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Complex seismic source inversion method with the data covariance matrix: Application to the 2010 Haiti earthquake

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In general, it is difficult to approximate seismic source fault zone by a simple fault plane because of its complex geometry. Most of pervious study, however, applied the planar fault approximation for estimating the seismic source process of large earthquakes. Since the planar fault approximation should lead to a biased result in the seismic waveform analysis, it is important to formulate observed equation so as to mitigate modeling errors originated from complexity of fault geometry. Modeling errors of fault geometry can be divided into two parts: error of strike and dip of the fault, and error of location of the seismic source. Modeling error originated from a restriction on focal mechanism especially in strike and dip may be predominant in the analysis of teleseismic body wave, considering that travel time is insensitive to relative location of the seismic source. This modeling error can be mitigated by increasing freedom of mechanism solutions in assumed seismic source area.

We developed a waveform inversion method to estimate a spatio-temporal moment tensor distribution from teleseismic body wave (P-wave), which is able to describe a complex seismic source model that reflects complexity of geometry of real seismic source fault. We constructed mathematical formulation expanded from Yagi and Fukahata (2010), which considers data covariance components of observation and Green's function error, to stably obtain a solution through the model with high degree of freedom.

We applied the present method to the 2010 Haiti earthquake, whose seismic source process should be complex. P-axes distribution consistent with stress field of the region was obtained only with smoothness constraint in space and time. Moment tensor distribution suggests three faulting zones having different mechanism solution: near hypocenter, east and west of the hypocenter, were activated in the 2010 Haiti earthquake. Estimated Strikes for east-westward nodal planes of each faulting zone are consistent with hinge line of eastward displacement distribution obtained from InSAR data by Hayes et al. (2010). This consistency suggests that the 2010 Haiti earthquake occurred on unmapped fault whose strike is oblique to surface trace of the Enriquillo fault.

Focusing on the time variation, we found that the rupture propagation through shallow part of crust, which is weaker than deeper part and east fault zone were ruptured earlier than west one. Similarity of fault geometry between east and hypocenter are higher than that of west and hypocenter. Our result shows that the complex fault geometries controls rupture propagation manner. Aftershocks, whose mechanism solutions were different from that of the west fault, were triggered at west of the west fault. Westward rupture seems terminated at the focal mechanism transition zone.

Keywords: teleseismic body wave, the 2010 Haiti earthquake, complex fault geometry, seismic source inversion