Development of an Inversion Method for Estimating Internal Stress Fields from Centroid Moment Tensor Solutions of Earthquakes

Toshiko Terakawa[1]; Chihiro Hashimoto[2]; Mitsuhiro Matsu'ura[1]

[1] Dept. of Earth & Planetary Science, Univ. of Tokyo; [2] Univ. of Tokyo

The earthquake occurrence is a stress release process in the crust. This means that the observed data of seismic events contain firsthand information about a stress state in the crust. To estimate the crustal stress state from focal mechanism data, Michael (1984, 1987) and Gephart and Forsyth (1984) have proposed a stress inversion method, determining average deviatoric stress for each partitioned area, on the assumption that fault slip direction is parallel to the tangential component of traction vector acting on the fault. In this method only focal mechanism data are inverted, and so we can estimate the pattern of deviatoric stress but not the magnitude. Furthermore, the inverted stress pattern strongly depends on the way of area partition.

At the time of a seismic event a part of the crustal stress in the source region is suddenly released. In the present study, on this idea, we developed an inversion method to estimate the crustal stress fields related with earthquake generation (seismo-genetic stress field) from centroid moment tensor solutions of earthquakes. For small earthquakes without CMT solutions, we can use the moment tensors determined from the magnitude and focal mechanism of the events. In this method, first, we represent the centroid moment tensor of a seismic event by a weighted volume integral of the true but unknown crustal stress field. We use the 3-D normal distribution with its peak at the hypocenter and the variance proportional to the fault dimensions as the weight function for the volume integral. Next, we represent the crustal stress field by the superposition of a finite number of normalized bi-cubic B-splines to discretize the problem. Then, combining prior constraints on the smoothness of stress fields with observation equations, we can construct a Bayesian model with a hyperparameter that prescribes a relative weight between observed data and prior constraints. To select the best solution we use Akaike Bayesian Information Criterion (ABIC) on the basis of the entropy maximization principle. Applying this inversion method to a set of CMT solution data, we can estimate the six components of stress tensor at any point in the study area together with estimation errors. If we use a boxcar-type basis functions instead of bi-cubic B-splines, and neglect the prior constraints, the present inversion method gives a similar solution to the stress inversion method developed by Michael (1984, 1987) and Gephart and Forsyth (1984).

The stress release pattern estimated from the long-term, wide-ranging seismic data can be regarded as the stress accumulation pattern. Thus, we can directly compare the stress field inverted from seismic data with the seismo-genetic stress field computed from a plate-to-plate interaction model (Terakawa and Matsu'ura, 2005). With this inversion method we analyze 67427 seismic data (1975-2003) in southern California (2000-Hauksson: 3-D earthquake focal mechanisms), and compare the inverted stress filed with the computed seismo-genetic stress field to reveal the stress accumulation mechanism around the big bend segment of the San Andreas Fault.