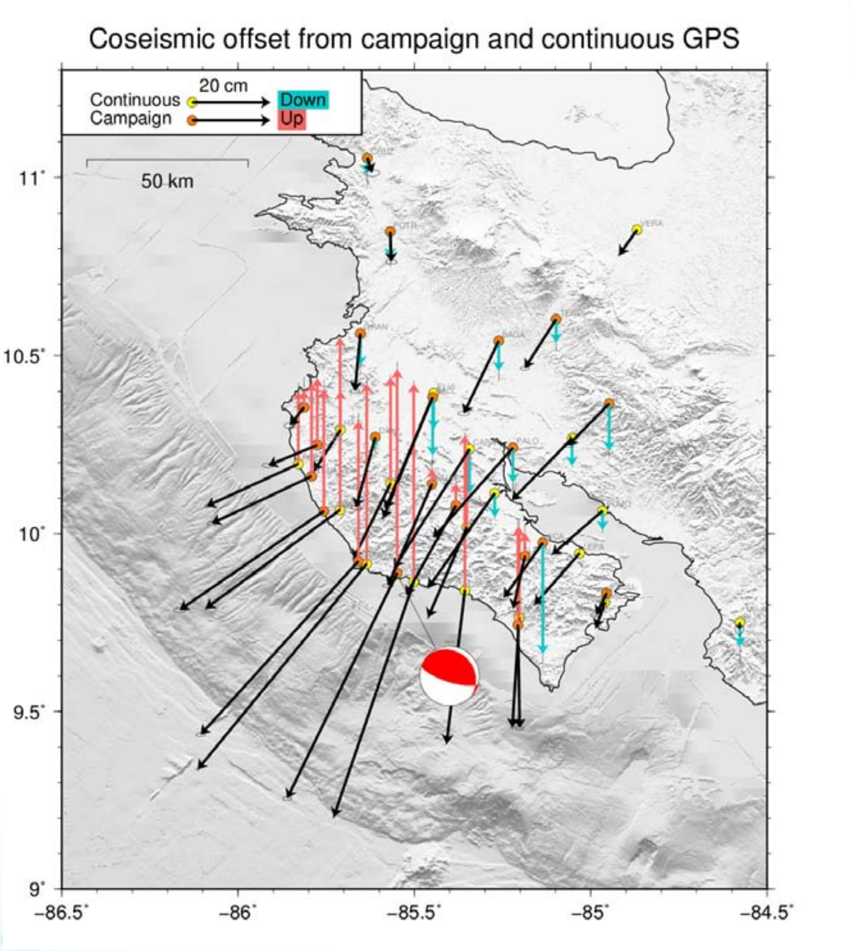
The Co-Seismic : September 5, 2012



Protti et al, Nature
Geosciences 2014

