Automatic detection of solutions of stress tensor inversion by fitting mixture probability distribution

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Stress tensor inversion from orientations of faults is a key technique to elucidate modern and ancient state of stress in the upper crust. In studies of structural geology, we need to detect multiple stress tensors responsible for multiple tectonic events in the geologic time. However, the detection of solutions of stress tensor inversion techniques has not been fully automated and there remains subjectivity in the result. This study aims at automating the detection of stress tensors. The input data for stress tensor inversion is called fault-slip data which carries fault plane orientations and slip directions. A reduced stress tensor, which is the unknown parameter with four degree of freedom to be determined in the inversion analysis, corresponds to a point on five-dimensional (5-D) unit sphere (Fry, 1999; Sato and Yamaji, 2006). Assuming that a fault slips along the shear stress acting on the fault plane, a fault-slip datum constrains stress tensor to the corresponding points on a great semicircle on the 5-D unit sphere. The Hough-transform-based stress tensor inversion method (Yamaji et al., 2006), hereafter HIM, superimposes the semicircles specified by observed faults to obtain the distribution of objective function to be maximized. The peaks of the distribution give optimal reduced stress tensors. The HIM requires us to set a threshold to detect the peaks or to visually recognize the peaks on stereograms. This study proposes to fit a mixture probability distribution to the distribution of objective function. The 5-D Kent distribution is employed as the component distribution in order to express the anisotropy caused by the shape of the great semicircle. The number of peaks is determined according to the Bayesian information criterion.
The new method was tested by the analysis of a synthetic fault-slip dataset, which consists of two groups of faults originated from different stress tensors. As the result, two given stress tensors are successfully detected. The new method was applied to meso-scale fault-slip data gathered from the Pleistocene Sekinan Group, Oita Prefecture, southwest Japan. Two stress tensors were detected with NNE-SSW and NNW-SSE horizontal tension axes, suggesting a temporal change of stress state.
References
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