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Simultaneous determination of tectonic stress field and individual focal mechanisms from seismic amplitude data

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The stress tensor inversion method solves for the orientation of the three principal stress axes and the relative magnitude of the principal stresses using suites of fault slip data. In seismology, focal mechanisms are generally used as the basis for searching the best fit stress model (e.g., Gephart and Forsyth, 1984; Michael, 1984). In the 90s, a sophisticated approach by inverting directly from polarity data of P-wave to a stress tensor was proposed (e.g, Horiuchi et al., 1995; Loohuis and van Eck, 1996; Abers and Gephart, 2001). In this study, we try to extend the approach by using seismic amplitude data, together with P-wave polarity.

The inversion procedure consists of two nested grid searches. The outer search is conduced over a range of the stress tensor, where the principal stress axes and stress ratio are gridded with an appropriate step size. The inner search is conducted to identify a focal mechanism for each earthquake that best fit the observations by testing stress-consistent focal mechanisms (SFM). Here SFM is the suite of focal mechanisms whose fault plane can have any orientations, but the slip direction must be aligned with the shear stress direction predicted by the stress tensor of the outer search. By summing the residual of each earthquake, we determine the misfit of the stress model (S). As a result of the two nested grid searches, we obtain the best stress tensor that minimizes the misfit S and individual focal mechanisms. In this study, we call the present method ”ASTI (Amplitude-based Stress Tensor Inversion)” and the original method using polarity alone ”POSTI (Polarity-based Stress Tensor Inversion)”, respectively.

In order to investigate the performance of ASTI and POSTI, we conducted numerical tests using synthetic data set. We generated 20 earthquakes whose fault planes were oriented in random directions. The slip direction of each fault plane was calculated so that it aligns with the shear stress direction predicted by the assumed stress tensor. Random angle values with the standard deviation of 10 degrees were added to the slip directions. For each earthquake, 20 observations (P-wave polarity and amplitude) were calculated. The result of the numerical test indicates that a correct solution of the stress tensor was determined by both methods, though some fault planes were incorrectly determined in the case of POSTI. When we decreased the observations for each earthquake down to 10, the ASTI method still succeeded in estimating the true stress tensor, while the POSTI method failed.

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