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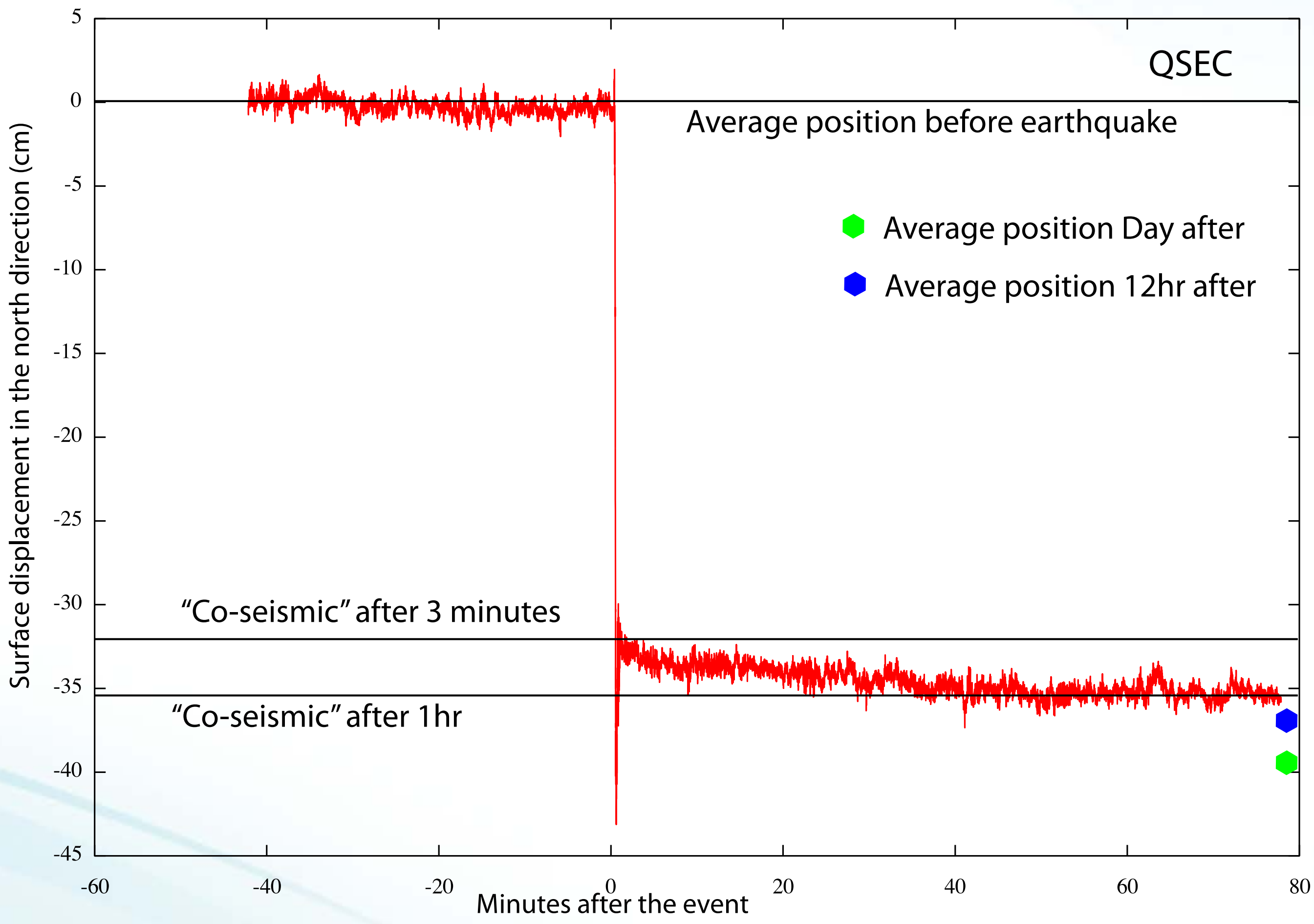
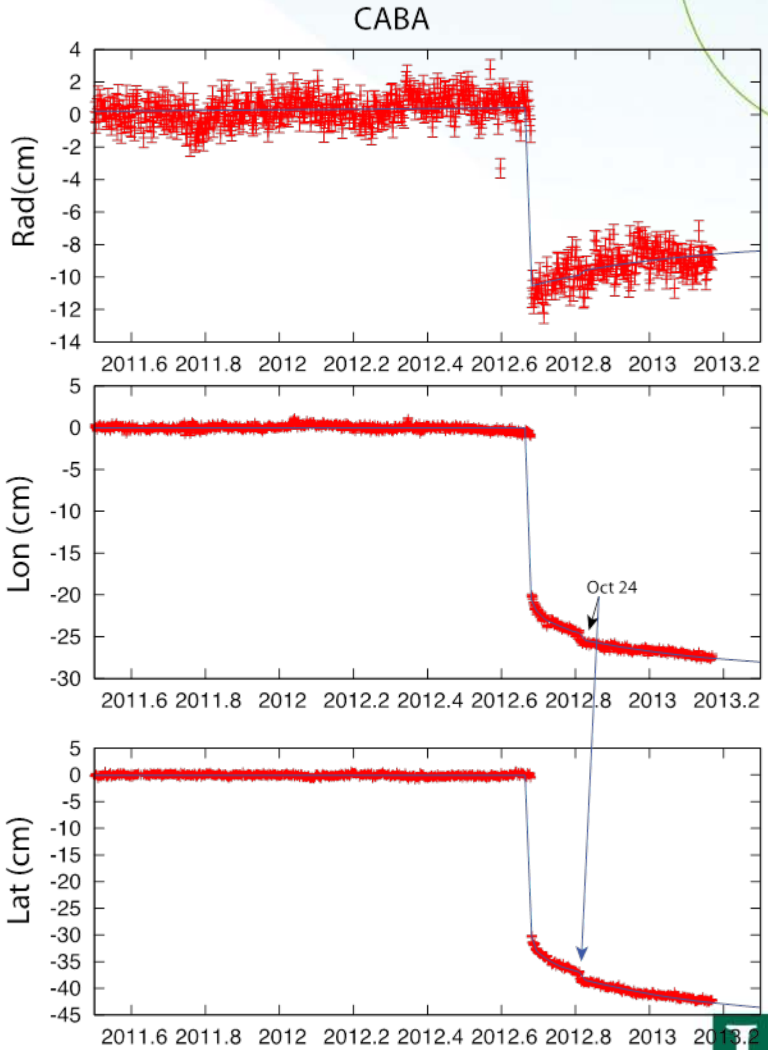
When does the earthquake stop?



