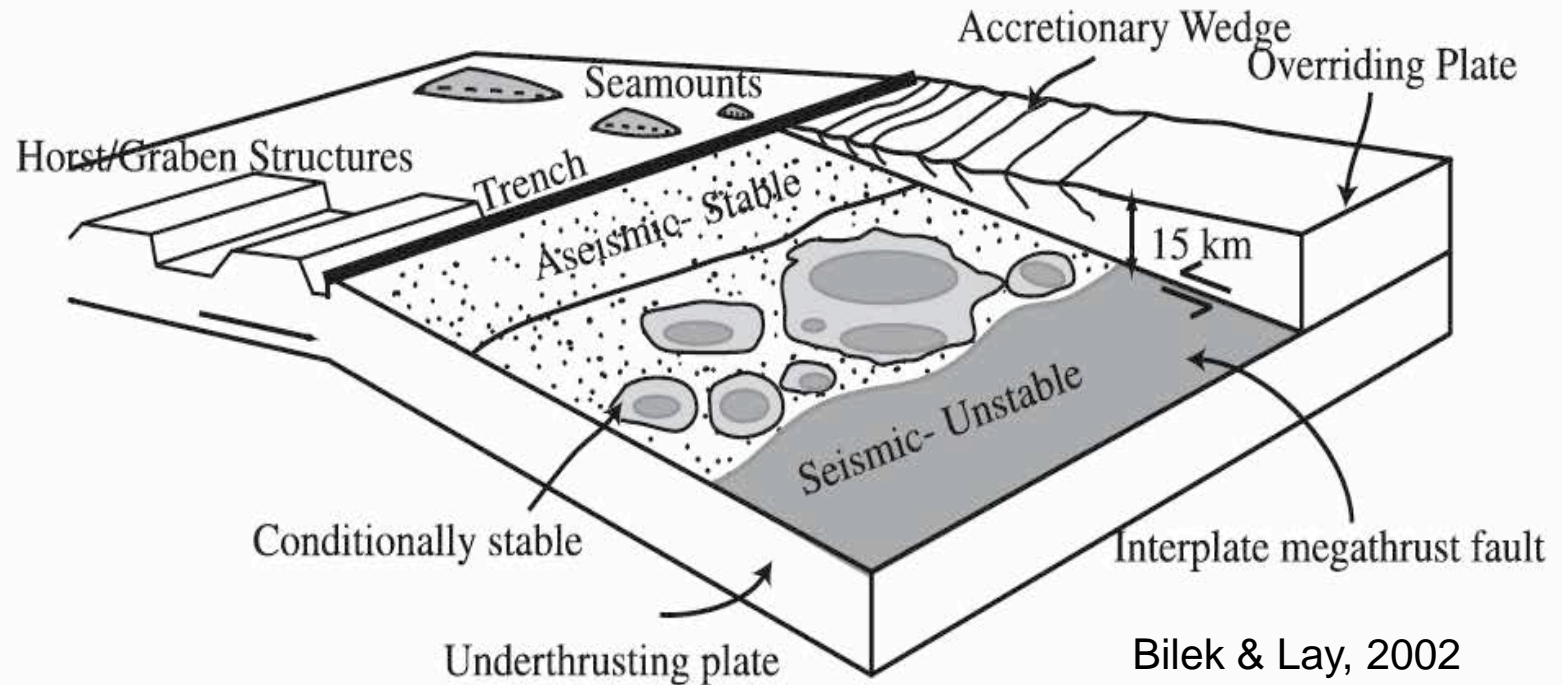
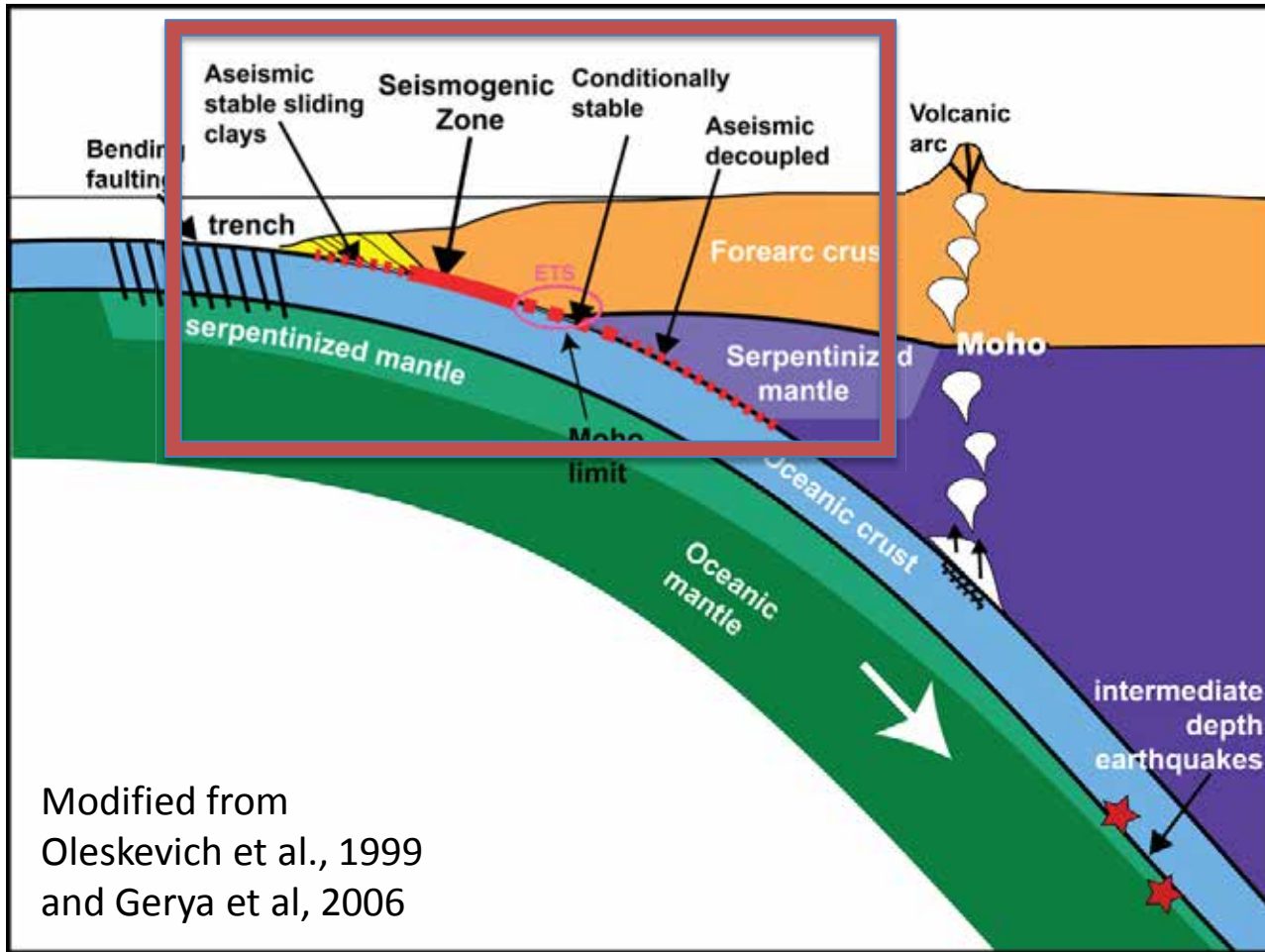


# The Seismogenic Zone

Jeffrey Freymueller, University of Alaska, Fairbanks



# Seismic, Aseismic



- Study of the Seismogenic zone is really about both seismic and aseismic slip behavior
- Slip budget and controls on modes of slip
- Aseismic and seismic slip zones interact in complex ways

# A Simple “Earthquake Cycle” Model

- Based on the 1D spring-slider analogue model
- Two “modes”: interseismic and coseismic
- Between earthquakes (interseismic):
  - Shallow fault is locked
  - Deeper fault is creeping at long-term slip rate
  - Stress builds up: elastic strain energy stored in crust
- During earthquake, shallow fault slips
  - Stress on fault reduced
- Cycle repeats forever

# How does Earth Deviate From Simple Model?

- Along-strike variations
  - Extent of slip deficit varies along strike: why?
- Slow slip events and transient slip
  - The locked to creeping transition is dynamic
- Postseismic deformation
  - Afterslip (on the plate interface)
  - Viscoelastic relaxation (in mantle wedge)
- Common theme: slip along interface varies with space and time – ***not just interseismic + coseismic in cross section.***

