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Nonlinear source inversion analysis for the 2011 Tohoku Mw 9.0 earthquake based on strong-motion records

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The Tohoku earthquake of Mw 9.0, which occurred on 11 March 2011, is estimated to occupy almost 500 km long and 200 km wide for its source rupture area in the plate boundary between the North American and the Pacific plates, based on the moment tensor solution and the aftershock distribution. Several source slip models have been presented for the main shock using teleseismic data, and many of these show large slip area in shallow area along the trench axes which is considered to be the source of the huge tsunami striking the eastern coast area of the Tohoku and Kanto district. On the other hand the strong-motion records observed in Japan also exhibited large peak amplitudes particularly in Miyagi Prefecture such as Tsukidate, Kurihara city where observed peak ground acceleration exceeded 2.7 g in NS component, though the asperity of the main shock is estimated to be far from the land. To reveal the contribution of the source effect to such large ground motions during the main shock the source model based on the broadband strong-motion records should be examined. In this study we applied the source inversion method using the empirical Green's function to the strong-motion records of the 2011 Tohoku earthquake and estimated the source model.

We adopted the foreshock of M 6.8 occurring on 10 March as the element event for the empirical Green's function method. The fault plane of the main shock is divided into 25 times 10 sub-faults based on the fault size of the element event. The moment density, rise time and rupture time at each sub-fault is searched during the inversion procedure with the simulated annealing. Strong-motion records at 15 stations are used for the inversion analysis. They are band-pass filtered in the frequency range from 0.05 to 0.5 Hz (2 to 20 seconds) and converted to displacement motions by the numerical integration. The data length of each component is 170 seconds after S-wave arrival.

The estimated source model for the main shock shows a large slip around the hypocenter. The area of asperity is about 100 to 150 km long and wide and the peak slip reaches 28 m assuming the rigidity as 48 GPa. The total moment release is 2.7E+22 Nm and the moment magnitude is 8.9, which is slightly smaller than other earlier reports based on the teleseismic data. This might be due to the limited frequency band of the empirical Green's functions used in the inversion. The average rupture velocity is about 1.8 km/s. During the inversion analysis the total moment, the asperity size and the largest slip are stably estimated independence from the initial values for generation of random numbers used for the simulated annealing, however the location of the asperity fluctuates around the hypocenter with different initial parameter settings. In future work we will correct such fluctuations and try to apply the inversion process to more broadband strong-motion data.

Keywords: 2011 Tohoku earthquake, source process, inversion analysis, strong motion, empirical Green's function