Final Technical Report

Improved monitoring of tremor, earthquakes and volcanoes by the PNSN with methods to search continuous waveforms

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Along the northern Cascadia margin, GPS observations provide evidence of periodic, 2-week-long movements of plate motion between the subducting slab and overriding continental crust [Rogers and Dragert, 2003]. This slip event coincides with an emergent, enduring, and low-frequency signal know as tremor. From a hazards perspective, slow slip events are important in assessing risk associated with the updip seismogenic zone in two ways. First, it is thought that slip relieves stress locally while increasing stress on the locked zone with the potential to trigger a megathrust earthquake [*Dragert et al.*, 2001]. Second, spatially resolving slow slip could help map the freely-slipping, transition, and locked segments of the subducting Juan de Fuca plate relative to the dense urban centers along the fault margin. The other aspect of this ETS phenomenon, tremor, could prove very useful in monitoring slow slip and understanding the parameters controlling it. Geodetic observations offer good macroscopic views of slow slip events; however, GPS detection of slip often occurs after or late-into the event with limited resolution. Thus, establishing a link between tremor and slip enables the possibility of using tremor activity as a proxy for slow slip in time and space. Tremor monitoring can provide more timely slip recognition, and a tremor catalog enables higher-resolution estimates of where this stress loading—and hence triggering potential—may occur.

We have developed a new autonomous seismic location and detection methodology that enables near real-time opportunities for high-resolution spatio-temporal monitoring of non-volcanic tremor [*Wech and Creager*, 2008]. Combining a unique cross-correlation technique with epicenter clustering analysis on PNSN, PBO, PGC, and TA data in northern Cascadia automatically yields tremor epicenters from the past four Episodic Tremor and Slip (ETS) events while routinely detecting and locating inconspicuous inter-ETS tremor bursts (Figure 1). Thousands of epicenters from each of the past four ETS events from 2004—2008 provide detailed map-view constraints that correlate with geodetic estimates of the simultaneous slow slip [*Wech et al.*, 2009]. Analysis of the latest 15-month inter-ETS period also reveals ageodetic tremor activity similar both in duration and extent to ETS tremor.

Although ETS events in this area produce about two weeks of continuous tremor, we find a nearly equal amount of tremor during the last 15-month inter-ETS period. The inter-ETS tremor does not yet correlate with geodetically observed slip, but this is likely because the slip is below current GPS detection levels. If true, inter-ETS tremor could account for the slip deficit not accommodated during ETS slip. The resulting ETS and inter-ETS epicenters occur in the slow slip region where the plate interface is 30-45 km deep and have a sharp, well-resolved updip boundary about 75 km east of current estimates of the downdip edge of the seismogenic megathrust zone.

Based on the correlation between tremor and slip and the tremor duration and slip magnitude relationship, we suggest that the well-resolved, sharp updip edge of tremor epicenters reflects a change in plate interface coupling properties. This region updip of the tremor epicenter boundary may accumulate stress with the potential for coseismic shear failure during a megathrust earthquake. Alternatively, slip in this region could be accommodated by continuous slow slip with no detectible tremor or by slow slip events with sufficiently long recurrence intervals that none have been detected during the past 10 years of GPS observations.

This method has been implemented in a near real-time system which auto-detects and locates tremor daily, sends tremor warning email notifications, and posts these and past results on an interactive googlemap-powered public website (Figure 2). We are in the process of expanding this monitoring effort beyond western Washington south through Oregon and north to S. Vancouver Island.