Post-Seismic

- After Slip vs Viscoelastic relaxation?
- Two different relaxation times fit the data ~30 days and ~150 days
- How does this change stress in the seismogenic zone?

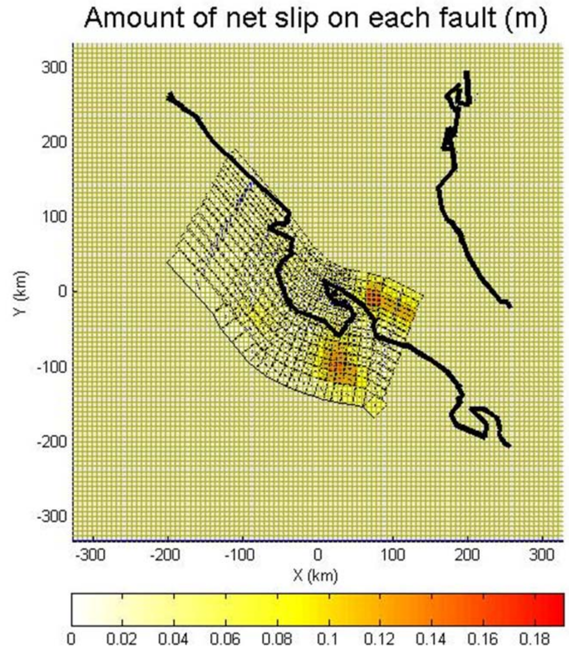


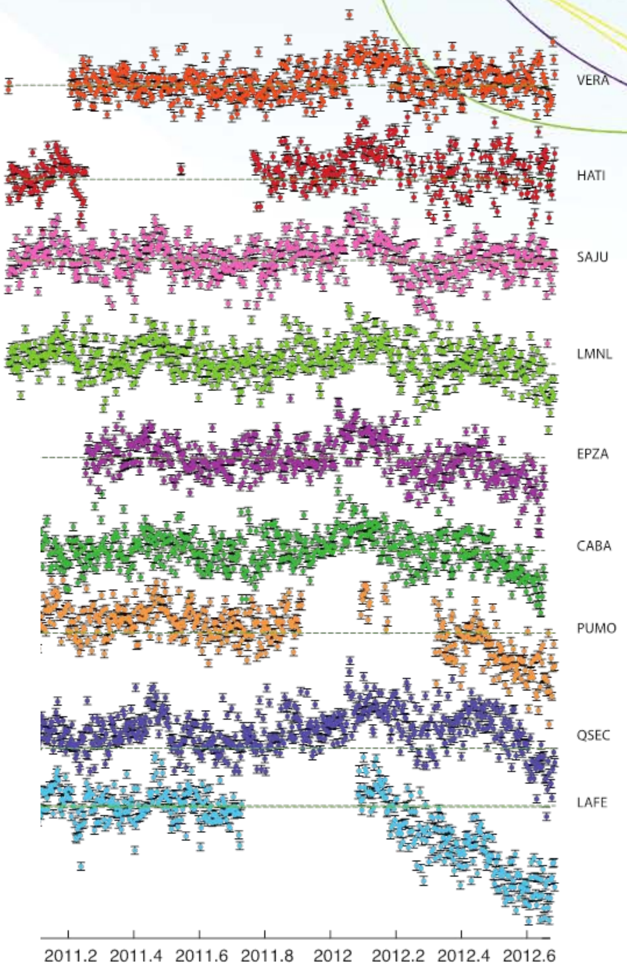
Tying the Phases together

- The 2012 M 7.6 Earthquake offers the unique opportunity to look for connections between the Earthquake Cycle phases.
- Only possible because of the long term continuous geodetic network and a little luck in “trapping” the large earthquake.

Slow Slip – Mega Thrust Interaction

- Did a Slow Slip event Trigger the megathrust event?
- In 2012 a Slow Slip event began just prior to the earthquake