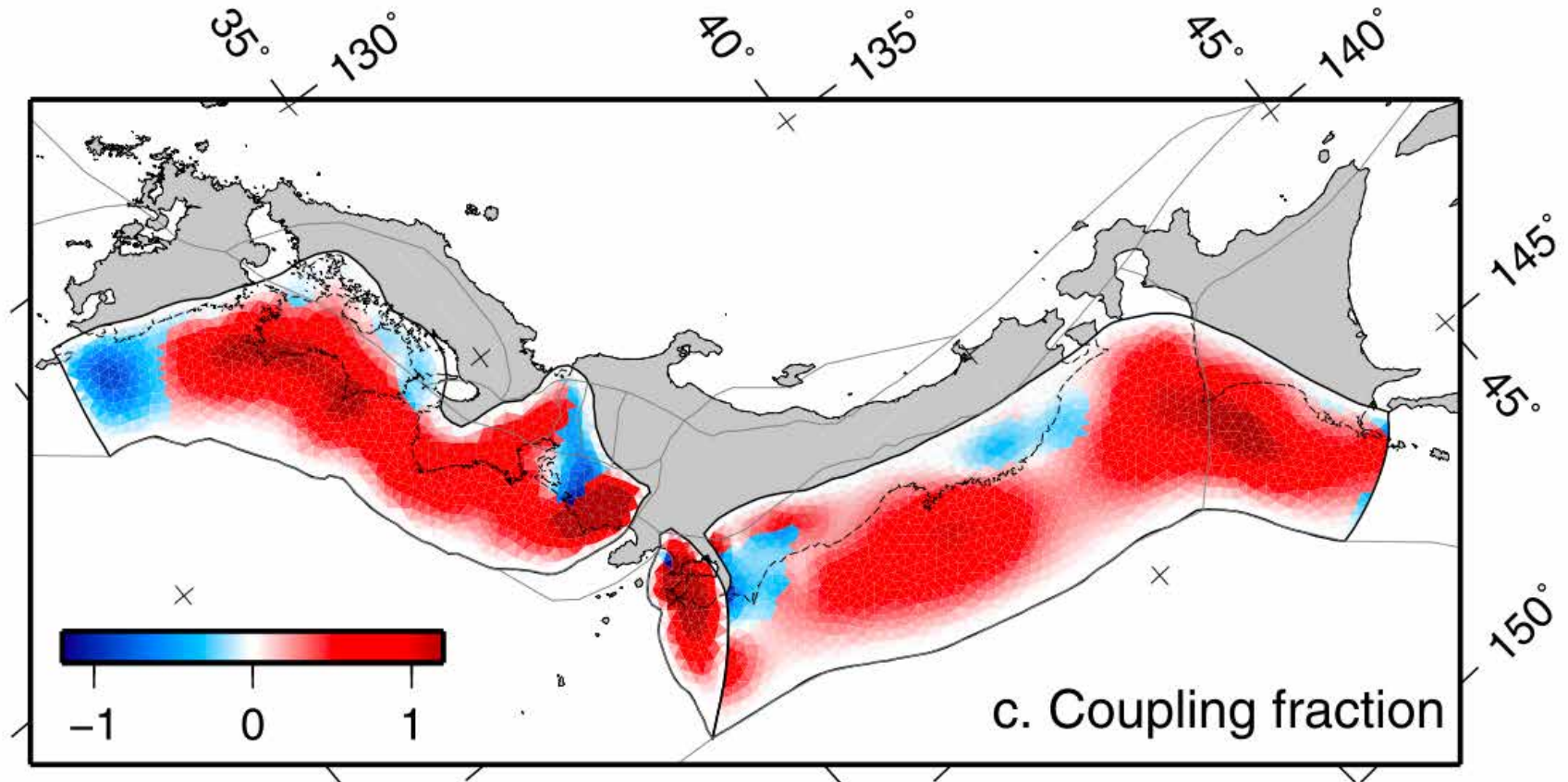
# 2011 Tohoku-oki Earthquake

Photo: BBC



# Estimated Plate Coupling

*from GPS data 1995-2000*

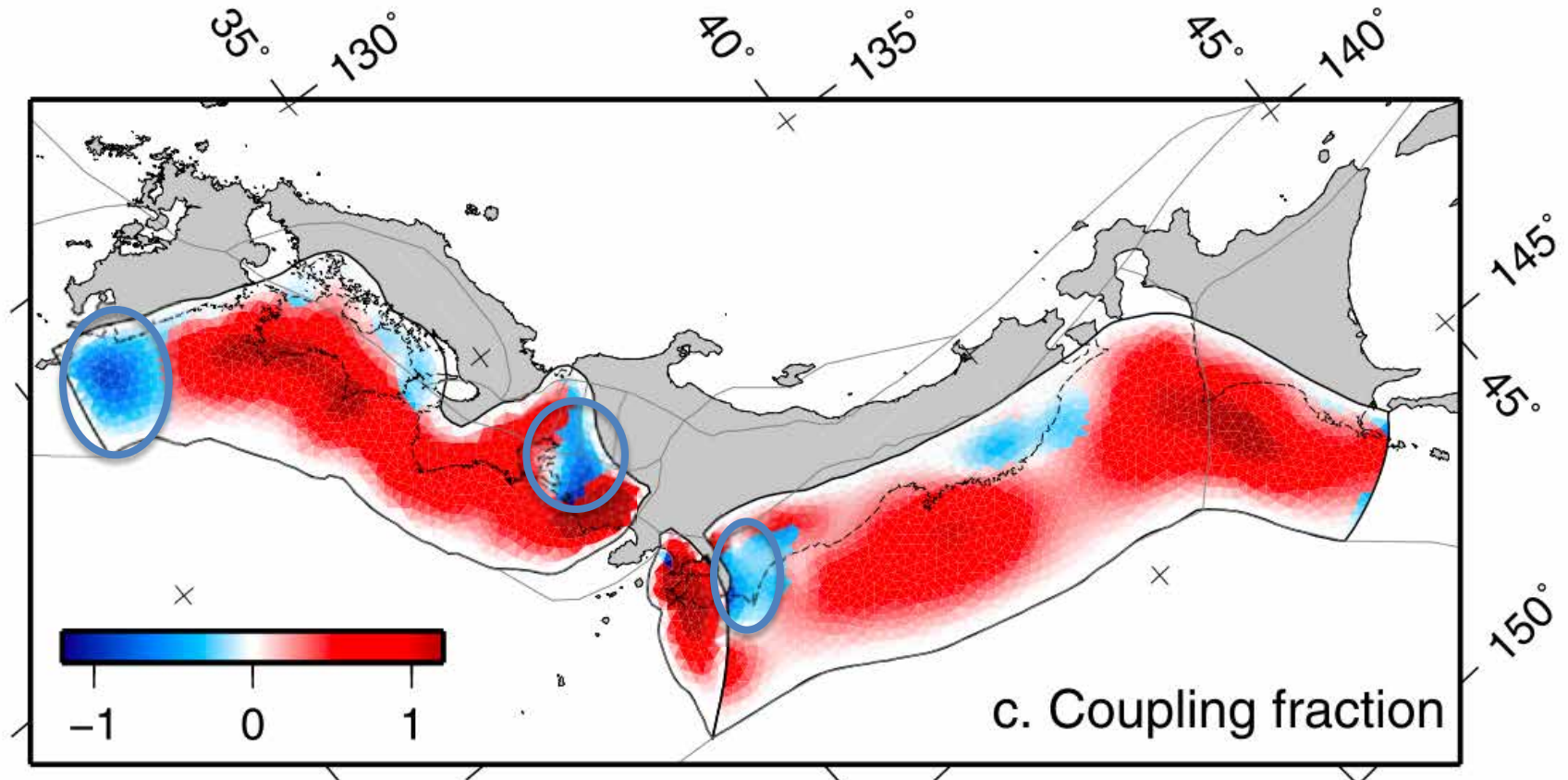


Meade and Loveless (2010)

