Triggered Seismicity and Temporal Change of Seismic Velocity in Salton Sea Geothermal Field

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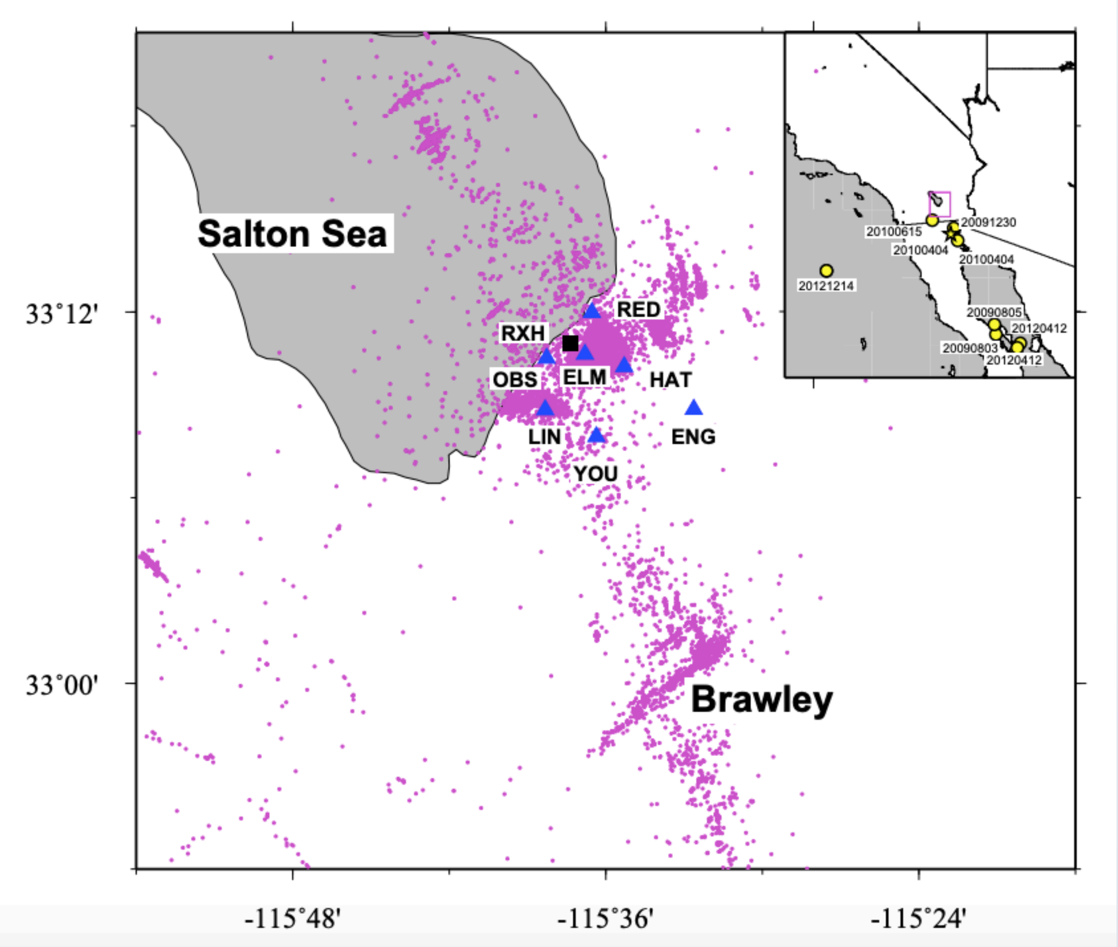
Introduction

