Award Number: 06HQGR0029

LOCATION OF NON-VOLCANIC TREMORS ALONG THE CASCADIA SUBDUCTION ZONE

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Abstract

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Extended-duration non-volcanic tremor sequences lasting 2-3 weeks occurred simultaneous with slow-slip beneath southern Vancouver Island during July 2004 and September 2005. These major tremor sequences, which we refer to as episodic, recur every 13-16 months. Shorter-duration tremor sequences, which we refer to as non-episodic, occurred in November 2004, January 2005, March 2005, April 2005, and July 2005, and lasted up to 5 days. To document the distribution of tremor activity during a complete slow-slip cycle, we have located several of these non-episodic sequences using the Source-Scanning Algorithm, and combined our results with locations obtained with the same method by the Geological Survey of Canada. Both episodic tremor sequences exhibited a northwestward migration along the margin. The non-episodic sequences of March 2005 and May 2005 may have exhibited a south-to-north and a north-to-south migration respectively, but the distribution of these tremors was not continuous along the margin, suggesting the alternative interpretation of separate tremor sequences. The distribution of non-episodic sequences that occurred over the 13 months between slow-slip events demonstrates a clear spatial gap in activity. It is at the edges of this seismic gap that the non-episodic tremors attain their greatest depths, over 60 km. The southern group of non-episodic tremor sequences also appears to be slightly displaced to the east relative to the mean geographic position of the episodic events. Assuming an association between tremor activity and slow slip, the non-episodic tremor sequences may be due to slip on small patches of the megathrust with too low a magnitude to be detected by monitoring of surface deformation. Alternatively, if non-episodic tremors can be shown to have a different geographical distribution than the episodic events, then at least some of the non-episodic sequences, i.e. those to the east, may result from slip above the presently inferred location of the subduction megathrust.

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1. Introduction

Over the years, there has been a gradual growth in the understanding of the tectonic structures of the Cascadia subduction zone, and the seismic hazard associated with megathrust, intraslab, and shallow crustal earthquakes. Recent discovery by surface-based deformation monitoring of episodic slip on the subduction megathrust faults in Japan and the Pacific Northwest (Ozawa et. al. 2002; Dragert et. al. 2001) has opened new avenues for research into the geodynamics and seismic hazard assessment of subduction zones.

In northern Cascadia, these slow slip events occur periodically every 13-16 months (Figure 1.1) and last 2-3 weeks (Rogers and Dragert, 2003). Although the time sequence of slip events has been identified, their depths are poorly constrained. In May 2003, it was found that low amplitude non-impulsive vibrations referred to as non-volcanic tremors are temporally and spatially associated with these slow slip episodes. Identification of the spatial location and sequence of episodic tremor activity coinciding with slow slip may make it possible to better estimate the depth at which slow slip occurs.

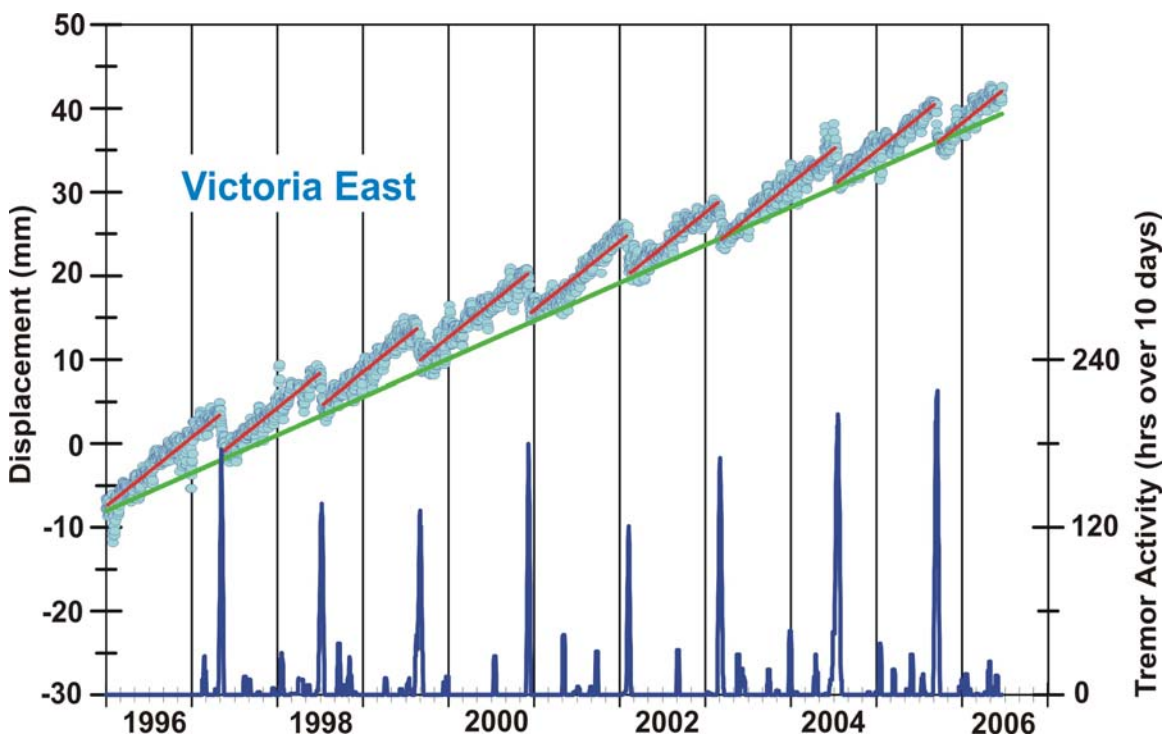

Figure 1.1. Comparison of slip and tremor activity near Victoria, B.C. Circles indicate daily change in east component of GPS data site ALBH (Victoria) with respect to Penticton. The continuous line shows the long-term (interseismic) eastward motion of the site. Sawtooth line segments show the mean elevated trends between slip events. The lower curve indicates the total number of hours of tremor activity observed for southern Vancouver Island within a 10-day sliding period, which is typical of a slow slip event (from Rogers and Dragert, 2003, updated by H. Dragert, pers. comm. 2007).

The implications of such possibilities are significant in that stress loading on the shallow part of the fault caused by one of these slip events will likely be a trigger for a great subduction

earthquake. Lower levels of non-volcanic tremor activity have also been detected in between episodes of slow slip but their origins are unknown.

In this study, tremor sequences are located with the objective of further understanding tremor source mechanisms by comparing their source locations and characteristics. The source locations of tremors may possibly provide important information on the structure of the megathrust interface. Identifying the locations of tremors, and understanding their association with megathrust, and perhaps other earthquake-related processes significantly advances the understanding of the tectonics of the Cascadia subduction zone and may lead to a more accurate assessment of the seismic hazard in the Pacific Northwest.

2. Background

2.1 Tremors and low frequency earthquakes

Tremors are seismic events with lower frequency content than local earthquakes, and appear to be uncorrelated with the deep or shallow earthquake pattern in the region. Each tremor comprises multiple pulses of energy that last approximately one minute with a frequency content between 1 and 5 Hz. Tremor amplitudes are barely visible above background environmental noise. Therefore they are detected only by correlating records from multiple stations. Identification of first arrivals and discrimination of phases is virtually impossible by visual inspection alone. Tremor waveforms have been found to be inconsistent from one seismograph station to another, the cause of which may be due to a poor signal to noise ratio or a time-varying radiation pattern.

Tremors have now been observed in a number of subduction zones and specifically in the same region as the deep slip events (e.g. Rogers and Dragert, 2003). Tremor has recently been discovered outside a subduction environment under the San Andreas Fault system south of Parkfield (Nadeau and Dolenc, 2005). This tremor, estimated to occur below the seismogenic zone at depths of 20–40 km, shares many characteristics with that observed in Japan and Cascadia. Like tremor in subduction zones, tremor on the San Andreas Fault occurs in a region previously thought to deform aseismically, but no associated deformation transient has yet been detected.

Tremors are strongest on horizontal seismographs and move across the network at shear wave velocities. Association between tremor and slip, referred to as episodic tremor and slip (ETS) may be used to provide a depth-constraint on the location of slow slip. If it is found that tremor activity and slow slip events are spatially coupled, then one possibility is that slow slip may be occurring in a vertically distributed region above the subducting Juan de Fuca plate. This structural mechanism correlates with the two megathrusts proposed on the basis of seismic reflection surveys in northern Cascadia (Calvert, 2004). It has been suggested that tremors are created by fluid flow in subsurface conduits at high pressure, which can create a resonance-like phenomenon (Julian, 2002). If this is in fact the source of tremor generation, tremor and slow slip need not be coincident, and tremor location may not provide the depth of slow slip events. It has been found in Japan that the highest frequencies in tremor activity have both preceded and followed conventional earthquakes (Obara, 2002). It is therefore of interest to investigate the nature of this association, and to determine whether or not tremor activity may serve as a precursor to earthquake activity in northern Cascadia. Though peak occurrence of tremor activity in Cascadia correlates with slow slip, there are several other peaks in tremor activity that do not appear to be linked to slow slip. If a spatial association between slow slip and tremor activity is

found, it may be that slow slip occurred below the limit of detection by the existing GPS monitoring array.

There is another new class of events denoted as low-frequency earthquakes (LFEs), which occur almost exclusively as part of an extended duration tremor signal with a frequency content very similar to tremors and lower than that of ordinary earthquakes (Obara and Hirose, 2006). They therefore correlate strongly with observed slow slip events. The LFEs and extended tremor also locate in approximately the same geographic region and exhibit similar migration behaviour along-strike in Japan (Obara et. al. 2004 and Obara and Hirose, 2006). Although it is uncertain whether or not LFEs and extended duration tremor represent a single phenomenon, their close association means that their mechanisms are probably connected. Figure 2.1 shows waveform records of a long-duration tremor sequence containing several LFEs (Shelly et. al., 2006). Also, an example of possible LFE in the Northern Cascadia subduction zone illustrated by an arrow at the top of vertical component velocity seismograms for 29 March 2005, beginning at 12:00 UTC during a tremor sequence as recorded at GSC and Polaris stations in Vancouver Island.

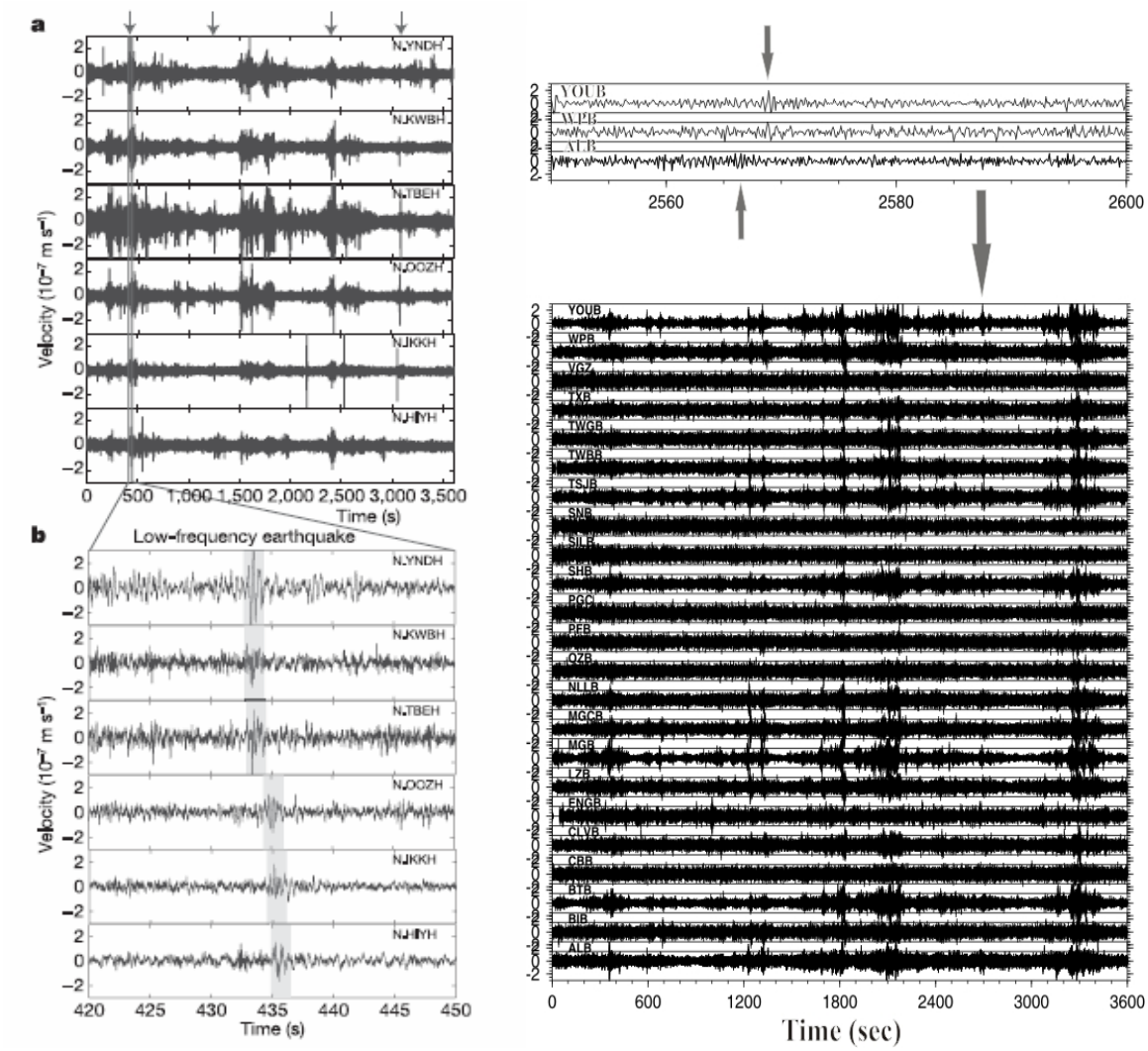

Figure 2.1. An extended period of tremor containing four identified LFEs. Left a) One hour of unfiltered east component velocity seismograms for 29 August 2005, beginning at 17:00 local time during a tremor sequence as recorded at six Hi-net borehole stations in western Shikoku. Arrows indicate times of LFEs.