# Estimated Plate Coupling

*from GPS data 1995-2000*

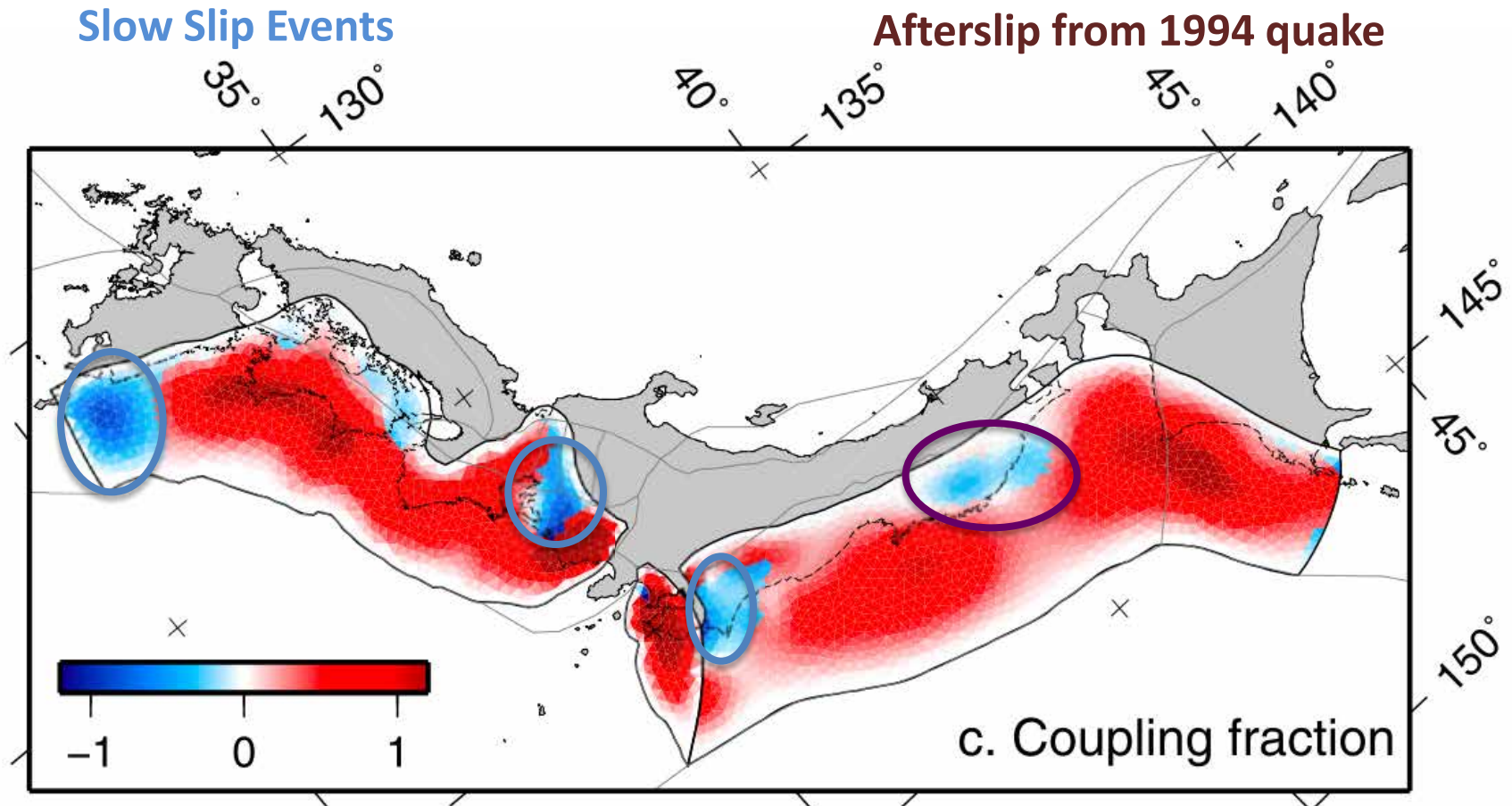
Slow Slip Events



Meade and Loveless (2010)

# Estimated Plate Coupling

*from GPS data 1995-2000*

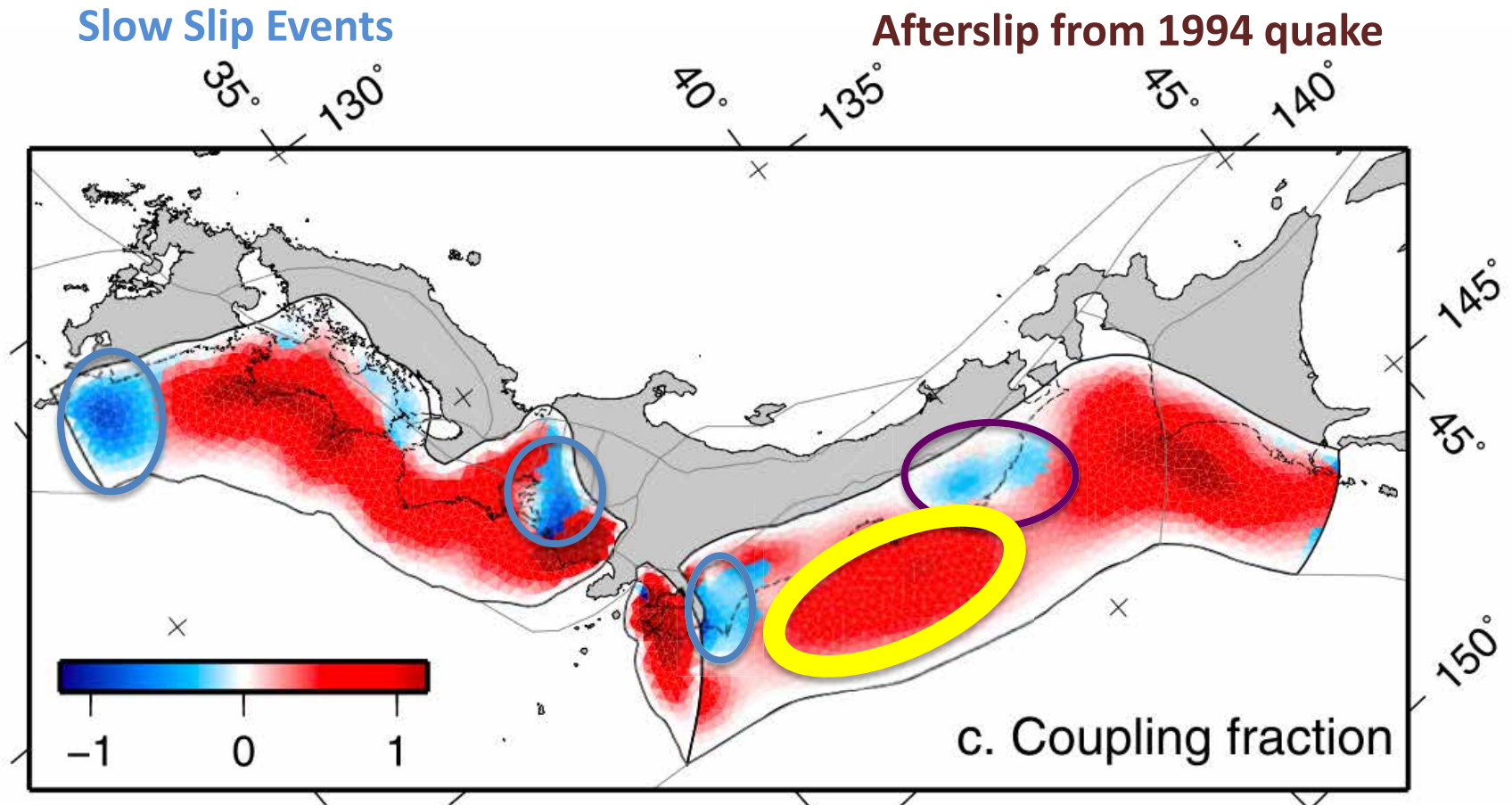


Meade and Loveless (2010)



