Integrating observations from the lower stability transition of the seismogenic zone

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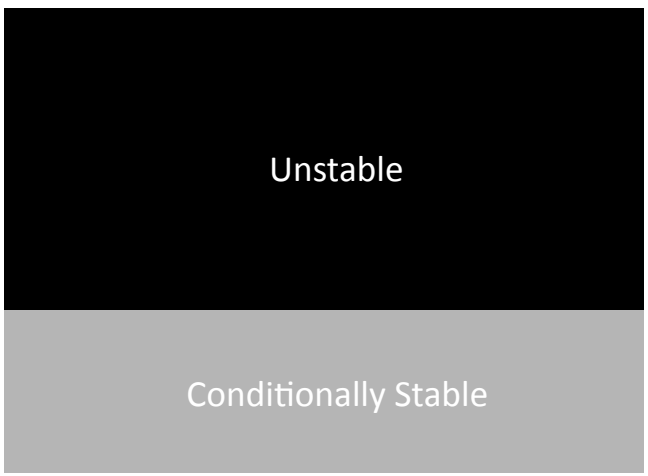
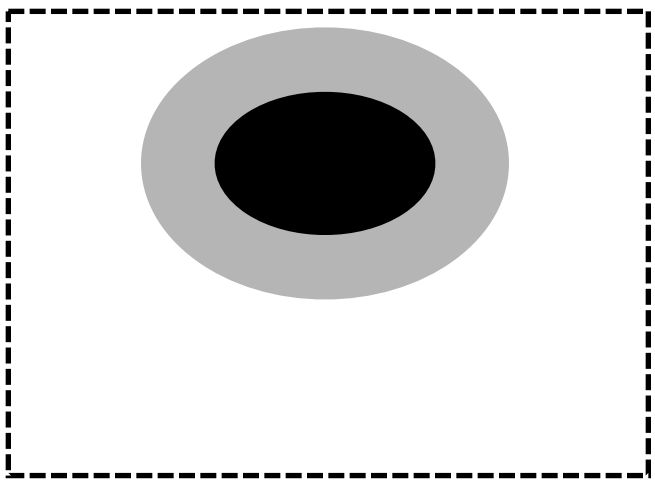
What happens at the down-dip end of the seismogenic zone?

- Transition via zone of conditional stability
  - Rupture propagates deeper than it can initiate
- Transition to zone of velocity strengthening
  - Prominent postseismic afterslip
- Transition to zone of oscillatory behavior
  - Episodic tremor and slip

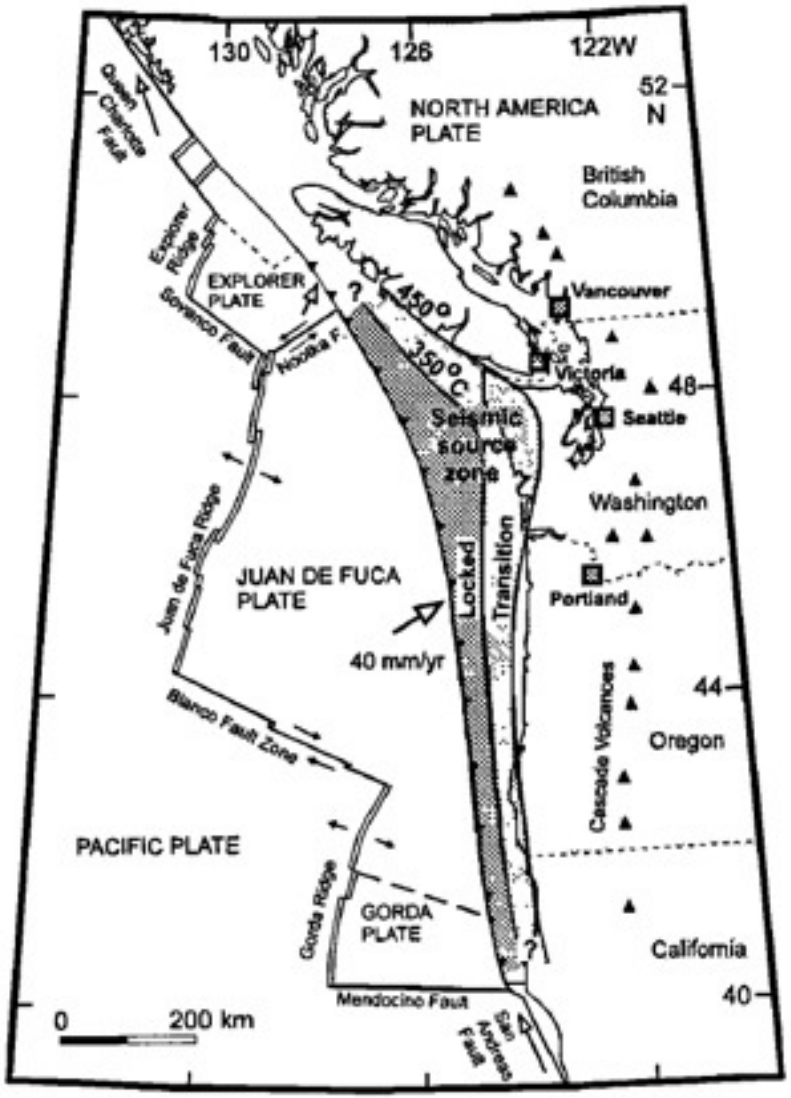
1) Transition via Conditional Stability

- Earthquake instability initiates in velocity weakening region and can propagates into conditional stability region



