The Parkfield patch and non-volcanic tremor in the San Andreas Fault

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Summary:

A mini seismic array is installed at Cholame near the San Andreas Fault (SAF). It is located near the Parkfield patch that breaks repeatedly producing M6 earthquakes. In addition, the location is a suitable place to record tremor activity identified adjacent to the Parkfield patch. The array is installed in April 2013. SCEC funding enables me to run this array continuously till date, and I am thankful for that. This array is capturing tremor activity in great detail. It detects about 5 times more duration of tremor activity compared to existing seismic networks [Nadeau and Guilhem, 2009]. We imaged prolific tremor activity under Cholame and Parkfield. It appears that there are several patches that produce majority of the tremor. Fortuitously, we captured 2014 Mw 6.0 South Napa earthquake. Interestingly, tremor activity increased dramatically after the Napa earthquake. This high-resolution broadband array is providing a close look at the faulting activity at the San Andreas Fault near Parkfield.

Technical report:

This project involves a mini-seismic array installed in April 2013. It is designed to capture high frequency signal from the nearby San Andreas Fault, which is about 9 km from the array. The array is located near the Parkfield patch in the SAF that breaks repeatedly to produces damaging M6 earthquake. This part of the SAF is particularly interesting because it is the transition between locked part in south-east and creeping part in north-west. This area also experiences prolific tremor activity [Nadeau and Guilhem, 2009]. Hence, the array is recording rich seismic activity including regular micro-earthquakes and tectonic tremor.

The array has been running in continuous mode for more than two years now. Regular service runs are carried out to check the health of the stations and collect data. The data is processed, analyzed, archived and managed in-house, and this model is working well so far. Data return is generally pretty good. We are currently dealing with some instrumental noise issues in some stations. We are currently working hard to fix it, and reanalyze the data with good stations.

A highlight of this year's data is the recording of the M6.0 south Napa earthquake on August 24, 2014. The array recorded this event nicely as high frequency waves propagate across the array (Fig. 1). We see clear impulsive arrivals of direct P- and S-waves. Protracted coda and coherent later phases are also visible. Recording of this event is completely fortuitous, and present a unique opportunity to apply array methods to this somewhat unexpected event. Came with it an interesting and surprising finding. Analyses of array data before and after the Napa earthquake reveal that tremor rate is much higher after the event compared to before. The elevated rate of tremor activity stays on for a few days after the mainshock. An example of such tremor activity is shown in Fig 2. Whether this tremor activity is somehow triggered by the Napa earthquake is an interesting question and we are currently exploring this possibility. Given that the mainshock epicenter is about 350 km away from the tremor sources, triggering by static stress transfer is unlikely. Dynamic stress may trigger this tremor sequence, even though no obvious triggering is noticeable during the passage of the seismic waves from the mainshock. We are continuing this work, and more detail analyses are needed before reaching a conclusion.

