Tremor, Triggering and Slow-Slip Phenomena

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Outline

• Remote triggering of tremor around the San Andreas Fault (Peng et al., 2008, 2009, 2010; Shelly et al., 2010)
• Remote triggering of tremor beneath the central Range in Taiwan (Peng and Chao, 2008; Tang et al., 2010; Chao et al., submitted)

Acknowledgements

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Maps showing where tremor and slow-slip events have been observed (Peng and Gomberg, NGEO, 2010)
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What we already knew about triggered tremor

Peng et al. (JGR, 2009)

Peng et al. (GRL, 2008)
2002 Mw7.8 Denali earthquake triggered tremors
at Parkfield, CA; Station: BK.PKD

Peng et al. (2008, 2009)
What we don’t know about triggered tremor

- Does triggered tremor consist of many low-frequency earthquakes (LFEs) like ambient tremor (Beroza and Ide, Science, 2009)?
- Does triggered tremor occur at the same places (depth) as the ambient tremor, with similar mechanism, except that the driving forces are different (Beroza and Ide, Science, 2009)?
- Can the triggered tremor be explained by the ‘clock-advanced’ model (Gomberg, JGR, 2010)?
- What are the relationship between ‘triggered’ tremor and slow-slip events (Smith and Gomberg, JGR, 2009)?
Global record section
The global surface wave displacements around the globe are shown. The closest shown station is in Argentina and the most distant one is in Mongolia. A 6.9 aftershock is visible for comparative scale near 90 minutes after the mainshock.
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Remotely triggered microearthquakes and tremor in Central California following the 2010 Mw8.8 Chile Earthquake (Peng/Hill/Shelly/Aiken, GRL, in review)

Shelly (Nature, 2010)
Shelly and Hardebeck (GRL, 10)
Probabilities of seeing a M3.5 or 4 M>=2 earthquakes in any given hour is less than 1%
Comparisons between the surface waves and triggered activity

Monday, November 1, 2010
Triggering potential for Love and Rayleigh waves from Coulomb failure criterion (Hill, BSSA, 2008, 2010)
Tremor migration

2010 Mw8.8 Chile
Triggered tremor migration triggered by the 2009 Mw8.1 Samoa and 2004 Mw9.2 Sumatra EQs (Shelly et al., submitted)

- 2009 Mw8.1 Samoa: ~80 km/hr
- 2004 Mw9.2 Sumatra: ~60 km/hr
Delayed triggering of tremor after surface waves

2002 Mw7.9 Denali Fault EQ

2008 Mw7.9 Wenchuan EQ

Time relative to mainshock (day)
Ambient Tremor migration - deep slow-slip
Ambient Tremor migration - deep slow-slip

Ghosh et al., G3 2010
Most triggered low-frequency eqs were at Cholame

Shelly et al. (submitted)

Peng et al. (JGR, 2009)
Triggering activity in southernmost family
Summary I

- Triggered and ambient tremor shares common sources (consisting of many low-frequency earthquakes) and a common physical mechanisms.

- Triggered earthquakes and tremor could be explained by the simple Coulomb failure criterion, although their timing with the surface waves are different.

- Some triggered tremor sequences show clear along-strike migrations, likely reflecting small triggered deep creep events.

- Some sequences have elevated tremor activities lasting a few days, similar to triggered earthquakes, perhaps indicating somewhat longer (and longer duration) slow-slip
Triggered tremor in Taiwan

Peng and Chao (GJI, 2008)

Tremor on the detachment beneath the central Range

Peng and Chao (GJI, 2008)
Triggered LFEs (Tang et al., GRL, 2010)
More triggered tremor observations in Taiwan (Chao et al., GJI, submitted)
Frequency dependence of triggering potential

Surface wave

Tremor
A greater ambient rate would correspond to higher likelihood of triggering.

Larger triggering waves would result in larger triggered tremor signals.
New observations:
1. Long-period Love waves did not trigger any tremor.
2. Tremor started 1-2 cycles after the Long-period Rayleigh waves.
3. Tremor continues during the high-frequency (<30 s) surface waves, and the tremor amplitudes does not correlate well with the surface wave amplitudes.
Summary II

- Triggered tremor in Taiwan also appear to be consisted of many low-frequency earthquakes, and may occur on a more vertical dipping faults rather than the shallow detachment fault.

- The triggering potential depends largely on the amplitude of the surface waves, and less on the incidence angle and the frequency content.

- Surface waves with larger amplitudes appear to trigger tremor with larger amplitude,

Shallow eq?

Deep tremor

Unstable Cond. stable Stable

Subduction zone
Dynamic triggering of shallow earthquakes in Beijing (Wu et al., GJI, submitted)

1. Triggered seismicity are extremely shallow (<3 km) and do not correlate with background seismicity.
2. Shallow creep observed at times.


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