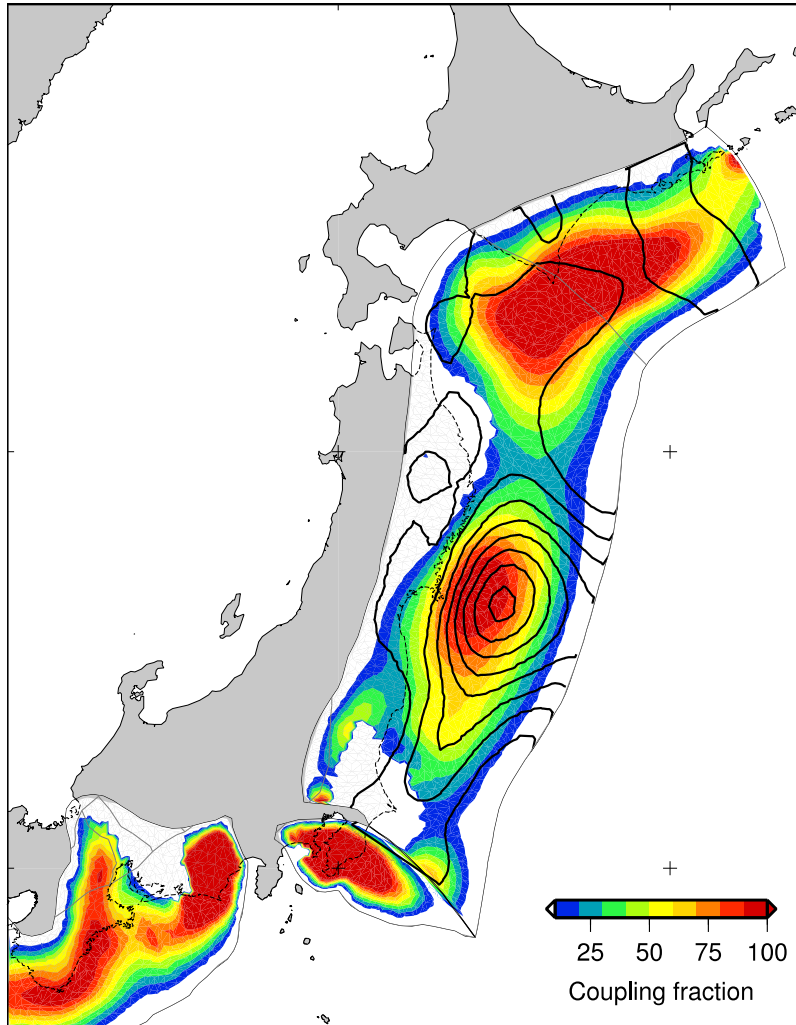
# Estimated Plate Coupling

*from GPS data 1995-2000*



Meade and Loveless (2010)

# Comparison of Locked Zone to Slip

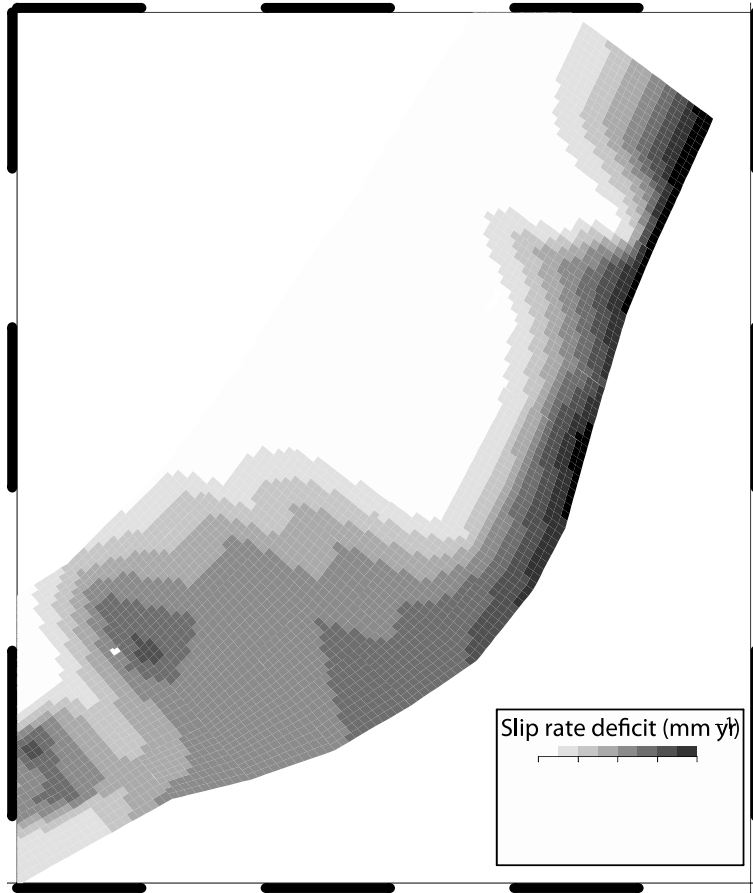


- Colors: Loveless and Meade (2010) interseismic model
- Contours: Jack Loveless' slip model contours
- **To first order, the rupture area of the earthquake is the same as the interseismic locked zone**

Loveless and Meade, 3/14/11  
Loveless and Meade (2011)

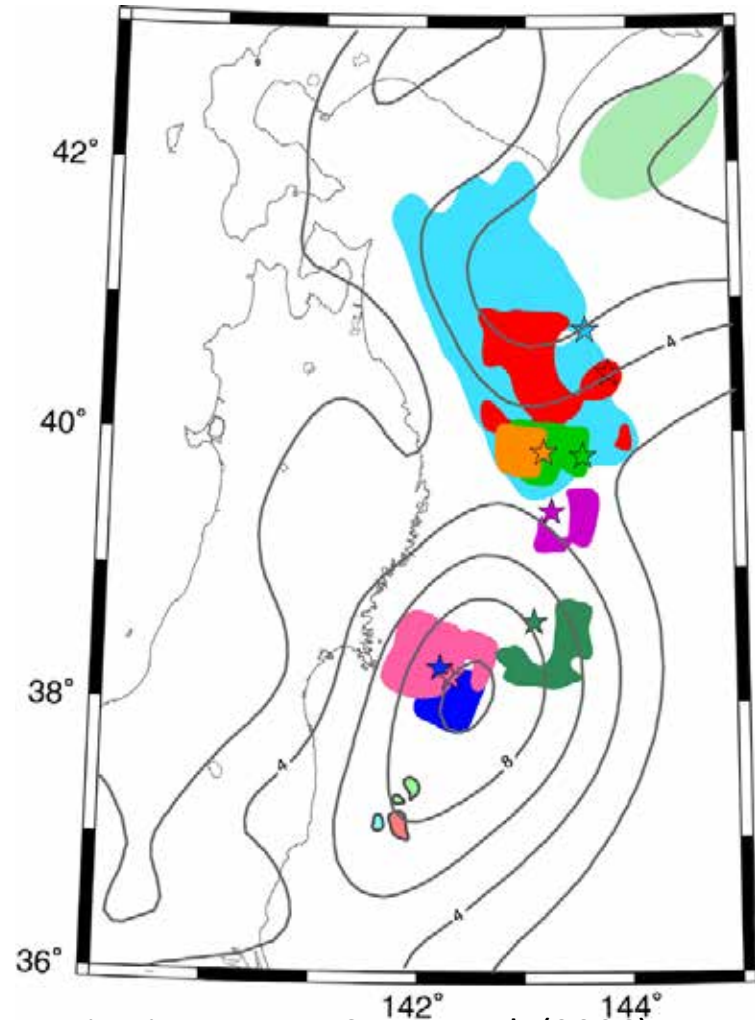
# Along-Strike Variations are Nearly Ubiquitous