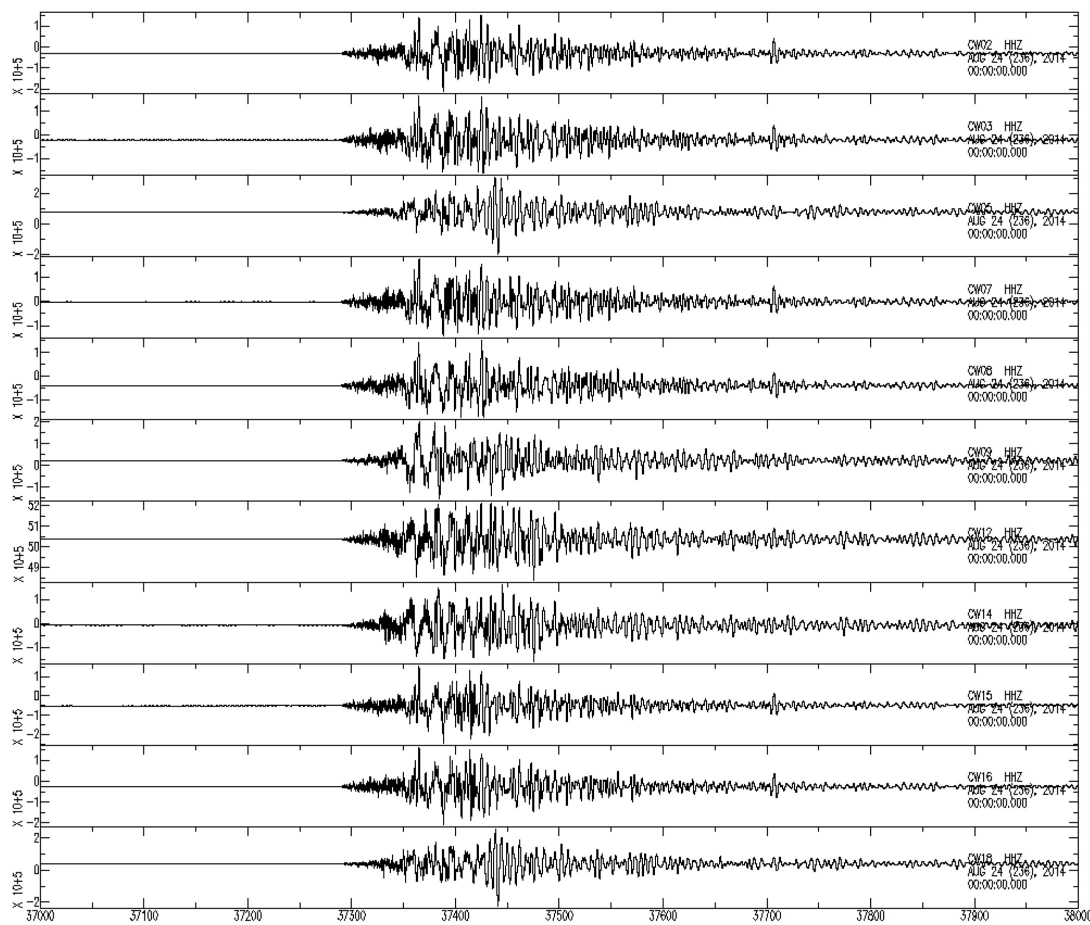

Figure 1: M6.0 south Napa earthquake on August 24, 2014, as recorded by the array. Only vertical channels are shown.

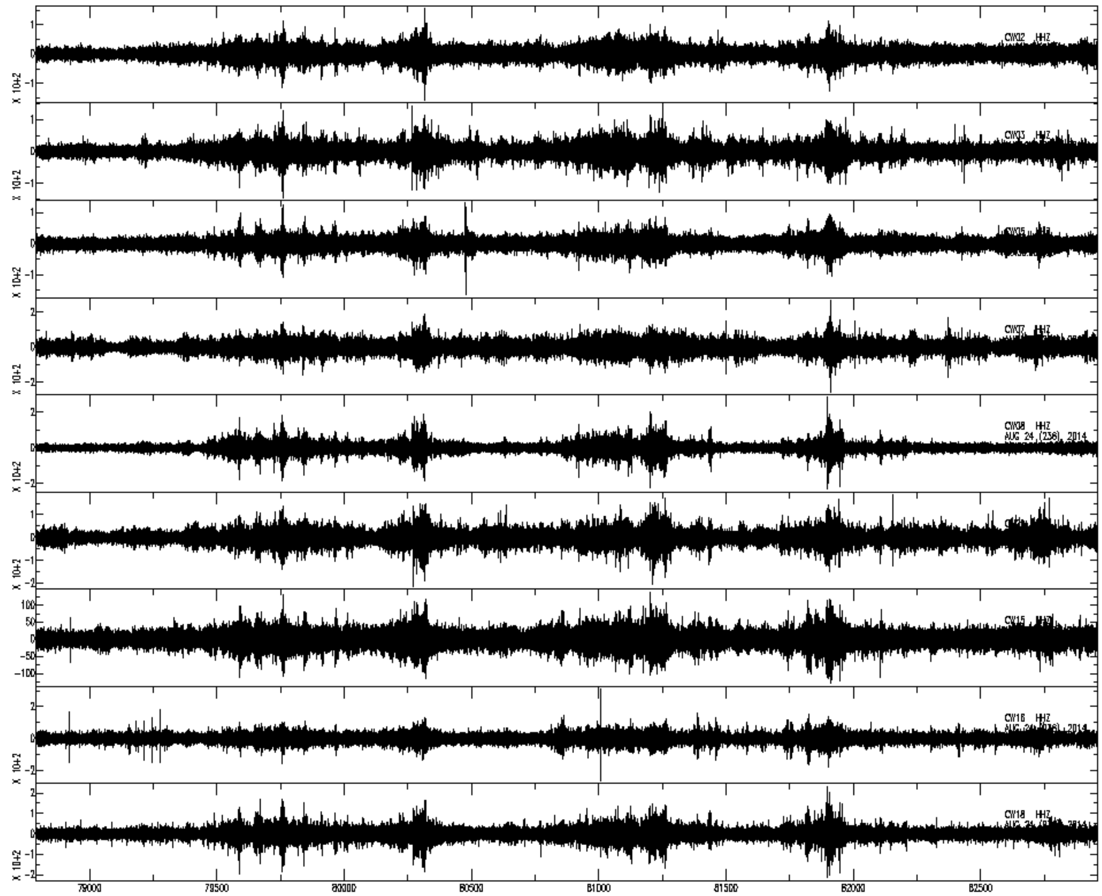

Figure 2: About an hour-long tremor sequence recorded by the array a few hours after the Napa earthquake.

