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

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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

Nankai

Suito and Freymueller, 2009

Ito ad Hashimoto, 2004

Mexico

Hutton et al., 2001
Estimates of Along-Strike Afterslip

Fukuda et al., 2009

Perfettini et al., 2010
Afterslip Triggered By Mainshock

Fukuda et al., 2009
Afterslip Drives Aftershocks

Sumatra (Nias)

Hsu et al., 2006

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Earthquake Swarms

Mainshock-Aftershock

Swarm

- Evidence for transient slip correlated with swarms in Boso, Salton Trough, Kilauea
Megathrust and Volcanic Swarms

Holtkamp and Brudzinski, submitted
Swarms occur in same location as afterslip, reduced coupling, segmentation
Transition Zone Behavior: ETS

Correa-Mora et al., 2008

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Spatial Distribution of Slip Phenomena

Brudzinski et al., 2010
Tremor and Earthquakes
Spatially Anticorrelated

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Conductivity
Conductivity

San Andreas: Tremor along High Conductivity
Becken et al., 2008

Cascadia: Tremor and Slow Slip in High Conductivity
Soyer and Unsworth, 2006

Mexico: Tremor in High Conductivity
Brudzinski et al., 2010

New Zealand: No High Conductivity, Slip triggers Earthquakes instead of Tremor
Ingham et al., 2001

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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