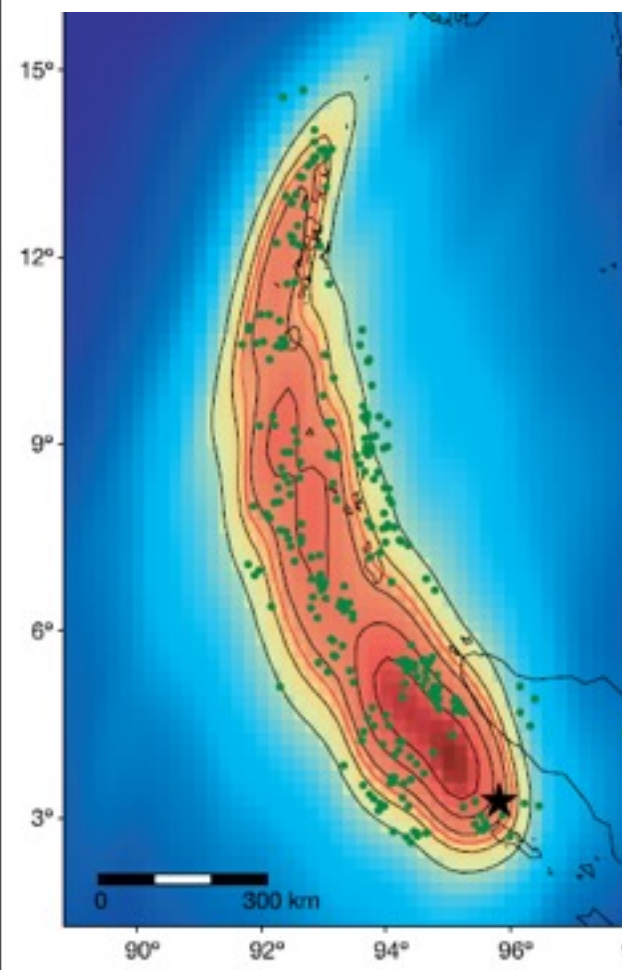


Thermal Estimates of Transition Zone

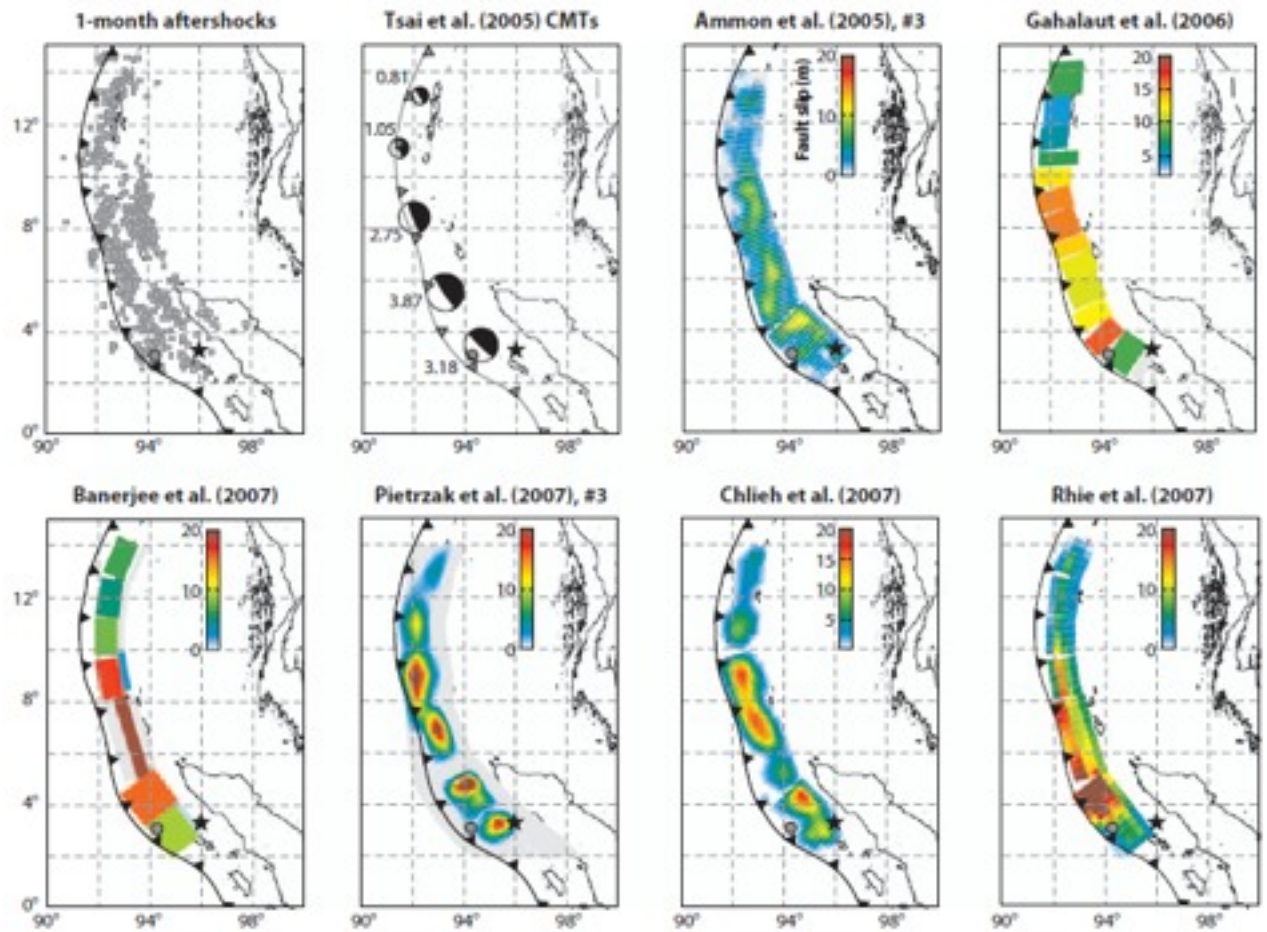


Hyndman and Wang, 1993; 1995

Yet megathrust rupture extent seems to match where aftershocks initiate

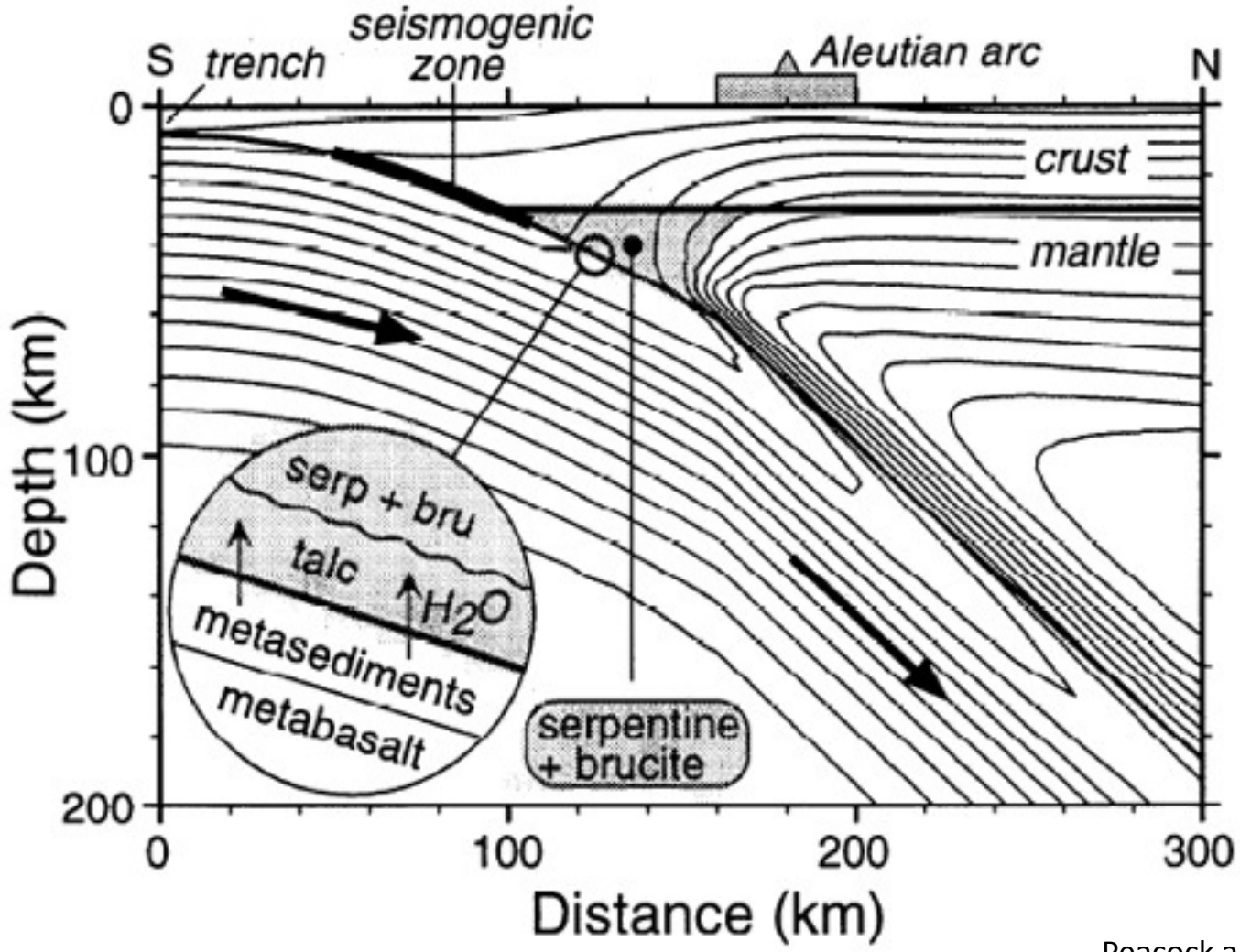


Ishii et al., 2005



Shearer and Burgmann, 2010

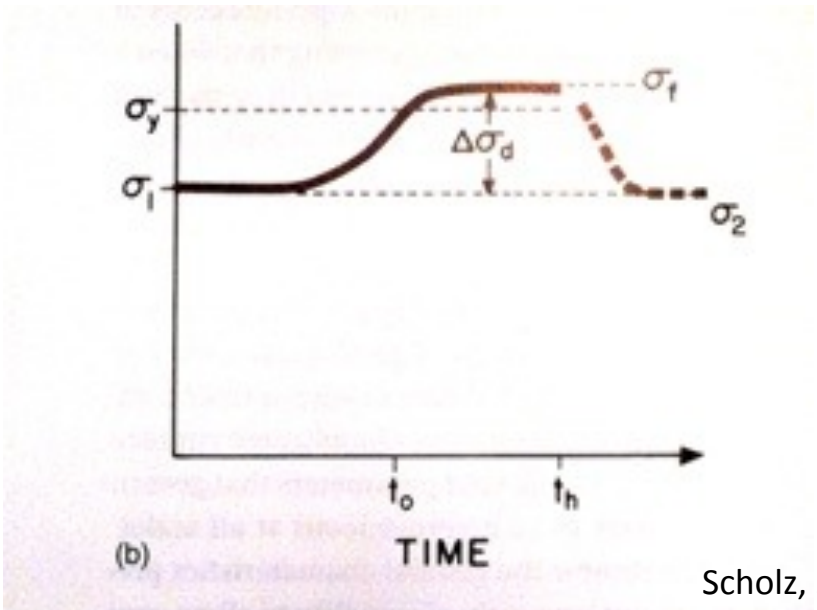
Perhaps Limited by Mantle Geology



Peacock and Hyndman, 1999

2) Transition to Afterslip

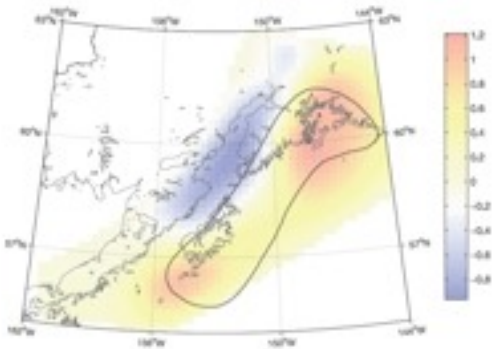
- Earthquake instability initiates in velocity weakening region and can propagate briefly into velocity strengthening region
- Return to initial stress state results in afterslip