Hikurangi



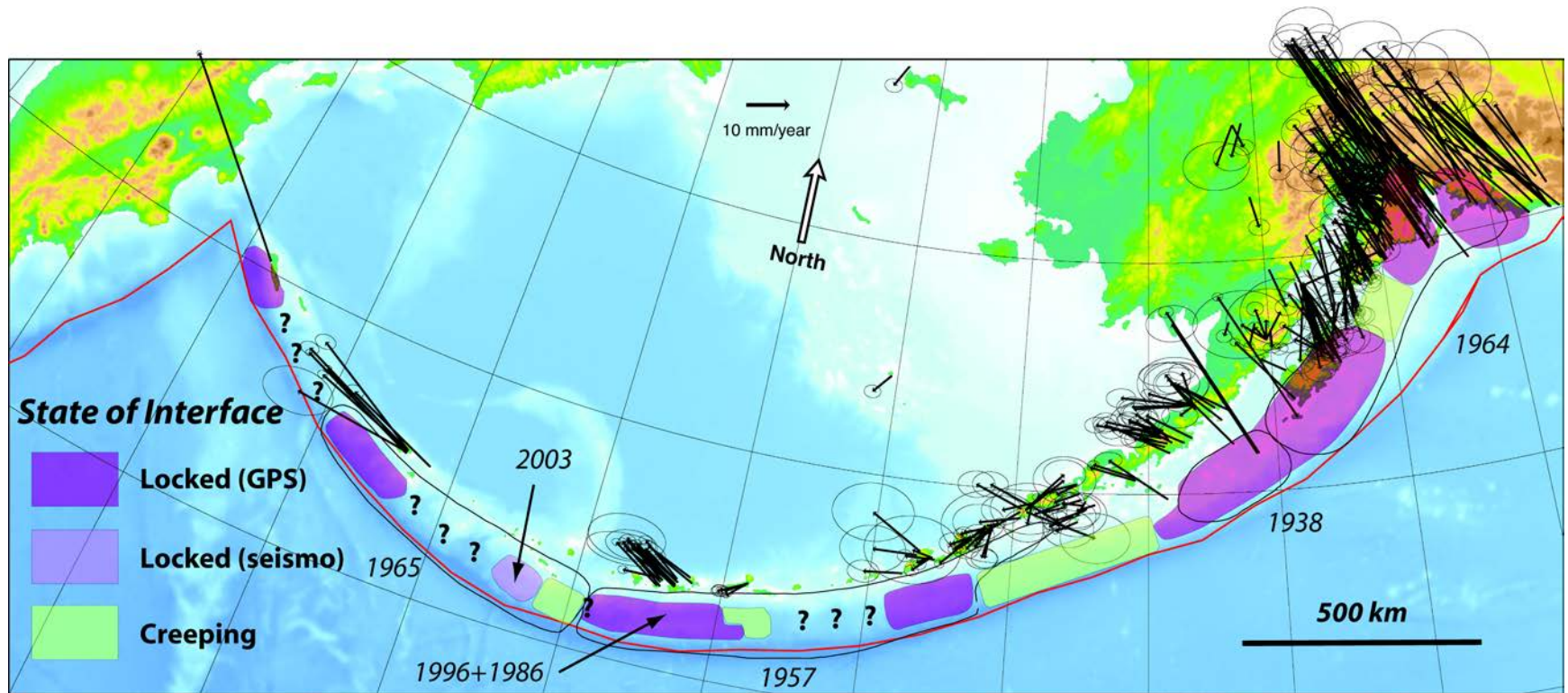
McCaffrey et al. (2008)

NE Japan



Interseismic contour: Suwa et al. (2006)  
Coseismic slip patches (Yamanaka and Kikuchi, 2002)

# Along-Strike Variations are Nearly Ubiquitous



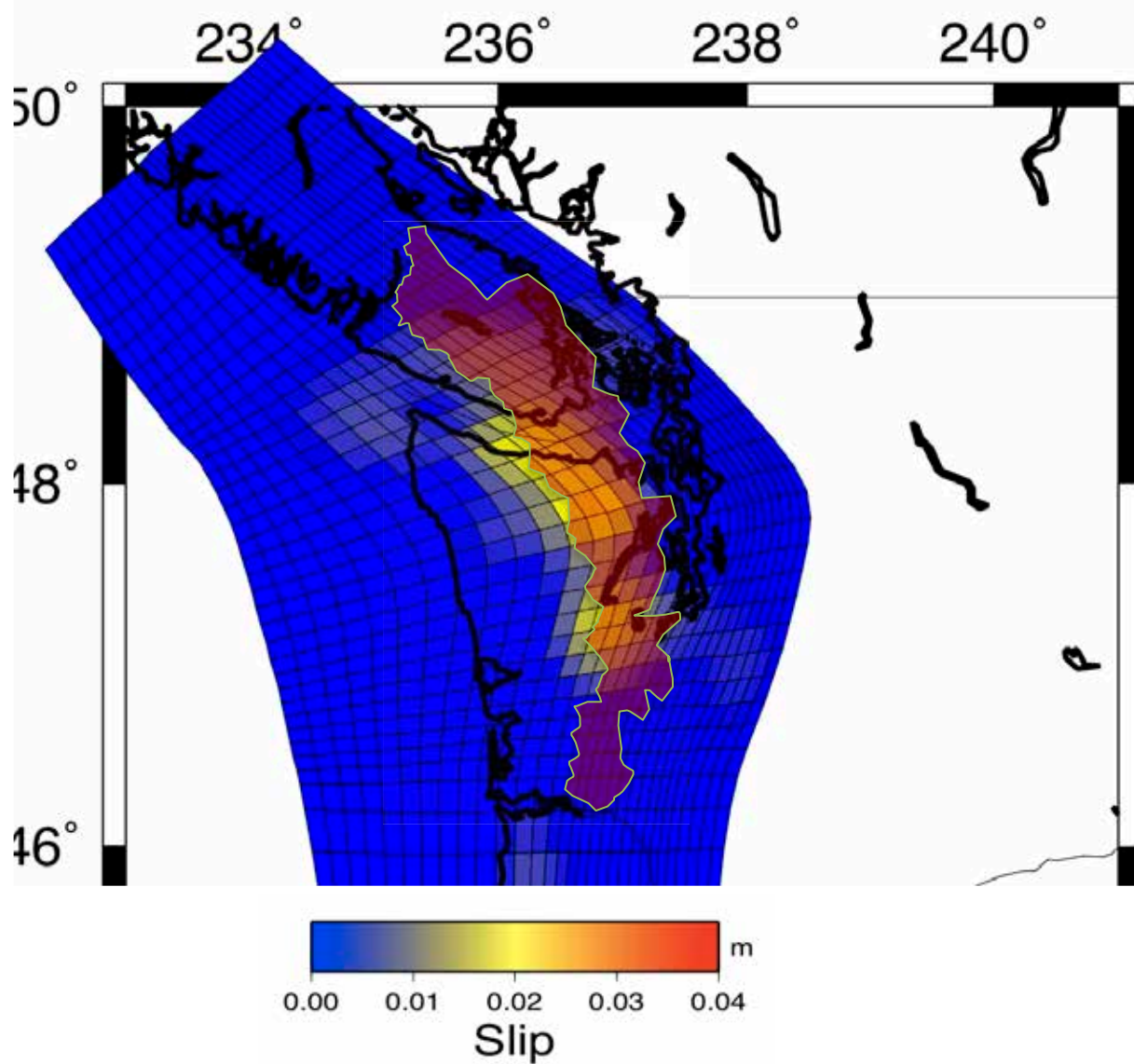
Freymueller et al. (2008)

**Q– *What controls along-strike variations in the extent of slip deficit?***

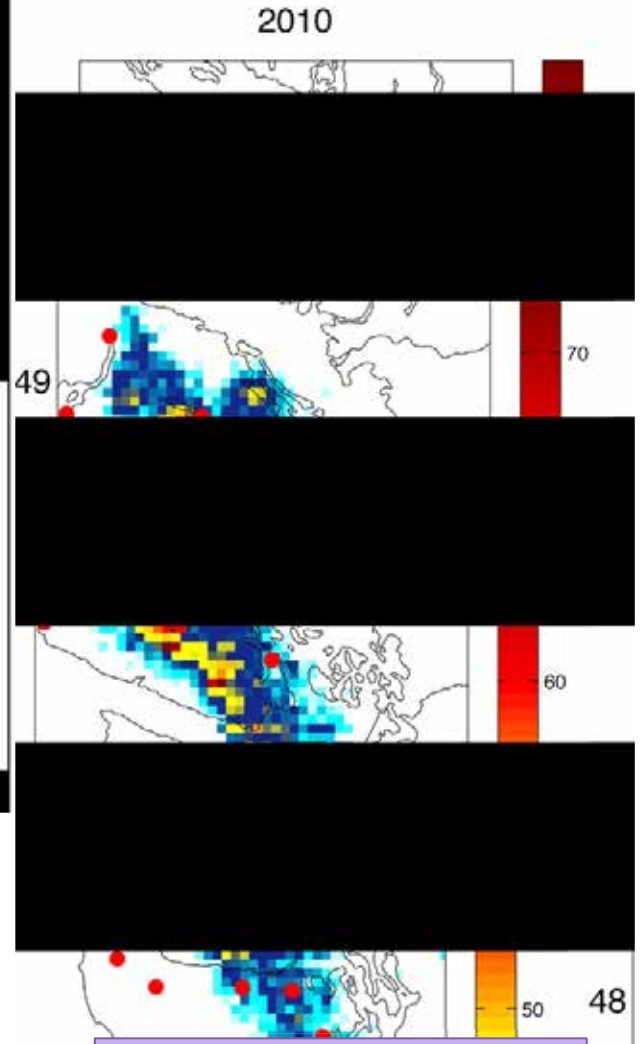
# Slow Slip and Downdip Transition

- The downdip end of the seismogenic zone is particularly dynamic.
- Slow slip events of various sizes observed in Cascadia, Alaska, Mexico, Japan, Costa Rica, ....
  - Durations of weeks to a few years
- Q– ***What is the relationship of slow slip to the generation of tremor?***
- Q– ***How do variations in the slip rate affect overall slip budget?***