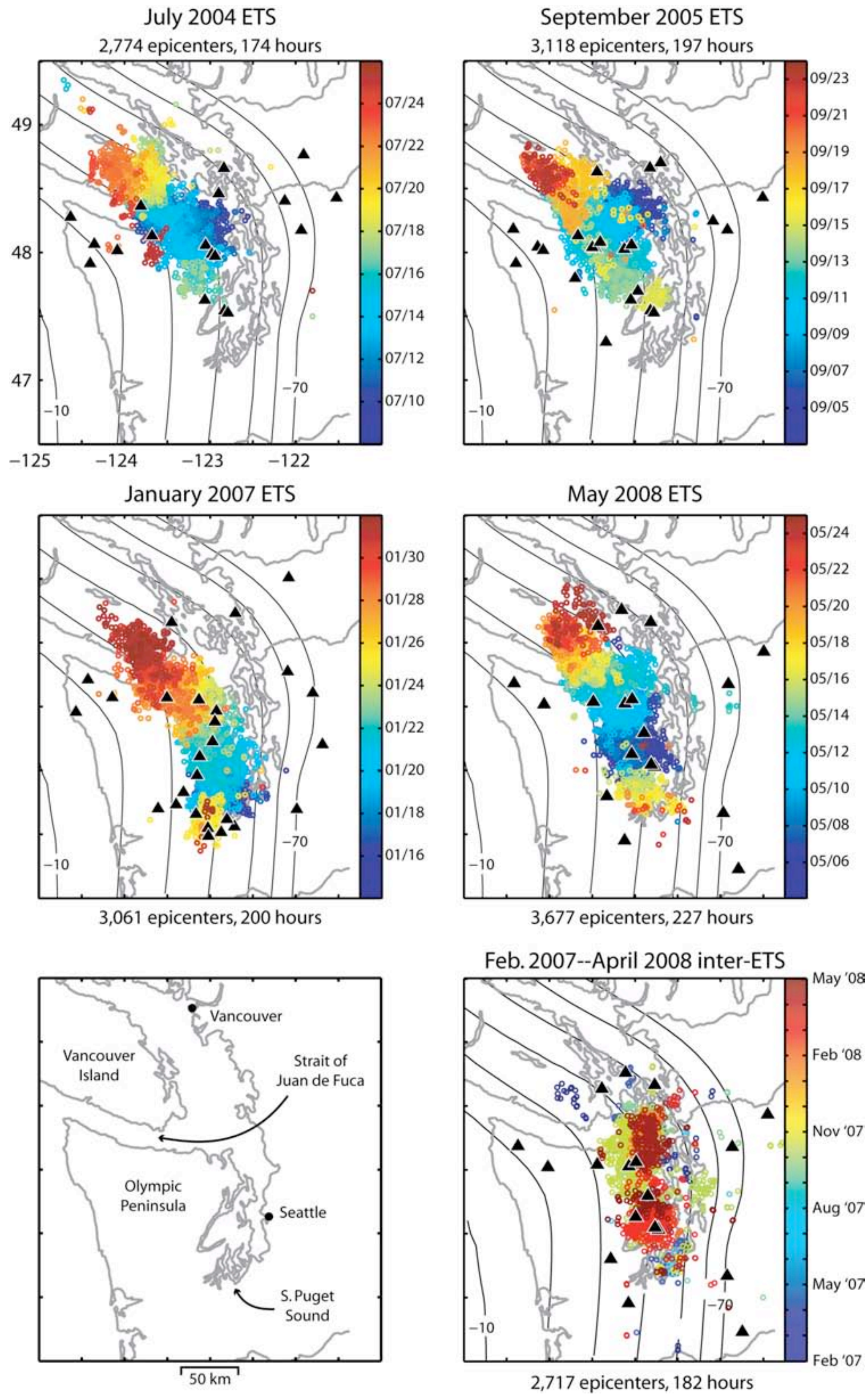

Figure 1. Results of automated detection and location efforts. Epicenters are colored to show temporal progression.

