Detection and Characterization of Very Low Frequency Earthquakes in the Cascadia Slip Transition Zone

Part I: Transcontinental Wavefields from the Transportable Array

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Earthquakes and slow earthquakes both accommodate interplate deformation at the Cascadia subduction zone (CSZ). However, slow earthquakes seem to occur ten kilometers deeper than the down-dip edge of the seismogenic zone, leaving a gap zone with poorly known physical nature. Here we document three seismic sources that occurred in or near this gap zone, which generated coherent, continental-scale surface wavefields. These sources were depleted in high-frequency radiation, therefore, likely very low frequency earthquakes (VLFEs). We use an array detector to identify the VLFEs, which has proven effective in using USArray data to detect and locate unconventional seismic sources. The most prominent VLFE likely had a moment magnitude of 5.7, with slip on a subhorizontal fault plane, and is the largest known VLFE to date. We further show that the VLFEs were dynamically triggered by the 2009/08/03 Mw 6.9 Canal De Ballenas earthquake in the Gulf of California, Mexico, and the VLFEs may relate to the 2009 Cascadia episodic tremor and slip event. In a companion piece for these same proceedings, we document the geodetic signatures of the Mw 5.7 VLFE that were recorded by NOTA borehole strainmeters. Our results show that the Cascadia megathrust fault might also slip rapidly at some spots in this gap zone, and that such permissible slip behavior has direct seismic hazard implications for coastal communities and perhaps further inland.

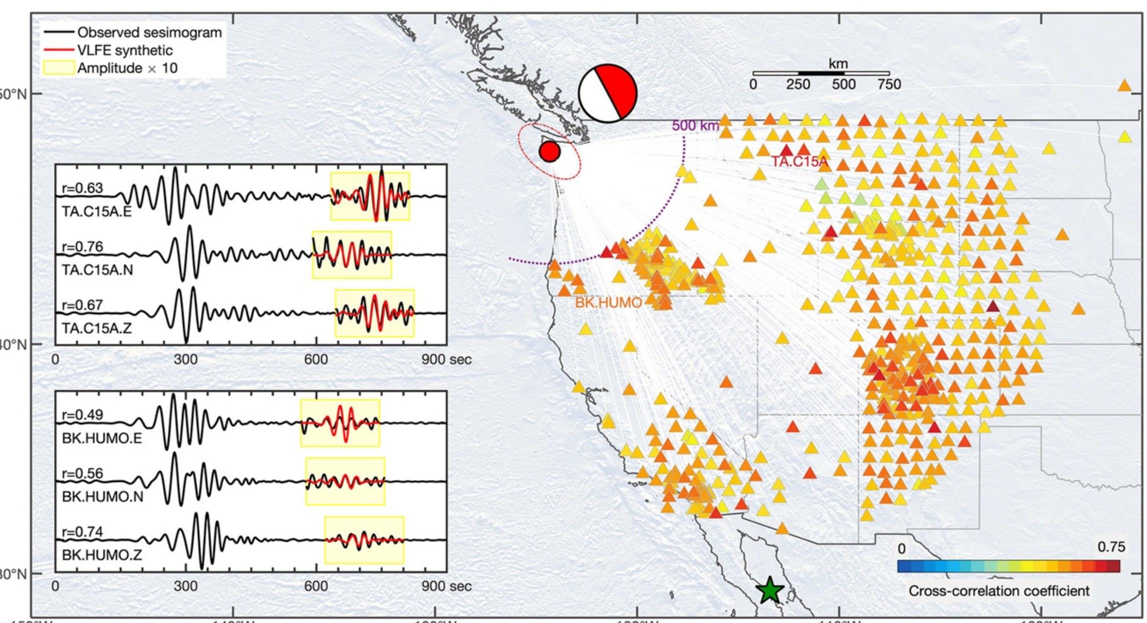

Figure 1: Seismic observations of E3 showing the average cross-correlation coefficients of the synthetic and observed waveforms of the very low frequency earthquake (VLFE) E3. [Figure 4 from Fan et al (2022b).]

