Depth of the source of the tectonic tremor in the eastern Olympic Peninsula, Washington

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Abstract

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1 Introduction

General question - Description of tremor and slow slip

Specific question - Depth of the low-frequency earthquake on the plate boundary. More difficult for the tremor because no phase onset

La Rocca et al. (2009)) stacked seismograms over all stations of the array for each component, and for three arrays in Cascadia. They then computed the cross-correlation between the horizontal and the vertical component, and found a distinct and persistent peak at a positive lag time, corresponding to the time between P-wave and S-wave arrivals. Using a standard layered Earth model, and horizontal slowness estimated from array analysis, they computed the depths of the tremor sources. They located the sources near or at the plate interface, with a much better depth resolution than previous methods based on seismic signal envelopes, source scanning algorithm, or small-aperture arrays. They concluded that at least some of the tremor consisted in the repetition of low-frequency events as was the case in Shikoku. A drawback of the method was that it could be applied only to tremor located beneath an array, and coming from only one place for an extended period of time. Part of the specific question - Just on the plate boundary or overlying layer and how thick the layer is?

If the source is on the plate boundary, you should have a constant time lag between P-wave and S-wave arrivals, and a peak in the cross correlation between the vertical component and the horizontal component.

Explain here why it is going to work (No problem with tremor streaks)

2 Data

The data were collected during the Array of Arrays experiment. Eight small-aperture arrays were installed in the northeastern part of the Olympic Peninsula, Washington. The aperture of the arrays was about 1 km, and station spacing was a few hundred meters. The arrays were around 5 to 10 km apart from each other (Figure 1). Most of the arrays were installed for more than a year, between June 2009 to September 2010, and were able to record the main August 2010 ETS event. Some of the arrays were also recording during the August 2011 ETS event. Ghosh et al. (2012) used a multibeam-backprojection (MBBP) technique to detect and locate tremor. They bandpass filtered the seismic data between 5 and 9 Hz. They divided the data into one-minute-long sliding independent (no overlap) time windows. They performed beam forming in the frequency domain at each array to determine the slowness vectors, and backprojected the slownesses in the 3-D space to locate the source of the tremor for each time window. We thus have two catalogs of tremors. The first one is a catalog of 28902 one-minute-long time windows during which tremor was detected between June 20th 2009 and September 30th 2010. For each time window, we have the beginning time, the end time, and the location (latitude and longitude) of the source of the tremor. The second one is a catalog of 5600 one-minute-long time windows between August 10th 2011 and September 6th 2011.

3 Method

We take a 5 km by 5 km grid cell located not too far (less than 25 km) from a given array. We then take all the one-minute-long time windows when tremor was detected and the source of the tremor was located inside this cell. For each one-minute-long time

