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Computerized identification of stress tensors from heterogeneous fault-slip data by combining multiple inverse method and K-means clustering

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Stress tensor inversion of fault-slip data has applied to many areas in the world since the early 1980s to understand paleostresses in the upper crust. Several numerical techniques have been proposed in the last decade for separating stresses from heterogeneous fault-slip data.

The multiple inverse method (Yamaji, 2000) is one of them. It iteratively samples k-element subsets (usually $k = 5$) from the fault-slip data and determines stress tensors for these subsets by exhaustive grid search. The number of subsets is, ${}_N\mathrm{C}_k = N!/[k!(N-k)!]$, where N is the total number of fault-slip data. Significant stresses are indicated by clusters in stereograms that show principal stress orientations, which are specified by three Euler angles (θ, ϕ, ψ), and stress ratios (Φ) by color. The method has been applied to several areas, and has revealed temporarily variable stress fields in Japanese island arcs. In those studies, the clusters have been so far recognized by eyes. Therefore, the recognition was sometimes subjective, unless distinctive clusters appeared.

The purpose of this study is to recognize plural stresses automatically and objectively. We applied K-means clustering technique (Lloyd, 1982) to the stress tensors yielded by the multiple inverse method. In clustering, we utilized recently developed parameter space in which a stress tensor is represented by so-called σ-vector (Fry, 1999; Sato and Yamaji, 2005) instead of the four parameters θ, ϕ, ψ and Φ. Furthermore, the space has a suitable metric, the stress difference (Orife and Lisle, 2003), to compare σ-vectors. These conditions enabled us to apply the clustering to stress tensors.

The procedure is as follows.

1. Set the division number K. Initial centers of clusters are randomly given.
2. Calculate the distance between each σ-vector and centers of clusters. The vector belongs to its nearest center.
3. The centers move to centroids of possessing σ-vectors.
4. Step 2 and 3 are repeated until the memberships become unchanged.

This study showed that K-means clustering technique is valid to examine clusters of stress tensors recognized by eyes. Firstly, the technique is tested by an artificial dataset, and then is applied to field data.

References

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