Left b) Expanded view of seismograms showing one LFE from a. S-wave arrivals can be identified on these seismograms between 433 s and 436 s and are highlighted in grey. Traces are ordered by the time of the S-wave arrival, with the earliest arrival on top (From Shelly et. al. 2006). Right, an example of possible LFE in the Northern Cascadia subduction zone illustrated by an arrow at the top of vertical component velocity seismograms for 29 March 2005, beginning at 12:00 UTC during a tremor sequence as recorded at GSC and Polaris stations in Vancouver Island. Expanded view for three seismograms was illustrated at the top.

The coupled phenomena of tremor, LFEs and episodic slow slip events may represent a mode of failure for a transition zone between a locked and continuously creeping fault. In a subduction zone, this corresponds to the transition between the locked megathrust source region up dip and the continuously slipping region down dip. The correlation between LFEs and regular seismicity, the fact that LFEs are primarily composed of shear waves, and the remarkable correspondence with slow slip events argue that LFEs represent shear slip on this interface (Shelly et. al., 2006). LFEs may be generated by local slip accelerations at geometric or frictional heterogeneities that accompany large slow slip events on the plate interface. Long-duration tremor may result simply from a superposition of many concurrent LFEs. Alternatively, long-duration tremor might represent a combined signal of shear slip and fluid flow. If LFEs are direct signals of episodic slow slip, they would illuminate aseismic slip at depth with temporal and spatial precision well beyond that attainable with surface geodetic instruments. Consequently, LFEs may provide critical information for monitoring the seismic hazard in a variety of tectonic settings.

2.2 The Source Scanning Algorithm

Conventional source-determination methods involve first constructing a forward model to generate synthetic seismograms (predicted data) followed by an appropriate inversion method that minimizes the difference between the observed and predicted arrival times of various phases at a number of seismic stations.

There are two major drawbacks to these methods: firstly: impulsive arrivals are often required to reduce phase picking errors. These errors are mapped directly into the uncertainty of the location and/or time of origin. Secondly, the correct association of the phases belonging to the same source at different stations becomes difficult when multiple source events occur close together in space and time. In other words, phase-picking methods are most useful for individual events that are well separated in time and generate clear arrivals at seismic stations with relatively low background noise. As well, nearly all waveform inversion methods must make a priori assumptions about the geometry and dimension of the involved fault or faults. This is often impossible for smaller events.

For these reasons, a new method called Source Scanning Algorithm (SSA) has been created to map the source distribution without any a priori knowledge of the orientation or geometry of the actual fault plane (Kao and Shan, 2004). The SSA uses waveform information (namely, travel-times and amplitudes) from an array of seismic stations to determine whether or not it is possible for a seismic source to exist at a particular time and location. By systematically scanning through the volume of space, and range of time, of interest, we are able to recover the source distribution without the need to either identify accurately the arrival times of seismic phases or calculate synthetic seismograms. This is important for the location of non-volcanic tremors, because the different phases do not have a clear onset.

The coherence measure calculated by the source-scanning algorithm, referred to as "brightness" is recovered from the constructive addition of seismic waveform amplitudes from each station of the seismograph array. Brightness of a spatial position η at a potential tremor origin time τ is defined as:

$$br(\eta, \tau) = \frac{1}{N} \sum_{n=1}^{N} |u_n(\tau + t_{\eta n})| \qquad \textbf{(2.1)}$$

Where u_n is the normalized seismogram amplitude recorded at station *n* and $t_{\eta n}$ is the predicted travel time of the *S* phase from the subsurface position η to the recording station *n*. The brightness of a hypothetical tremor source at a trial location and origin time provides an estimate of the likelihood that the tremor source exists at this location and origin time. The calculation uses a 3-D *S*-wave velocity model, which is scaled from the SHIPS 3-D *P*-wave model (Ramachandran, 2001) using the approximate Vp/Vs ratio of the region.

3. Vp/Vs ratio

Crustal V_p and Vs structures are the two most essential components for a reliable seismic event location. In order to estimate an average Vp/Vs ratio for the region of the 3D velocity model in southern Vancouver Island, two methods were used. 30 well-located earthquakes were selected in the area with magnitudes between 1.5 and 4.0. The location accuracy of these events is estimated to be within 5 km based on the reports of Geological Survey Canada (GSC). Local network locations are accurate to within 5 km, with a 95 percent confidence level when the network meets the following criteria: (1) There are 10 or more stations, all within 250 km, (2) The azimuthal gap is less than 110º, (3) The secondary azimuthal gap is less than 160º and (4) At least one station is within 30 km (Bondar et. al., 2004). In this case, earthquake locations are relatively stable and do not depend strongly on the velocity model. In both methods the propagation path for both P and S waves is assumed to be identical.

3.1 Chatelin method

For all of the earthquakes, the differences between the arrival times of P waves at pairs of stations were calculated. At the next step the difference between S-arrival times at the same stations was provided and the Vp/Vs ratio was calculated using the following equations (Chatelin, 1978):

$$T_p^i - T_p^j = (d^i - d^j)/V_p \quad (3.1)$$

$$Ts^i - Ts^j = (d^i - d^j)/Vs \quad (3.2)$$

Then,

$$V_p/V_s = (Ts^i - Ts^j) / (T_p^i - T_p^j) \quad (3.3)$$

where T_p^i and T_p^j are arrival times of P wave at ith and jth recording station and d^i and d^j denote the distance between the source and ith and jth station. In a similar fashion, Ts^i and Ts^j are arrival times of S wave at ith and jth station. The Vp/Vs ratio is calculated by applying linear regression between $Ts^i - Ts^j$ and $T_p^i - T_p^j$ (Figure 3.1). The calculated ratio for southern Vancouver Island is 1.7609 +/- 0.0042. In this calculation, 364 couples of P and S wave arrival times used and the correlation coefficient is 0.998.

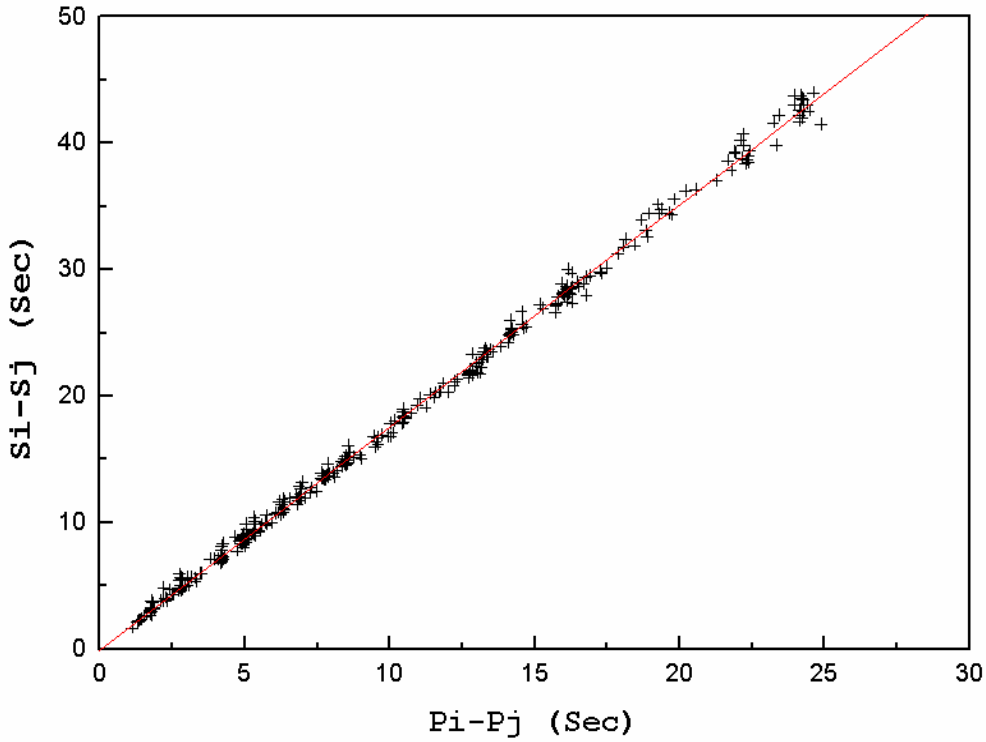

Figure 3.1. Calculation of the Vp/Vs ratio based on Chatelin method. 364 pairs of P and S wave arrival times used in this calculation with correlation coefficient of 0.998.

3.2 Wadati method

Another attempt to calculate average Vp/Vs ratio for the southern Vancouver Island is based on the Wadati method. It is possible to calculate that ratio by applying linear regression of the plot of the equation $T_s - T_p = f(T_p)$. In this equation T_s and T_p are the arrival times of S and P waves at a seismographic station. If T_0 is the origin time of an earthquake, then:

$$T_s = T_0 + d/V_s \quad (3.4)$$

$$T_p = T_0 + d/V_p \quad (3.5)$$

Hence,

$$T_s - T_p = f(T_p) = (1-V_p/V_s)\, T_0 + (V_p/V_s - 1)\, T_p \quad (3.6)$$

where d is the source-station distance. The result of this method is a Vp/Vs ratio of 1.7639 +/- 0.0045 for southern Vancouver Island with a correlation coefficient of 0.998 based on 370 observations of $T_s - T_p$. A histogram of calculated values of average Vp/Vs (Figure 3.2) shows a maximum value between 1.74 and 1.78.

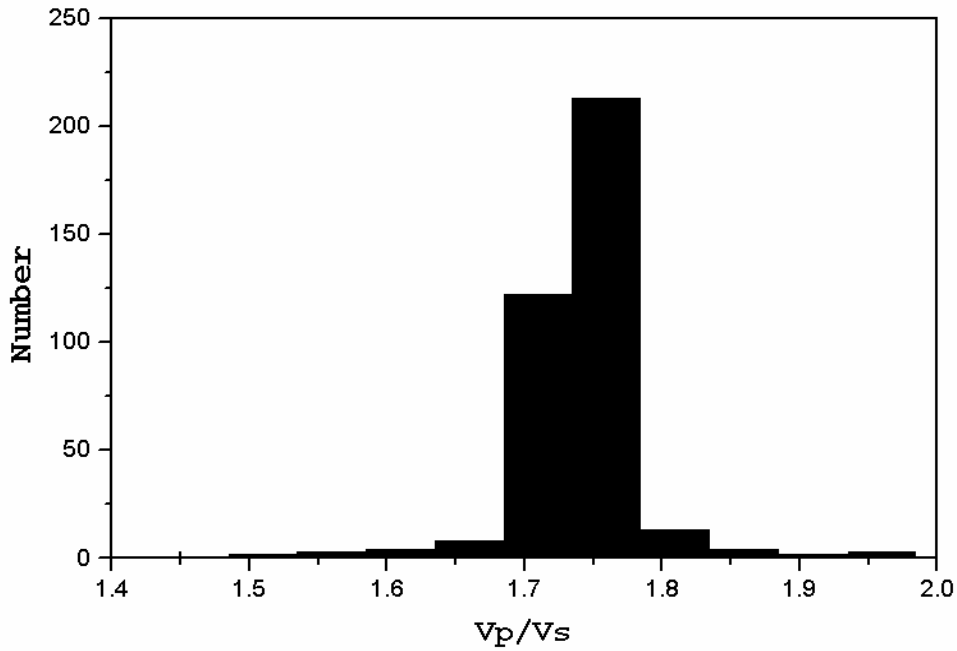

Figure 3.2. Histogram of average Vp/Vs values based on Wadati method. A ratio of 1.7639 was calculated from 370 observations of $T_s - T_p$.

4 Search method and location results

The spatial distribution of episodic and non-episodic tremor sequences will be examined and compared in this section in order to identify the distinct characteristics of each tremor class. Episodic tremor coincides spatially and temporally with slow slip, whereas non-episodic tremor sequences occur during periods when no aseismic slip has yet been identified.

The timing of sequences of non-volcanic tremor activity had initially been obtained by visual inspection of seismograph records (G. Rogers, pers. comm.). Initially, we analysed the days in January, March and July 2005 when periods of non-episodic activity are known to have occurred: January 11-15, March 11-15, March 27-30, July 13-14, July 16 and July 19-20. For other periods of activity we have included tremor location results provided by the Geological Survey of Canada (H. Kao, pers. comm.)

In this study our main goal was to establish a database of tremor locations during a full life cycle of tremor activity starting July 2004 and ending in September 2005, which are both episodic sequences, and non-episodic activities in between (Figure 4.1). Locations are provided in the appendices for the most of the these tremor sequences, but the sequences of September 2005 and November 2004, which were located by the Geological Survey of Canada, have been omitted since they have not yet been finalised.

The dimensions of the 3-D *S*-wave velocity model were used to define the dimensions of the volume searched. The velocity model extends from 1-87 km in depth, 46.9°N to 50.95°N in latitude and -126°E to -121°E in longitude, which translates approximately to 1-361 km in the *x*-direction and 1-451 km in the *y*-direction. For the purposes of comparing the onset, distribution, and migration of non-episodic tremor sequences, vertical component waveform data were

acquired for the entire days of tremor activity between June 2004 and the end September 2005 from a combination of 3-component broadband and vertical component short period seismograph stations of regional Canadian National Seismograph Network (CNSN) and Polaris.