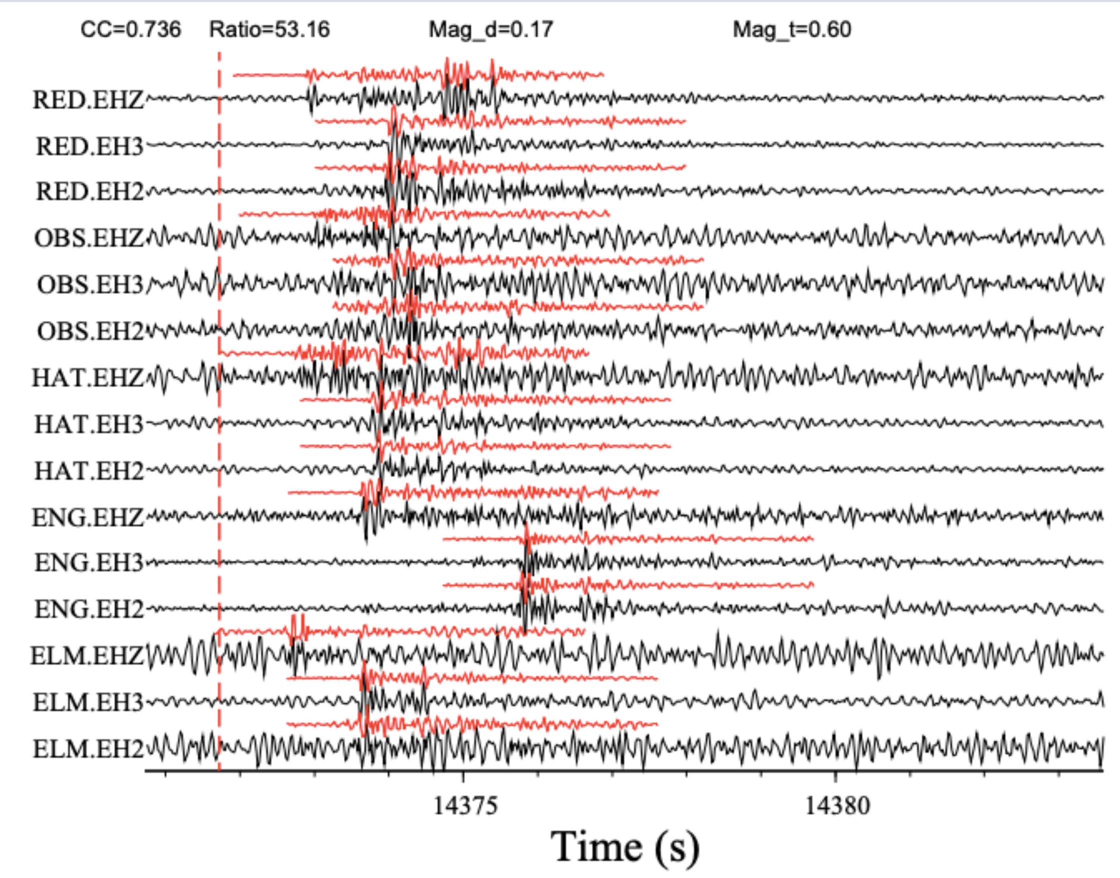
The Salton Sea Geothermal Field (SSGF) is one of the most seismically active and geothermally productive fields in California. Geothermal fields are sensitive to stress changes caused by distant and regional large earthquakes. In this study we analyze the temporal and spatial changes in seismicity in the SSGF during 2007-2014, with a newly detected catalog based on template matching with the borehole seismic network EN.