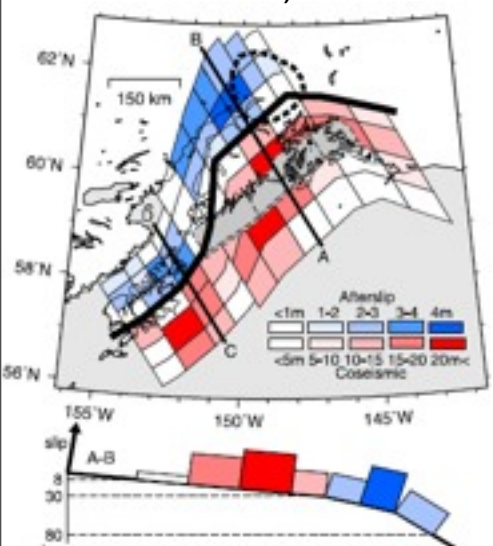
Scholz, 2002

Estimates of Deep Afterslip

Alaska

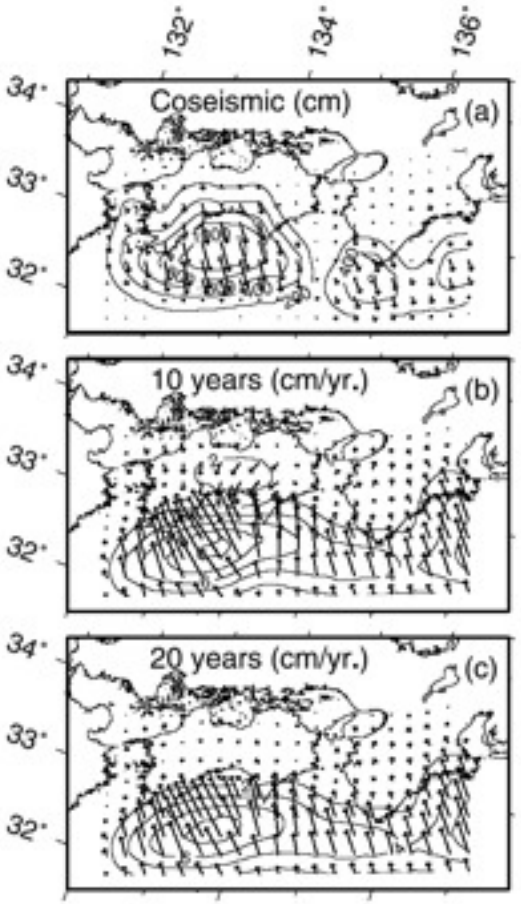


Zweck et al., 2002



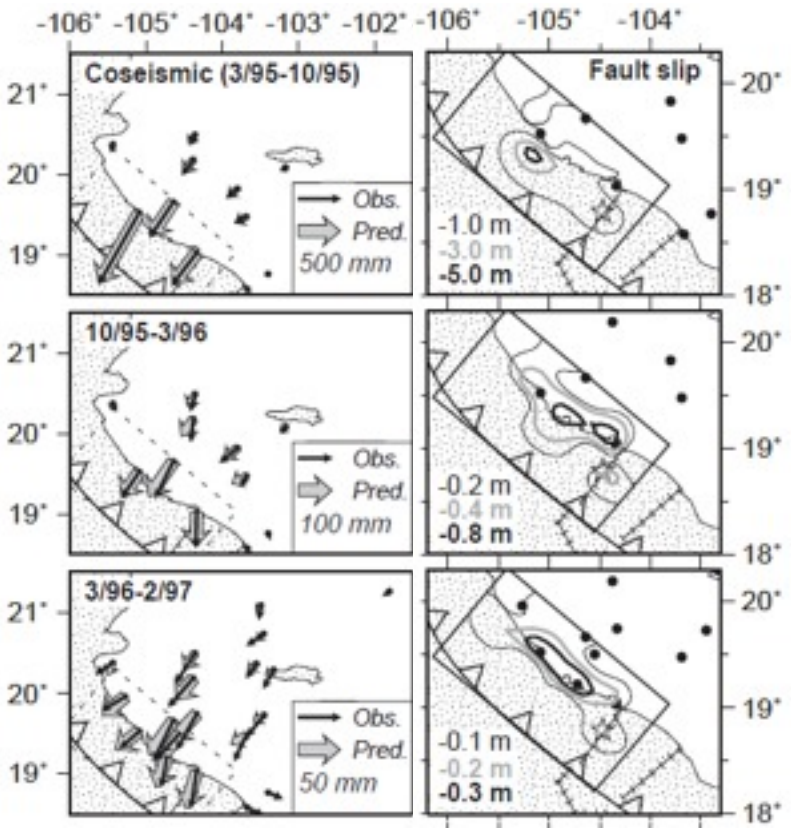
Suito and Freymueller, 2009

Nankai



Ito ad Hashimoto, 2004

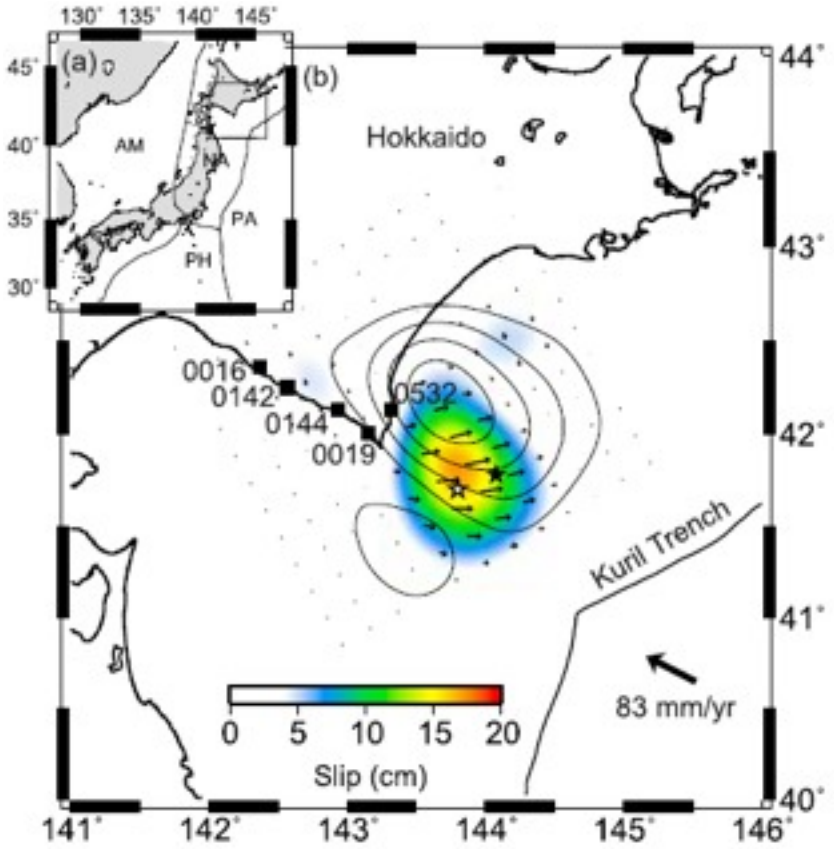
Mexico



Hutton et al., 2001

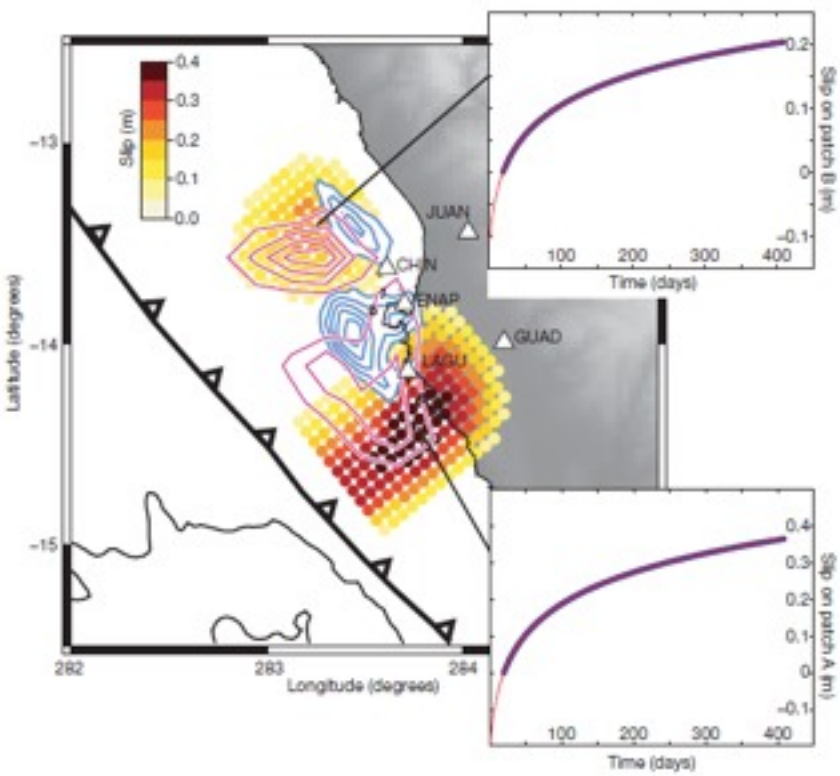
Estimates of Along-Strike Afterslip

NE Japan



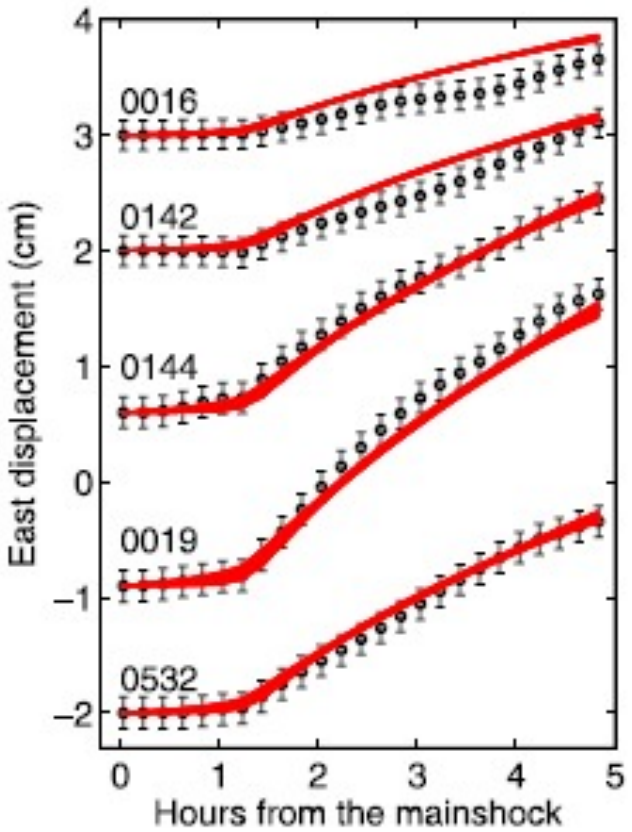
Fukuda et al., 2009

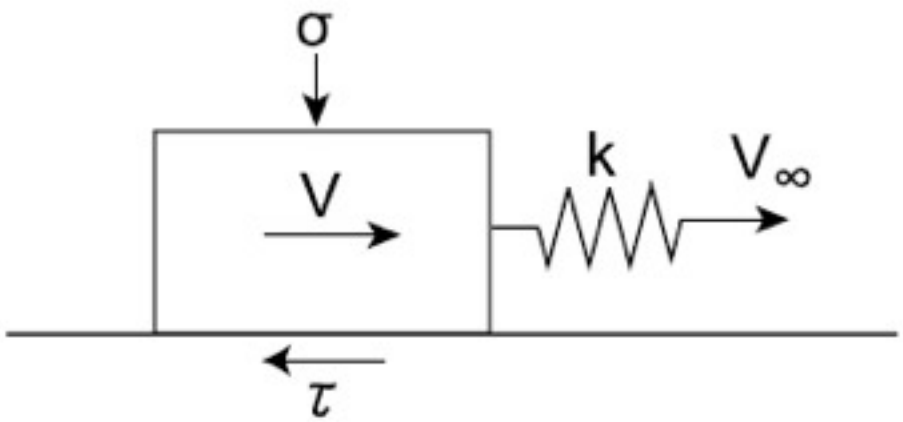
Peru



Perfettini et al., 2010

Afterslip Triggered By Mainshock

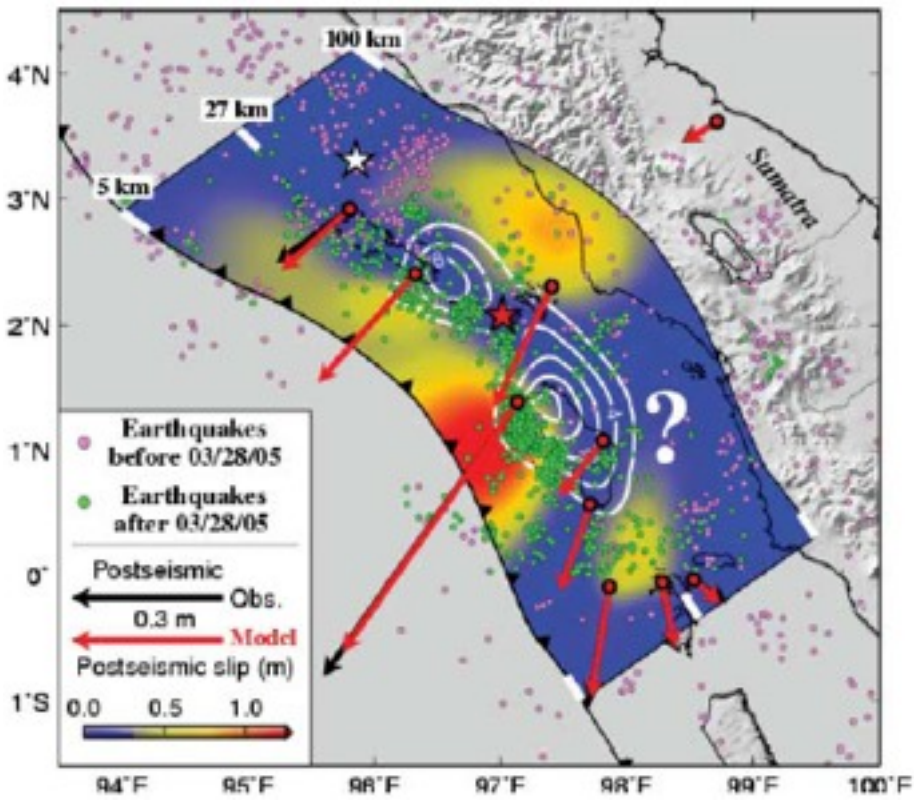


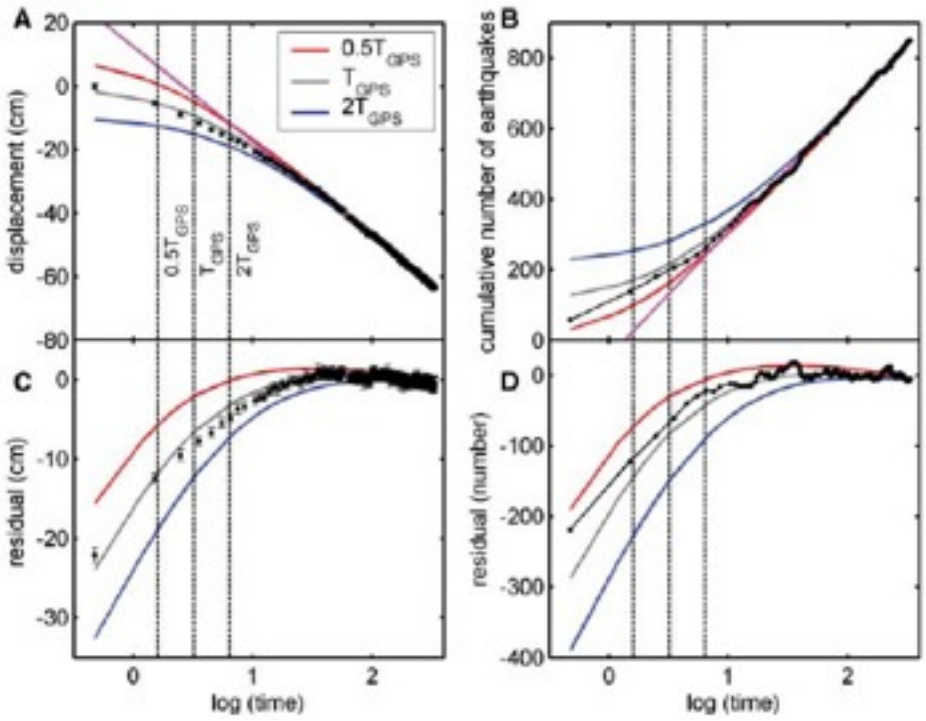


Fukuda et al., 2009

Afterslip Drives Aftershocks

Sumatra (Nias)