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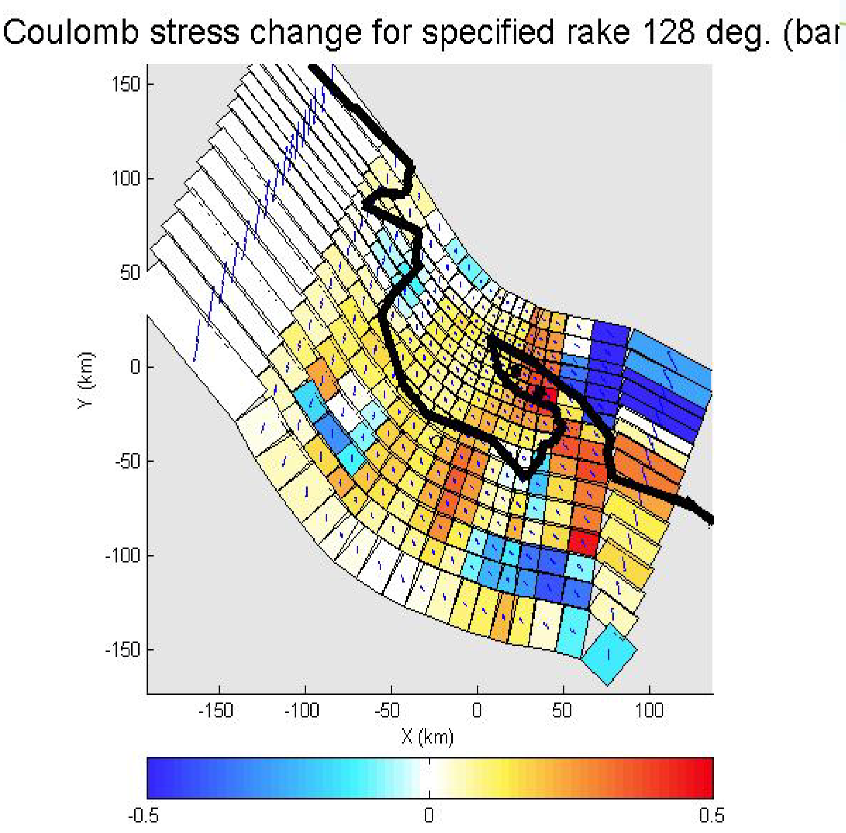
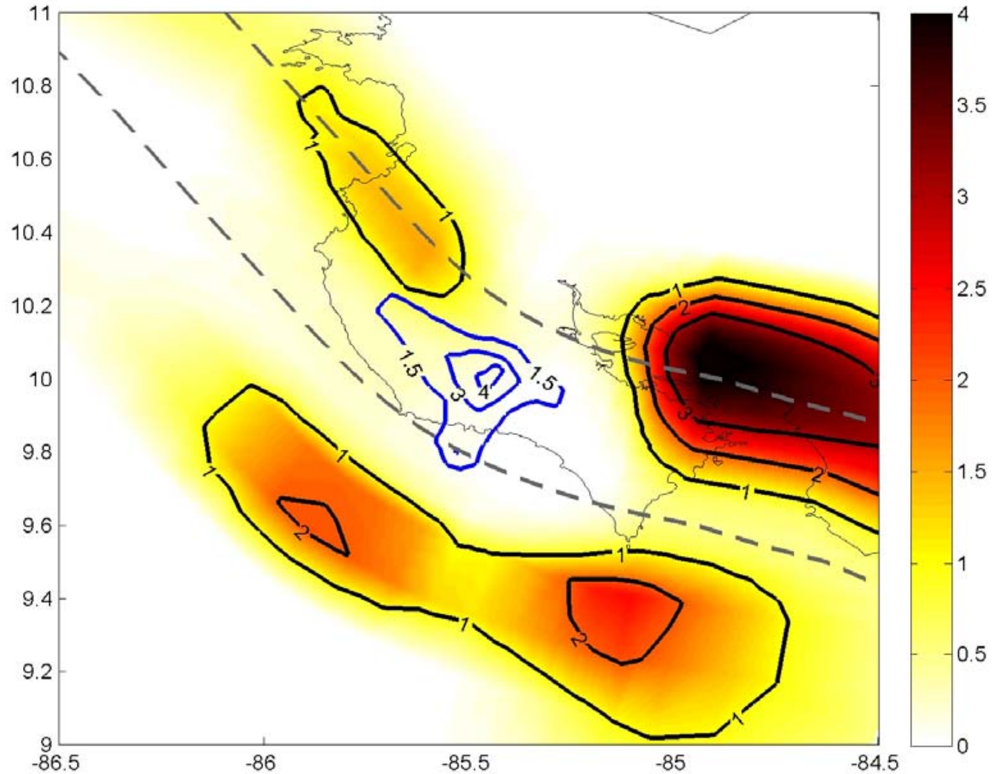
Coulomb Stress Change

- Measure of the relative change in Normal Stress to shear Stress.
- Less Normal and More Shear = More Likely to rupture.
- 0.5 Bars is the commonly accepted threshold for earthquake triggering.



Slow Slip defining rupture Dimensions for Mega-thrust?



Conclusions

- **The High Precision Continuous Geodetic network in Nicoya allows for a complete view of the earthquake cycle.**
- The continuous nature of the network allows us to characterize the evolution of stress in the lithosphere, a key component towards the goal of earthquake forecasting.
- The earthquake cycle is not a series of distinct processes but a dynamic cycle.

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