Methodology:

I analyze the data using a beam-backprojection [Ghosh et al., 2009; 2012] method. It is an array method to detect and locate tectonic tremor. This method is particularly useful for tremor analyses, as it does not require impulsive phase arrivals and fairly automatic. I filter the data in 4-12 Hz, and use 30 sec sliding independent time window to perform beamforming. The beamforming analyses provide us with slowness and azimuth of the incident seismic energy to the array. The windows with focused beam are flagged as potential events. Focused beam is a result of coherent energy sweeping across the array, which can potentially be radiating from an earthquake or tremor source. To eliminate coherent cultural noise, time windows only with low slowness values are kept. In addition, windows with cataloged earthquakes are removed. Finally, random visual check is performed to confirm the tremor detection. To locate tremor, the seismic energy is backprojected to the SAF, whose geometry is well constrained.

Results:

Based on the preliminary analyses, the array recorded tremor activity almost daily. Compared to a tremor catalog using conventional network data, the array detects about 5-times more duration of tremor activity. This suggests that tremor may be a bigger player in controlling fault dynamics in this part of the fault. While existing conventional network does a decent job of detecting tremor with higher amplitude, beam-backprojection method appears to be detecting tremor that is barely above the background noise. A higher detection allows us to image tremor activity at a level of detail not possible by existing network. The tremor locations in the slowness domain indicate that comparable duration of tremor activity at both sides of the parkfield patch. Tremor activity, however, seems to be spatially patchy. Interestingly, tremor appears to be streaking majority of the time. Streaking seems to be the major, if not the only, mode of tremor migration, although more analyses are needed to confirm this (Fig. 3).

This project has generated a rich set of continuous array data with recordings of numerous local, regional and teleseismic earthquakes. In addition, preliminary analyses confirm that tremor is abundant in this area as recorded by the array without the aid of any existing network station. Analyses of this data are providing new details of the seismic activity of the SAF near the Parkfield patch.

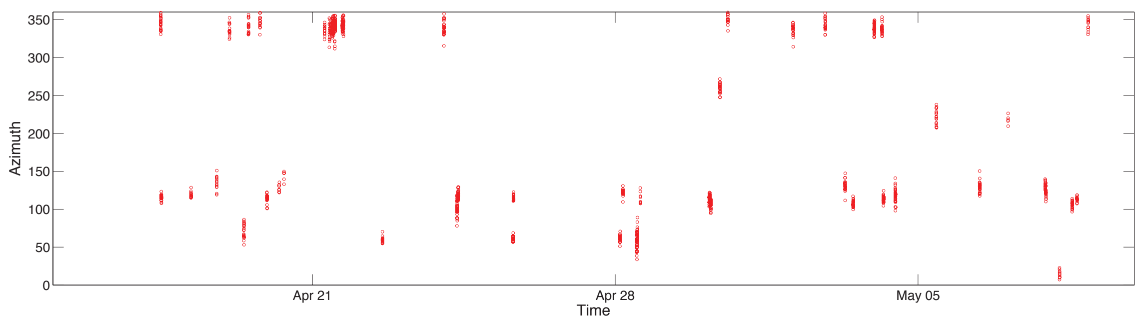

Figure 3: About 3 weeks of tremor activity as detected by the array analyses. Note the streaking nature of tremor propagation. Azimuth is with respect to the array center.

Intellectual merit:

This project studies the dynamics of the SAF near Parkfield. More specifically, it images the Parkfield patch that breaks quasi-periodically to produce M6 damaging earthquakes. The array records seismic radiation of a wide spectrum of fault motion – from regular microseismicity to tectonic tremor – which is critical to fully comprehend the different slip regimes, associated stress and their interaction. This study takes a step toward a better understanding of the complex issues of fault motion by using a well-designed mini-seismic array. It is providing us with the details of seismic activity of various flavors that may not be captured by standard seismic network.

Broader impact:

This work focuses on a fault patch in SAF that repeatedly produces damaging M6 earthquakes. Understanding how fault asperity works in this scale helps improve our estimates of seismic hazard in this area. In addition, this study explores at least two modes of fault slip, and the findings will help other branches of geosciences like, geodesy, tectonophysics, and rock physics to name a few. This project involves active participation of several undergraduate and graduate students. Through this project, they are able to get first-hand experience in cutting-edge seismology research. It helps a young scientist (the PI, Assistant Professor) build a quality research program in a minority serving institution (University of California, Riverside).

References:

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