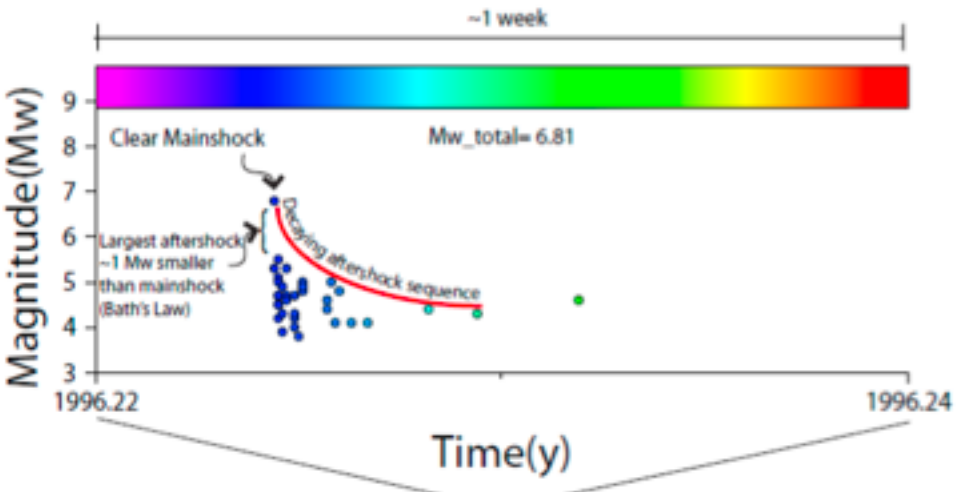




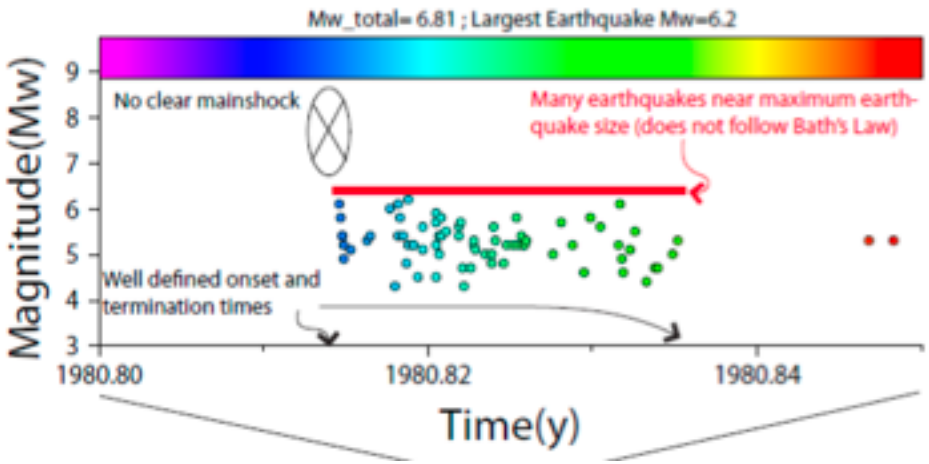
Hsu et al., 2006

Earthquake Swarms

Mainshock-Aftershock

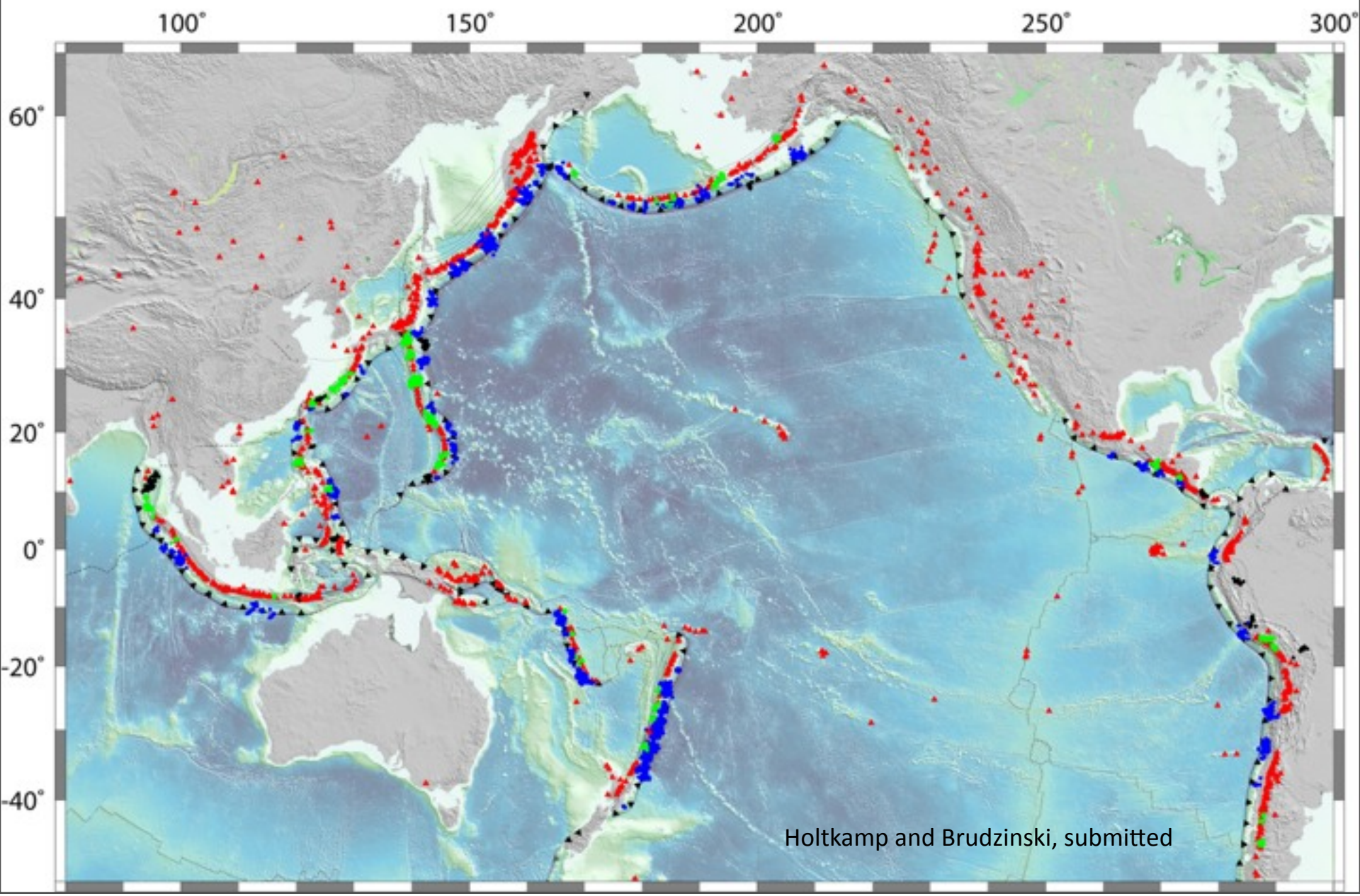


Swarm

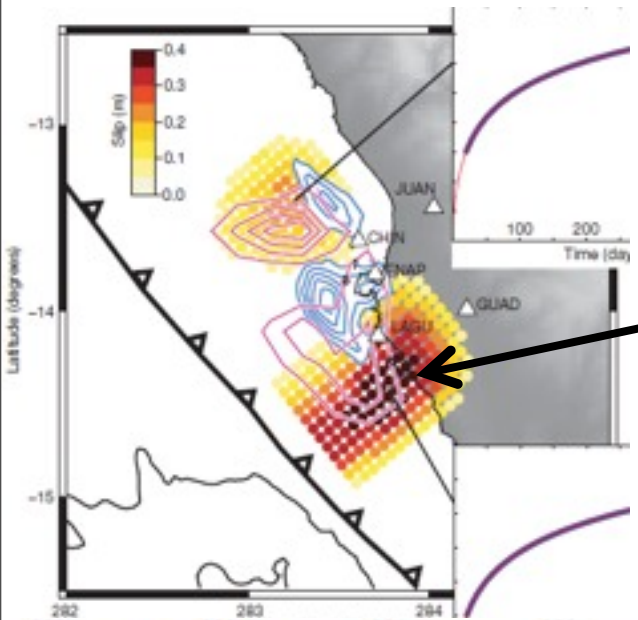


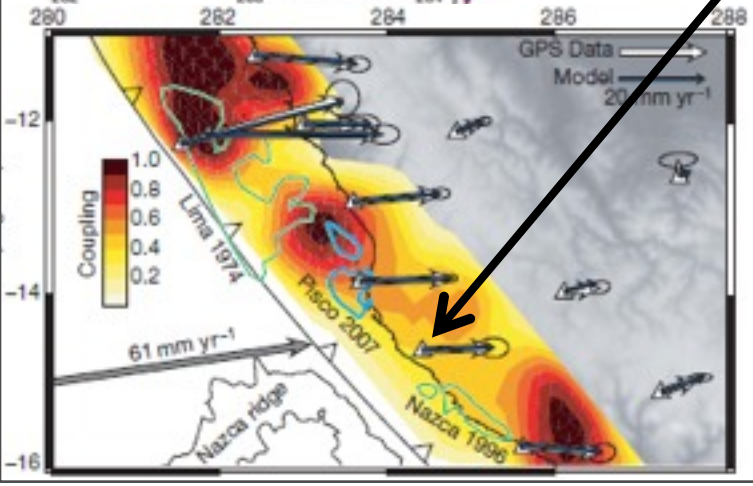
- Evidence for transient slip correlated with swarms in Boso, Salton Trough, Kilauea

