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Source process of the 2011 off the Pacific coast of Tohoku Earthquake determined from seismic waveform and geodetic data

Hisahiko Kubo[1*], Yasumaro Kakehi[1]

[1]Kobe University

In this study, Source process of the 2011 off the Pacific coast of Tohoku Earthquake is estimated from the inversion of seismic waves and geodetic data.

We assume a curved fault model for the fault plane source model of source process inversion. This fault model is consisted of three planar segments with gradually changing dip angles, based on the plate boundary by Miura et al. (2005). The lengths (along-dip direction) of three segments are all 480km. The widths (along-dip direction) of three segments are 60km, 60km and 90km. The dip angles of the three segments are 9 deg, 11 deg and 23 deg. Each fault segment is divided into 30km-30km subfaults for the inversion. The rupture starting point location is (38.1035 deg, 142.1035 deg, 17.8km), which is the epicenter determined by JMA and the depth of the plate boundary modeled by Miura et al. (2005). The strike angle of 201 deg is used based on Global CMT solution.

For the inversion of seismic waves, waveforms of teleseismic P-waves at 42 IRIS (Incorporated Research Institutions for Seismology) stations with epicentral distance 50-100 deg are used. In order to cover the long duration of source process of the huge earthquake, P-wave part of vertical displacement waveform with time length of 180 s (beginning 10 s prior to the P-wave onset) is basically used. For the 6 stations with epicentral distance 60-70 deg and for the 8 stations with epicentral distance 50-60 deg, shorter time lengths of 160 s and 140 s are used, respectively. This is for avoiding PP phase coming into the time length for inversion analysis. Displacement waveforms are bandpass ?ltered from 10 s to 100 s and resampled with 0.5 s sampling interval.

Theoretical waveforms from a point source located in the center of each subfault are calculated using the program by Kikuchi and Kanamori. In the calculation, we use the structure model referred to Miura et al. (2005). The waveform inversion is done using multiple time-window analysis. The number of time windows is 14. Each time window has duration of 8.0 s, and one time window is put after the previous one with a time lag of 0.5 s. Rake angles of the subfaults are variable within 85 deg +- 45 deg, where central angle 85 deg is adopted from Global CMT solution. Smoothing constraint is given in the spatial and temporal distribution of slip. Weight of smoothing constraint is determined using minimum ABIC condition.

In the model by the waveform inversion, the total seismic moment is $1.9*10^{22}$ N*m, and the maximum slip is 18.1 m. Variance reduction is 79 % and waveform fitting is good. Large slip area is seen in shallow part.

The geodetic data consist of horizontal ground displacement at stations from GEONET GPS data (F3 solution processed by GSI). Theoretical internal deformations from a point source located in the center of each subfault are calculated using the program by Okada (1992). In the waveform of geodetic data, rake angles of the subfaults are variable within 85 deg +- 45 deg, where central angle 85 deg is adopted from Global CMT solution. Smoothing constraint is given in the spatial distribution of slip. Weight of smoothing constraint is determined using minimum ABIC condition.

In the model by the geodetic inversion, the total seismic moment is $2.05*10^{22}$ N*m, and the maximum slip is 28.0 m. Overall, the slip is smoother than that of the seismic wave model.

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Keywords: The 2011 off the Pacific coast of Tohoku Earthquake, Source process, Seismic waveform, Geodetic data