Study Region



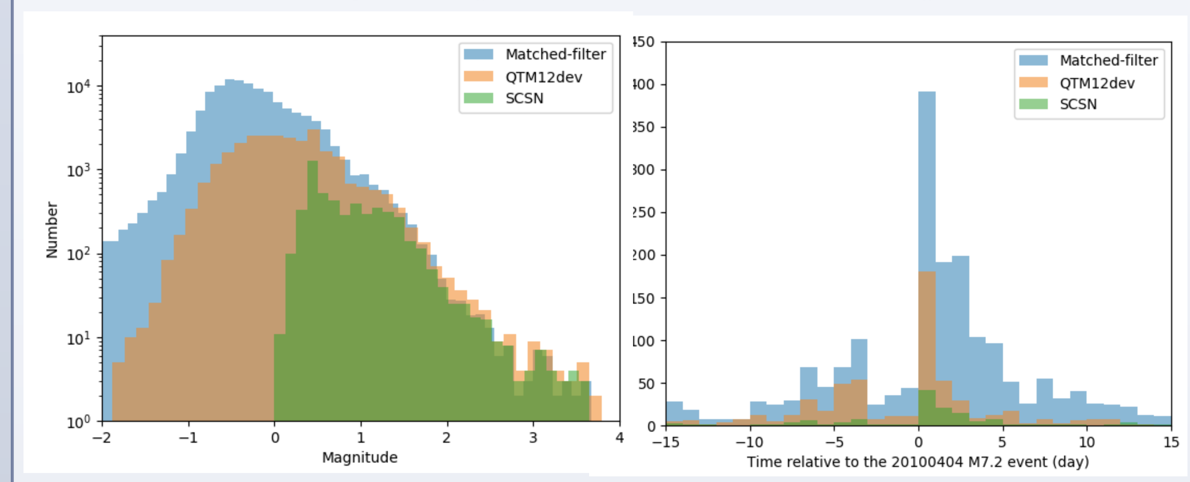
Salton Sea Geothermal Field and EN stations, the violet dots are relocated template events from 2007/12/31 to 2014/01/11 [Hauksson et al., 2013]. Blue triangles are EN stations and RXH is a broadband station in CI. Inset shows location of SSGF, the yellow dots are regional target events for study of triggering.

Matched-Filter Detection



Example of an event detected by the matched-filter technique, the red traces are template P/S window. The waveforms are bandpass filtered 5-20 Hz.