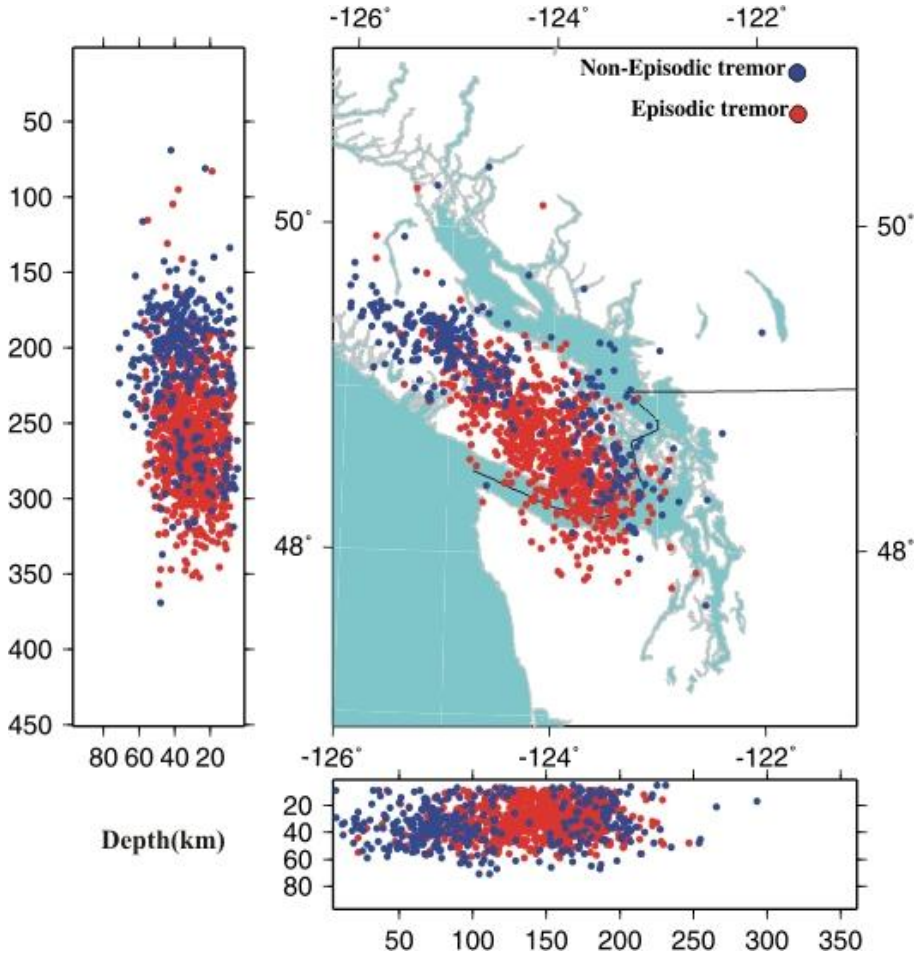

Figure 4.1. Map showing the distribution of well-located tremor hypocenters during one full life cycle of activity in 2004 and 2005. Events in northern parts of Vancouver Island were not included.

All waveform data were downloaded from the Geological Survey of Canada's National Waveform Archive. Travel times from each station to all grid points in the search volume were calculated using a 3-D finite-difference travel time code (Hole and Zelt, 1995) at a spatial mesh interval of 1 km. These travel times were used to generate a set of reference travel time files for each station. The source-scanning algorithm uses the travel times from each station's reference file and the absolute trace amplitude of corresponding waveforms to compute brightness values for each combination of source location and origin time.

All waveform pre-processing was carried out on one-hour segments of waveform data using the Seismic Analysis Code (SAC), after conversion of the data from SEED format. Waveforms were anti-aliased and down-sampled to a sampling interval of 0.1 s. The data were deconvolved to remove instrument responses and a high-pass filter was applied using a corner frequency of 1 and 5 Hz to remove low-frequency background noise.

Each waveform trace was normalized to compensate for amplitude variations due to transmission losses and geometric spreading. Tremor waveforms were normalized such that 2 standard deviations of the absolute amplitude are set to 1.0. This normalization has been found to improve the visibility of tremor arrivals and facilitate the search method. Smoothed envelopes of trace amplitude data were also calculated, using a 25-point (2.5 s) running average of trace amplitudes. Brightness values were calculated for each one-hour segment of waveform data using both absolute trace amplitudes and trace envelopes.

Tremor sources that are considered well-located are those that have been obtained using both absolute trace amplitudes and trace envelopes of the waveform data, and agree to within 20 km in *x*-, *y*-directions and within 50 km in z direction and have origin times within 10 s. Also local earthquakes and located events with a depth of 0 km (surface-related environmental noises) are discarded. For completeness, we have included in the listings shallow events with depths less than 5 km, but recognise that some of these may be related to surface noise given a likely error in location depth of at least 5 km.

The grid search method requires the storage of the travel timetables, and is computationally expensive. Our Sun Blade 200 workstation is used to evaluate and develop the source-scanning algorithm. The routine tremor search is carried out on the WestGrid supercomputer.

4.1 Epicentral distribution of episodic tremors

Two extended periods of episodic tremor activity have been located using the source-scanning algorithm (Kao et al., 2006a) during the end of June, all days of July and beginning of August 2004, and also September 2005 (Kao et al., 2006b), which has been anticipated since slow slip episodes have occurred during those times.

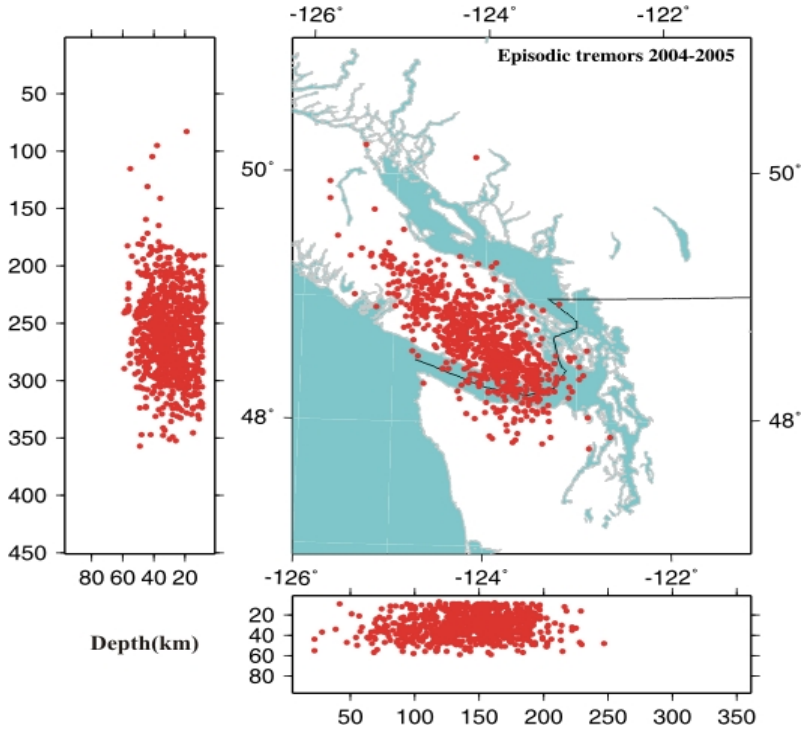

Figure 4.2. Map showing the distribution of well-located episodic tremor hypocenters. Events in northern parts of Vancouver Island were not included.

The depths of theses events vary between 0 and 60 km (Figure 4.2). The first ETS period started on 27th June 2004 and continued to 5th of August 2004. This sequence comprises of 529 well-located events with an average depth of 26 km and maximum depth of 55 km. The second cluster of ETS events started on 4th of September 2005 and ended on 26th of September 2005 including 346 well-located events with average depth of 26 km and maximum depth of 45 km. At the onset of the episodic tremor sequences, tremors were located near the southeast tip of Vancouver Island. A gradual migration of tremor sources from south to north and along the strike of the subduction zone (Figure 4.3) was detected (Kao et al., 2006a). This migration coincides with the movement of the surface displacement transient that has been found to occur during each slow slip episode (Dragert et. al. 2001).

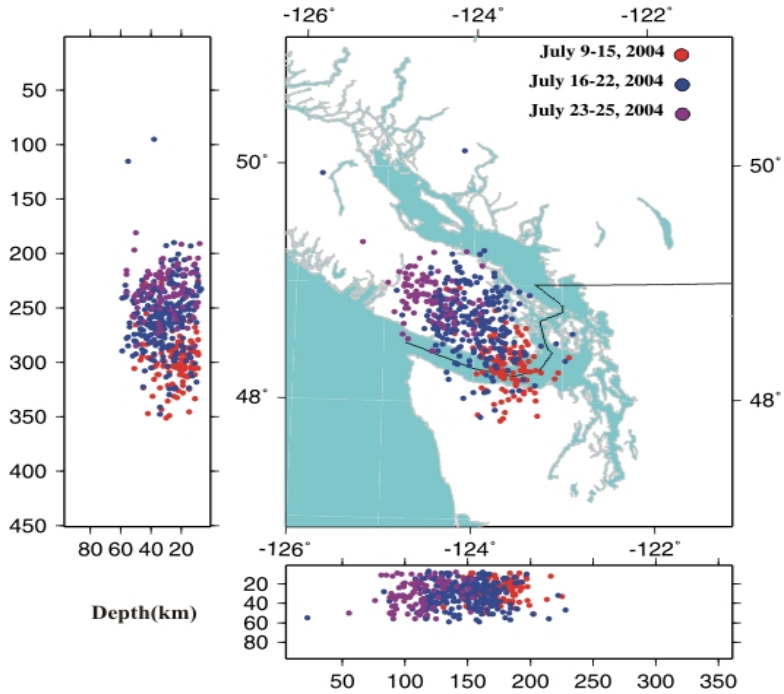

Figure 4.3. Map showing the migration of tremors from southern parts of Vancouver Island to the northwest during the episodic sequence of tremor activity in July 2004.

4.2 Epicentral distribution of non-episodic tremors

Non-episodic tremors in the database including events in November 2004, January, March, April, May and July 2005 are located in generally similar regions to the episodic sequences that have been associated with slow slip, but non-episodic tremors appear to concentrate in two regions in south and central Vancouver Island (Figure 4.4). The non-episodic tremors in the south also appear to be slightly further east than the epidosic sequences (Royle, 2005). Migration from south to northwest is not frequently observed. Among the six sequences of non-episodic tremors, only the two cases of March 2005 (Fig. 4.6a) and May 2005 (Fig. 4.7a) exhibited migration along strike. Observations of migration are limited by the short duration and small number of events in the non-episodic sequences: for November 2004, 11 days and 109 well-located events; for January, 4 days and 37 events; for March, 6 days and 90 events; for April, 11 days and 142 events; for May, 9 days and 57 events; for July, 5 days and 34 events. These results raise the

possibility that the non-episodic tremors indicate slow slip on the megathrust, but at a magnitude too low to be detected by GPS monitoring of surface deformation.

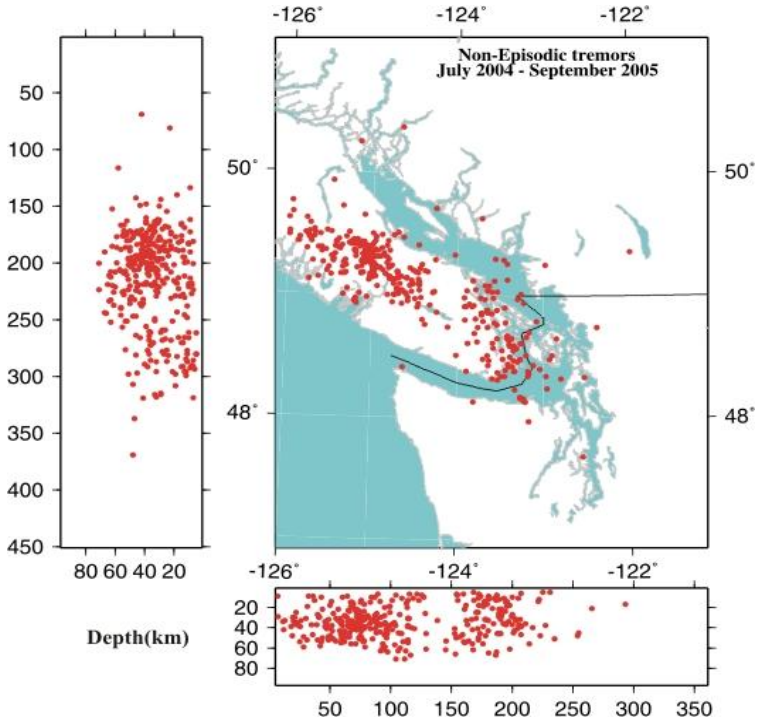

Figure 4.4. Map showing the distribution of well-located non-episodic tremor hypocenters. Events in northern parts of Vancouver Island were not included.

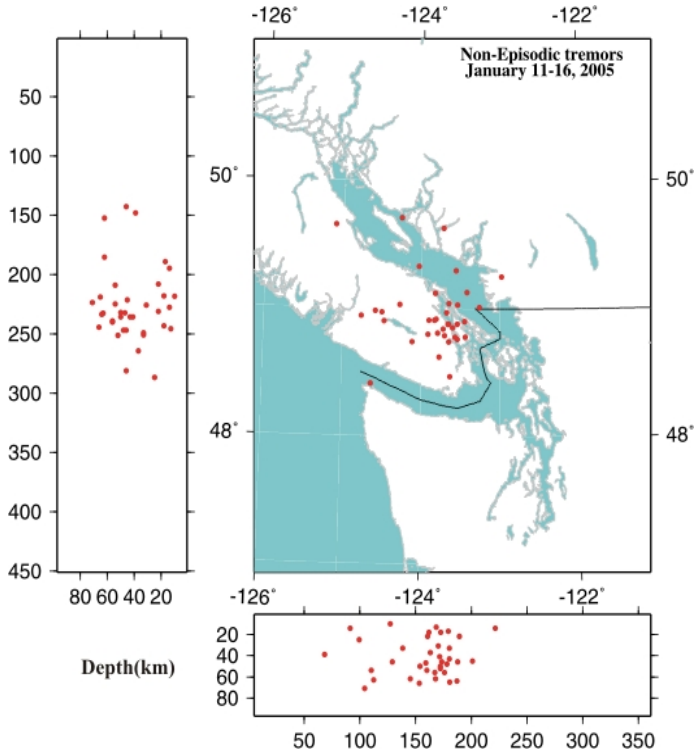

Figure 4.5. Map showing the distribution of well-located non-episodic tremor hypocenters in January 2005.