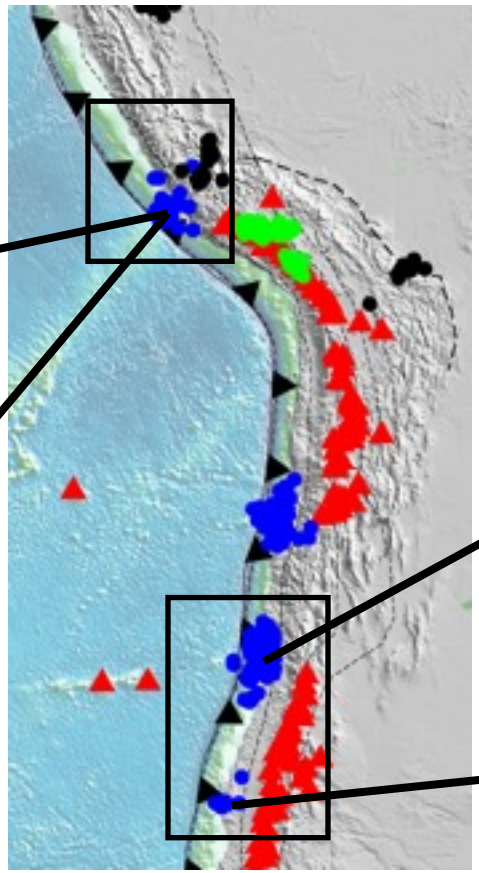
Megathrust and Volcanic Swarms

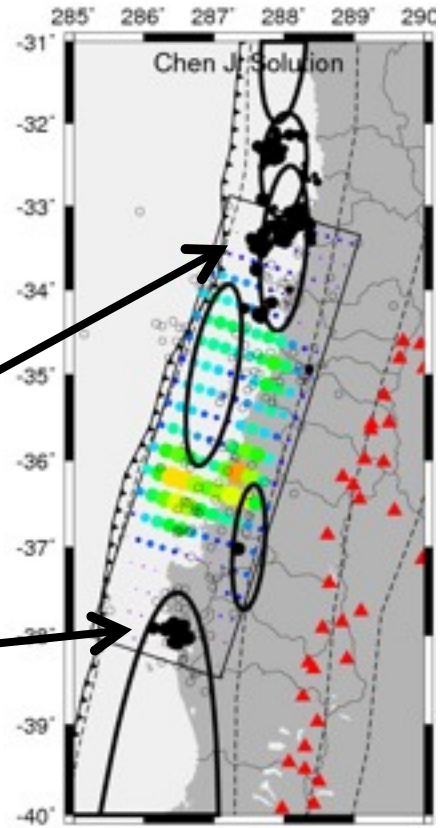


Swarms occur in same location as afterslip, reduced coupling, segmentation

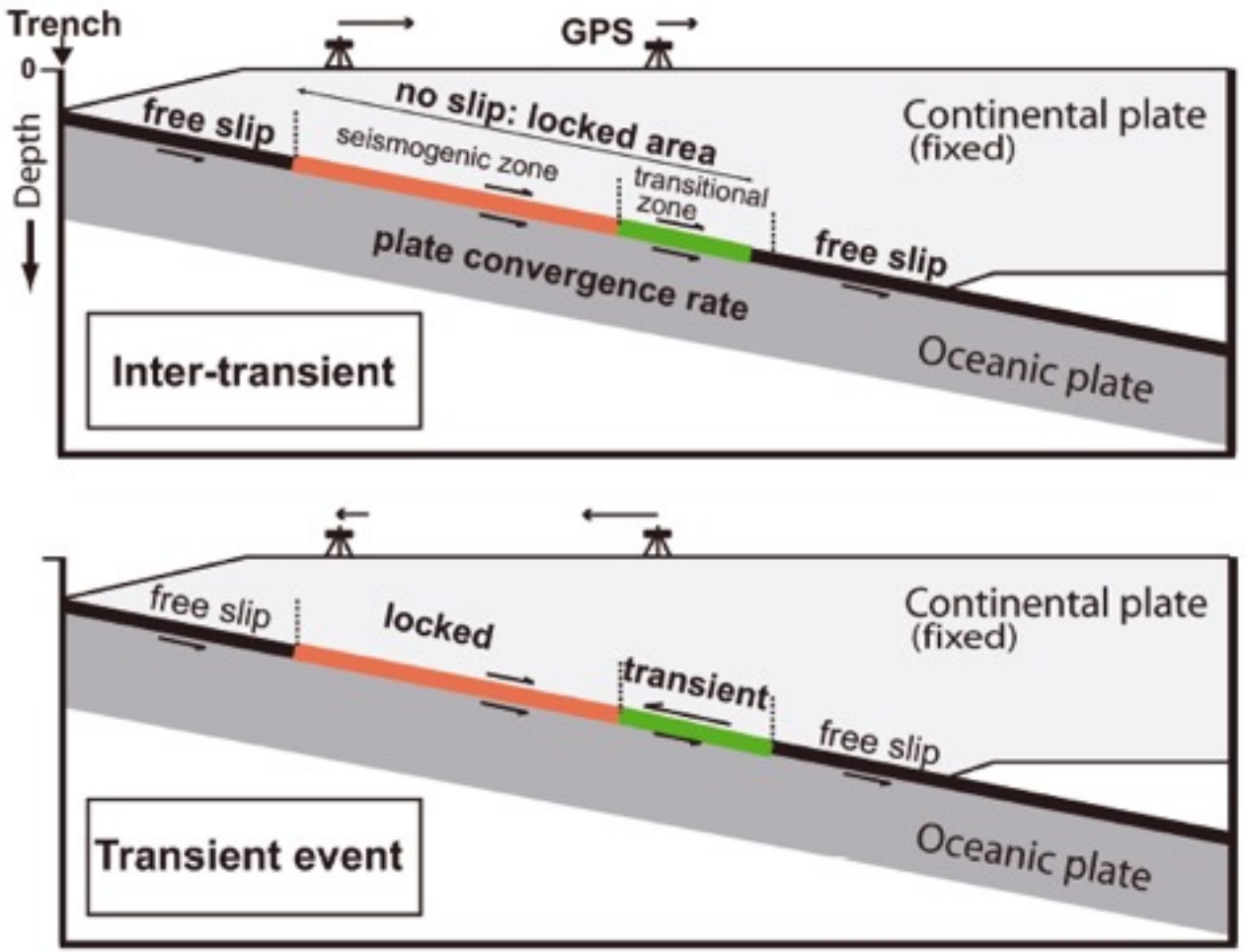






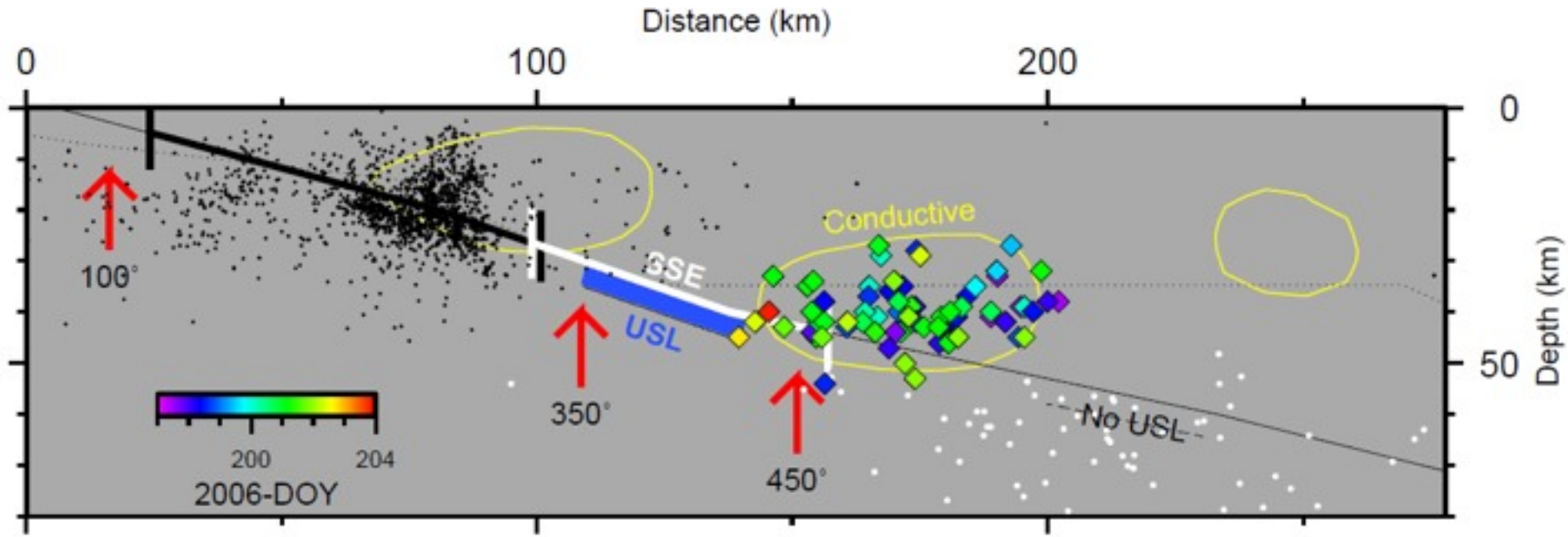


Transition Zone Behavior: ETS



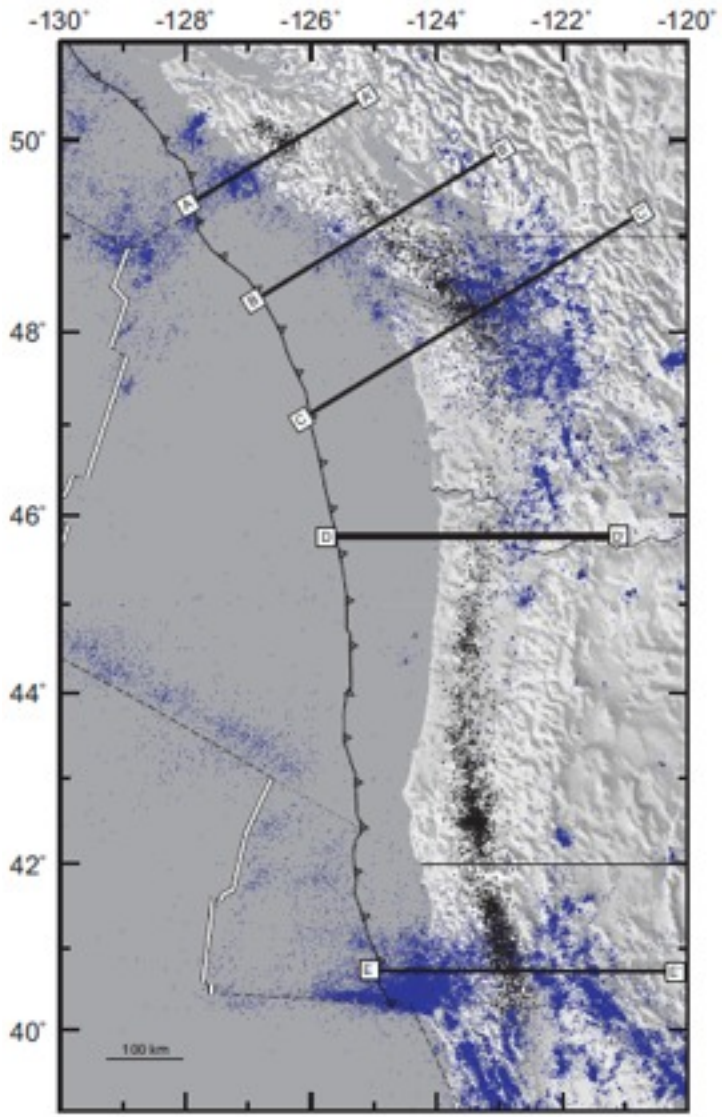
Correa-Mora et al., 2008

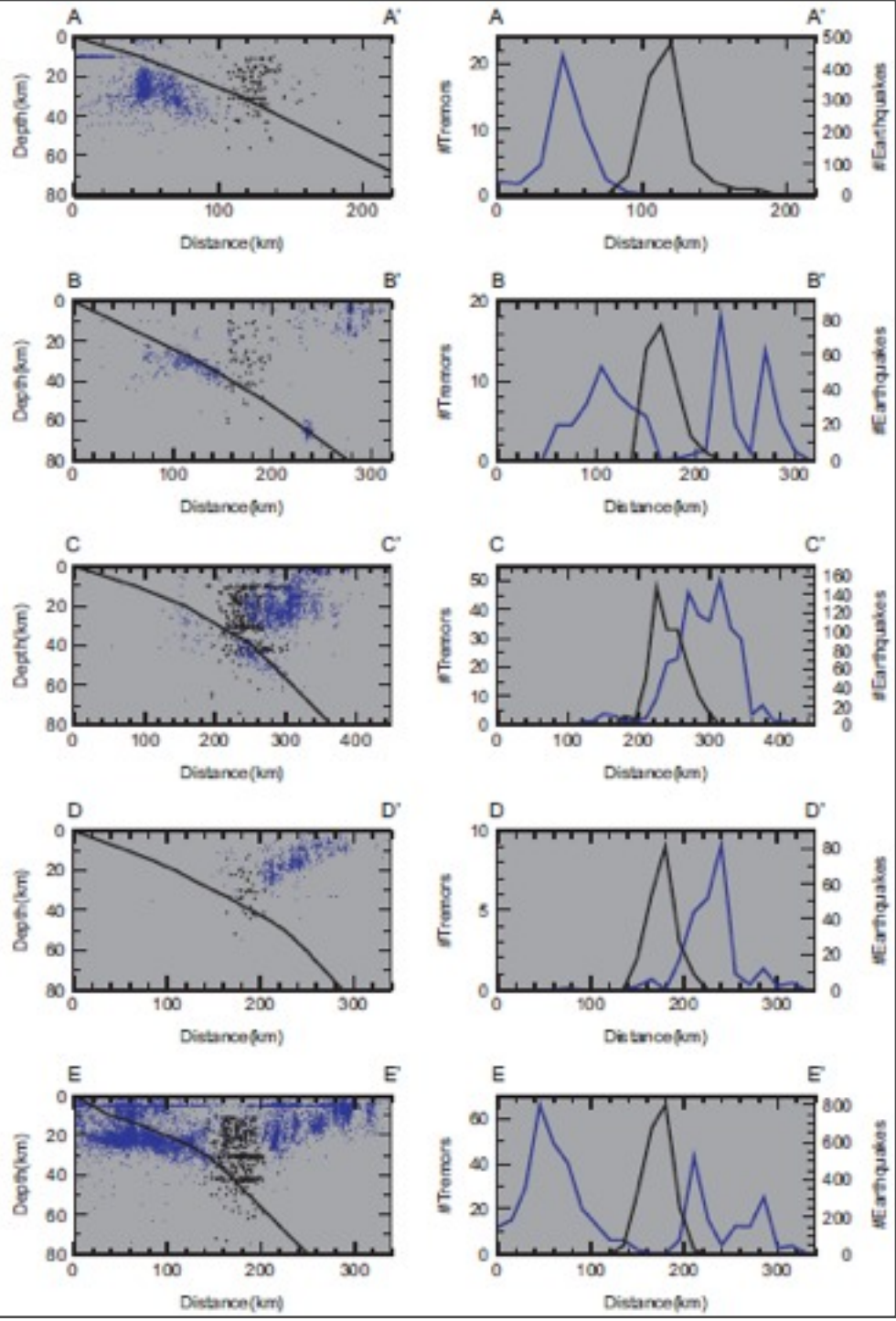