Comparing with Other Catalogs

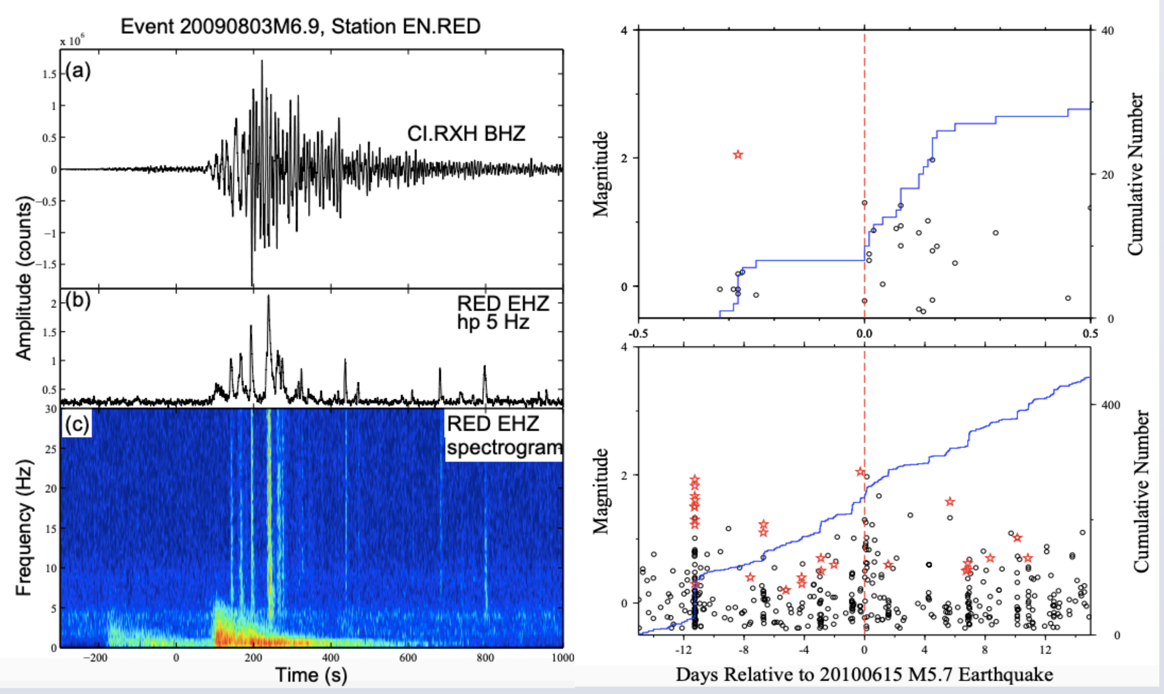


(a) Magnitude distribution for three catalogs (b) Number of events each day around 2010-04-04 M7.2 El-Mayor earthquake. Three catalogs are: matched-filter detected catalog in this study, the QTM catalog from Ross et al. (2019) and the relocated catalog from Hauksson et al. (2013).

Searching for Triggered Seismicity Change

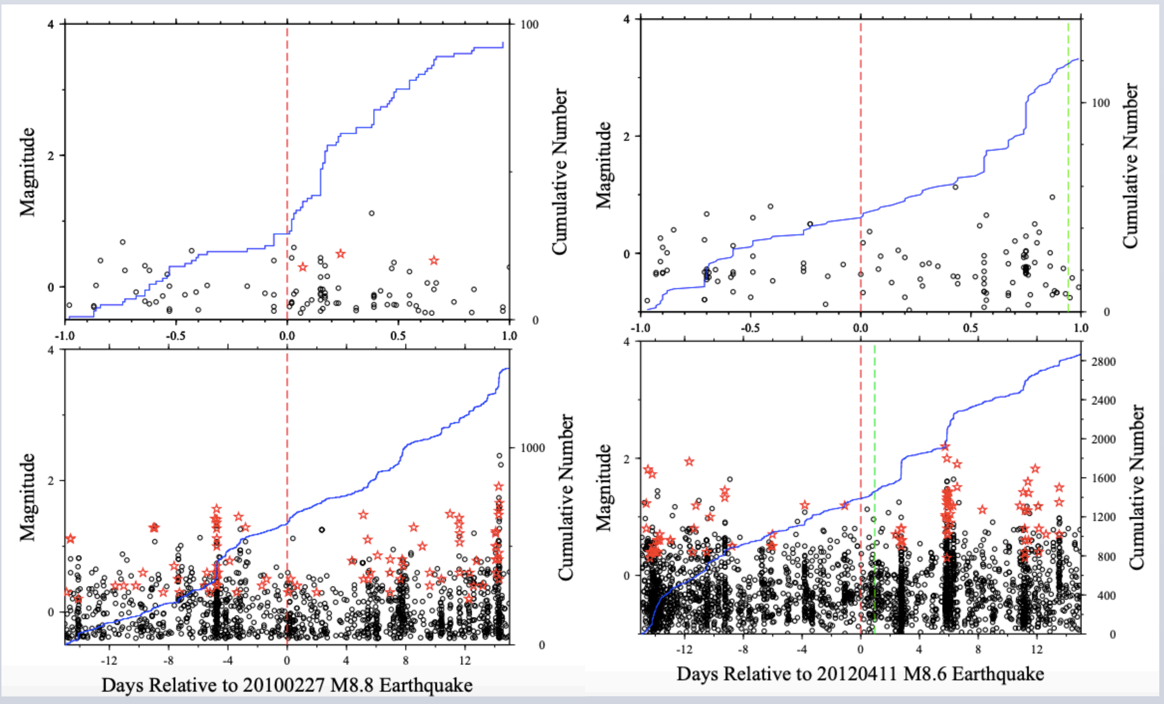
We search for seismicity change following 40 M>5.5 earthquakes with distance larger than 50 km with the matched-filter catalog, by computing β-value around different time windows: 5 hours, 1 day, 3 days, 15 days and 30 days.

