Array Analysis of Cascadia Deep Tremor

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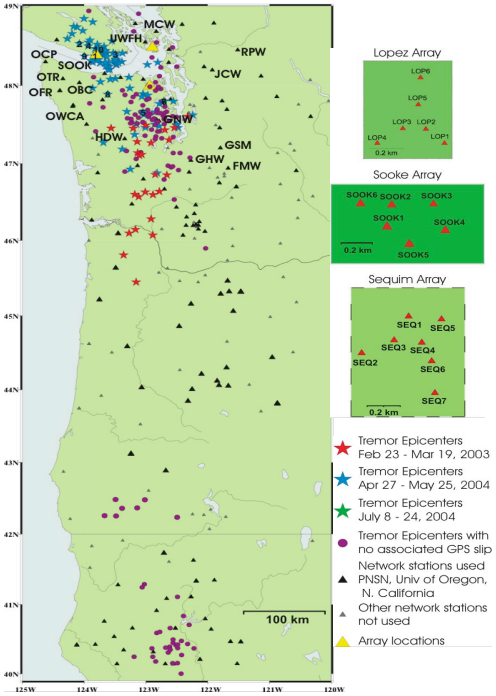
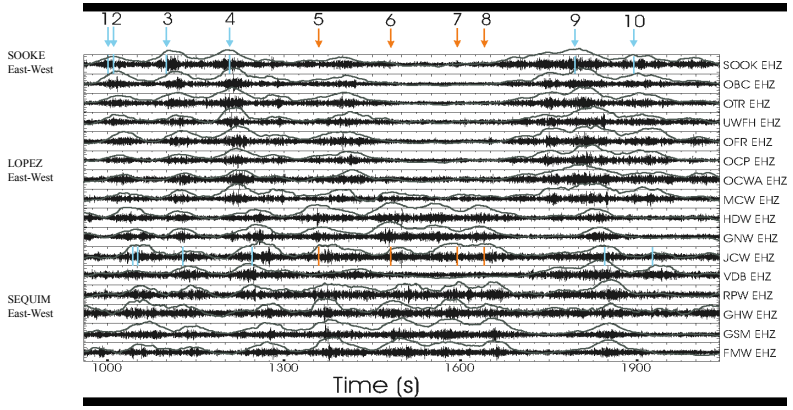
Abstract

In July, 2004 an episode of non-volcanic deep tremor was recorded on three arrays of short-period three-component seismometers. Each array consisted of 6 to 7 seismometers with an aperture of 500 meters. The arrays straddled the Straights of Juan de Fuca with separation distances of 50 to 80 km. Tremor migrated under the array from south to north. Signals within an array are highly correlated in the frequency band from about 2 to 6 Hz, providing a high fidelity view of the source. However, there is no correlation from one array to the next. We have implemented the following Kirchhoff migration procedure which takes advantage of the correlated phase within each array. First we band-pass filter the seismograms at 2-4 Hz. For each of many target points within the Earth, we calculate the travel time and slowness vector to each array using a high-resolution 3-D model. We stack the waveforms at the appropriate slowness; time shift them according to the predicted travel time; calculate their envelope functions and apply a low pass filter. A source is identified as point in which the resulting time series from the three arrays are similar. This is identified in both the time domain at fixed points, and by viewing analyzing movie of slices of the Earth's interior as a function of time. Examples of each will be shown at the poster, as well as the potential of this approach to determine accurate source depths, which have proven to be an especially difficult to constrain by other methods.



Epicentral locations were determined by picking relative arrival times of energy bursts on the bandpass filtered (2-6Hz), rectified and smoothed time signal for network data. The picks are refined using cross-correlation of the envelopes of the energy bursts. During active periods, many tremor sources may be occurring simultaneously, complicating location efforts. Errors in epicenter are on the order of a kilometer. Errors in the depth for the best locations are on the order of 10 kilometers, determined by the RMS residual. The tremor signals move across network stations with an apparent velocity of ~4 km/s, and the signals are strongest on the horizontal components.

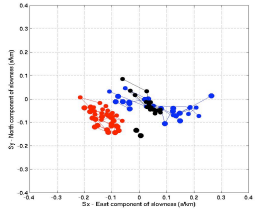


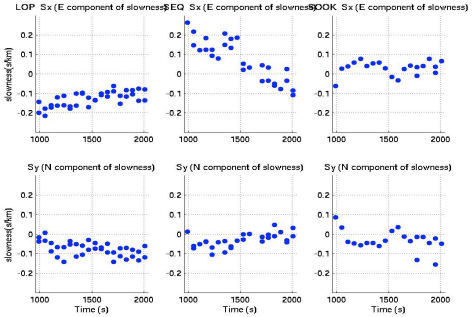
Time axes all are in seconds after July 15, 2004 08:03:55. Eleven tremor bursts are identified and located using the regional network data. Their locations are given by the numbers on the map. Events 4, 5, 6, and 10 are shown above with seismograms aligned according to predictions for an S-wave model and the source locations determined using the network data. Seismograms are filtered into two bands: 0.4-1.7 Hz and 1.4-7.0 Hz. Many of the bursts align across all three networks and, extend to frequencies as low as 0.5 Hz.

RESULTS

1. Tremor signals are coherent across the stations of the arrays.
2. The tremor occurs both with changes in the amplitude and as a low-level relatively constant signal.
3. Multiple signals can be active any given time.
4. Small aperture arrays can resolve these multiple sources.
5. Tremor source locations can remain constant over several seconds
6. There is a general migration of the tremor epicenters from the point of initiation to the northwest and to the south.
7. Tremor is observed at frequencies as low as 0.5 Hz using high-frequency sensors.

Broadband arrays are needed to better characterize the frequency content of the tremor.





Slowness estimated across a broad frequency range from 0.4-5 Hz for 60 second windows at each of the arrays, using both horizontal channels. Upper plot shows same results for LOPEZ (red), SEQUIM(blue) and SOOKE (black).