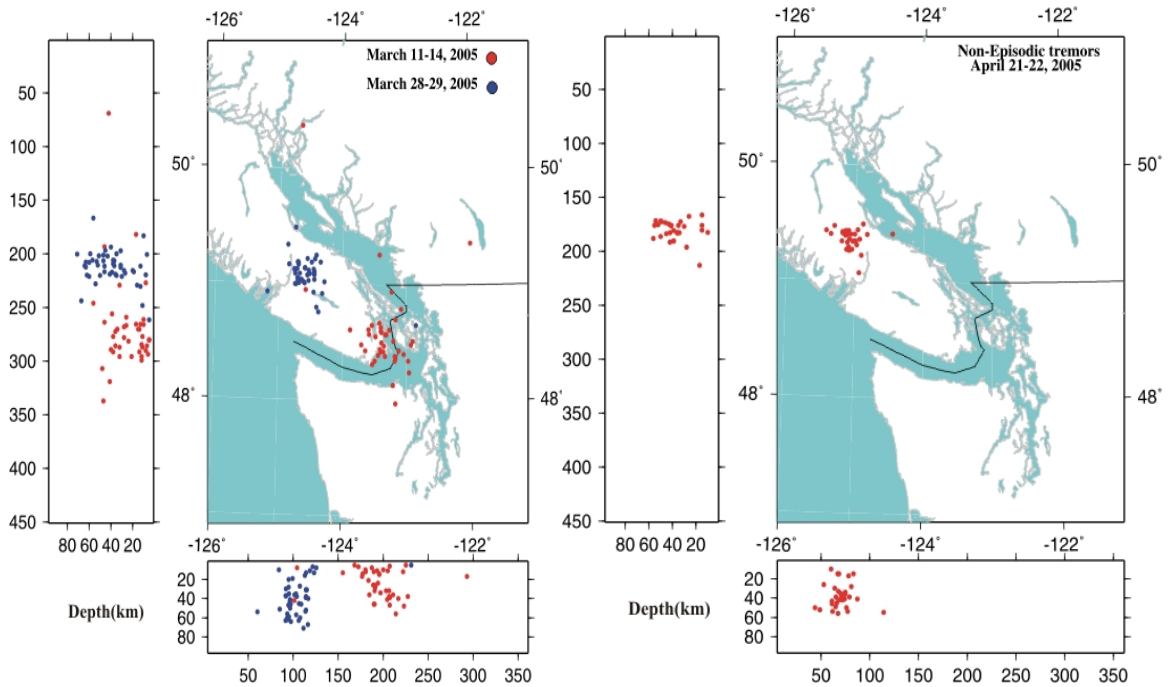

Figure 4.6. Map showing the distribution of well-located non-episodic tremor hypocenters in March 2005 (left) and April 2005 (right).

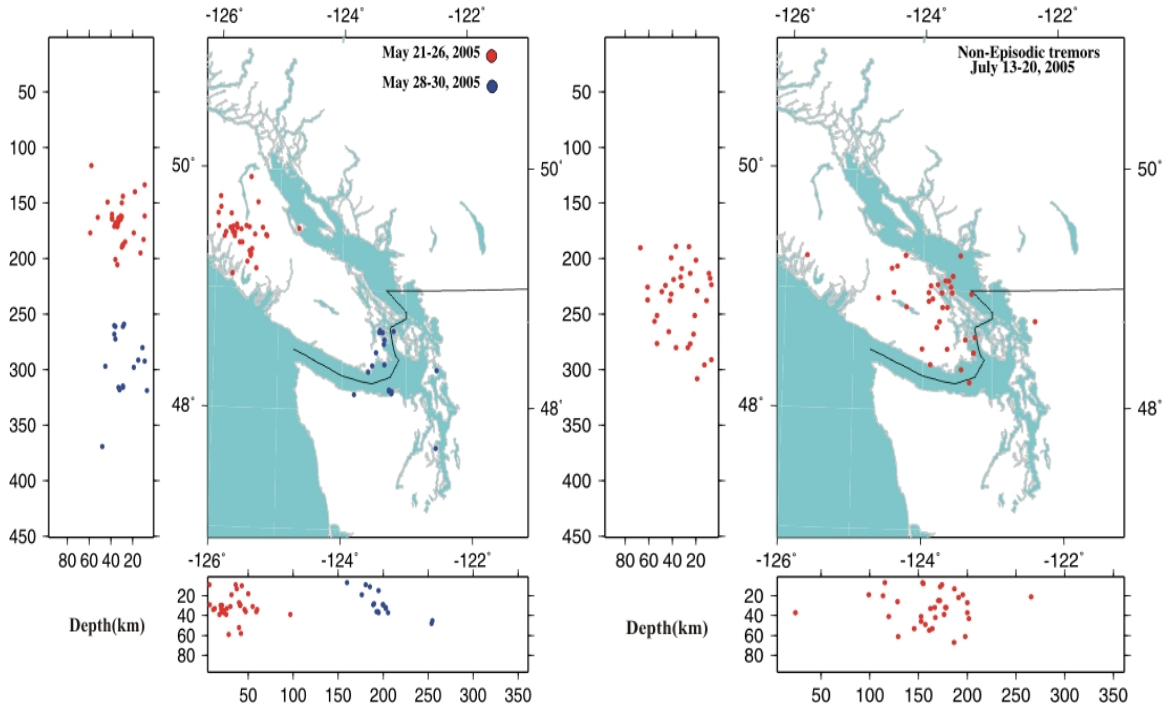

Figure 4.7. Map showing the distribution of well-located non-episodic tremor hypocenters in May 2005 (left) and July 2005 (right).

4.3 Estimated location error

It is clear that accuracy in the results of location methods strongly depends on the amount and coverage of the data used in the processing. The SSA method, which exploits waveform information by systematically scanning through a range of trial source locations and origin times, is a powerful tool, but data quality, the total number of stations and the accuracy of the velocity model used in the calculation limit its resolution.

For example, by checking the gradient of the brightness function in the previous study of tremors in February and September 2002 an average horizontal error of 7 km and an average vertical error of 9 km was found for both episodic and non-episodic tremors (Royle, 2005). These errors were largely attributed to a reduced station coverage relative to the subsequent episodic tremor sequence of March 2003, for which an average horizontal error of 3 km and an average vertical error of 5 km was estimated (Kao et. al. 2005) that make use of a total of 40 broadband and short-period seismograph stations.

In order to have a better idea of the location accuracy of the SSA method, 30 earthquakes in southern Vancouver Island were located using SSA. According to GSC reports the location accuracy of these events based on the station coverage and the number of P and S phases used in the location process is within 5 km. In this case, earthquake locations are relatively stable and do not depend strongly on the velocity model.

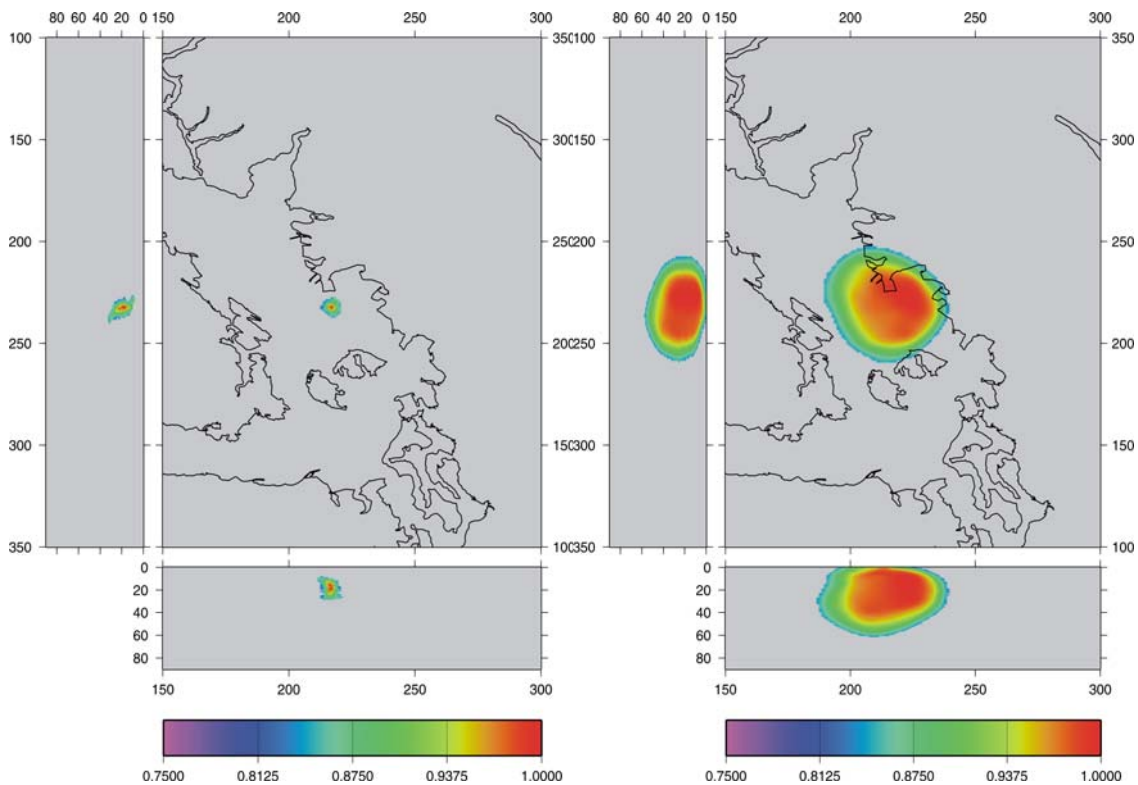

Figure 4.8. Brightness intensity plots of amplitude data (left) and envelope of amplitude (right) for an earthquake in southern Vancouver Island in November 2001.

We obtained locations from the trace amplitude data, but also used brightness intensity plots from envelope data to check the results (Figure 4.8). The average of absolute difference in epicenter between GSC reports and SSA results is less than 3 km and for the depth is more than 5 km but there are some cases with a difference in depth of more than 10 km which is partly related to to the difference in the velocity models used. The GSC earthquake location method uses a locally established 1-D velocity model. For locating these earthquakes we used roughly the same number of stations (between 20 and 25 based on the availability of data) as we used for the tremors.

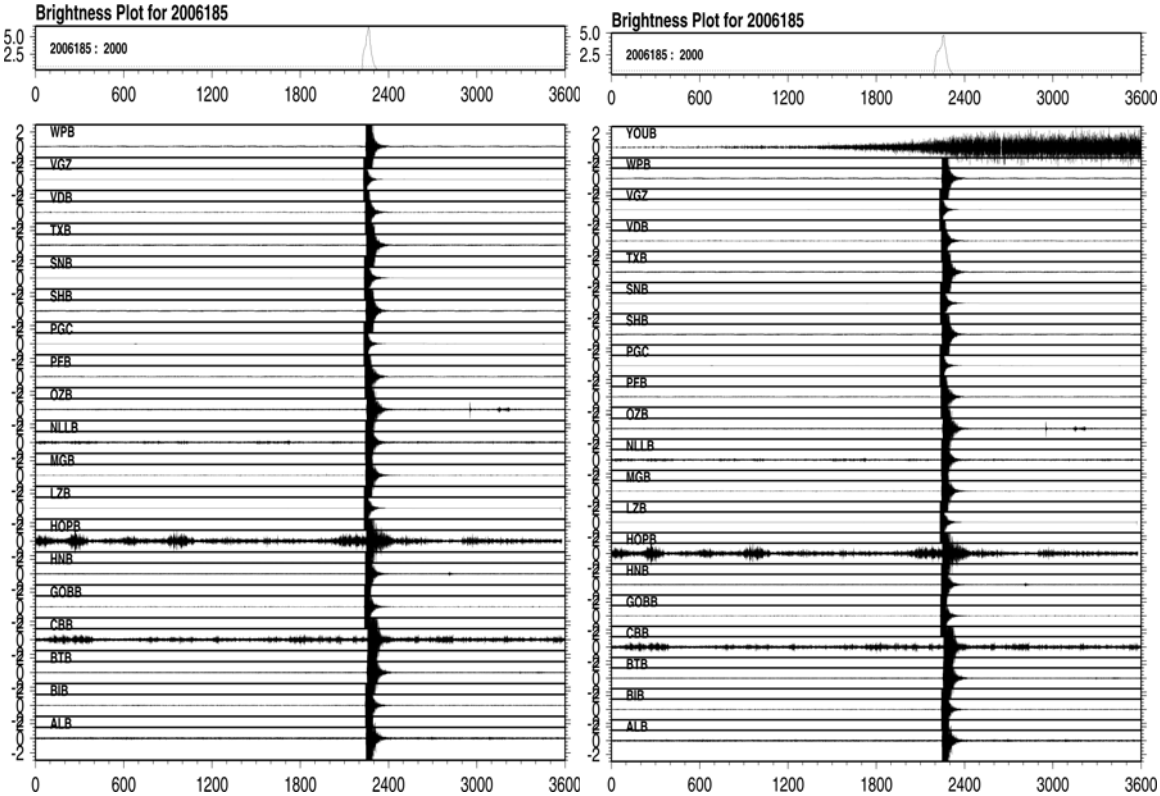

Figure 4.9. Seismograms of an earthquake recorded at CNSN and Polaris station on 4th of July 2006. Left) waveforms of the earthquake at 19 stations, mostly very well recorded. In this case maximum calculated brightness is 6.22 and the location results are in good agreement will GSC reports. Right) adding one noisy station causes a decrease in brightness to 4.64 and 72 km shifts in epicenter and 30 km in depth.