# Relationship of Slow Slip and Tremor



Slide from Heidi Houston, UW

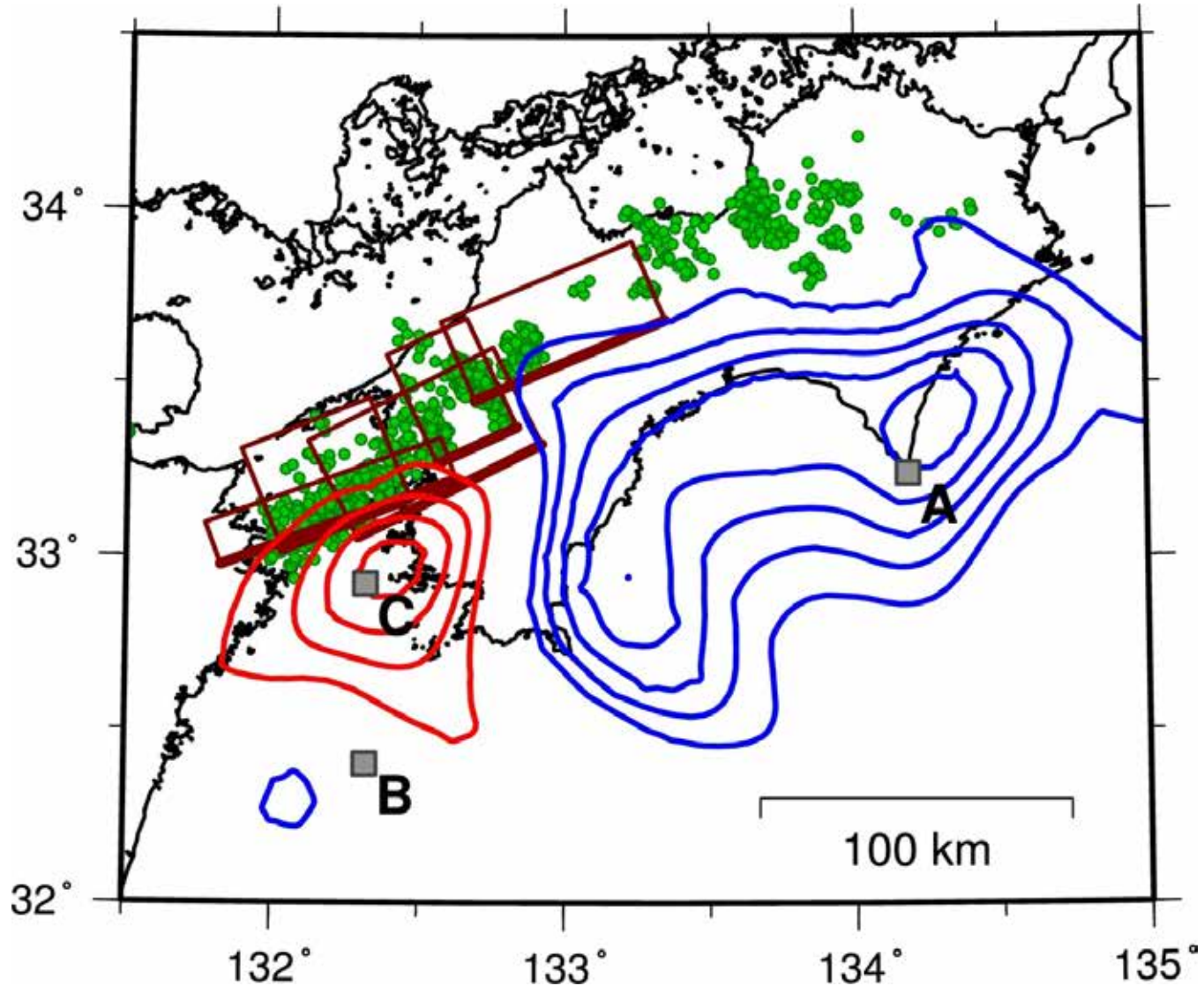


Melbourne

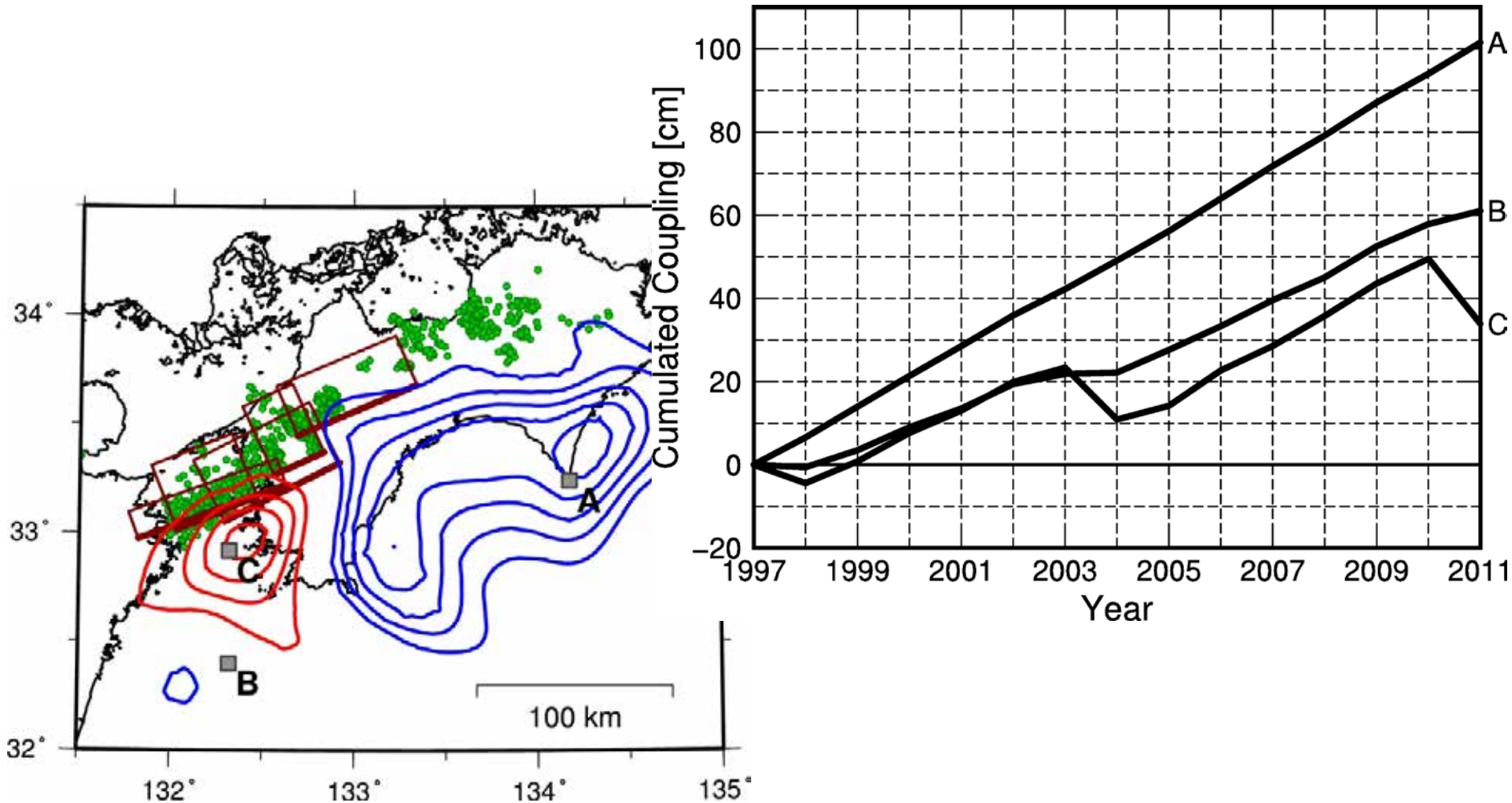
Similar results from Schmidt and Krogstad