Part II: Crustal Deformation from the Plate Boundary Observatory Strainmeter Network

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Very low frequency earthquakes (VLFEs) are an enigmatic class of slow earthquakes, as they seem to always occur in the company of tectonic tremor and have not been recorded geodetically before, leaving their slip processes unclear. Here we show the first set of static deformation signals that were generated by a Mw 5.7 VLFE occurring between the seismogenic and tremor zone in Cascadia. The event is the largest VLFE that has been reported, and with its shallow depth, the moment release permits examining whether the event caused measurable crustal deformation. We document geodetic analyses that confirm both the magnitude and location of the event, as determined independently by seismic analyzes. We use high-frequency borehole strainmeter data from the Plate Boundary Observatory strainmeter network (now part of the Network of the Americas) to show that robustly measured static strain signals are coincident with the timing of the event (also determined independently from seismic analyses). Further, the observed static strain field agrees with the predicted strain field using the seismic-derived focal mechanism; we tested the sensitivity of this agreement to the source location, finding that the most likely location given the observed strain pattern is within a few kilometers of the seismic derived location, in the slip transition zone. Thus, our results appear to simultaneously represent the first geodetic observation of a VLFE, and the largest VLFEs reported to date across the Earth. This raises important questions about the fault conditions in the gap zone in Cascadia and the interrelations between various slip events in the region.

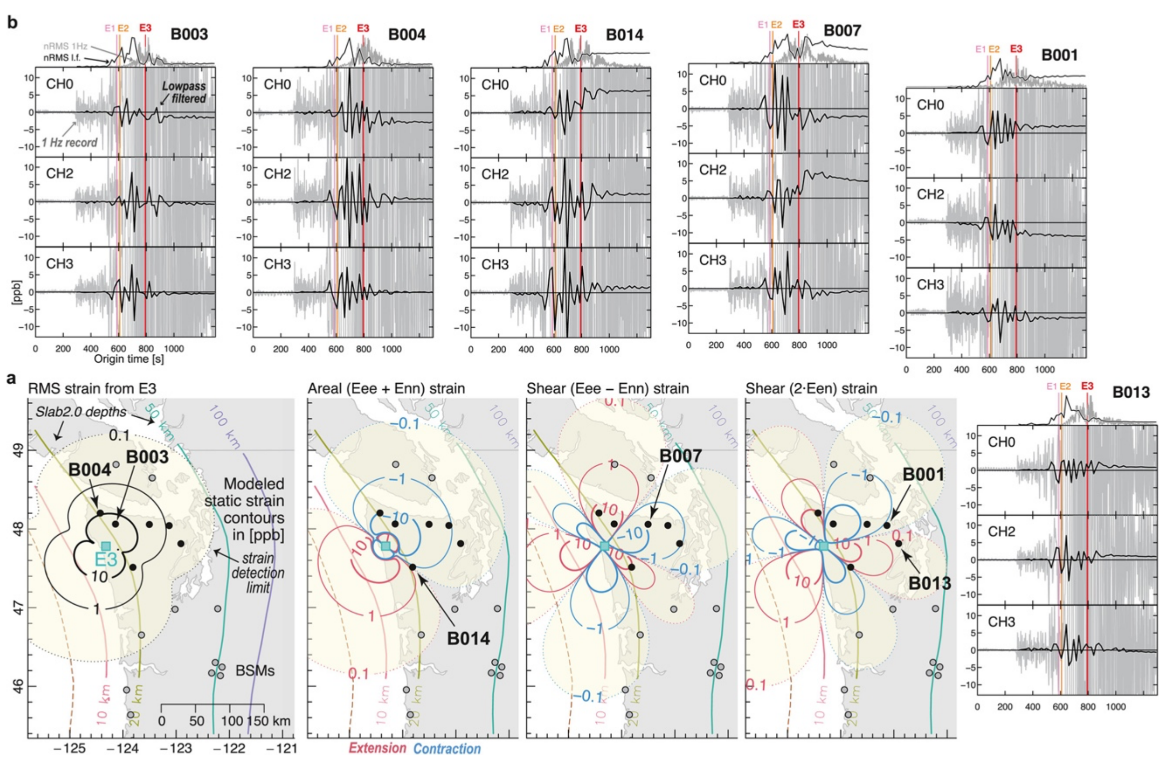

Figure 2: Static strains associated with triggered very low frequency earthquakes (VLFE) detection E3. [Figure 6 from Fan, et al., (2022b).]

References:

Bartlow, Miyazaki, Bradley, and Segall (2011). Space-time correlation of slip and tremor during the 2009 Cascadia slow slip event. Geophysical Research Letters, 38(18), doi:10.1029/2011GL048714

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