Instantaneous Triggering



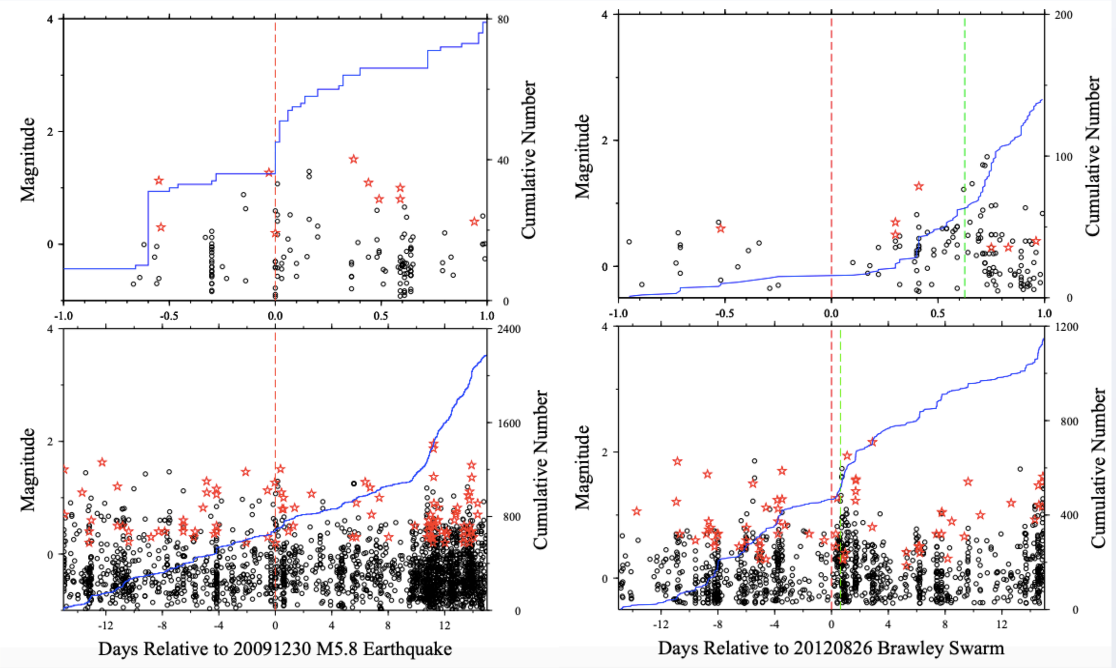
Example of instantaneous triggering, which corresponds to seismicity increase during passage of surface waves or within 5 hours from the target earthquakes. Red stars are templates, black circles are new detections.

