

Foreshock activity detection by a threshold-free matched-filter technique

*Shiro Hirano¹, Hironori Kawakata¹, Issei Doi²

1. Department of Physical Science, College of Science and Engineering, Ritsumeikan University, 2. Disaster Prevention Research Institute, Kyoto University

Revisiting earthquake catalogs have revealed that 40% or more of major earthquakes are accompanied by foreshock activities, at least in California [Abercrombie & Mori 1996 Nature] and Japan [Tamaribuchi et al. 2018 EPS].

To investigate whether the foreshocks are magnification and activation of background seismicity, we have to compare waveforms due to the foreshocks and background events that might be sometimes uncataloged because of their small sizes.

We can mine even small seismic signals similar to some template waveforms from continuous waveform records by using a matched-filter analysis based on cross-correlation coefficients (CC) between the template waveforms and continuous records.

However, in the conventional analysis, we have to define a threshold of CC to detect similar seismic waveforms, which have been chosen subjectively and empirically.

Then, we propose a threshold-free method to detect outliers from the empirical distribution of CC among seismic waveforms.

In our framework, empirical distributions of the coefficients are modeled by the theory of extreme value statistics, and the detectability is automatically determined from Akaike's Information Criterion (AIC), depending on data.

We applied the method of seismic signal detection to 2-years-continuous records before an M5.4 earthquake in Nagano, Japan (June 30, 2011) that followed 27 foreshocks cataloged by JMA.

First, we found that the empirical frequency distribution of CC between the continuous records and foreshocks did not follow a normal distribution, which means that we cannot estimate the possibility of a false positive by assuming the normal distribution as a model.

Instead, we also found that the maximum value of CC in every few seconds follow the Gumbel distribution after elimination of some outliers.

The elimination can be achieved by comparing AICs of data including and excluding the outlier candidates.

Given this method, we found a similar event ~2 months before the mainshock and 3 similar events 3-4 days before the mainshock.

This result implies that the foreshocks were not similar to background events, and hence, not magnification or activation of them.

Keywords: matched-filter technique, foreshock activity, extreme value statistics, AIC