Quantification of the cross-correlation criteria for small foreshock detection

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Recently, small foreshocks have been frequently detected using a cross-correlation technique (e.g., Bouchon et al., 2011, Science). For inland earthquakes, foreshocks whose hypocenters were estimated to be adjacent to the mainshock hypocenter were detected from several tens of minutes before the main shock occurrence (Doi and Kawakata, 2012, GRL; 2013, EPS). Toyomoto et al. (2015, SSJ) tried to detect foreshocks of an M 5.4 earthquake in central Nagano prefecture on June 30, 2011, in a similar manner to Doi and Kawakata (2013). Using the continuous waveforms of the vertical component at N.MWDH (Hi-net) station (the epicentral distance of the mainshock is 4.5 km), they newly detected 14 foreshocks with a cross-correlation criterion of 0.6, in addition to 27 foreshocks listed in the JMA (Japan Meteorological Agency) unified hypocenter catalogs. To efficiently detect small foreshocks for other inland earthquakes, it is necessary to design how to set the cross-correlation detection criterion for foreshock detection.
In this study, we carried out foreshocks detection of the same earthquake in the same method as Toyomoto et al. (2015, SSJ) using the waveform record of N.MNYH (Hi-net) station (epicentral distance of main shock is 5.3km). In this case, the maximum correlation coefficients during one minute tended to be higher than those for records at N.MWDH station, and the result of detection strongly depends on a threshold employed in a cross-correlation method. This indicates that we should not use a universal threshold independent of data. One of alternative way is to use the standard deviation of cross-correlation coefficients. Then, we made a histogram of the cross-correlation coefficients of 1-day data. The histogram of N.MWDH data is Gaussian and the cross-correlation coefficients obey a normal distribution with the average of zero. Although the histogram of N.MNYH data is not Gaussian, so the cross-correlation coefficients have a large-deviation. In such a case, a criterion depending on the standard deviation is inadequate.

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