Generally, it seems that SSA is a powerful tool for locating tremors. Tests with synthetic data shows that SSA is capable of recovering the original source location even after adding a high level (70 per cent of the largest amplitude) of random noise (Kao & Shan, 2004). But there is no doubt that very high level of noise can affect the performance of SSA. This is the case for an earthquake on 4th of July 2006. By adding a high level of long duration noise (station YOUB) the epicenter and depth of the event was shifted 72 km and 30 km respectively (Figure 4.9 and Table 4.1). Therefore using the closet stations and those with the highest quality and lowest noise level in the process is of great importance. In addition to the high level of noise, an inaccurate velocity model also can affect the performance of SSA.

Method	Date-Hour	Seconds	Lat.N	Long.E	Depth	Mag.	Stations (number)	Reference Station
GSC report	20060704_2300	2222.89	48.328	-123.204	46	4.0	124	-
SSA	20060704_2300	2222.99	48.203	-123.390	40	-	19	MGB
SSA	20060704_2300	2223.29	48.557	-124.206	70	-	20	YOUB

Table 4.1. Location parameters of an earthquake on July 4th 2006 in southern Vancouver Island.

5. Possible Correlation between tremors and earthquakes

Because episodic tremors and aseismic slip associate both temporally and spatially, a common stress interaction between slow slip and in-slab seismicity could indicate that the source mechanism(s) of episodic tremors and in-slab earthquakes are also related. Earthquake seismicity may remove asperities along faults and enable or enhance the propagation of fluids being dehydrated from the subducting slab, and in this sense, may induce tremor activity. Alternatively, the removal of asperities along fault systems may result in the fault clamping shut. Because strain changes caused by earthquakes can alter pore-fluid pressures in rocks at a distance from the hypocenter (Julian, 2002), a relationship (whether direct or inverse) between tremors and earthquakes is possible.

In a previous study, Royle (2005) shows that episodic tremors appear to nucleate where local earthquakes do not, which further supports the theory that tremors are generated by fluid flow, which decreases the shear strength along faults. Non-episodic tremors do not correlate temporally with slow slip, but one event did occur during a month of elevated crustal earthquake seismicity (Royle, 2005).

In order to compare the spatial and temporal location of tremors from previous slow slip and non-slip events along the Cascadia margin with the local earthquake locations at the same periods of time reported by GSC (M>0.4), two separate database of earthquakes and tremors for the time period between July 2004 and the end of September 2005 for the region of southern Vancouver Island were established, corresponding to one full life cycle of tremor activity. Clusters of tremors in January, March and July 2005 that were not reported by the GSC were located using SSA method. The searching area is equal to the dimensions of the 3-D *S*-wave velocity model, which extends from 1-87 km in depth, 46.9°N to 50.95°N in latitude and -126°E to -121°E in longitude.

Comparing episodic and non-episodic sequences, it was clear that the number of tremors is higher during the episodic activity (Table 5.1). Despite significant tremor activity, earthquake seismicity during episodic periods is relatively quiescent and the average depth of tremors and earthquakes is more or less the same (considering the errors in depth estimation). During the slow slip episode, fluids released from the subducting slab reduce the shear strength along the subduction interface, resulting in the aseismic release of shear stress. It is possible that an insufficient amount of the accumulated stress remains to generate earthquake seismicity.

Using the location information from two episodic sequences of tremor activity in February 2002 and March 2003 (Royle 2005; Kao et al., 2006a) it is possible to establish a linear relation between the number of well-located tremors and reported earthquakes per day just with 4 data points (which is all available data at the moment) as equation (5.1);

$$Ne = 0.28 + 0.03\ Nt \qquad (5.1)$$

in which Ne and Nt are the average number of earthquakes and tremors per day.

During the non-episodic periods lower levels of tremor activity have been found however larger levels of weak earthquakes (crustal and inter slab events) experienced. It may be that shallow non-episodic tremors are dependent on earthquake seismicity by inducing local pore fluid pressure gradients, which drive fluids through fault systems. It is not possible to find a simple relation between the number of tremors and earthquake in this case.

In summary, more earthquakes during non-episodic tremor activity occur in comparison to ETS periods but at the same time there are two problems with this analysis. First of all, we considered just well-located tremors that are a subset of the entire tremor sequence and secondly, not all earthquakes in the region are recorded in the GSC catalogue.

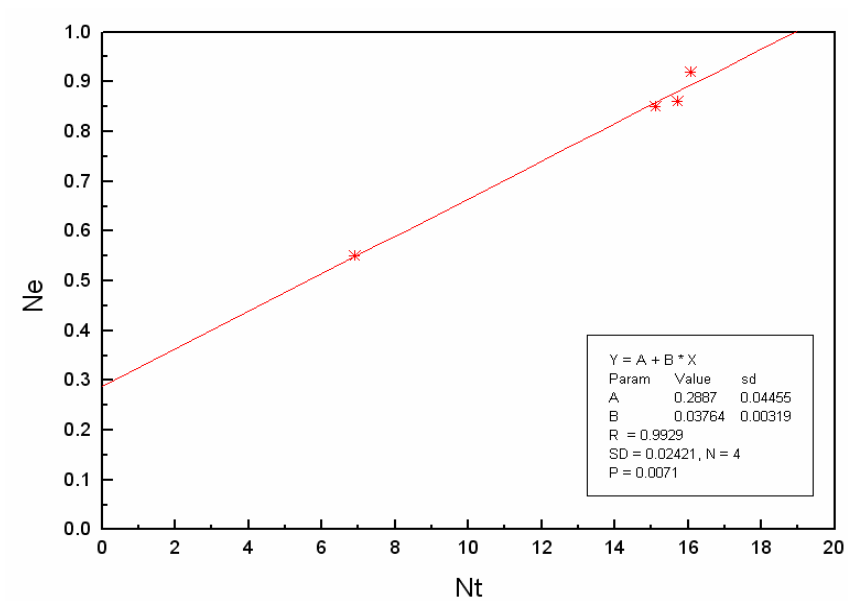

Figure 5.1. Linear regression between the average number of earthquakes per day and well-located tremors during slow slip events.

Events	Number of well-located tremors	Average number of well-located tremors per day	Number of reported earthquakes	Average number of earthquake per day	Average Depth of tremor	Average Depth of (earthq.)	Max. Depth of tremor	Max. Depth (earthq.)
Episodic tremor (2004/06/27-2004/08/05)	529	14.3	30	0.85	26	26	55	67
Non-Episodic tremor (2004/11/20-2004/11/30)	109	9.9	13	1.18	31	24	55	66
Non-Episodic tremor (2005/01/11-2005/01/16)	37	9.2	7	1.16	37	19	67	59
Non-Episodic tremor (2005/03/11-2005/03/29)	90	15	7	1.16	28	22	67	51
Non-Episodic tremor (2005/04/19-2005/04/30)	142	12.9	15	1.36	29	13	52	47
Non-Episodic tremor (2005/05/21-2005/05/30)	57	6.3	9	1.00	26	33	55	67
Non-Episodic tremor (2005/07/13-2005/07/20)	34	6.8	9	1.80	29	8	63	33
Episodic tremor (2005/09/04-2005/09/25)	346	15.7	19	0.86	26	26	45	45

Table 5.1. Number and depth information of well-located tremors and earthquakes during the periods of episodic and non-episodic activity in Southern Vancouver Island in 2004 and 2005.

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Appendix 1: Episodic tremors in June, July, and August, 2004 (see Kao et al., 2006a for further details)

Date	Hour	Second	Lat.N	Long.E	Dep.
20040627	05	2894.63	49.19	-124.47	30
20040627	05	3157.23	49.07	-124.62	19
20040627	05	3150.87	48.91	-124.76	45
20040627	06	486.79	49.12	-124.66	44
20040627	06	1473.72	49.03	-124.68	29
20040627	07	3336.39	49.14	-124.80	46
20040627	07	3441.18	49.14	-124.62	35
20040627	08	1293.62	49.15	-124.60	32
20040627	08	1801.04	49.13	-124.75	43
20040627	08	1937.86	49.13	-124.69	10
20040627	08	2594.16	49.12	-124.67	38
20040627	08	3054.98	49.18	-124.69	16
20040628	17	1373.39	48.84	-124.65	54
20040628	20	2287.45	49.17	-124.56	25
20040628	20	2614.04	49.07	-124.55	37
20040629	00	3523.21	49.11	-124.49	6
20040701	00	75.19	49.71	-125.25	32
20040701	09	1796.23	49.49	-125.65	33
20040701	19	2333.57	49.31	-125.13	37
20040701	19	3206.63	48.93	-124.99	10
20040701	19	3209.26	49.34	-125.09	53
20040701	19	3243.24	49.33	-125.50	30
20040701	19	3394.07	49.26	-125.05	50
20040701	20	753.73	49.02	-125.44	5
20040701	20	2024.59	49.30	-125.06	20
20040701	22	1166.99	49.44	-125.08	40
20040702	03	48.48	49.33	-125.28	38
20040702	03	477.80	49.24	-124.97	43
20040702	03	1070.30	49.27	-124.65	8
20040702	04	1245.10	49.33	-125.16	38
20040702	06	877.38	49.35	-125.11	44
20040702	06	1091.93	49.13	-124.96	26
20040709	05	1806.40	48.70	-123.97	39
20040709	08	1057.67	48.25	-123.75	8
20040709	08	2152.65	48.45	-123.59	39
20040709	11	2204.91	48.19	-123.51	13
20040709	19	1221.14	48.39	-123.66	8
20040709	19	2563.28	48.68	-123.94	9
20040709	21	1363.96	48.63	-123.87	40
20040709	21	1636.33	48.33	-123.69	21
20040710	01	2716.31	48.27	-123.67	22
20040710	01	3290.11	48.05	-123.54	15
20040710	02	1134.58	47.86	-123.66	24
20040710	03	160.59	48.16	-123.52	34
20040710	03	1580.78	48.38	-122.93	29
20040710	04	2716.84	48.49	-123.39	5
20040710	04	3328.78	48.20	-123.09	32
20040710	06	2307.95	48.55	-123.76	6

20040710	06	2523.98	48.20	-123.56	31
20040710	06	3058.13	48.37	-123.66	17
20040710	06	3142.83	48.32	-123.67	28
20040710	07	251.34	47.84	-123.69	26
20040710	07	2879.96	48.22	-123.69	24
20040710	07	3320.52	48.27	-123.30	33
20040710	08	195.60	48.11	-123.67	25
20040710	08	342.63	48.31	-123.72	21
20040710	09	1750.30	48.37	-123.58	19
20040710	09	2138.59	48.36	-123.78	5
20040710	09	2185.71	48.09	-123.63	30
20040711	01	396.59	48.01	-123.30	19
20040711	01	2443.46	48.27	-123.47	14
20040711	03	96.40	48.56	-123.66	29
20040711	03	1581.09	48.47	-123.65	16
20040711	04	1390.02	48.39	-123.47	22
20040711	04	2842.29	48.33	-123.50	16
20040711	04	2983.35	48.34	-123.50	21
20040711	05	1704.32	48.38	-123.54	21
20040711	05	2277.06	48.24	-123.65	14
20040711	05	2762.05	48.25	-123.55	10
20040711	05	2777.88	48.20	-123.65	7
20040711	06	1297.43	48.22	-123.65	16
20040711	06	3164.00	48.26	-123.39	35
20040711	06	3209.77	48.43	-123.47	19
20040711	07	51.57	48.20	-123.44	17
20040711	08	2473.68	48.35	-123.74	42
20040711	08	2532.20	47.91	-123.64	29
20040711	08	2687.08	48.26	-123.77	10
20040711	08	2963.23	48.29	-123.73	18
20040711	09	2104.55	48.26	-123.36	20
20040711	11	642.31	48.25	-123.24	47
20040711	12	1639.22	48.59	-123.76	7
20040711	15	2906.96	48.42	-123.46	14
20040711	15	2991.88	48.47	-123.46	34
20040711	15	3035.18	47.88	-123.28	38
20040711	16	1520.66	48.26	-123.74	14
20040711	17	268.76	48.35	-123.38	23
20040711	17	612.93	48.08	-123.31	11
20040711	18	1481.13	48.37	-123.53	14
20040711	21	1824.84	48.41	-123.45	9
20040711	21	1949.26	48.33	-123.65	13
20040711	22	2849.64	48.31	-123.43	27
20040712	03	1698.01	48.02	-123.60	35
20040712	03	1733.66	48.29	-123.44	15
20040712	03	1809.02	48.19	-123.40	14
20040712	04	3247.43	48.18	-123.50	12
20040712	05	1009.80	48.41	-123.47	21
20040712	05	1370.62	48.46	-123.66	18
20040712	06	2649.04	48.34	-123.47	36
20040712	06	3313.82	48.27	-123.42	9
20040712	08	1531.00	48.40	-123.46	24
20040712	09	1474.18	48.52	-123.41	17

