Source Rupture Process and Strong Ground Motion of the 2002 Denali, Alaska, Earthquake

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A MW 7.9 inland crustal earthquake occurred at the Denali fault system, Alaska, on November 3, 2002 at 22:12 (UTC). This earthquake has generated the surface rupture of 300 km long (Fuis and Wald, 2003). Strong ground motion records from this event were obtained at several strong motion stations. GPS-measured horizontal coseismic displacements has been obtained and processed by Hreindottir et al. (2003). It is a quite important issue in seismology to analyze the source process and ground motions of a great inland crustal earthquake, which occurs infrequently, based on observed records.

A source process of the 2002 Denali earthquake is estimated by the multiple time-window linear kinematic waveform inversion (Sekiguchi et al., 2000) using velocity waveforms at strong motion stations and static horizontal displacements at GPS stations. A laterally homogeneous underground structure model is assumed based on the result of the refraction and wide-angle reflection survey by Beaudoin et al. (1992). Green's functions are calculated using the discrete wave number method (Bouchon, 1981) and reflection transmission matrix method (Kennett and Kerry, 1979). A fault plane consisting of four segments is assumed from the surface rupture (Eberhart-phillips et al., 2003) and the aftershock distribution (Ratchkovski et al., 2003). We also use a slip-direction constraint and a spatio-temporal smoothing constraint (Sekiguchi et al., 2000).

The existence of supershear rupture propagation has been reported for the 1979 Imperial Valley, the 1992 Landers, the 1999 Kocaeli, Turkey, and the 2001 Kunlunshan, China, earthquakes. The 2002 Denali earthquake has the tectonic environment similar to these earthquakes. The inverted source model suggests that the first time-window propagation velocity should be changed from about 2.8 km/s to about 3.4 km/s during the rupture, which means that average rupture propagation velocity did not exceed the shear-wave velocity in source region. However, we observed some portions of the whole fault with more than 4.0 km/s rupture propagation velocity that exceeds the shear-wave velocity of the source region. This source model could explain both the observed strong motion waveforms and GPS-measured displacements. Especially, the waveforms at PS10, which is the nearest station from the fault and located at forward direction, are well simulated.

Large slips on the fault plane are observed at about 80 - 90 km east and about 150 - 200 km east from the hypocenter. These features are consistent with observed surface rupture information (Eberhart-phillips et al., 2003) and the other inversion results using teleseismic body waves (Kikuchi and Yamanaka, 2002), and our inverted source model has more detailed information both in time and space than that from teleseismic body waves. It also supports the assumption that the active fault information could be related to the rupture process at the source. The rupture area estimated here is compared with two kinds of the empirical relationships based on different source scaling models. We find that that the relation between the rupture area and seismic moment of this earthquake follows the bilinear L-model scaling (Hanks and Bakun, 2002) rather than the self-similar source scaling model (Somerville et al., 1999). Combined area of asperities is a little smaller than that expected from the empirical scaling relationship by Somerville et al. (1999).

Finally, a forward ground motion simulation using the finite difference method (Pitarka, 1999) was conducted to estimate the influence of the heterogeneous source process obtained here on the spatial distribution of strong ground motions. Calculated ground motions are relatively large above and around the large slip area and also at the region east from the fault area because of the forward directivity effect of unilateral rupture propagation. This feature is consistent with the questionnaire surveyed seismic intensities map.