Development and evaluation of modified envelope correlation method for deep tectonic tremor

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We develop a new location method for deep tectonic tremors, as an improvement of widely used envelope correlation method, and applied it to construct an updated tremor catalog in western Japan. Using the cross-correlation functions as objective functions and weighting components of data by the inverse of variances, the envelope cross-correlation method is redefined as a maximum likelihood method. This method is also capable of multiple source detection, because when several events occur almost simultaneously, they appear as local maxima of likelihood.

The average of weighted cross-correlation functions, defined as ACC, is a nonlinear function whose variable is a position of deep tectonic tremor. The optimization method has two steps. First, we fix the source depth to 30 km and use a grid search with 0.2 degree intervals to find the maxima of ACC, which are candidate event locations. Then, using each of the candidate locations as initial values, we apply a gradient method to determine horizontal and vertical components of a hypocenter. Sometimes, several source locations are determined in a time window of 5 minutes. We estimate the resolution, which is defined as a distance of sources to be detected separately by the location method, is about 100 km. The validity of this estimation is confirmed by a numerical test using synthetic waveforms. Applying to continuous seismograms in western Japan for 4 years, the new method detected 27% more tremors than a previous method, owing to the multiple detection and improvement of accuracy by appropriate weighting scheme.

The distribution of ACC tends to be anisotropic, even after removing the anisotropy due to the inhomogeneous distribution of stations. When we fit the ACC as a quadratic function of travel time difference, the insensitivity direction is consistent with the dip direction. It suggests the tremor source extends along the dip direction. The sensitivity of ACC is decreased with the duration, and the slope can be fitted as the inverse of the square root of duration. This suggests tremor migrates diffusively in duration. These features of tremor source should reflect the heterogeneity on the plate surface. From tremor activity, the source has been considered as brittle patches aligned along the dip direction in a ductile background. The result of this thesis is consistent the concept and suggests the tremor source has the anisotropy in the smaller scale.

Keywords: Deep tectonic tremor, Location method

