Hierarchical Cluster Analysis of Dense GNSS Data in Taiwan

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Taiwan Island is composed of many geological structures. The main tectonic ingredient is the collision of the Luzon volcanic arc with the Eurasian continent, which propagates westward and generates complicated crustal deformation. One way to model crustal deformation is to divide Taiwan inland into many rigid blocks that more relatively each other along the boundaries (deformation zones) of the blocks. Since earthquake tend to occur in the deformation zones, identification of such tectonic boundaries is important. So far, many tectonic boundaries have been proposed in Taiwan on the basis of geology, geomorphology, seismology and geodesy. However, which is the most significant boundary depends on disciplines and there is no way to objectively classify them. Here, we introduce a hierarchical clustering method (Simpson et al. 2012) to objectively identify tectonic boundaries from observed GNSS data.

We apply a hierarchical agglomerative clustering algorithm to horizontal components of dense GNSS velocity data in Taiwan. A distinctive merit of the hierarchical representation of the clustering results is that we can consistently explore crustal structures from larger to smaller scale. Because a higher hierarchy corresponds to a larger crustal structure, and a lower hierarchy corresponds to a smaller crustal structures. We can also estimate relative motion between clusters by comparing centroids of clusters in the velocity space.

The first major boundary is identified along the eastern margin of the Longitudinal Valley, which corresponds to the geological separation of the Philippine Sea plate and the Eurasian continental margin. But the cluster boundary branched off at the middle part of the Longitudinal Valley. The second major boundary appears along the Chaochou fault and the Chishan fault in southwestern Taiwan. The third major boundary appears along the eastern margin of the coastal plane. In addition, the identified major clusters were divided into several smaller blocks. For examples, the Fengshun fault, concealed beneath thick sediment layers, was identified as a cluster boundary. As a subdivision of the Taiwan mainland cluster, one of the cluster boundaries corresponded to the fault of the 2018 Hualien earthquake. Furthermore, obtained relative motion across the boundary was strike slip sense, which was consistent with the CMT solution of the Hualien earthquake.

The hierarchical cluster analysis of the GNSS data in Taiwan well reflected tectonic settings of Taiwan, corresponded with major earthquakes distribution, and indicated applicability of the method to an earthquake hazard assessment.

