Application of Cluster Analysis to GNSS Data in the Angular Velocity Space: Identification of Crustal Blocks and Evaluation of Plate Interaction

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The motion of a rigid plate on a sphere is expressed as rotation around an axis that passes through the center of the earth. Recently, statistical approaches were proposed to identify boundaries of crustal blocks from observed GNSS data. Simpson et al. (2012) showed that through a cluster analysis of GNSS data, block boundaries can be distinguished objectively. Savage and Simpson (2013) extended the study by adding an iterative algorithm to take account of the effect of spherical geometry. These studies successfully showed a way to identify block structures in the West Coast of the U.S.
However, it is still difficult to apply the method to global GNSS data in order to identify plate blocks considering the effect of spherical geometry. So, we developed a more intuitive method to tackle this problem.
The relationship among the geographical location of the GNSS station, observed velocity at the GNSS station, and candidates of the Euler pole can be expressed as a vector equation: the cross product of an angular velocity vector and a position vector of a GNSS station is an observed velocity vector.
From this relationship, candidates of the Euler pole can be expressed as a straight line in the angular velocity space. We can expect that each line that correspond to each GNSS data in the same rigid crustal block crosses at a point in the angular velocity space.
To spot a crossing point, we made a matrix whose components correspond to the distance between lines. In order to find a structure in the matrix, we analyzed this matrix using a clustering algorithm called a Bayesian Community Detection model. The method provides a block matrix structure within it for a given threshold. By this analysis, we can spot the candidates of Euler poles as a crossing point based on the distances of lines in the angular velocity space. Each identified crossing point would represent a cluster, namely a crustal block.
However, an actual crustal block has internal deformation in it. So, we considered how such deformation affect the deviation of the lines from their original crossing point. We first analyzed the same data set of Simpson et al. (2012) in the San Francisco Bay Area, West Coast of U.S. for comparison.
The obtained result had four major crossing points, which was almost the same as Simpson et al. (2012). However, if we gave a smaller threshold, we obtained 16 minor clusters which reflect internal deformation of crustal blocks. The minor crossing points almost aligns on a straight line that connects the major crossing points.
These minor crossing points can be attributed to the effect of coupling on the faults that bound major blocks in this area. If there is some coupling on such faults, crustal movement must systematically deviate from the rigid block rotation due to internal elastic deformation caused by fault coupling. In other words, we can extract information about fault coupling from this clustering analysis.