Spatial Distribution of Slip Phenomena



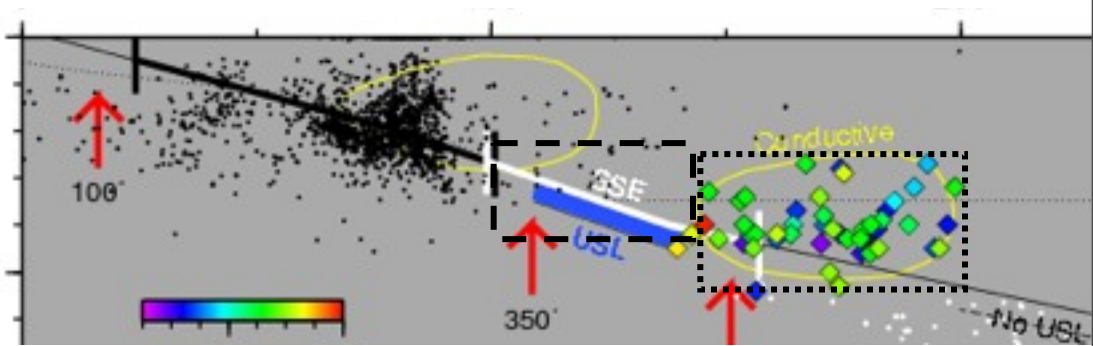
Brudzinski et al., 2010

Tremor and Earthquakes Spatially Anticorrelated



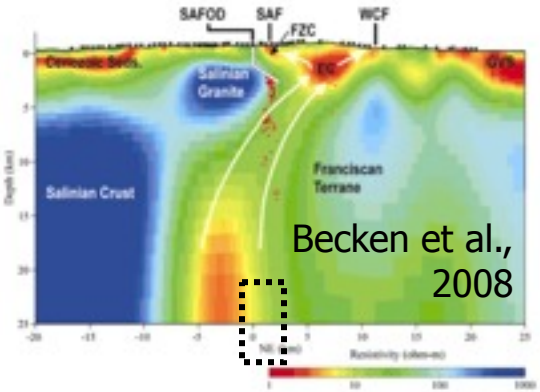


Conductivity

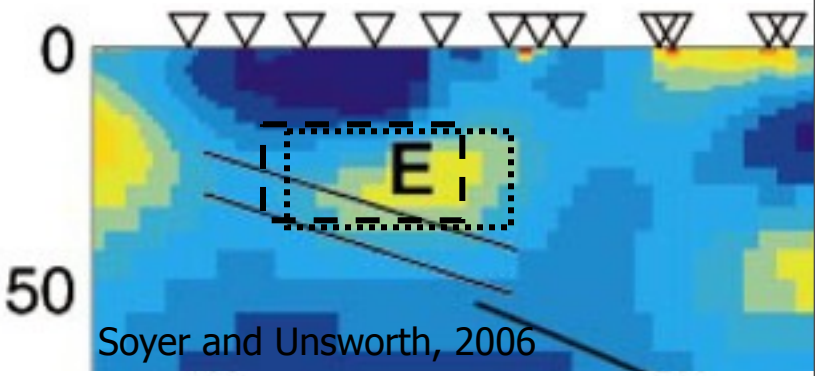


Conductivity

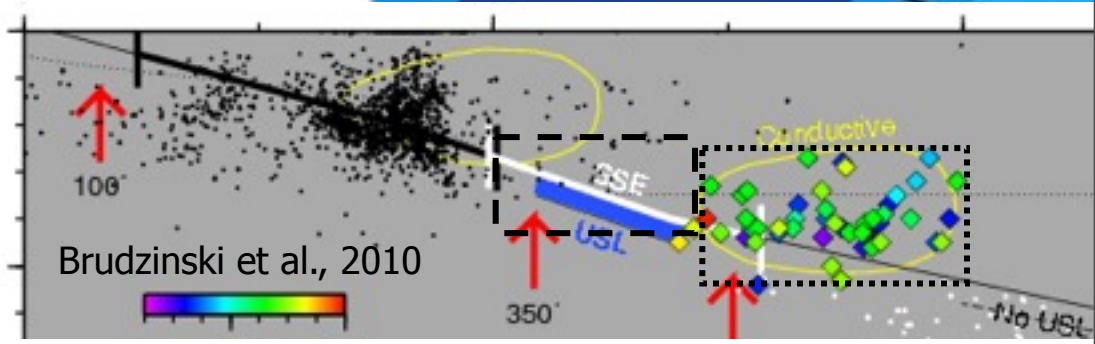
San Andreas:
Tremor along High Conductivity



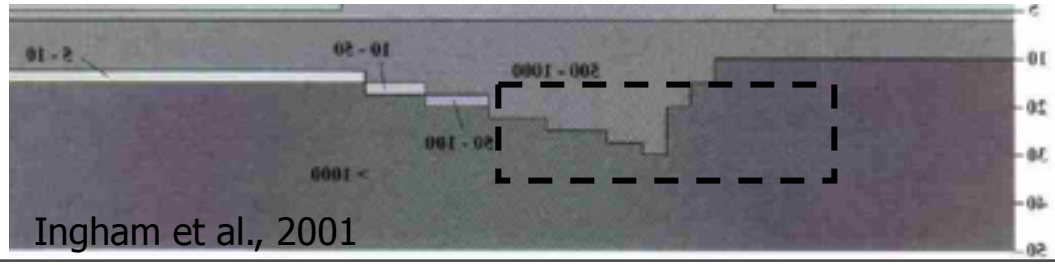
Cascadia:
Tremor and Slow Slip in High Conductivity