20040712	11	2701.37	48.57	-123.46	28
20040713	02	3214.59	48.39	-123.32	8
20040713	03	693.38	48.33	-123.49	13
20040713	03	1050.97	48.02	-123.48	21
20040713	04	1510.35	48.11	-123.36	15
20040713	05	1719.14	48.09	-123.43	41
20040713	06	3159.30	48.63	-123.41	18
20040713	09	2419.21	48.60	-123.50	34
20040713	10	1003.64	48.40	-123.91	8
20040713	11	206.22	48.34	-123.46	21
20040713	11	3011.46	48.35	-123.72	22
20040713	13	2165.11	48.26	-123.77	17
20040713	13	2404.94	48.34	-123.69	38
20040713	14	1080.26	48.64	-123.52	11
20040713	17	2261.92	48.10	-123.85	21
20040713	18	544.65	48.29	-123.80	32
20040713	18	717.93	48.12	-123.90	22
20040714	03	3047.83	48.07	-123.43	18
20040714	08	896.22	48.48	-123.54	10
20040714	09	1963.43	48.56	-123.81	22
20040714	09	3154.48	47.98	-123.76	25
20040714	11	1577.65	48.45	-123.91	42
20040714	12	2271.37	48.39	-123.72	10
20040714	12	2576.29	47.89	-123.94	11
20040714	14	58.06	48.61	-123.77	46
20040714	14	1046.52	48.36	-123.55	34
20040714	14	1683.32	48.43	-123.83	25
20040714	16	850.85	48.46	-123.88	30
20040714	19	3289.19	48.68	-123.64	11
20040714	19	3533.58	48.25	-123.89	5
20040714	20	1775.24	48.26	-123.71	25
20040714	20	3324.91	48.46	-123.80	29
20040714	20	3471.44	48.24	-123.96	17
20040714	20	3513.06	48.46	-124.00	9
20040714	21	457.90	48.32	-123.74	43
20040714	21	779.94	48.00	-123.68	7
20040714	22	2474.79	48.27	-123.62	19
20040714	03	1376.40	48.41	-123.89	20
20040715	01	3001.49	48.42	-123.59	22
20040715	02	214.63	48.14	-123.52	15
20040715	02	679.76	48.25	-123.05	8
20040715	02	870.74	48.37	-123.49	5
20040715	02	1002.19	48.42	-123.55	12
20040715	03	3159.34	48.27	-123.44	28
20040715	01	1564.20	48.38	-123.91	5
20040715	01	2355.00	48.78	-123.76	31
20040715	01	3002.80	48.47	-123.92	18
20040715	08	1346.70	48.97	-124.16	5
20040715	08	1442.10	48.58	-124.21	34
20040715	08	1537.40	48.70	-123.81	23
20040715	08	1603.60	48.30	-123.75	9
20040715	08	2133.10	48.76	-124.25	19
20040715	09	1821.90	48.87	-124.41	35

20040715	09	2230.30	48.96	-124.31	29
20040715	10	931.00	48.95	-124.22	40
20040716	00	128.32	48.23	-123.85	40
20040716	00	2937.74	48.93	-123.87	37
20040716	01	3281.40	48.50	-123.07	52
20040716	02	1561.26	48.37	-123.85	34
20040716	02	2331.40	48.41	-123.41	42
20040716	06	1272.75	48.50	-123.64	22
20040716	06	1426.99	48.33	-123.86	20
20040716	06	1878.25	48.42	-123.53	25
20040716	09	1023.31	48.33	-124.20	21
20040716	10	668.84	48.40	-123.42	15
20040716	10	878.27	48.29	-123.74	7
20040716	11	2200.69	48.94	-123.72	18
20040716	11	2348.93	48.95	-123.67	21
20040716	11	2405.55	48.81	-123.94	41
20040716	11	3093.80	48.79	-123.73	26
20040716	12	32.25	48.59	-123.62	15
20040716	12	1019.78	48.94	-123.49	53
20040716	12	1118.79	48.95	-123.79	23
20040716	13	830.17	48.84	-123.49	37
20040716	13	974.94	48.89	-123.74	43
20040716	14	967.51	48.86	-123.64	38
20040716	14	2693.97	48.44	-123.99	24
20040716	14	3520.43	48.08	-123.99	21
20040716	16	1208.10	48.48	-123.24	47
20040716	16	2624.17	48.77	-123.86	38
20040716	17	786.64	48.38	-123.80	41
20040716	17	2120.76	48.46	-123.76	31
20040716	20	2216.95	48.46	-123.70	37
20040716	20	2744.31	48.70	-123.68	47
20040716	21	2227.87	48.76	-124.21	13
20040716	22	1570.10	48.64	-123.67	15
20040716	22	2513.71	48.91	-123.37	14
20040716	23	2520.68	48.44	-123.70	33
20040716	23	2779.87	48.98	-123.63	42
20040716	06	2093.80	49.19	-124.22	18
20040716	07	2498.70	48.85	-123.82	43
20040716	11	57.60	49.71	-126.76	38
20040716	11	977.30	50.30	-126.71	9
20040716	11	3127.40	50.13	-126.85	32
20040716	11	3236.10	50.10	-127.38	9
20040716	11	3310.50	49.80	-126.91	3
20040716	12	653.20	50.20	-126.81	41
20040716	12	2027.80	49.77	-126.93	4
20040716	15	1149.40	48.58	-123.95	34
20040717	00	3317.23	48.34	-123.54	10
20040717	01	1252.59	48.41	-123.68	29
20040717	01	2092.20	48.50	-123.95	27
20040717	01	2467.22	48.47	-123.93	36
20040717	01	2551.19	48.36	-123.84	11
20040717	02	61.20	48.36	-123.55	20
20040717	02	252.25	47.93	-123.75	30

20040717	05	464.01	48.81	-123.65	34
20040717	05	510.13	48.79	-123.55	10
20040717	06	2514.38	48.89	-123.85	44
20040717	08	2884.28	48.53	-123.72	36
20040717	09	487.91	48.51	-123.68	38
20040717	09	1762.77	48.94	-123.87	20
20040717	10	595.49	48.14	-123.31	6
20040717	11	3031.91	48.88	-123.85	16
20040717	11	3292.12	48.53	-123.80	47
20040717	12	3089.20	48.50	-123.77	15
20040717	13	124.85	48.77	-123.90	19
20040717	14	494.11	48.57	-123.66	32
20040717	14	1441.92	48.51	-123.54	51
20040717	18	1792.42	47.87	-123.91	30
20040717	18	2422.78	48.37	-123.50	46
20040717	20	2696.69	48.42	-123.99	28
20040717	20	3493.00	48.39	-123.92	40
20040717	22	2289.63	48.43	-124.22	28
20040717	22	2359.57	48.63	-123.67	20
20040717	22	2802.63	48.31	-123.75	21
20040717	22	2981.03	48.08	-123.87	24
20040717	23	361.92	48.31	-124.04	34
20040717	23	426.47	48.03	-124.10	24
20040717	01	1269.90	49.01	-124.09	15
20040717	01	2091.70	48.52	-123.80	31
20040717	01	2567.10	48.83	-123.78	37
20040717	02	3281.10	49.04	-124.11	22
20040717	03	2659.20	49.02	-124.05	19
20040717	05	907.40	48.67	-124.18	35
20040717	05	1656.70	48.85	-123.78	36
20040717	05	2421.50	49.12	-124.18	29
20040717	06	1252.60	50.14	-124.13	34
20040717	07	443.70	49.07	-123.99	17
20040717	07	1307.70	48.75	-123.94	32
20040717	07	1440.70	49.15	-124.17	20
20040717	07	2046.30	48.89	-123.79	4
20040717	08	2149.50	49.00	-124.04	25
20040717	08	2661.10	49.03	-124.07	23
20040718	00	2271.62	48.60	-123.60	23
20040718	02	2742.04	48.10	-123.48	41
20040718	02	3472.31	48.59	-124.10	50
20040718	03	2564.57	48.61	-123.89	28
20040718	03	2896.52	48.38	-123.67	19
20040718	03	3014.41	48.09	-123.56	11
20040718	04	304.82	48.31	-123.75	13
20040718	04	504.28	48.81	-124.10	48
20040718	04	853.48	48.67	-123.90	15
20040718	05	1367.81	48.69	-123.86	22
20040718	05	1413.43	48.35	-122.97	28
20040718	05	1535.90	48.62	-123.76	33
20040718	05	1708.65	49.06	-123.93	24
20040718	06	2908.73	48.62	-123.64	34
20040718	07	2154.72	48.62	-123.69	39

20040718	08	2196.50	48.69	-123.86	11
20040718	09	2115.22	48.71	-123.69	26
20040718	09	3477.95	48.85	-123.79	9
20040718	11	2829.16	48.70	-123.69	33
20040718	11	3119.19	48.85	-124.05	52
20040718	11	3402.67	48.57	-123.70	31
20040718	13	544.21	48.27	-123.61	25
20040718	13	871.34	48.52	-123.88	42
20040718	14	1011.54	48.43	-123.43	15
20040718	14	2064.55	48.58	-122.89	43
20040718	18	1295.38	48.19	-123.44	9
20040718	20	1691.81	48.21	-123.79	10
20040718	20	1789.65	48.58	-123.91	18
20040718	21	801.93	48.73	-123.64	22
20040718	23	1976.57	48.71	-123.57	45
20040718	23	2067.54	48.63	-123.67	31
20040718	23	2199.92	48.71	-123.79	17
20040718	01	1132.30	49.10	-124.14	21
20040718	01	1556.60	48.68	-123.83	36
20040718	03	2564.70	49.07	-123.77	6
20040718	03	2908.20	49.01	-124.18	14
20040718	03	3407.20	48.61	-124.21	31
20040718	05	1597.40	48.73	-124.06	8
20040718	05	1839.30	49.10	-123.77	19
20040718	05	2556.00	49.14	-124.19	23
20040718	12	1386.30	49.01	-124.19	5
20040718	12	2309.70	48.76	-124.01	21
20040719	02	744.00	48.57	-123.66	22
20040719	02	2719.85	48.88	-124.11	30
20040719	05	1822.48	48.58	-123.65	27
20040719	05	1866.36	48.42	-123.53	10
20040719	05	2003.41	48.97	-123.60	34
20040719	06	867.41	48.84	-124.38	30
20040719	06	2678.14	48.77	-124.50	18
20040719	10	2138.82	48.35	-124.04	48
20040719	12	3144.61	48.52	-124.04	40
20040719	15	699.85	48.98	-123.75	23
20040719	19	1205.53	48.67	-124.02	19
20040719	03	1776.80	50.00	-126.17	45
20040719	03	1976.10	49.93	-125.76	51
20040719	03	2152.20	50.06	-126.17	25
20040719	03	2940.90	50.00	-126.42	23
20040720	01	3370.07	48.85	-123.72	6
20040720	04	764.47	48.83	-123.83	55
20040720	04	843.41	48.91	-123.70	32
20040720	05	706.43	48.79	-123.72	47
20040720	05	1058.99	49.14	-124.49	14
20040720	08	1087.94	48.75	-123.98	30
20040720	09	3023.63	48.88	-124.41	52
20040720	10	95.97	49.26	-123.94	10
20040720	10	189.01	48.65	-123.88	15
20040720	10	304.59	48.74	-123.91	16
20040720	11	468.97	48.39	-124.15	55

20040720	11	2377.67	48.71	-123.91	20
20040720	13	354.28	49.01	-124.33	23
20040720	13	485.85	48.44	-123.65	22
20040720	15	1714.20	48.75	-124.01	25
20040720	16	115.84	48.63	-123.99	28
20040720	17	3217.79	49.26	-124.25	26
20040720	04	690.80	48.88	-123.85	41
20040720	04	771.80	49.02	-123.97	14
20040720	04	2766.50	48.90	-123.78	32
20040720	11	1393.50	49.06	-124.30	18
20040720	23	698.70	50.14	-126.39	11
20040720	04	540.10	50.05	-126.48	14
20040721	02	1392.69	48.65	-123.92	24
20040721	02	1495.29	48.44	-123.86	16
20040721	02	1738.69	48.73	-124.52	11
20040721	04	2138.47	48.54	-123.97	33
20040721	05	160.42	48.51	-123.93	29
20040721	05	1329.07	48.31	-123.85	28
20040721	06	1545.53	48.62	-124.55	42
20040721	08	2528.01	48.71	-124.06	24
20040721	08	3494.25	48.69	-124.50	46
20040721	09	103.11	48.68	-124.02	29
20040721	09	335.43	48.73	-124.13	22
20040721	10	1982.28	48.78	-123.98	11
20040721	11	192.24	48.81	-124.13	42
20040721	13	3190.89	48.52	-124.23	30
20040721	13	3506.03	48.70	-123.94	28
20040721	16	1548.48	48.66	-124.05	19
20040721	16	1646.55	48.47	-124.14	46
20040721	17	610.78	48.53	-124.12	27
20040721	18	1919.81	48.63	-123.83	6
20040721	19	2250.91	48.62	-124.21	31
20040721	20	267.29	48.68	-124.11	18
20040721	21	1084.22	48.79	-124.16	8
20040721	21	1973.54	48.62	-124.23	27
20040721	21	2396.76	48.32	-124.17	36
20040721	22	1662.15	48.53	-124.29	44
20040721	22	3426.51	48.72	-124.21	23
20040721	23	924.85	48.94	-124.20	22
20040721	13	1622.90	49.03	-124.20	22
20040721	16	926.20	48.19	-124.27	24
20040721	16	1655.60	48.87	-124.19	14
20040721	17	621.90	49.04	-124.31	9
20040721	17	1302.10	48.87	-124.31	12
20040721	22	364.00	48.09	-123.83	20
20040722	00	224.66	48.67	-124.22	32
20040722	00	1471.89	48.59	-124.25	36
20040722	00	2143.13	48.58	-124.31	36
20040722	01	677.82	48.66	-124.44	43
20040722	01	804.15	48.62	-124.29	36
20040722	01	2736.83	48.43	-124.39	51
20040722	01	2848.69	48.61	-124.19	24
20040722	02	1949.84	48.46	-124.16	29