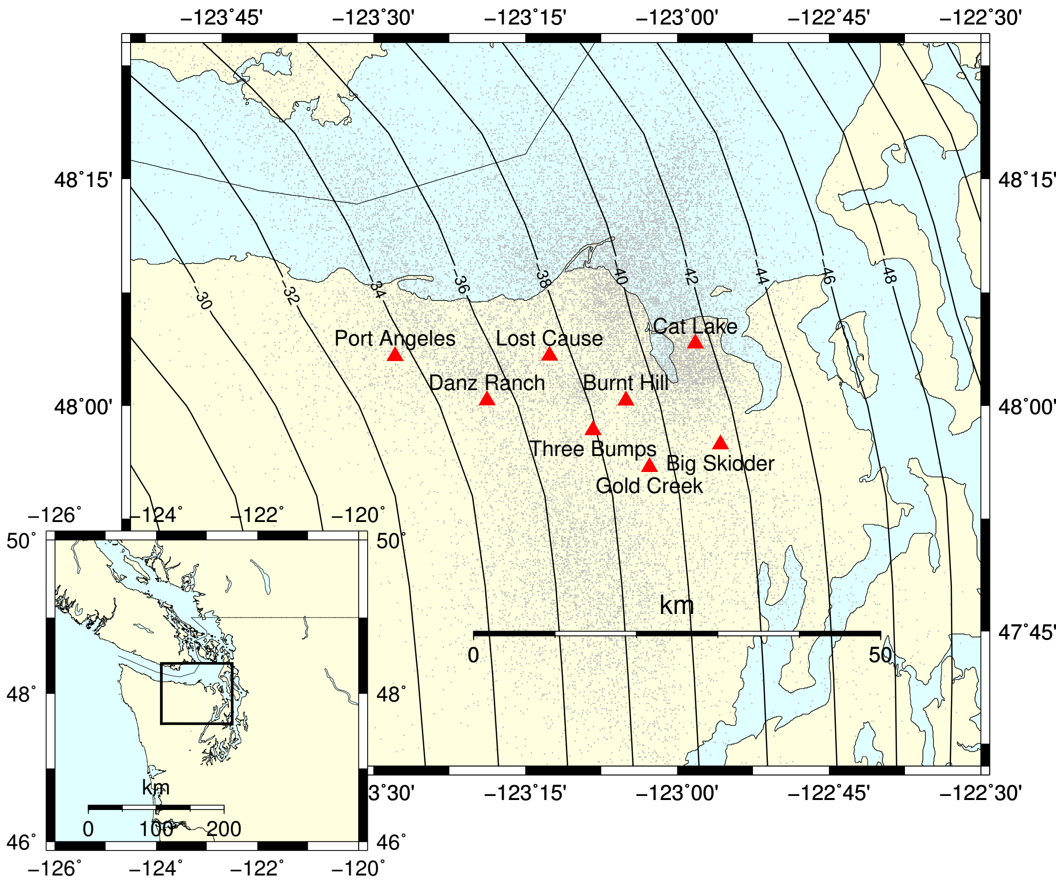

Figure 1. Map showing the location of the eight arrays (red dots) used in this study. Blue dots are the locations of the source of the tremor recorded by the arrays. Inset shows the study area with the box marking the area covered in the main map. Contour lines represent a model of the depth of the plate interface (McCrory et al., 2006).

window, we download the seismic data for each seismic station of the array. Then, for each seismic station and each channel, we detrend the data, taper the first and last 5 seconds of the data with a Hann window, remove the instrument response, bandpass filter between 2 and 8 Hz, and resample the data to 20 Hz. All these preprocessing operations are done with the Python package obspy. For each seismic station and each one-minute-long time window, we cross correlate the vertical component with the East-West horizontal component and the North-South horizontal component. Then, we stack the cross correlation functions over all the seismic stations. We experiment with a linear stack, a power stack, and a phase-weighted stack. Figure 2 shows an example of the cross correlation functions as function of time for the Big Skidder array for the 82 one-minute long time windows when tremor was detected in a 5 km by 5 km grid cell centered on the array. We can see that for about half of the tremor window, there is a peak in the cross correlation at about 4.7 s. As the energy of the P-waves is expected to be higher on the vertical component, and the energy of the S-waves to be higher on the horizontal components, we assume that this peak corresponds to the time lag between the arrival a direct P-wave and a direct S-wave. We then stack the cross correlation functions over all the one-minute-long time windows. Again, we experiment with a linear stack, a power stack, and a phase-weighted stack. We get the time of the maximum absolute value of the peak of the stack to be the time lag between direct P-wave and direct S-wave.

We notice that only about half of the cross correlation functions have a distinct peak that coincide with the peak in the stacked cross correlation functions. We want

Grid cells

Cross correlation HV Stack cross correlation over arrays

Stack cross correlation over time windows

peak about 5-6 s

Divide time windows into two clusters based on

New stack with only the good one

One image here to show the stacking

Time lag betwee direct P and direct S wave

Velocity model -¿ tremor depth

4 Results

use all data

Quality of depth

Some sort of least square regression

One image here to show the depth

5 Discussion and Conclusion

Where are the other tremor? Not wee located? Not on the plate boundary?

How analysis addresses the part of the specific question

How analysis addresses the specific question

How analysis addresses the general question

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