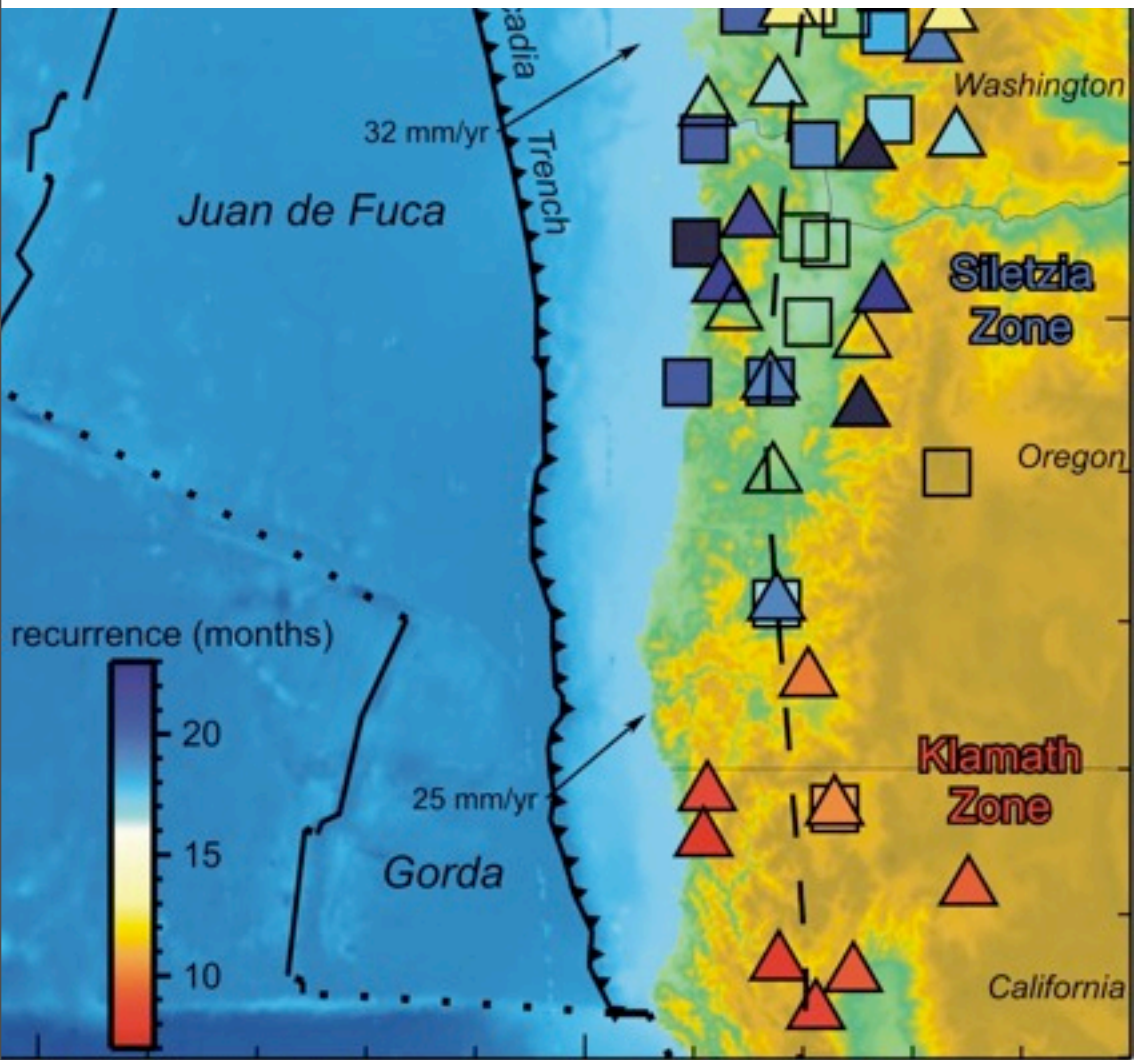
Mexico:
Tremor in High Conductivity

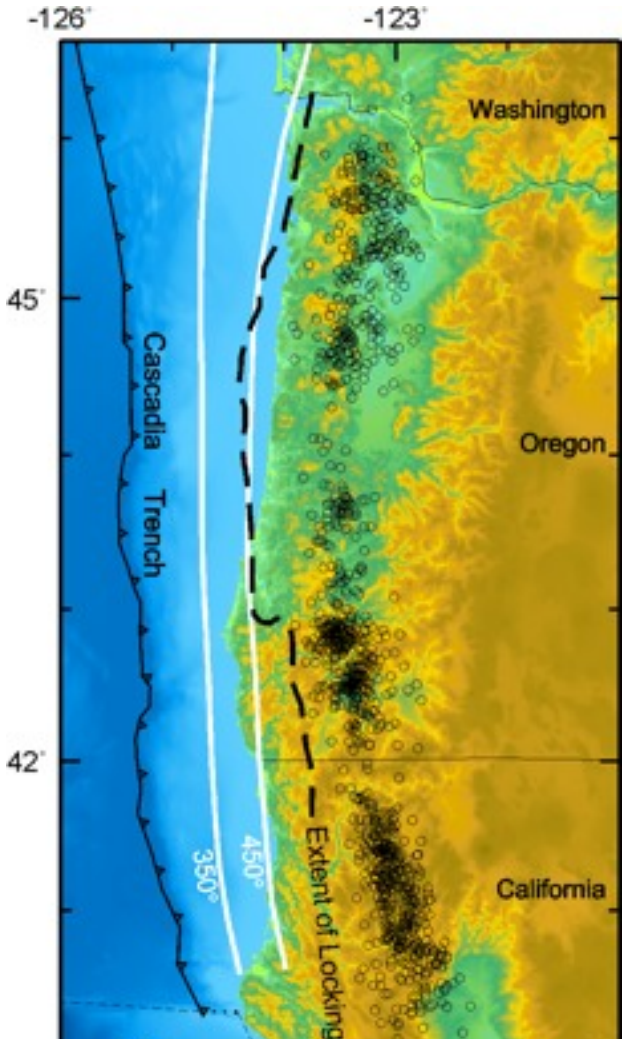


New Zealand:
No High Conductivity,
Slip triggers Earthquakes instead of Tremor

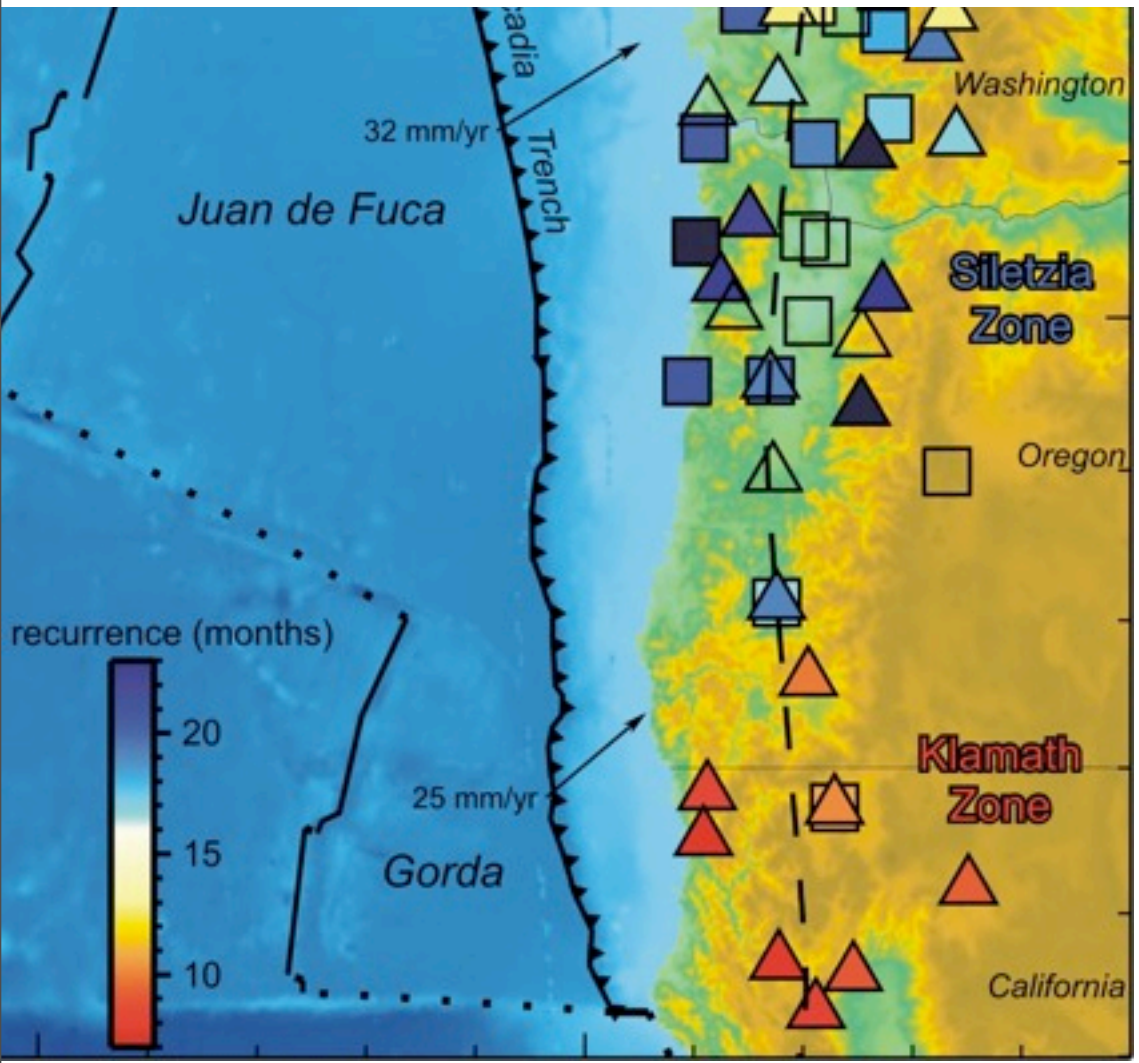


Geologic Controls on ETS and Locking

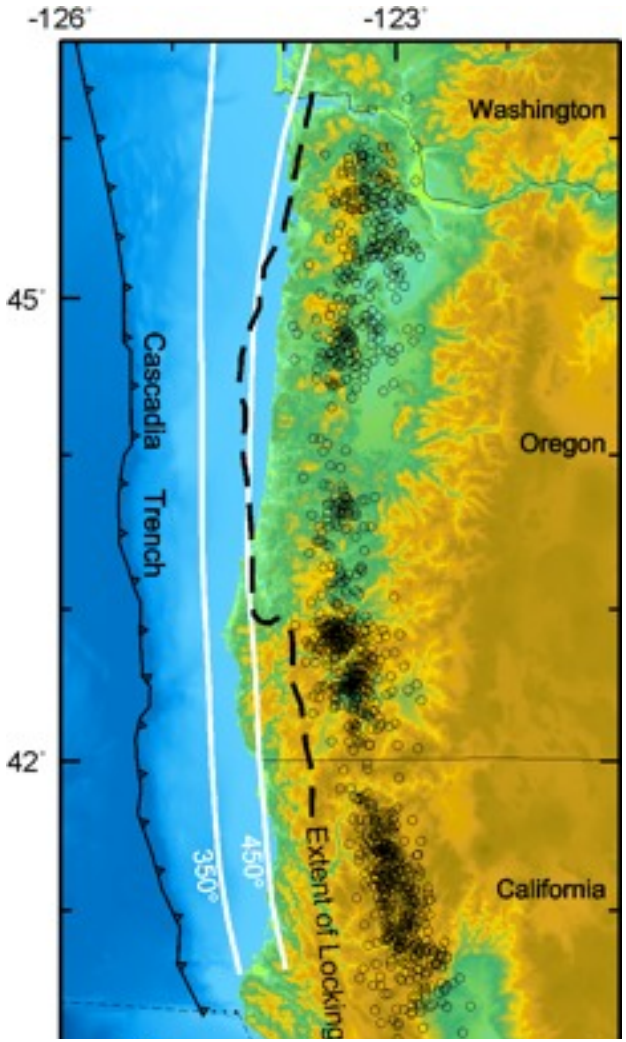




Geologic Controls on ETS and Locking



Brudzinski and Allen, 2007

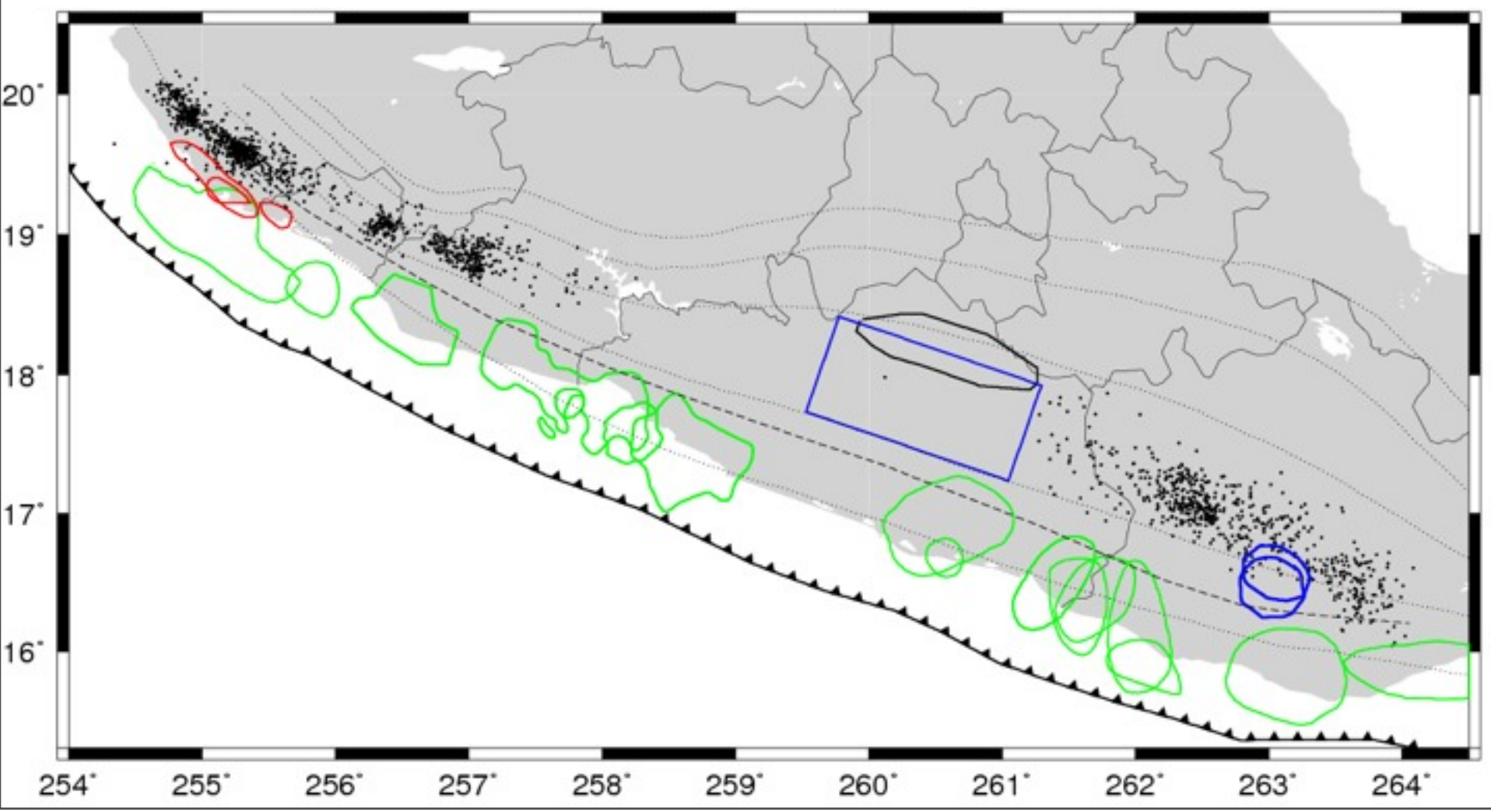


Gomberg et al., 2010

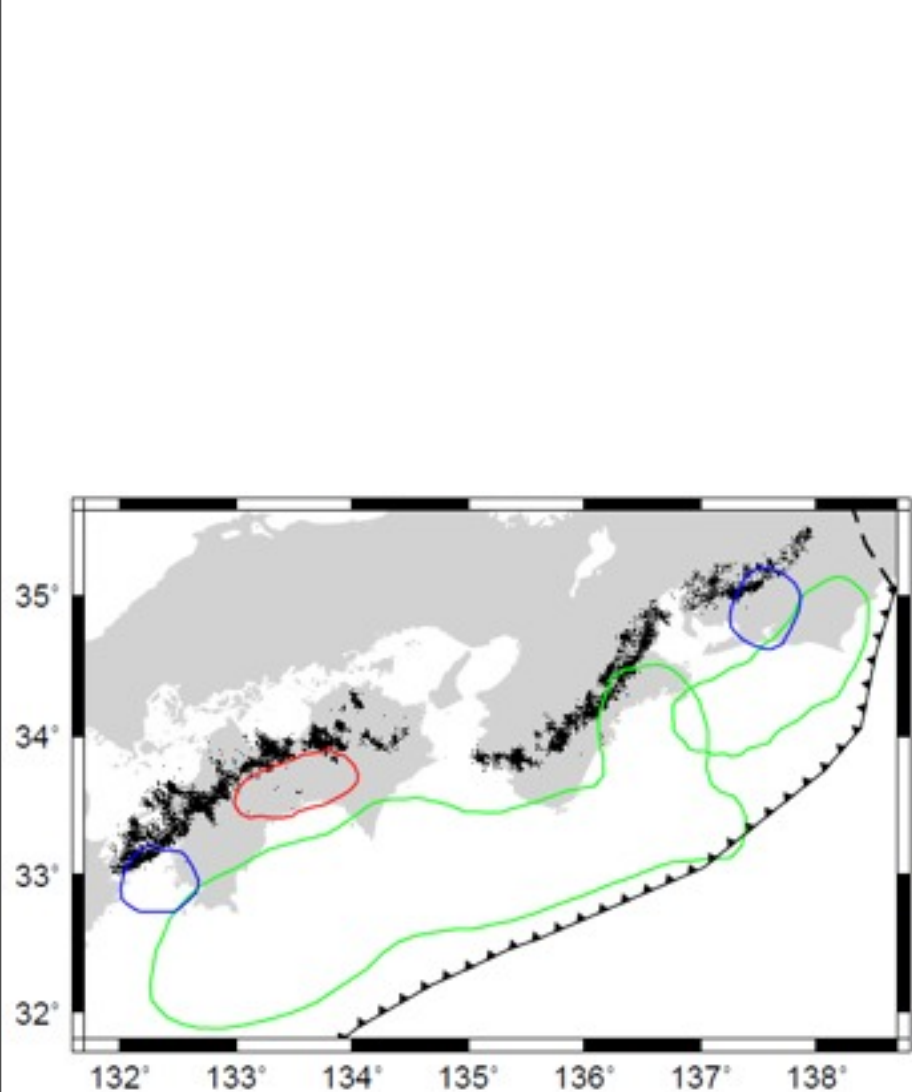
Integrating Observations of the Transition Zone

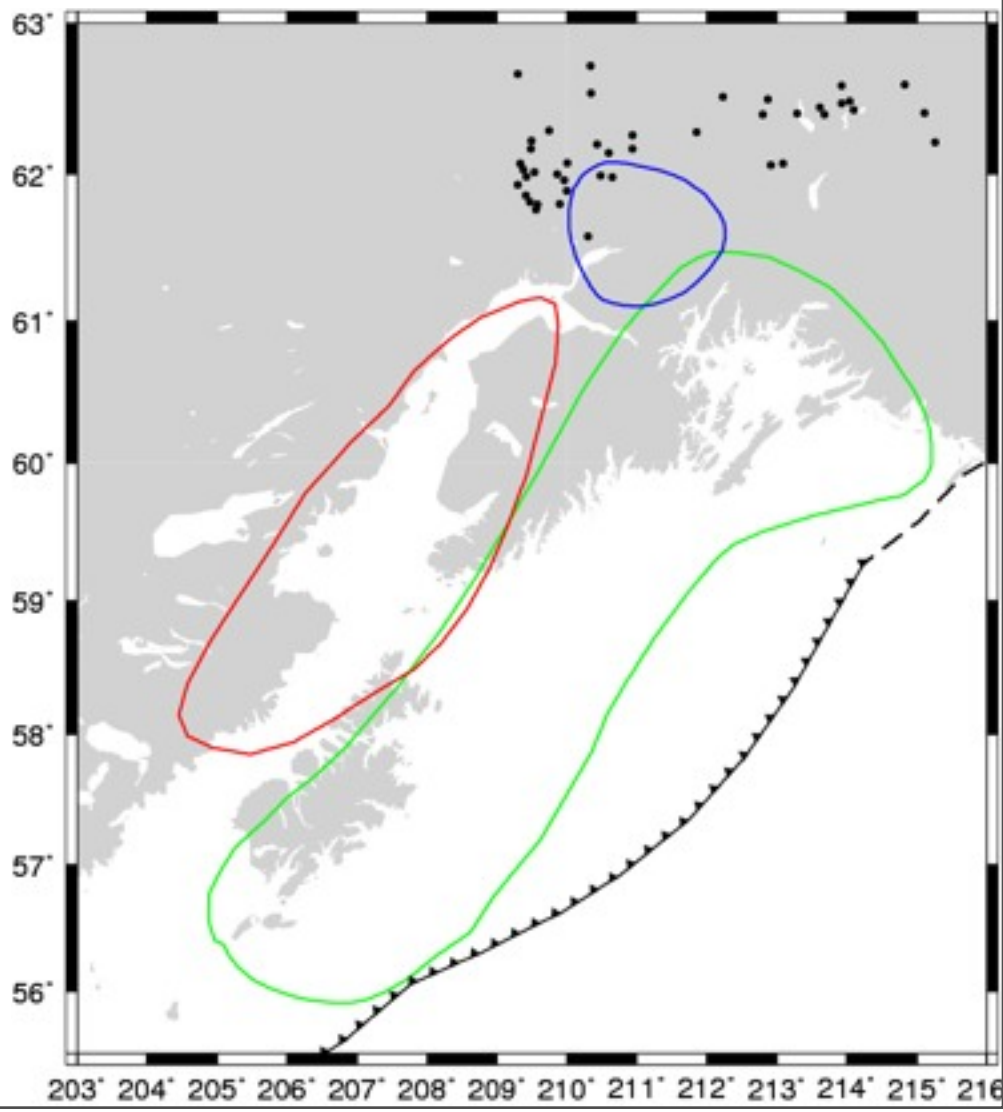
- Need to compare distribution of earthquakes, afterslip, episodic tremor and slip
- Expectation:
  - Earthquakes in velocity weakening
  - ETS near the transition
  - Afterslip in velocity strengthening

Earthquakes, Afterslip, Slow Slip, NVT in Mexico



