Variations in remote triggering susceptibility along the Hikurangi margin and implications for the time-dependent strength of subduction zones

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Triggered micro-seismicity and tremor are tools for investigating the time-dependent strength of fault zones, revealing when faults are critically stressed and sensitive to small perturbations. Changes in triggerability may occur as a fault approaches a slow slip event or a large earthquake [*Savage and Marone*, 2008]. The Hikurangi subduction zone offers a unique window in which the recurrence time between slow slip events is short and fairly periodic, allowing for accurate sampling of the whole stick-slip cycle.

Preliminary work shows that Hikurangi has one of the highest rates of microseismic triggering of any subduction zones studied to date (Fig. 1). The high triggering susceptibility in Hikurangi may be related to the uniquely low coupling in this region, evidenced by episodic slow slip at relatively shallow depths (~15 km) [*Wallace et al.*, 2009]. In the Cascadia subduction zone, tremor is more sensitive to triggering by earth tides or passing surface waves during or near the occurrence of a slow-slip event than in the intervening stretches [*Rubinstein et al.*, 2009]. Micro-seismicity in several subduction zones has been shown to correlate more strongly with tidal stressing in the years before large megathrust earthquakes, including the 2011 M_W9.1 Tohoku earthquake [*Tanaka*, 2010; 2012]. Over the longer term, however, this subduction zone is relatively insensitive to triggered microseismicity from passing surface waves [*Harrington and Brodsky*, 2006; *van der Elst and Brodsky*, 2010]. Susceptibility to triggering therefore appears to evolve in response to changing strength or stability conditions on the fault.

Using a stacking method to pull out subtle triggered rate changes in large populations of micro-seismicity (previously applied to California and Japan [*van der Elst and Brodsky*, 2010]) we find that the northern Hikurangi margin responds strongly and systematically to surface waves from remote earthquakes (Fig 1). Spatial variations in the susceptibility to dynamic triggering along the subduction zone are evidence of the differences in strength between seismically coupled and uncoupled portions of the Hikurangi plate margin. The region of highest micro-seismic triggerability corresponds to the location of shallow slow slip events [*Wallace and Beavan*, 2010]. These two phenomena have not previously been observed to coincide. Cascadia and Japan, for example, both appear at least a factor of 3 less triggerable using the same method, with essentially no triggered micro-seismicity resolved in either location.

What do these triggered signals tell us about the distribution of strength and sliding stability along the Hikurangi plate margin? What do they tell us about the likelihood of large megathrust earthquakes here and in other subduction zones that lack remote triggering? The relationship between slow-slip, tremor, triggered micro-earthquakes and damaging megathrust events is only beginning to be worked out. The Hikurangi margin offers the unique possibility of studying the relationship between all of these sliding modes, throughout the slow-slip cycle.

References:

Harrington, R. M., and E. E. Brodsky (2006), The absence of remotely triggered seismicity in Japan, *Bulletin of the Seismological Society of America*, *96*(3), 871-878.

Rubinstein, J. L., J. Gomberg, J. E. Vidale, A. G. Wech, H. Kao, K. C. Creager, and G. Rogers (2009), Seismic wave triggering of nonvolcanic tremor, episodic tremor and slip, and earthquakes on Vancouver Island, *Journal of Geophysical Research-Solid Earth*, *114*

Savage, H. M., and C. Marone (2008), Potential for earthquake triggering from transient deformations, *Journal of Geophysical Research*, *113*(B5), B05302, doi 05310.01029/02007jb005277.

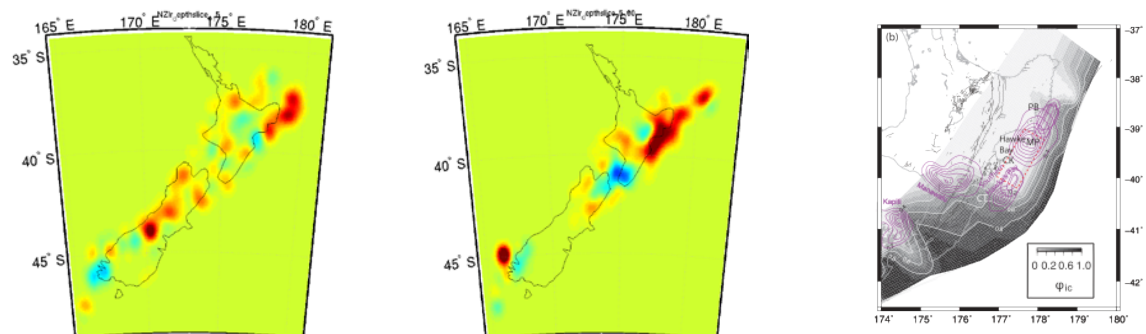
Tanaka, S. (2010), Tidal triggering of earthquakes precursory to the recent Sumatra megathrust earthquakes of 26 December 2004 (M-w 9.0), 28 March 2005 (M-w 8.6), and 12 September 2007 (M-w 8.5), *Geophysical Research Letters*, *37*

Tanaka, S. (2012), Tidal triggering of earthquakes prior to the 2011 Tohoku-Oki earthquake (M-w 9.1), *Geophysical Research Letters*, *39*

van der Elst, N. J., and E. E. Brodsky (2010), Connecting near-field and far-field earthquake triggering to dynamic strain, *J. Geophys. Res.*, *115*(B07311)

Wallace, L. M., M. Reyners, U. Cochran, S. Bannister, P. M. Barnes, K. Berryman, G. Downes, D. Eberhart-Phillips, A. Fagereng, S. Ellis, A. Nicol, R. McCaffrey, R. J. Beavan, S. Henrys, R. Sutherland, D. H. N. Barker, N. Litchfield, J. Townend, R. Robinson, R. Bell, K. Wilson, and W. Power (2009), Characterizing the seismogenic zone of a major plate boundary subduction thrust: Hikurangi Margin, New Zealand, *Geochemistry Geophysics Geosystems*, *10*

Wallace, L. M., and J. Beavan (2010), Diverse slow slip behavior at the Hikurangi subduction margin, New Zealand, *Journal of Geophysical Research-Solid Earth*, *115*



(a) 0-15 km **(b)** 15-100 km **(c)**

Figure 1. Susceptibility to dynamic triggering along the Hikurangi margin. ***(a)*** *Micro earthquake triggering susceptibility in the upper 15 km; warm colors reflect regions that respond more strongly to the surface waves of remote earthquakes. Cool colors (blue) reflect apparent negative rate changes and give an estimate of the uncertainty in the measurement.* ***(b)*** *Triggering susceptibility in the 15-100 km depth range. The peak triggering rates (red) are about 3 earthquakes/hr/per 100 km^2.* ***(c)*** *Zoom in on the north island, showing the zones of weak inter-seismic coupling and the location of slow slip events (violet contours) (from Wallace et al., 2009). The zones of weak coupling are also zones of strong remote triggering.*