Development of a non-linear inversion method to estimate fault geometry from teleseismic data

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A recent advance in developing a new framework of finite-fault modeling, where five basis double-couple components are adopted for representing fault slip along an assumed model-fault plane, has enabled us to construct a source model represented as spatiotemporal distribution of potency density tensor (Shimizu *et al.*, 2020, GJI). The new framework of inversion makes it possible to infer both rupture evolution and fault geometry that are included in teleseismic data. However, the location of resultant potency density tensor along the assumed model plane can be largely deviated from the true location, and hence it is difficult to directly interpret the potency density tensor distribution as a fault geometry. In this study, we propose a way of constructing fault geometry by using only teleseismic data with an iterative process of finite-fault inversion resolving potency density tensor, which is efficient for directly evaluating relationship between rupture propagation and fault geometry. We construct a non-planar model-fault geometry with the following steps: (1) initially inputting a single planar model-fault plane comprising a finite number of flat subfaults, (2) estimating potency density tensor distribution on the input model plane by performing the potency-density inversion, (3) calculating the absolute value of an inner product between the normal vector of each input subfault and that of the fault plane consistent with the estimated potency density tensor on this subfault, and (4) updating the input model-fault geometry to be consistent with the strike and dip angles of the potency density tensor distribution, and then going back to the step (2) unless the average of the absolute value of the inner products at all subfaults becomes acceptably close to 1. We adopted either strike or dip angle distribution for configuring non-planar model plane in order to reduce the number of iterations. Synthetic tests were performed to confirm that our proposed method successfully retrieved an input model-fault geometry with a few iterations for the cases varying either a strike or a dip angle of an input fault. We applied this approach to the M_W 7.7 2013 Balochistan, Pakistan and M_W 7.9 2015 Gorkha, Nepal earthquakes, which are thought to have occurred along a geometrically complex fault system. For the Balochistan and the Gorkha earthquakes, strike angles and dip angles were changed, respectively. The resultant fault models of the Balochistan earthquake showed a curved fault with clockwise rotation of strike angle from northeast to southwest, which was consistent with the location as well as the curved pattern of observed surface rupture distribution of the Balochistan earthquake. The resultant fault model of the Gorkha earthquake showed lower dip angles around the depth of the hypocenter than those in the up- and down-dip regions, which is consistent with the ramp-flat-ramp pattern of fault geometry inferred from the analyses of geodetic and geologic data. These results suggest that this approach works well for constraining geometrically smooth fault of an earthquake.

Keywords: teleseismic waveform, fault geometry, non-linear inversion, finite-fault inversion, 2013 Balochistan Pakistan earthquake, 2015 Gorkha Nepal earthquake