Short-Term Triggering



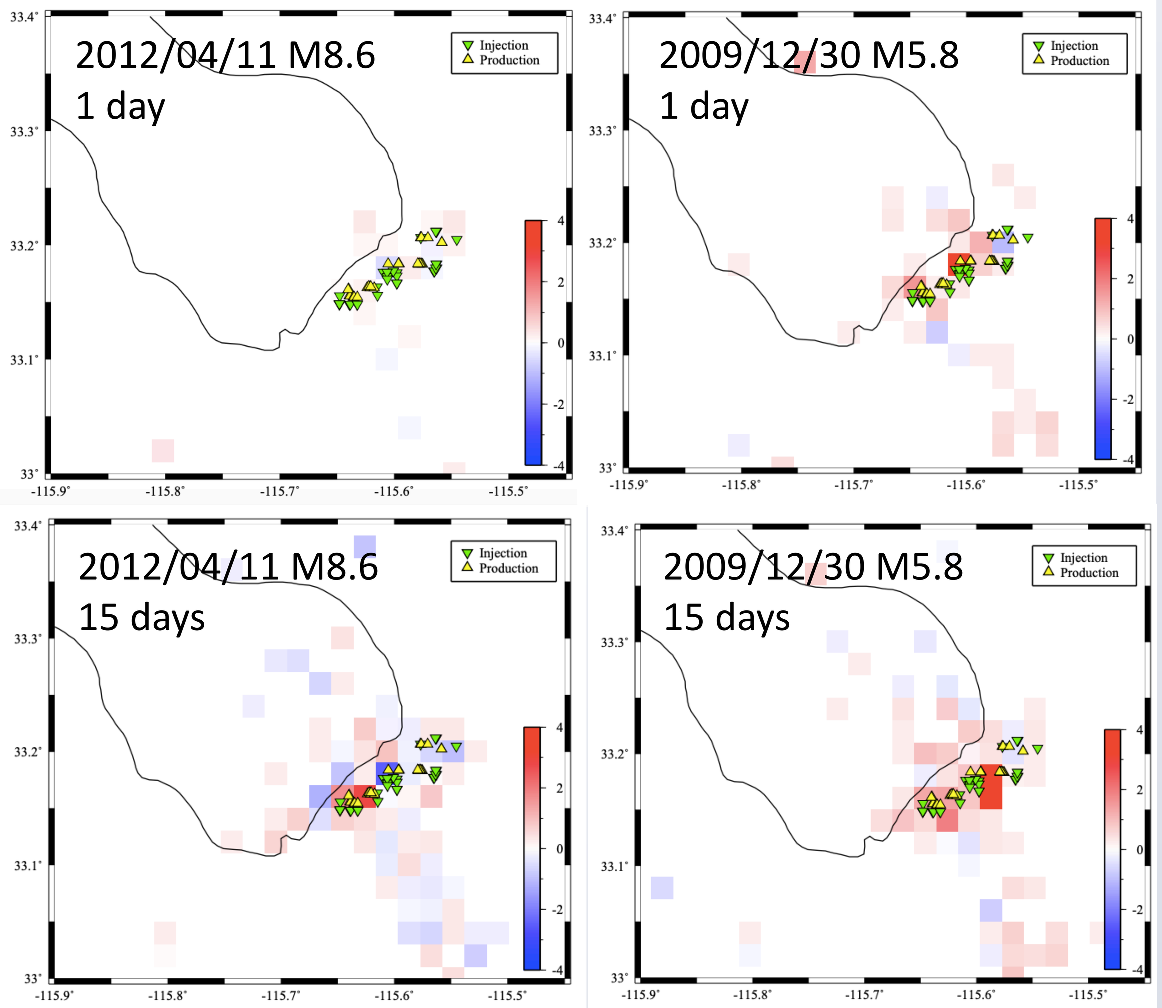
Example of short-term triggering following two M>8 earthquakes, which means β>2.0 for time window of 1-3 days. The green dashed line is another M7.4 earthquake in Baja California.

Long-Term Triggering



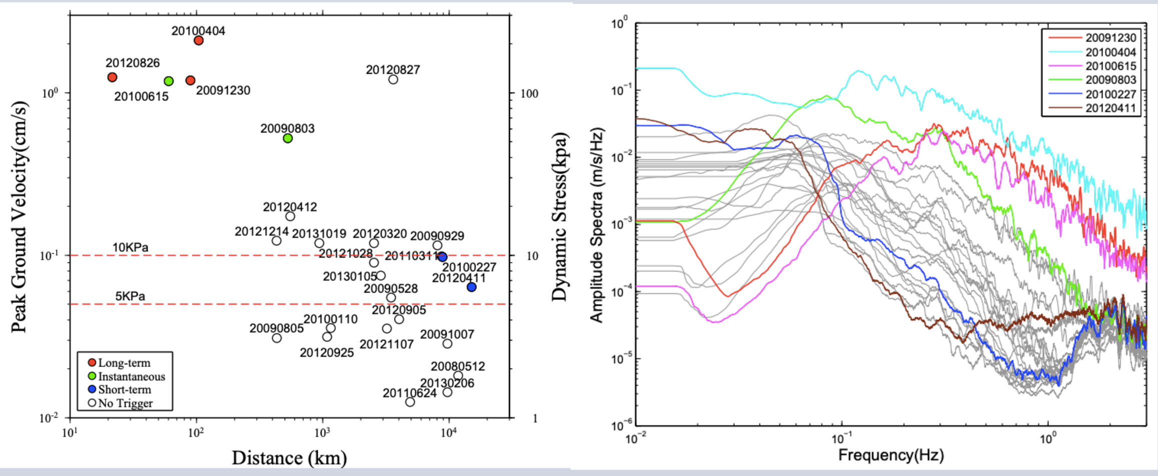
Example of target earthquakes that showed β>2.0 for all time windows.