Delbridge and Houston

# Long Term SSE vs. Short Term SSE

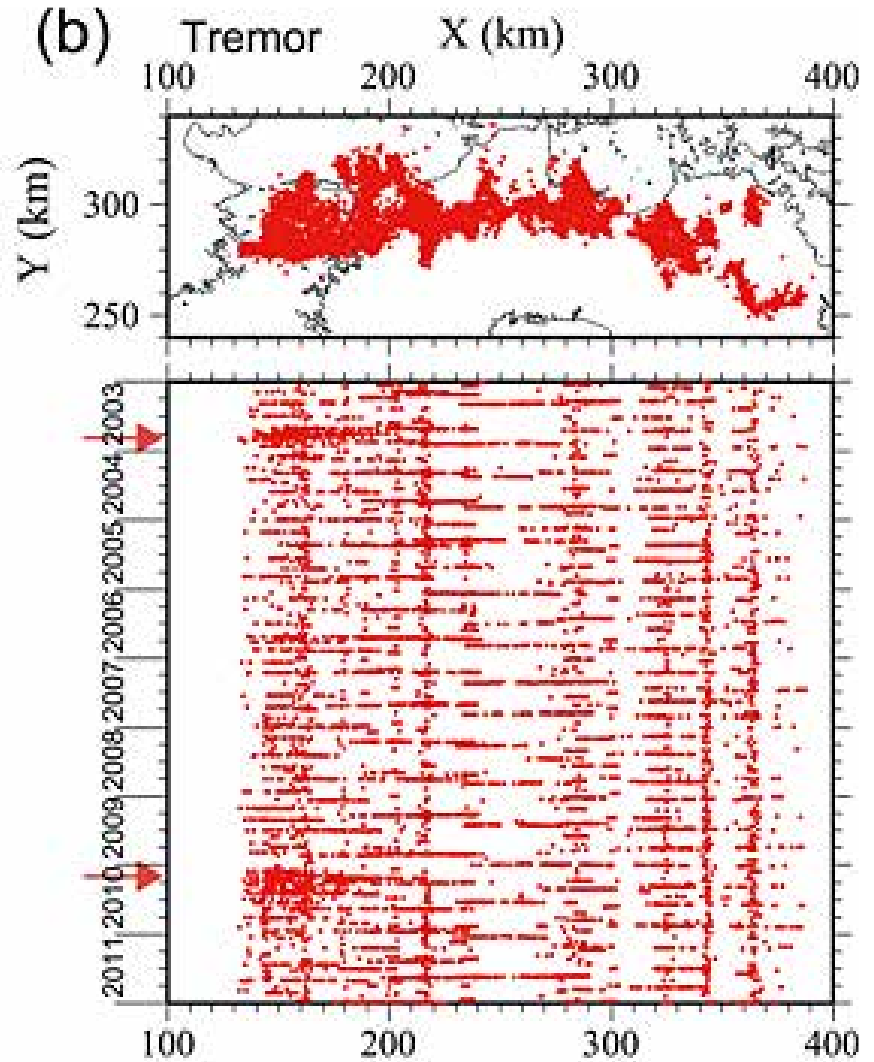
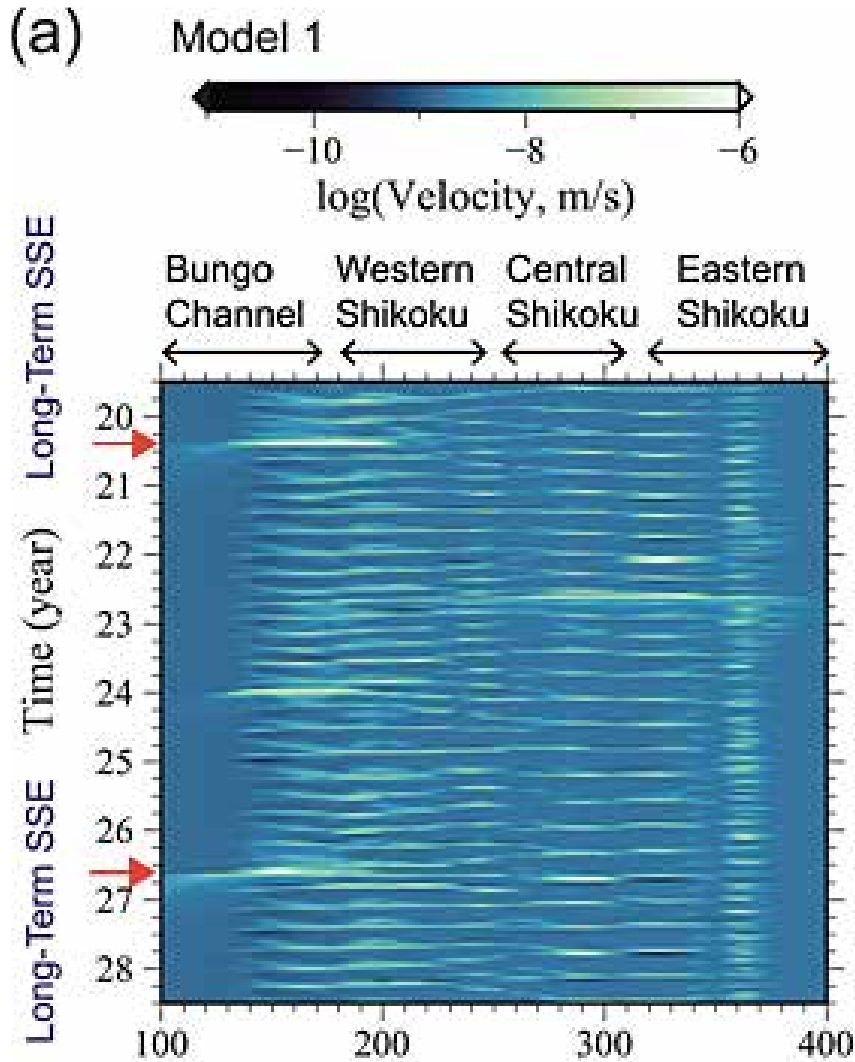


