A new algorithm to find earthquake clusters using neighboring cell connection and tests in northern Honshu, Japan

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To study the earthquake interaction, it is important to find a group of earthquakes occurred closely in space and time objectively and quantitatively. Earthquake clusters are chosen with previous clustering techniques that characterize them as mainshock-aftershock sequences or swarm sequences with empirical laws such as Omori-Utsu law or direct assumptions about physical processes such as rate/state Coulomb stress transfer, transient stress loading, fluid migration, and structural heterogeneity. Recently several papers proposed non-parameterized techniques such as kernel-based smoothing methods (e.g., Helmstetter & Werner, 2012). The cumulative rate clustering method (CURATE, Jacobs et al., 2013) is one of the approaches without any direct assumptions. The CURATE method was applied in Central Volcanic Region of New Zealand and provided a good result for selecting the swarm sequence comparing with ETAS models. However, it is still difficult to choose a proper confined area and a proper time interval for combining sequences. To reduce the arbitrary and subjective choices of space and time parameters in the CURATE method, here we propose a new method modifying the CURATE approach. We first identify the spatial clusters by looking into the spatial distribution with time in a 2-D cell-gridded map. The spatial clusters defined as a cell size (S) which contains earthquakes and connecting its neighborhood cells if the neighborhood cells also contain earthquake events in a time window T. From the selected spatial clusters, we then evaluate temporal clustering which is defined as the increase of the transient seismicity rate at a target event comparing to the rate from the target event to the end of the sequence. This approach gives only two free parameters, T and S, for the declustering process. We tested this method for the JMA catalog and focus on the Chuetsu region (Niigata Prefecture), with earthquakes shallower than 20 km and magnitude range from 2 to 6.9. We choose the parameter ranges from T = 1 to 100 days and S = 0.01°to 0.1°, the results show that the number of the cluster events increases with longer T and larger S. By choosing the T = 30 days and S = 0.05°, we successfully selected the long aftershock period sequences associated with the 2004 M6.8 Chuetsu earthquake and 2007 M6.8 Chuetse-oki earthquake, while other empirical physical models and CURATE method fail to select. It suggests that this method better finds the seismic clusters including secondary aftershocks, and thus shows better declustering performance than the others.