Spatial Distribution of Triggered Seismicity



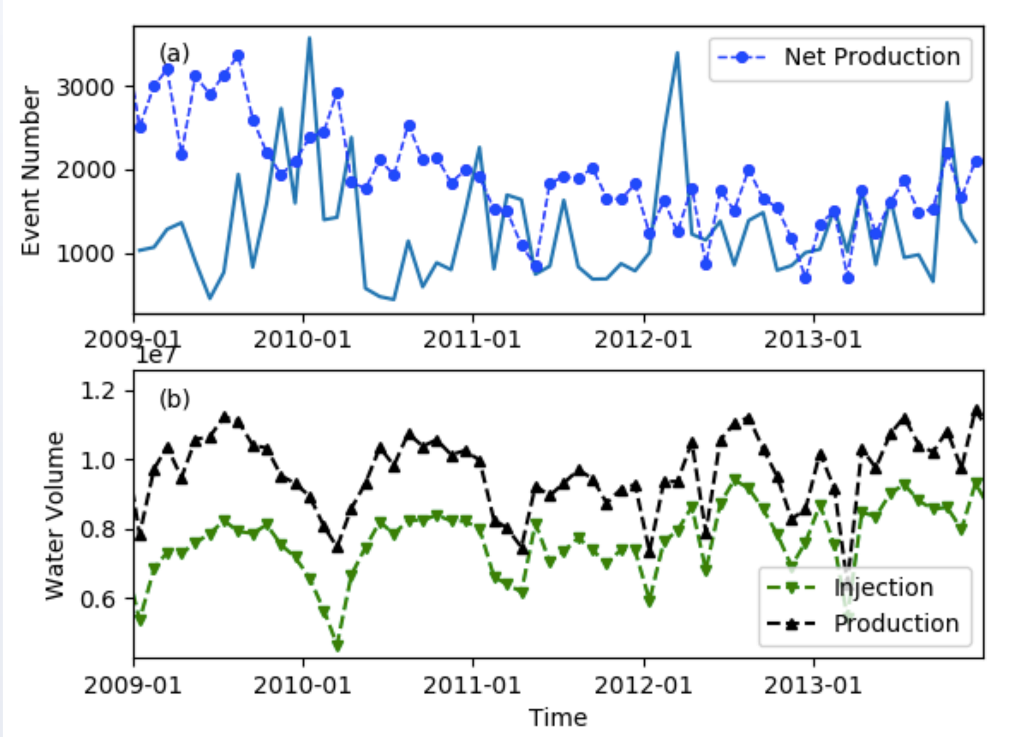
Spatial distribution of triggered seismicity in SSGF after the 2012/04/11 M8.6 and 2009/12/30 M5.8 earthquakes. It shows that the 2M5.8 triggered more seismicity than the M8.6 earthquake. But there is no clear pattern for spatial distribution of triggered seismicity.