# Long Term SSE vs. Short Term SSE





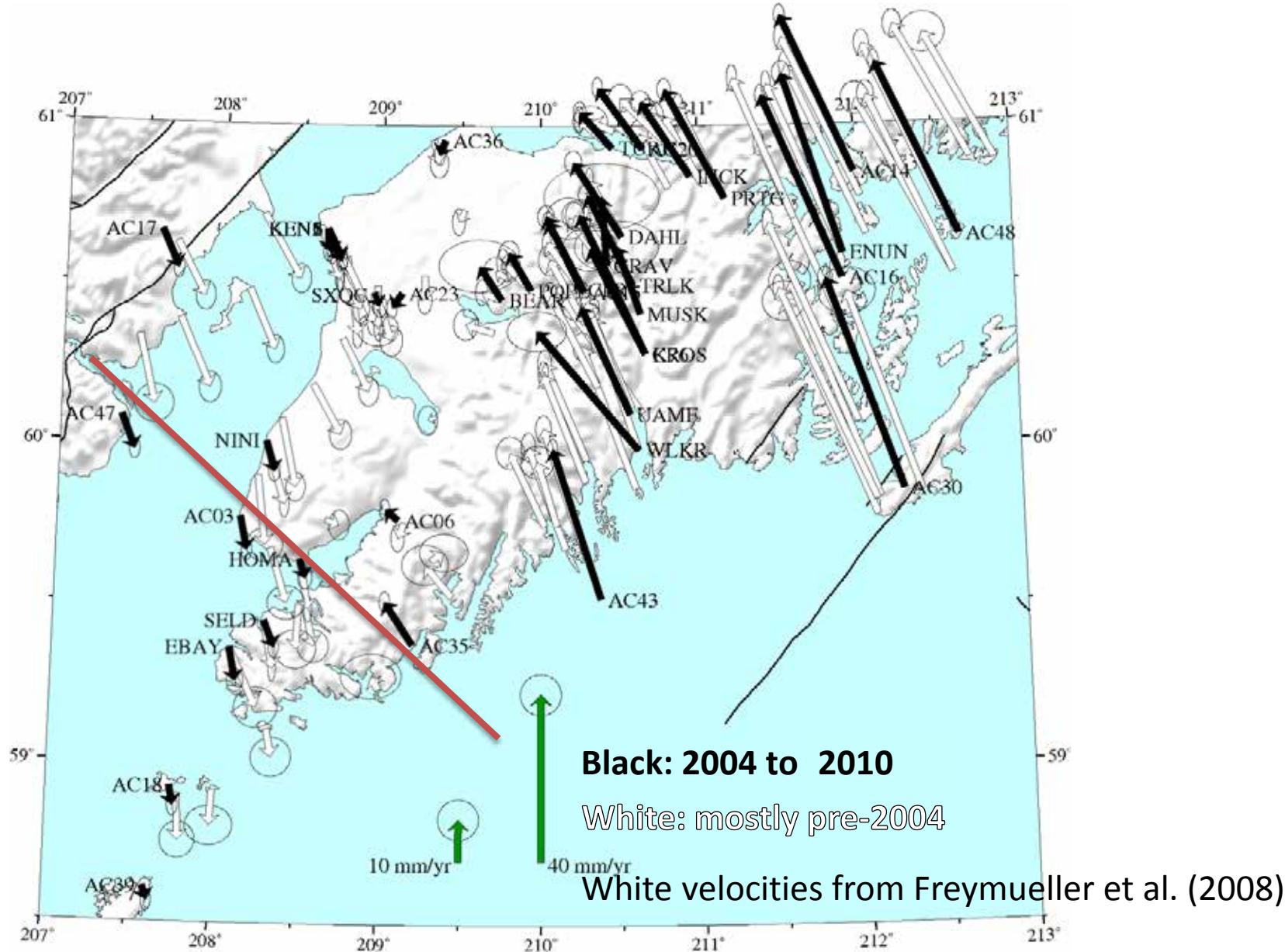
# Progress in Modeling



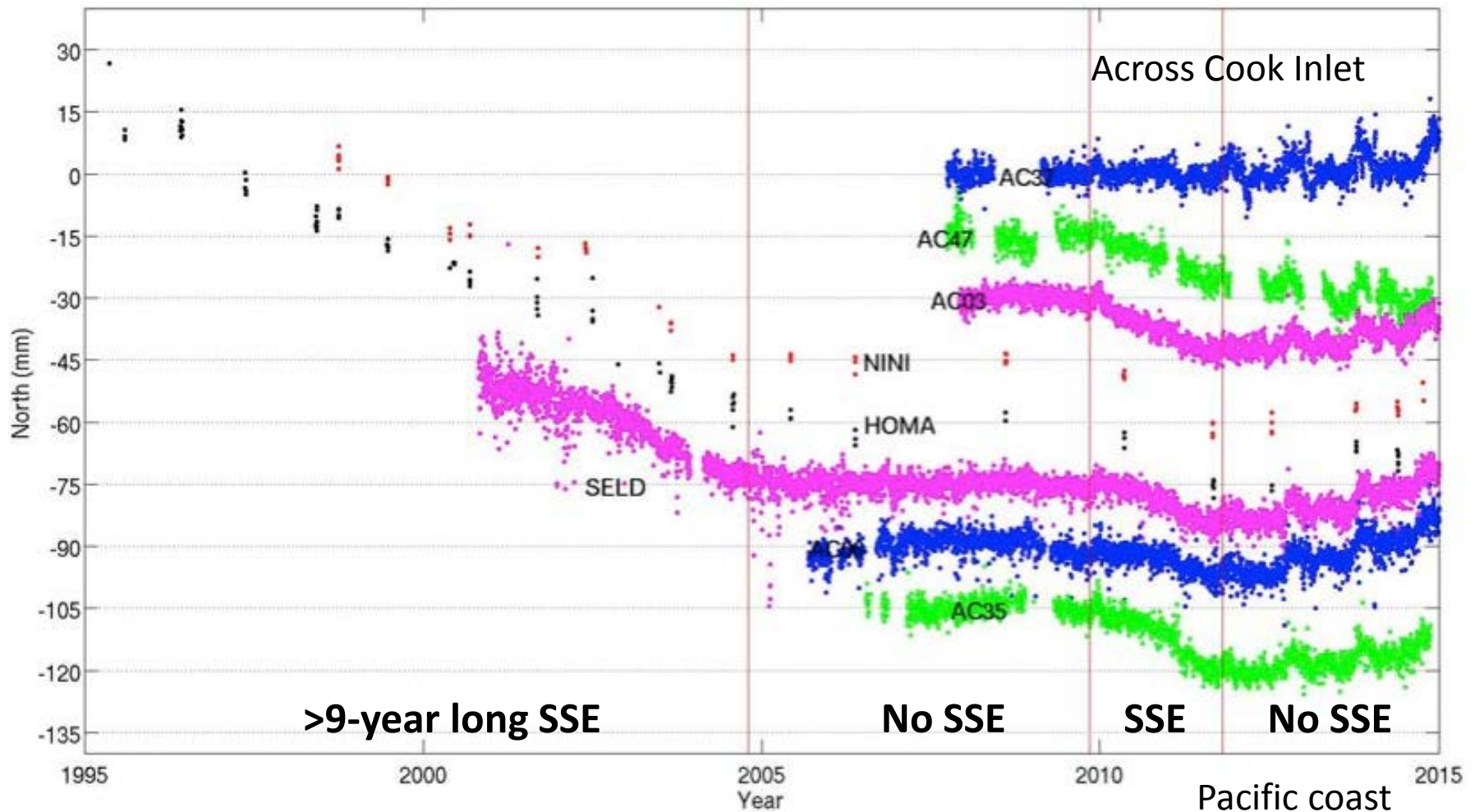
Matsuzawa et al. (2013)

$(a-b)\sigma_e$  decreases with depth

# Significant Velocity Changes in 2004, 2010

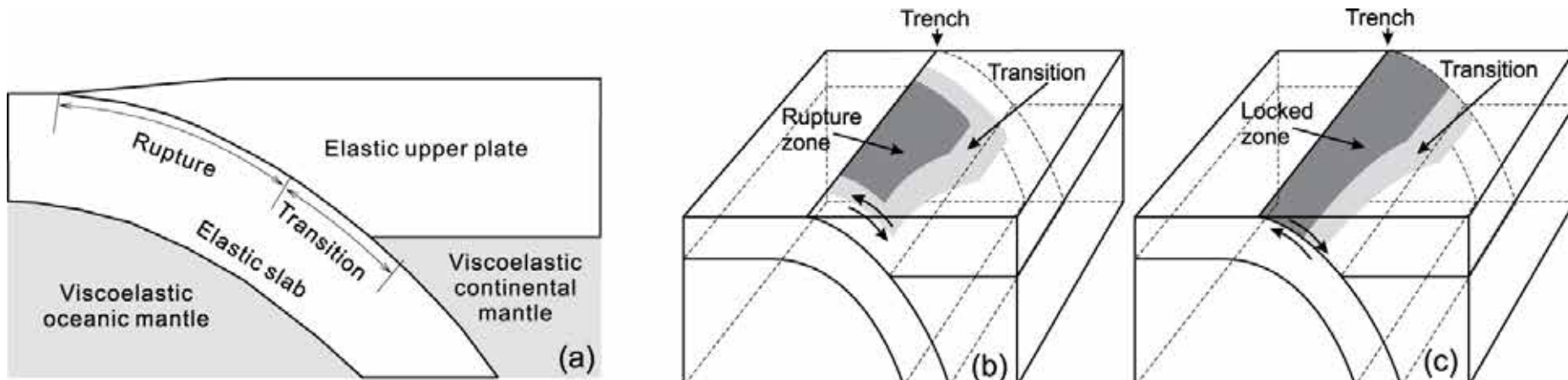


# SSEs can be ~Decadal Scale



# Postseismic Deformation

- Large and great earthquakes cause postseismic deformation, mostly due to:
  - Afterslip/focused shear on the plate interface
  - Viscoelastic relaxation within mantle wedge
- But variable from earthquake to earthquake



# Key Outstanding Questions

- What controls the extent of seismogenic (unstable) and aseismic (stable) slip, and why do these vary with space and time?
  - How well do interseismic locked patches correspond to future earthquake rupture patches?
    - Especially challenging given model resolution limits of inversion problems
  - Can we describe the slip budget for various segments of the subduction zone?
- Can we develop mechanical models that include realistic rheology and stress transfer between patches of seismic, aseismic, transient, etc behavior?