20040722	02	3010.05	48.25	-124.29	36
20040722	02	3290.11	48.61	-124.23	16
20040722	04	2537.23	48.89	-124.45	35
20040722	05	1067.41	48.84	-123.86	53
20040722	05	1798.01	48.60	-124.40	38
20040722	06	2585.77	48.64	-124.41	10
20040722	07	377.09	48.65	-124.43	37
20040722	07	855.64	48.62	-124.45	44
20040722	07	1028.56	48.68	-124.20	19
20040722	07	1150.71	48.48	-124.42	34
20040722	08	1894.89	48.49	-124.34	39
20040722	08	2171.98	48.57	-124.40	43
20040722	10	1723.08	48.62	-124.40	50
20040722	11	1777.43	48.75	-124.29	35
20040722	11	1829.35	48.54	-124.34	33
20040722	11	2856.35	48.73	-124.80	34
20040722	11	3436.44	48.93	-124.11	34
20040722	12	3510.74	48.67	-124.45	32
20040722	13	1562.30	48.85	-124.23	8
20040722	14	2125.69	48.74	-124.28	36
20040722	14	2155.24	48.64	-124.33	42
20040722	15	2217.75	48.72	-124.24	27
20040722	15	2710.57	48.56	-124.38	41
20040722	17	2838.66	48.76	-124.35	33
20040722	17	2899.22	48.73	-124.36	36
20040722	17	3129.46	48.87	-124.35	10
20040722	18	102.12	48.89	-124.45	11
20040722	18	190.02	48.94	-124.24	5
20040722	18	1467.39	48.73	-124.43	40
20040722	19	134.01	48.74	-124.33	28
20040722	19	2787.03	48.83	-124.25	14
20040722	19	3392.79	48.71	-124.39	30
20040722	21	149.20	48.82	-124.14	15
20040722	21	2505.12	48.73	-124.36	33
20040722	22	294.29	48.95	-124.39	5
20040722	22	455.09	48.65	-124.29	29
20040722	22	563.21	48.62	-123.80	23
20040722	23	1204.76	48.81	-124.36	29
20040722	01	2728.40	48.78	-124.39	23
20040722	01	2867.50	48.94	-124.87	24
20040722	02	2781.30	48.18	-123.77	26
20040722	02	3293.30	48.73	-124.09	14
20040722	03	755.70	48.88	-124.35	27
20040722	03	2639.00	48.44	-124.19	45
20040722	07	669.60	49.29	-123.89	21
20040722	07	857.80	48.63	-124.34	29
20040722	11	96.90	48.90	-124.38	3
20040722	13	777.60	48.66	-124.41	24
20040722	13	1563.00	48.92	-124.39	6
20040722	15	2219.90	48.79	-124.27	17
20040722	15	2714.80	48.70	-124.29	25
20040722	16	130.40	49.09	-124.49	21
20040722	16	1070.60	49.03	-124.15	6

20040722	16	1805.80	48.65	-123.99	16
20040722	02	1105.00	49.99	-127.03	37
20040723	00	2544.44	48.74	-124.27	30
20040723	01	385.17	48.75	-124.24	15
20040723	02	2533.18	48.67	-124.39	48
20040723	02	2728.68	48.73	-124.32	23
20040723	02	2848.75	48.86	-124.42	37
20040723	03	2881.76	48.91	-124.62	30
20040723	05	2029.50	48.63	-124.33	41
20040723	05	2228.56	48.62	-124.00	31
20040723	05	2277.14	48.84	-124.16	13
20040723	06	1462.04	48.68	-124.47	48
20040723	06	1514.30	48.79	-124.31	5
20040723	06	1586.98	48.88	-124.24	9
20040723	09	2779.70	48.93	-124.43	42
20040723	10	2287.74	49.00	-124.44	31
20040723	10	2487.89	49.09	-124.78	8
20040723	12	3026.44	48.84	-124.43	21
20040723	14	3062.54	48.66	-124.78	47
20040723	14	3289.38	49.08	-124.58	28
20040723	15	1235.13	48.57	-124.07	19
20040723	15	1409.28	49.03	-124.25	10
20040723	17	1557.40	48.69	-124.21	21
20040723	17	3043.37	48.43	-124.45	46
20040723	18	38.04	48.91	-124.19	15
20040723	19	2490.83	48.83	-123.90	30
20040723	19	2533.08	48.87	-123.94	21
20040723	20	1846.07	48.75	-124.67	6
20040723	21	1292.66	48.89	-124.66	28
20040723	22	779.89	48.76	-124.89	7
20040723	23	447.35	48.86	-124.49	45
20040723	00	2552.90	49.02	-124.49	15
20040723	01	668.20	48.91	-124.52	21
20040723	01	1812.40	48.84	-124.01	24
20040723	02	2725.70	48.65	-124.21	20
20040723	02	2847.30	48.66	-124.36	8
20040723	03	796.80	49.05	-124.55	24
20040723	03	1722.20	49.28	-124.09	4
20040723	03	3138.90	48.87	-124.30	52
20040723	04	3435.70	49.35	-125.27	46
20040723	09	2782.10	49.02	-124.44	37
20040723	10	2845.50	49.16	-123.91	11
20040723	11	1919.80	49.15	-124.67	28
20040723	11	2259.00	49.27	-124.46	16
20040723	11	3074.20	48.74	-124.45	35
20040723	22	464.60	49.10	-124.85	7
20040723	22	773.70	48.85	-124.53	18
20040723	22	956.80	48.91	-124.67	29
20040724	00	129.23	48.94	-124.65	34
20040724	00	2468.40	48.89	-124.73	42
20040724	00	3396.02	48.91	-124.56	40
20040724	00	3461.06	48.95	-124.28	14
20040724	01	521.29	48.89	-124.64	15

20040724	01	653.71	48.91	-124.52	37
20040724	01	2774.24	48.43	-124.46	7
20040724	01	3067.29	48.90	-124.71	29
20040724	01	3173.09	48.86	-124.66	16
20040724	02	305.70	48.53	-124.73	32
20040724	04	594.40	49.05	-124.77	52
20040724	04	1751.56	48.85	-124.65	19
20040724	05	697.33	48.57	-124.79	30
20040724	05	1174.62	49.06	-124.53	13
20040724	05	2306.14	48.99	-124.59	39
20040724	06	2730.57	49.22	-124.62	47
20040724	06	2914.37	48.85	-124.80	46
20040724	06	3090.29	48.93	-124.76	29
20040724	07	425.25	48.79	-124.77	45
20040724	07	602.69	48.83	-124.76	47
20040724	07	651.99	49.03	-124.55	25
20040724	09	2345.58	49.00	-124.78	39
20040724	11	2506.57	48.75	-123.92	45
20040724	11	2971.17	48.58	-123.99	12
20040724	11	3021.91	48.98	-124.71	28
20040724	12	1299.18	49.04	-124.59	30
20040724	14	1279.05	49.03	-124.57	6
20040724	15	2980.31	48.83	-124.47	26
20040724	16	1380.85	49.02	-124.64	29
20040724	17	1656.83	48.92	-124.57	16
20040724	17	2144.70	49.02	-124.53	52
20040724	18	3201.33	48.82	-124.32	40
20040724	19	2283.10	49.11	-124.41	18
20040725	00	3480.07	49.15	-124.73	5
20040725	02	1998.65	49.08	-124.71	20
20040725	03	2152.08	48.98	-124.79	26
20040725	03	2297.05	48.99	-124.75	31
20040725	03	2809.14	49.01	-124.97	33
20040725	05	1492.91	49.04	-124.75	38
20040725	05	2117.86	49.14	-124.75	29
20040725	06	637.25	48.79	-124.74	30
20040729	04	1272.00	49.02	-124.96	30
20040729	07	2635.80	48.94	-124.69	41
20040729	08	3306.11	48.90	-124.73	31
20040729	08	3417.77	48.91	-124.83	43
20040729	11	1589.77	48.85	-124.87	31
20040729	11	1659.98	48.88	-124.77	27
20040729	11	1976.11	48.96	-124.79	19
20040729	11	2176.50	48.77	-124.84	24
20040729	12	1999.77	48.98	-124.58	26
20040729	12	2220.70	48.88	-124.68	18
20040729	12	2480.01	48.95	-124.75	36
20040729	12	2979.77	48.95	-124.80	26
20040802	10	3440.40	49.74	-126.43	24
20040802	13	2150.30	49.67	-126.17	54
20040802	14	2541.80	50.23	-125.37	15
20040802	14	3102.40	50.20	-127.47	3
20040804	15	968.30	49.56	-126.24	11

20040804	15	1502.70	49.79	-125.75	40
20040804	15	1601.20	49.63	-126.45	5
20040804	15	1709.20	49.72	-126.04	34
20040805	06	425.70	50.21	-126.14	45

Appendix 2: Non-Episodic tremors in January, 2005

Date	Hour	Second	Lat.N	Long.E	Dep.
20050111	15	2519.42	48.47	-123.63	42
20050114	08	2752.81	49.65	-125.10	35
20050114	20	1837.02	48.78	-123.57	44
20050114	20	3014.79	48.78	-123.44	42
20050114	22	380.24	48.76	-123.54	29
20050114	22	1344.62	48.88	-123.65	46
20050114	22	3357.25	48.41	-124.63	21
20050114	23	796.74	49.12	-123.82	50
20050114	23	1741.63	48.80	-123.91	62
20050115	00	3575.31	48.79	-123.70	9
20050115	01	2766.79	48.97	-124.50	50
20050115	02	2688.98	49.01	-123.26	41
20050115	03	1009.49	48.84	-123.72	52
20050115	03	1292.94	48.97	-123.68	27
20050115	03	1372.24	48.91	-123.83	43
20050115	03	1500.80	48.74	-123.65	48
20050115	04	535.78	48.85	-123.60	52
20050115	05	2227.20	48.98	-124.58	67
20050115	06	1801.29	48.92	-123.81	18
20050115	07	2770.70	49.04	-123.65	14
20050115	08	2055.01	49.71	-124.26	42
20050115	10	1080.67	49.03	-123.54	61
20050115	10	2002.67	49.63	-123.72	58
20050115	12	2345.34	49.13	-123.42	18
20050115	15	2302.53	49.33	-124.03	58
20050115	15	2770.75	48.74	-124.11	29
20050115	15	3080.59	48.62	-123.77	33
20050115	16	1974.19	48.91	-123.90	46
20050115	18	592.41	48.94	-124.76	10
20050115	18	1087.55	48.81	-123.79	14
20050115	18	2075.47	48.90	-124.47	59
20050115	19	1149.65	48.90	-123.45	60
20050115	19	1278.02	48.88	-123.66	37
20050115	19	1364.71	48.88	-123.54	39
20050115	19	2616.42	49.30	-123.56	13
20050116	01	3022.73	49.03	-124.27	6
20050116	03	3400.20	49.25	-122.98	10

Appendix 3: Non-Episodic tremors in March, 2005

Date	Hour	Second	Lat.N	Long.E	Dep.
20050311	07	521.39	48.34	-123.49	17
20050311	07	709.06	48.13	-123.21	37
20050311	09	2981.35	48.24	-122.96	44
20050311	11	318.93	48.48	-122.93	1
20050311	12	3393.65	48.95	-124.58	4
20050311	14	693.70	48.47	-123.35	20
20050311	14	869.50	48.57	-123.58	10
20050311	14	1372.69	48.36	-123.17	2
20050312	03	2978.85	48.59	-123.39	24
20050312	22	1184.64	48.61	-123.27	6
20050312	22	2823.65	48.34	-123.18	28
20050312	22	3012.48	48.50	-123.39	24
20050312	22	3154.98	48.57	-123.31	30
20050312	23	1798.73	48.61	-123.88	9
20050312	23	2737.76	49.26	-123.42	42
20050312	23	2870.37	48.40	-123.04	36
20050313	02	900.38	48.57	-123.33	11
20050313	04	131.43	48.94	-123.23	28
20050313	04	610.91	49.36	-121.99	13
20050313	04	1910.30	48.79	-123.08	52
20050313	04	2561.85	48.42	-123.36	7
20050313	06	2220.41	48.65	-123.54	6
20050313	06	2789.69	48.67	-123.42	22
20050313	06	3460.74	48.43	-123.64	3
20050313	07	70.43	48.51	-123.20	7
20050313	07	3571.34	48.63	-123.40	42
20050313	08	1816.19	48.70	-123.17	35
20050313	08	2149.94	48.44	-123.41	8
20050313	08	3263.50	48.39	-123.44	4
20050313	10	1207.52	48.51	-122.90	34
20050313	10	2325.39	48.38	-123.18	34
20050313	12	3418.91	48.43	-123.12	32
20050313	13	2140.88	48.61	-123.59	13
20050313	15	1112.81	48.55	-123.48	32
20050313	15	2971.64	48.60	-123.40	22
20050313	15	3206.31	47.97	-123.17	43
20050313	15	3468.64	48.34	-122.97	8
20050313	16	77.07	48.42	-123.40	28
20050313	16	222.05	48.48	-123.70	1
20050313	17	724.27	48.38	-123.33	10
20050314	03	417.17	48.31	-123.53	8
20050314	14	2297.62	50.37	-124.67	38
20050328	04	786.25	49.05	-124.71	16
20050328	05	2765.80	48.65	-122.85	1
20050328	05	3576.21	48.80	-124.41	63
20050328	12	1476.38	49.02	-124.69	37
20050328	12	1777.40	49.00	-124.75	26
20050328	12	3190.64	49.01	-124.60	31
20050329	01	1037.18	49.05	-124.71	24
20050329	02	340.87	49.19	-124.71	31

20050329	03	1192.48	48.93	-125.18	50
20050329	03	2056.29	49.13	-124.46	49
20050329	03	2346.66	49.02	-124.62	32
20050329	03	3114.92	49.01	-124.69	46
20050329	04	743.44	49.01	-124.72	58
20050329	04	1061.34	49.12	-124.54	56
20050329	04	1422.51	49.22	-124.56	41
20050329	04	3184.91	49.34	-124.87	6
20050329	05	202.88	48.76	-124.38	7
20050329	05	725.85	48.92	-124.32	9
20050329	05	914.40	49.09	-124.45	9
20050329	05	1304.23	49.02	-124.29	4
20050329	05	2592.82	49.19	-124.49	67
20050329	06	1785.32	49.04	-124.65	15
20050329	06	1944.89	49.19	-124.35	3
20050329	10	181.27	49.08	-124.56	59
20050329	10	500.77	49.10	-124.45	27
20050329	10	833.29	49.08	-124.45	27
20050329	10	957.63	49.11	-124.45	34
20050329	11	2338.20	49.03	-124.54	23
20050329	11	2468.28	49.09	-124.52	42
20050329	11	2550.17	49.00	-124.73	56
20050329	11	2803.14	49.13	-124.76	33
20050329	12	345.71	49.25	-124.42	36
20050329	12	1216.46	49.04	-124.45	35
20050329	12	1301.21	49.04	-124.68	42
20050329	12	1676.15	49.14	-124.59	34
20050329	12	1801.11	49.17	-124.70	39
20050329	12	2087.38	49.10	-124.45	48
20050329	12	3268.65	49.09	-124.68	60
20050329	13	1031.46	48.93	-124.46	12
20050329	13	1460.56	49.18	-124.70	43
20050329	13	1611.74	49.09	-124.75	33
20050329	13	1690.22	49.14	-124.60	53
20050329	13	2074.72	49.13	-124.72	43
20050329	13	2533.87	49.17	-124.85	47
20050329	14	1273.14	49.12	-124.76	59
20050329	14	2527.68	49.22	-124.44	27
20050329	15	800.56	49.19	-124.71	55
20050329	15	2760.25	49.49	-124.75	52