Triggering Threshold



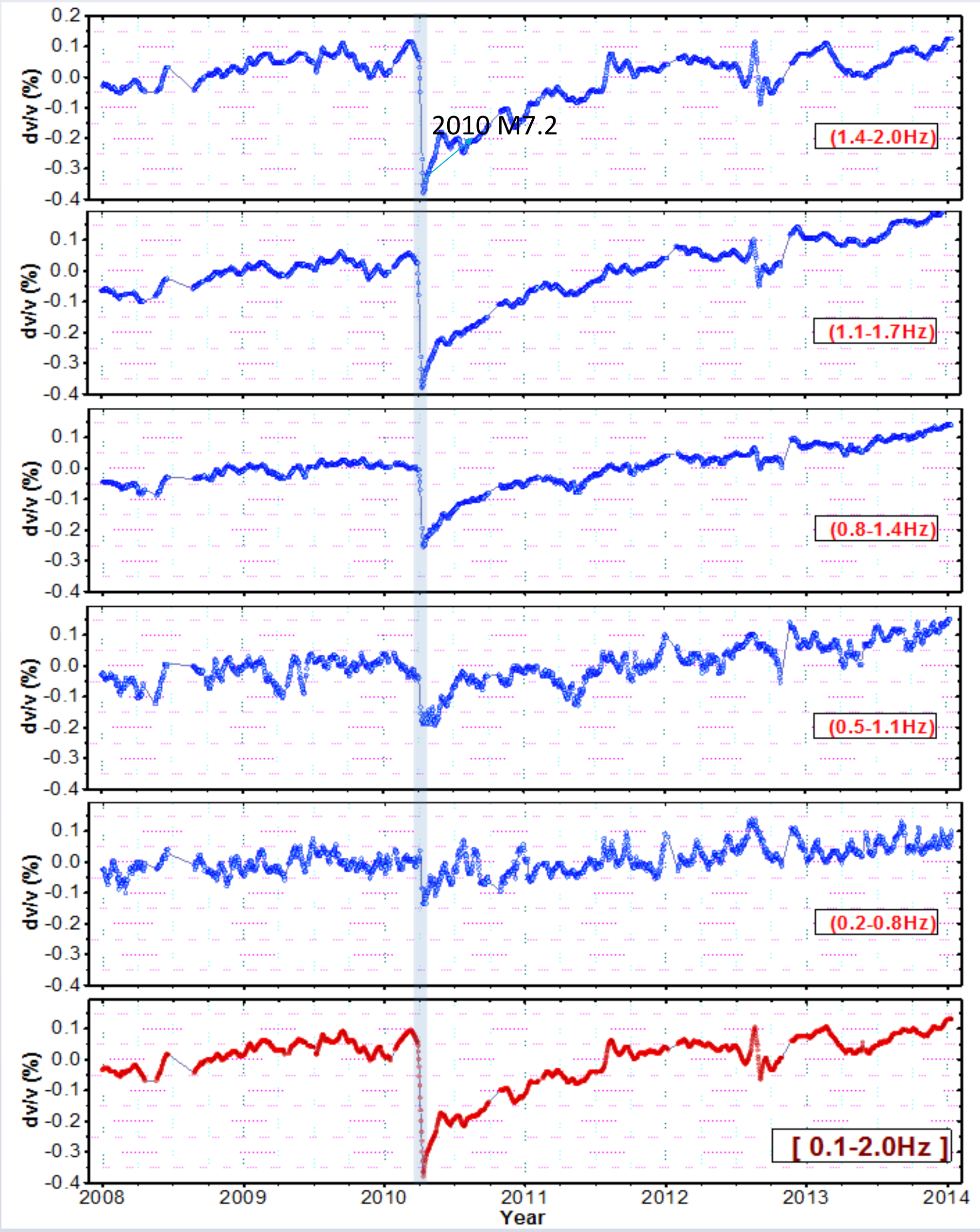
(a) Peak ground velocity in station CI.RXH and estimated dynamic stress change versus distance from SSGF. (b) Amplitude spectra for all events, the waveform between surface wave velocity of 2km/s and 5km/s are used.

Long-term Seismicity Change



Earthquake history from 2009 to 2013 compared to operational fluid volumes at the Salton Sea Geothermal Field.

Seismic Velocity Change



Long-term temporal changes of seismic velocity using waveforms of different filter band from ambient-noise analysis, after Zhang et al., in prep.

Summary

- With a 6-year matched-filter detected catalog in SSGF, we find more evidences of triggered seismicity.
- The M 5-7 events within 500 km are more likely to trigger long-term seismicity in SSGF than teleseismic M>8.0 earthquakes, likely because they produce larger dynamic stresses, especially at shorter periods
- There is no obvious correlation between between geothermal operation, seismicity rate, and seismic velocity changes

Acknowledgement

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