Earthquakes, Afterslip, Slow Slip, NVT in Nankai and Alaska





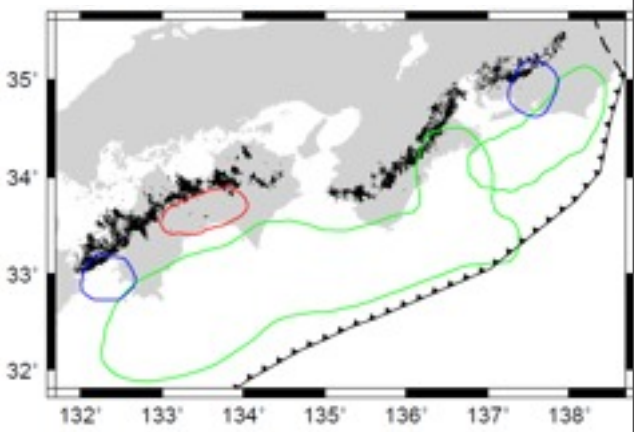
Coseismic Slip, Afterslip, Slow Slip Magnitudes

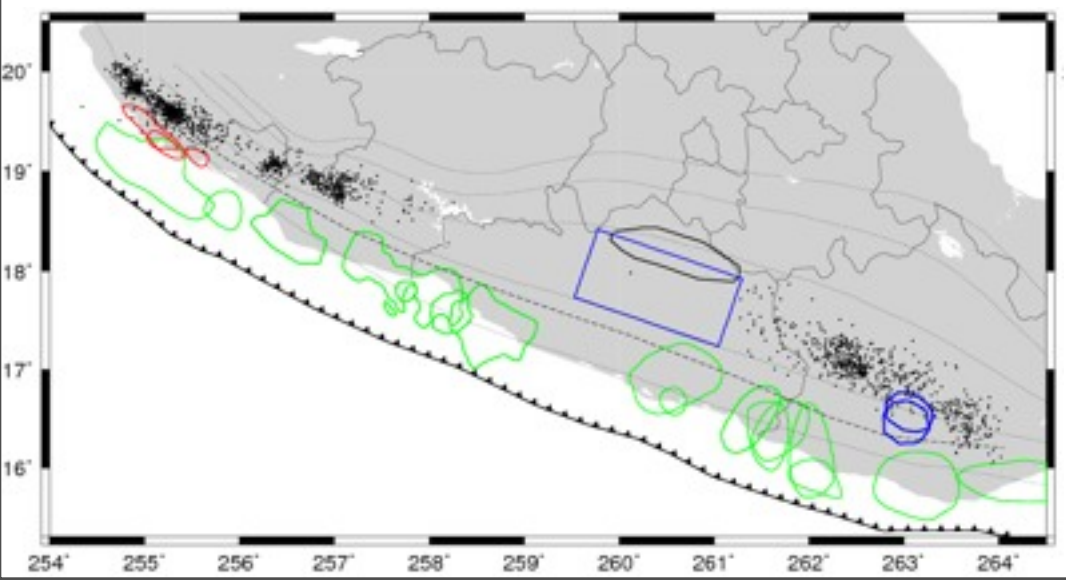
Alaska, Nankai, Mexico

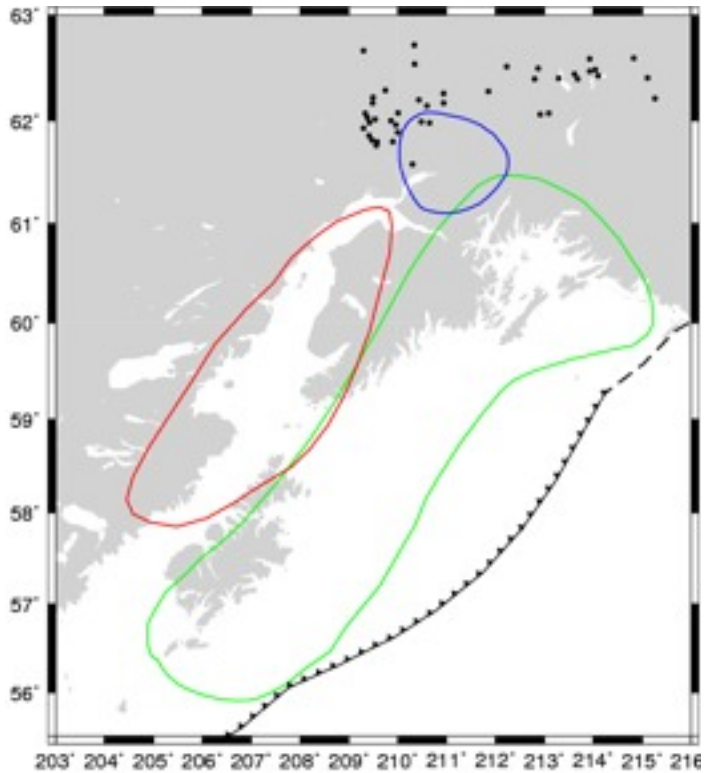
Coseismic: ~10m, ~5m, ~1m

Afterslip: ~20-40 cm/y @ 1 y

Slow slip: 4, 5, 10 cm/y







How can afterslip occur in the same relative location as episodic slip?

- Hypothesis 1: Heterogeneous frictional properties along strike: regions of episodic slip are deep asperities
- Hypothesis 2: Frictional behavior varies with strain rate: coseismic strain causes strengthening, interseismic strain causes weakening

Some observations associated with fault slip that I think will shed new light on the frictional stability transition

- (Earthquakes, Tremor and Slow Slip)
- Afterslip
- Earthquake swarms
- High conductivity regions
- Geologic terranes