Appendix 4: Non-Episodic tremors in April, 2005 (see Kao et al., 2007 for further details)

Date	Hour	Second	Lat.N	Long.E	Dep.
20050419	08	2755.40	49.97	-126.39	28
20050419	09	1703.90	50.03	-126.45	26
20050419	09	2438.40	49.98	-126.39	21
20050419	10	1065.90	49.98	-126.36	28
20050420	08	1851.50	49.95	-126.29	21
20050420	08	2955.40	49.94	-126.32	22
20050420	09	2604.30	49.97	-126.39	27
20050420	09	3230.40	50.03	-126.36	15
20050420	09	3524.10	50.04	-126.20	49
20050420	10	164.70	49.97	-126.39	13
20050420	11	405.90	49.88	-126.08	28
20050420	13	152.20	49.98	-126.54	39
20050420	13	257.00	49.97	-126.47	32
20050420	13	706.80	50.05	-126.33	8
20050420	14	848.40	49.95	-126.08	38
20050420	14	1008.50	50.01	-126.15	33
20050421	10	2290.80	49.40	-125.01	37
20050421	10	2518.40	49.44	-124.97	50
20050421	13	186.10	49.34	-125.00	30
20050421	13	2985.30	49.34	-125.00	32
20050421	14	1193.80	49.31	-124.98	46
20050421	14	2681.90	49.34	-125.04	38
20050421	15	2853.60	49.43	-125.10	29
20050421	16	412.00	49.34	-125.02	32
20050421	18	3450.40	49.34	-125.20	6
20050421	19	414.90	49.43	-125.14	45
20050421	19	597.30	49.40	-124.83	37
20050421	20	2091.90	49.07	-124.94	13
20050421	20	2234.90	49.29	-125.10	52
20050421	20	2693.90	49.36	-124.94	35
20050422	01	514.50	49.40	-125.11	11
20050422	01	2251.90	49.42	-125.19	42
20050422	03	522.90	49.44	-126.20	32
20050422	04	2594.00	49.36	-125.09	11
20050422	05	908.40	49.22	-124.91	24
20050422	05	1512.20	49.41	-125.19	39
20050422	06	1144.60	49.41	-124.46	51
20050422	06	1276.70	49.26	-125.09	38
20050422	06	3427.70	49.27	-125.13	35
20050422	08	1939.20	49.43	-125.43	46
20050422	09	874.40	49.47	-125.31	22
20050422	09	1330.60	49.39	-125.15	26
20050422	12	2824.30	49.27	-125.05	35
20050422	12	3083.50	49.49	-124.89	11
20050422	13	1560.40	49.41	-125.18	50
20050422	13	2445.80	49.40	-125.36	48
20050422	13	2724.00	49.33	-125.12	41

20050422	14	3061.80	49.40	-125.07	31
20050423	13	1505.50	50.44	-127.11	17
20050423	13	1865.00	50.11	-126.76	32
20050423	19	1074.60	50.22	-126.81	29
20050423	20	1063.20	50.19	-126.84	35
20050423	20	1344.60	50.11	-126.87	42
20050423	20	1398.30	50.18	-126.80	24
20050423	21	1590.60	50.47	-126.76	18
20050423	21	1640.10	50.13	-126.81	16
20050423	21	3257.60	49.97	-126.49	51
20050423	22	575.10	50.26	-126.92	20
20050423	22	1305.90	50.21	-126.21	8
20050423	22	2687.10	50.22	-126.72	10
20050423	22	3438.40	50.16	-126.88	34
20050424	00	1791.20	50.05	-126.93	37
20050424	01	3006.60	49.79	-126.99	15
20050424	02	711.30	50.05	-126.79	36
20050424	02	1058.60	50.15	-126.79	35
20050424	02	1271.40	50.18	-126.81	38
20050424	04	3459.10	50.15	-126.86	27
20050424	06	1081.40	50.07	-126.90	44
20050424	06	1222.20	49.67	-126.30	9
20050424	07	2475.20	50.21	-126.90	34
20050424	07	2567.70	50.17	-126.89	38
20050424	07	2717.40	50.17	-126.91	36
20050424	10	2792.80	50.17	-126.88	32
20050424	11	688.80	50.15	-126.89	34
20050424	11	1093.20	50.19	-126.03	35
20050424	11	1360.90	50.17	-126.87	33
20050424	11	1718.40	50.13	-126.86	43
20050424	11	1827.10	50.18	-126.85	36
20050424	21	140.00	49.84	-126.52	34
20050425	02	1956.20	49.81	-126.66	17
20050425	02	3208.20	50.02	-126.57	38
20050425	03	408.80	50.00	-126.04	15
20050425	04	1935.60	50.20	-126.76	52
20050425	08	2485.00	50.05	-126.81	40
20050425	08	2556.90	50.08	-126.70	39
20050425	08	3086.80	50.09	-126.79	47
20050425	09	2437.60	49.92	-126.47	13
20050425	11	1264.80	50.17	-126.82	29
20050425	12	1122.10	50.12	-126.83	34
20050425	12	1268.80	50.17	-126.72	37
20050425	12	2135.80	50.06	-126.75	38
20050425	12	3525.40	50.15	-126.68	30
20050425	13	2458.90	50.14	-126.22	51
20050425	14	690.60	50.12	-126.74	39
20050425	14	1018.70	49.76	-126.42	3
20050425	15	1726.10	50.12	-126.88	22
20050425	16	1078.60	50.12	-126.51	43
20050425	16	1539.60	50.08	-126.77	31
20050425	17	790.80	50.07	-126.56	16
20050425	17	1391.30	50.12	-126.75	40

20050425	17	3015.00	50.11	-126.82	26
20050426	01	2404.30	50.00	-126.89	31
20050426	01	2566.00	50.12	-126.94	36
20050426	05	154.70	50.17	-126.85	22
20050426	15	1292.50	50.09	-127.01	34
20050426	16	831.30	49.96	-126.89	30
20050426	17	1394.10	50.13	-127.11	16
20050426	17	1715.00	50.09	-126.96	30
20050426	18	1463.70	49.91	-126.73	5
20050426	18	1673.00	50.10	-127.03	26
20050426	19	3223.20	49.91	-127.03	36
20050426	20	1268.30	50.12	-127.04	12
20050426	20	1380.00	50.12	-127.10	26
20050426	20	1524.70	50.11	-126.92	17
20050426	20	1676.80	50.09	-127.28	44
20050426	22	1899.10	50.22	-127.20	52
20050427	00	1152.10	50.05	-126.90	23
20050427	00	2682.20	50.18	-126.96	17
20050427	01	1952.40	50.11	-127.11	33
20050427	02	3456.70	49.97	-127.14	22
20050427	06	825.60	49.81	-127.57	38
20050427	06	1391.60	50.13	-126.95	24
20050427	10	600.00	50.04	-127.04	12
20050427	10	2301.90	50.09	-127.04	28
20050427	12	1165.70	50.13	-127.17	36
20050427	12	2272.40	50.10	-127.00	15
20050427	13	764.70	50.13	-126.95	23
20050427	13	2401.50	50.06	-126.94	30
20050427	14	240.40	49.78	-126.64	5
20050427	15	1297.90	50.16	-126.94	37
20050427	15	2288.50	50.16	-127.23	39
20050427	15	3192.60	50.04	-126.97	7
20050427	16	284.50	50.03	-126.90	33
20050427	16	391.10	50.09	-126.92	29
20050427	16	686.70	49.89	-126.76	39
20050427	16	767.00	49.94	-127.19	36
20050427	18	2650.30	49.67	-127.09	22
20050427	18	2782.20	50.47	-126.79	32
20050428	03	3310.70	49.89	-127.25	35
20050430	14	1193.50	50.14	-126.14	46
20050430	14	1312.60	50.08	-127.00	23
20050430	18	841.00	49.89	-127.06	33

Appendix 5: Non-Episodic tremors in May, 2005 (see Kao et al., 2007 for further details)

Date	Hour	Second	Lat.N	Long.E	Dep.
20050521	02	2029.00	49.48	-125.76	29
20050521	02	2029.80	49.51	-125.75	26
20050521	02	2124.10	49.27	-125.46	26
20050521	02	2124.60	49.28	-125.46	25
20050521	02	2124.80	49.29	-125.46	25
20050521	11	2806.50	49.68	-126.05	32
20050521	12	199.20	49.62	-125.99	39
20050521	12	1251.70	49.93	-125.48	54
20050522	00	2123.20	49.62	-126.05	31
20050522	04	893.70	49.76	-125.96	5
20050523	02	830.70	49.17	-125.37	32
20050523	03	762.50	49.12	-125.74	30
20050523	05	3227.60	49.38	-125.64	55
20050523	06	383.90	49.51	-124.70	35
20050523	10	2143.30	49.52	-125.54	5
20050524	01	2447.00	49.62	-125.78	26
20050524	02	2306.60	49.51	-125.49	48
20050524	02	3422.50	49.46	-125.86	29
20050524	03	292.50	49.53	-125.69	35
20050524	13	1930.00	49.49	-126.02	11
20050524	16	1380.00	49.50	-125.68	29
20050524	16	1380.90	49.49	-125.62	27
20050524	16	1783.80	49.50	-125.79	35
20050524	16	1925.10	49.45	-125.40	30
20050525	00	2915.80	49.90	-126.05	4
20050525	00	3088.50	49.89	-126.06	20
20050525	02	821.30	49.67	-125.95	25
20050525	02	1083.00	49.43	-125.72	33
20050525	04	806.40	49.72	-125.36	14
20050525	04	1055.80	49.22	-125.51	9
20050525	04	2493.70	49.46	-125.75	32
20050525	12	2693.30	49.38	-125.60	15
20050525	15	2283.30	49.46	-125.72	31
20050525	15	2433.60	49.45	-125.22	32
20050525	15	2433.90	49.44	-125.21	30
20050526	03	2373.60	49.43	-125.88	30
20050526	03	2471.20	49.31	-125.48	23
20050526	03	2938.00	49.33	-125.44	6
20050526	03	3073.70	49.51	-125.28	27
20050526	04	228.60	49.51	-125.98	27
20050528	09	2479.00	48.33	-122.53	41
20050528	09	3021.60	48.48	-123.47	7
20050528	09	3223.50	48.65	-123.42	25
20050528	10	458.40	48.38	-123.34	11
20050528	11	544.40	48.65	-123.37	32
20050528	11	3555.50	48.13	-123.81	3
20050528	12	35.60	48.66	-123.20	33

20050528	14	2383.60	47.68	-122.55	44
20050529	01	864.30	48.37	-123.53	5
20050529	02	3073.20	48.14	-123.23	28
20050529	02	3073.50	48.16	-123.23	29
20050529	02	3074.30	48.16	-123.27	25
20050529	02	3074.50	48.17	-123.27	25
20050529	06	3070.10	48.55	-123.35	32
20050529	10	1996.00	48.67	-123.41	24
20050529	12	1201.60	48.32	-123.59	15
20050530	04	2719.00	48.59	-123.34	33

Appendix 6: Non-Episodic tremors in July, 2005

Date	Hour	Second	Lat.N	Long.E	Dep.
20050713	02	82.56	48.38	-123.89	3
20050713	02	437.73	48.93	-124.65	15
20050713	06	876.61	49.08	-123.63	5
20050713	08	2397.30	48.86	-124.24	57
20050714	03	1836.87	48.86	-123.65	7
20050714	04	263.02	48.74	-123.76	49
20050714	08	1869.30	49.27	-125.70	33
20050714	08	1890.32	49.20	-124.38	37
20050714	20	2030.06	49.08	-123.68	21
20050714	22	1899.64	48.86	-123.72	38
20050714	23	380.33	49.04	-123.89	4
20050714	23	818.70	48.98	-123.58	28
20050714	23	857.61	48.98	-123.92	42
20050714	23	1059.38	49.05	-123.79	29
20050714	23	2022.97	48.91	-123.92	37
20050714	23	2145.76	48.93	-123.86	45
20050716	00	1314.69	48.74	-122.38	17
20050716	05	792.03	49.29	-124.26	22
20050716	07	1931.44	48.98	-124.43	3
20050716	07	2136.93	49.29	-123.46	63
20050716	13	2982.34	48.97	-123.30	57
20050716	14	2697.70	49.03	-123.60	35
20050716	15	3177.22	49.18	-124.46	16
20050716	20	3043.13	48.98	-123.73	28
20050716	23	1851.42	48.51	-124.01	49
20050719	03	362.77	49.12	-123.57	28
20050720	00	354.01	48.69	-123.80	51
20050720	02	1666.25	48.51	-123.65	21
20050720	02	2688.00	48.61	-123.25	39
20050720	04	954.10	48.48	-123.27	23
20050720	10	2385.24	48.23	-123.33	15
20050720	10	2513.80	48.34	-123.45	9
20050720	10	2623.90	48.59	-123.39	18
20050720	10	3173.26	48.48	-123.27	33