

Quantification of the Complexities in Rupture Processes of Small Earthquakes

by Multiple Spectral Ratio Analyses

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Summary

- The multiple spectral ratio analyses revealed the complexities in earthquake source spectra.
- The residual spectra of the spectral ratio analyses for different empirical Green's function (EGF) events had coherent peaks and troughs, which are probably due to the earthquake source process of the target events.
- The trough-to-peak amplitudes (i.e., the source complexities) are not correlated to the hypocenter locations.

Data

This study uses the 2019 Ridgecrest Earthquake Dataset created for the community stress drop validation (Baltay et al., 2021). The data are 100 sampled per second and of three components. I chose 360 target events with M_w 3.0 – 4.0 for quantifying the rupture complexities (Figure 1).

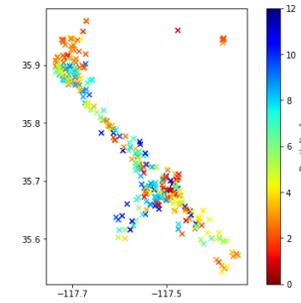


Figure 1. Epicenters of 360 target events, colored by the event depth.

Result 1: Residual Spectra

Here shows randomly picked nine examples (Figure 3). Majority of EGF events produced coherent shapes in the residual spectra. The deviation of source spectra from the omega-square model are evident for some of the cases. According to the trough-to-peak ratios, I could not clearly divide “simple” and “complex” earthquakes (Figure 4).

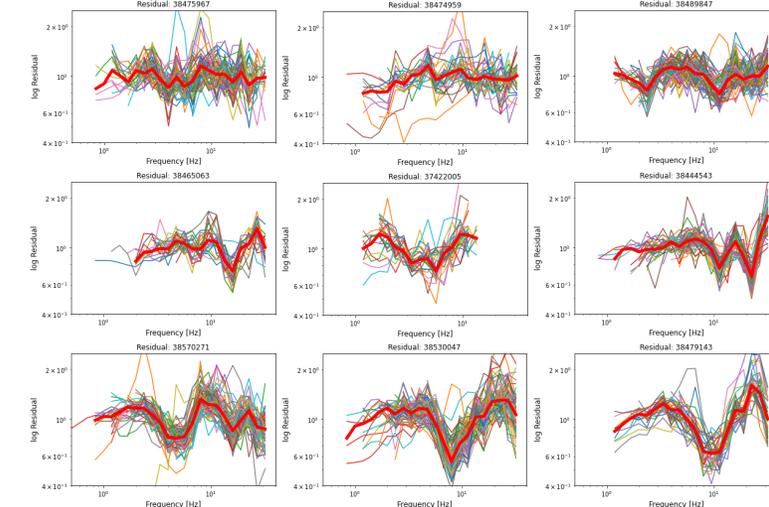


Figure 3. Examples of residual spectra. Red thick curves are the median stack of the residual spectra from different EGF events.

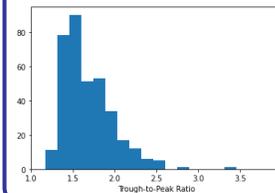


Figure 4. Histogram of the trough-to-peak ratio of the stacked residual spectra.

Method

Following the multiple spectral ratio analysis (Uchide and Imanishi, 2016; Figure 2), we quantify the complexities in earthquake rupture process as follows:

- Prepare EGF events for a particular target event
 - Within 1 km from the target event
 - 20 or more EGF events are required.**
- Median-stack spectra of seismograms over stations
 - Suppress the directivity effect
- Fit spectral ratios of target event and EGF events by the omega-square model.
 - Unknown parameters are corner frequencies of the target events and EGF events
- Stack the residual spectra
 - Suppress errors due to slight offset of the hypocenter locations of EGFs from that of the target event, etc.
 - Therefore, we consider that the remained complexities are mainly from the source complexities.

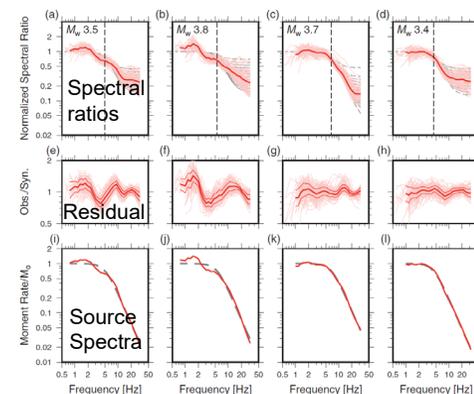


Figure 2. Four examples of the multiple spectral ratio analyses (Uchide and Imanishi, 2016). Pink traces in the top and middle panels are spectral ratios and residual, respectively, of the target event and each EGF event. The red ones are the median stack.

Result 2: Correlation with Hypocenter Locations

I investigated the correlation of the source complexities to the hypocenter locations. Here, I used the trough-to-peak ratio of the residual spectra as an indicator of the source complexity.

So far, I could not find the dependency of the source complexity on hypocenter locations (Figures 5 & 6).

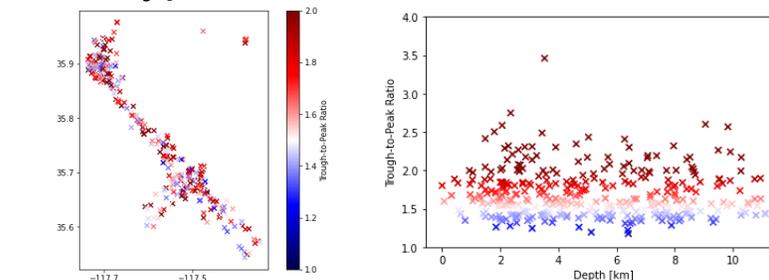


Figure 5. Hypocenter distribution of the target events colored by the trough-to-peak ratio of the residual spectra

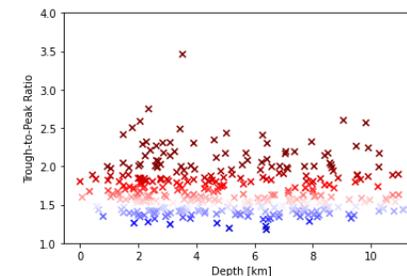


Figure 6. Trough-to-peak ratio of the residual spectra as a function of the event depth.

Acknowledgment

I used the 2019 Ridgecrest Earthquake Database compiled by Taka'aki Taira under the SCEC Community Stress Drop Validation Study led by Rachel Abercrombie and Annemarie Baltay:
<https://scedc.caltech.edu/data/stressdrop-ridgecrest.html>

References

- Baltay, A., Abercrombie, R. E., Taira, T. (2021), A Community Stress Drop Validation Study Using the 2019 Ridgecrest Earthquake Dataset, SSA Annual Meeting 2021.
- Uchide, T. & Imanishi, K., 2016. Small earthquakes deviate from the omega-square model as revealed by multiple spectral ratio analysis, Bull. Seismol. Soc. Am., 106, 1357-1363, doi:10.1785/0120150322.