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Extreme value statistics of interval maximum amplitudes due to aftershocks and its application for early forecast

Kaoru Sawazaki
National Research Institute for Earth Science and Disaster Resilience, Earthquake and Tsunami Research Division, Tsukuba, Ibaraki, Japan (sawa@bosai.go.jp)

Waveforms from many aftershocks occurring immediately after a large earthquake tend to overlap in a seismogram, which makes it difficult to pick their P- and S-wave phases. Accordingly, to determine hypocenter and magnitude of the aftershocks becomes difficult and thereby causes deterioration of earthquake catalog. Using such deteriorated catalog may cause misevaluation of ongoing aftershock activity. Since aftershock activity is usually most intense in the early period after a large earthquake, requirement of early aftershock forecast and deterioration of the aftershock catalog are impatient.

Several methods for aftershock forecast, using deteriorated automatic earthquake catalog (Omi et al., 2016, 2019) or continuous seismic envelopes (Lippiello et al., 2016), have been proposed to overcome such a situation. In this study, I propose another method that evaluates excess probability of maximum amplitude (EPMA) due to aftershocks using a continuous seismogram. The proposed method is based on the extreme value statistics, which provides probability distribution of maximum amplitudes within constant time intervals. From the Gutenberg-Richter and the Omori-Utsu laws and a conventional ground motion prediction equation (GMPE), I derived this interval maximum amplitude (IMA) follows the Frechet distribution (or type Ⅱ extreme-value distribution). Using the Monte-Carlo based approach, I certified that this distribution is well applicable to IMAs and available for forecasting maximum amplitudes even if many seismograms are overlapped.

Applying the Frechet distribution to the first 3 hour-long seismograms of the 2008 Iwate-Miyagi Nairiku earthquake (M_W 6.9), Japan, I computed the EPMAs for 4 days at 4 stations. The maximum amplitudes due to experienced aftershocks proceeded following mostly within the 10 % to 90 % EPMA curves. This performance may be acceptable for a practical use.

Differently from the catalog-based method, the proposed method is almost unaffected by overlap of seismograms even in early lapse times. Since it is based on a single station processing, even seismic “network” is not required, and can be easily deployed at locations of poor seismic network coverage. So far, this method is correctly applicable for typical mainshock-aftershock (Omori-Utsu-like) sequence only. However, potentially, it could be extended to multiple sequences including secondary aftershocks and remotely triggered earthquakes.