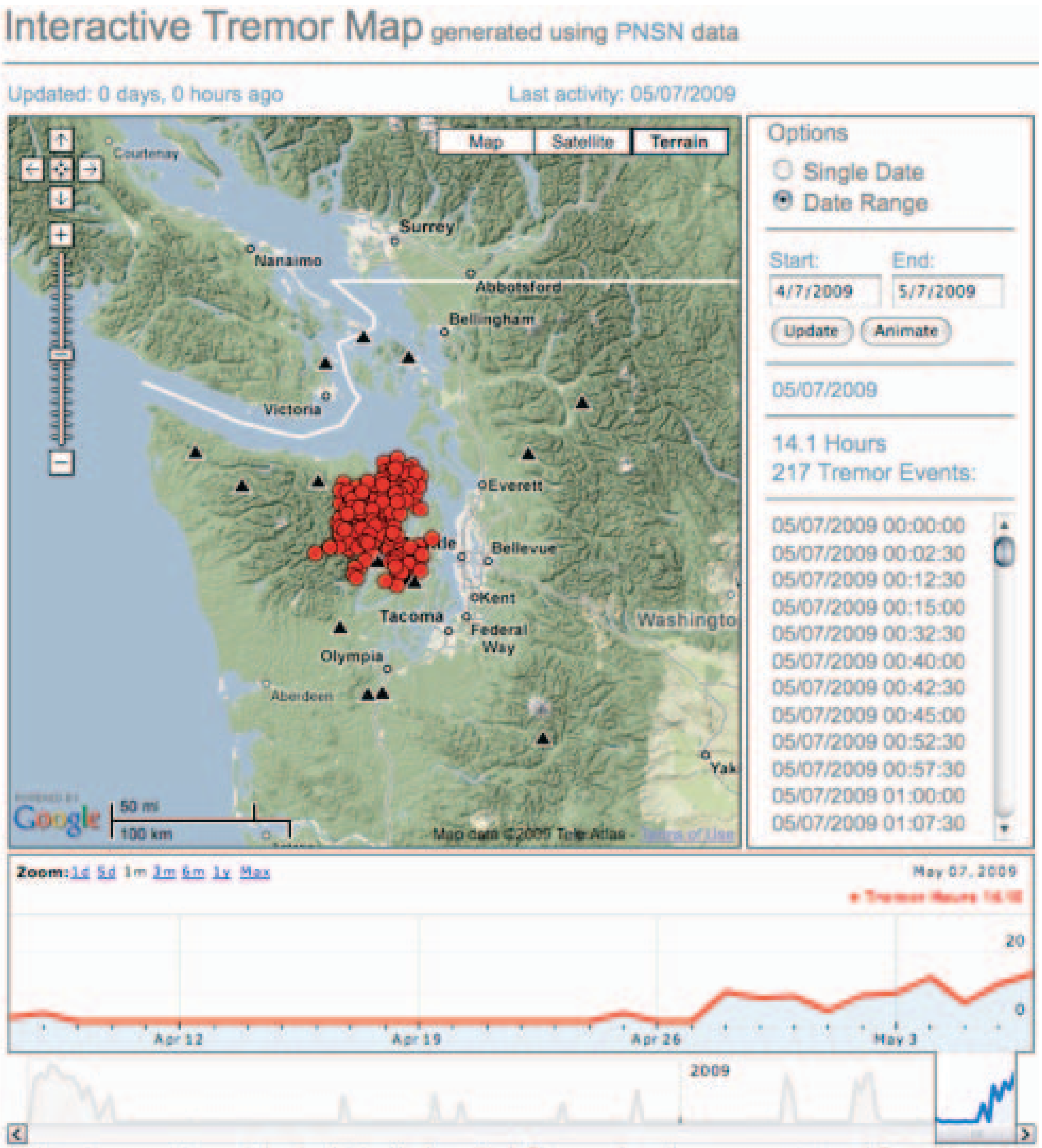

Figure 2. Example from interactive, auto-updated webpage that displays recent and past tremor activity.

URL:
http://earthweb.ess.washington.edu/~wech/tremor/

Rogers, G., and H. Dragert (2003), Episodic tremor and slip on the Cascadia subduction zone: The chatter of silent slip, *Science*, *300*, 1942-1943.

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