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Source process of the 2011 off the Pacific coast of Tohoku Earthquake

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We analyzed the source process of the 2011 off the Pacific coast of Tohoku Earthquake using teleseismic body wave or strong motion data.

1. Source process determined by teleseismic waveform

Spatio-temporal distribution of slip is analyzed by broadband data with UD-components of teleseismic P-waves using Kikuchi and Kanamori (2003)'s program. The data are integrated to displacement and band-pass filtered between 0.002 to 1.0 Hz. The size of fault plane is assumed to be 480 km x 240 km by the aftershock distribution and the assumed strike and dip angles of fault are fixed to be 203 and 10 degrees referred to the low-angle nodal plane of the JMA CMT solution. Optimal maximum rupture velocity is selected to 1.8 km/s to minimize residuals between observed and synthetic waveforms by trial and error. We get following results. Total seismic moment is 4.0×10^{22} Nm (MW9.0). There are three large slip stages (asperities). The three asperities are ruptured at about 20-40 s, 40-90 s, and 100-160 s after the initiation of rupture, respectively. First and second asperities are located near the hypocenter and last one in southern part. The variance reduction is about 76% and the overall fitting between observed and synthetic data is well.

2. Source process determined by strong motion waveform

23 strong motion seismograms of K-NET and KiK-net stations deployed by NIED and JMA stations, are used in this analysis. Acceleration seismograms are integrated to velocity. The data are band-pass filtered between 0.01 to 0.15 Hz, and decimated to 0.5 Hz. The fault size is assumed to cover the aftershock distribution. The fault is divided into subfaults with a size of 25x25km. We use the linear multiple time window inversion method with constraints on the smoothness of spatio-temporal slip distribution selected to minimize ABIC. Total seismic moment is 3.4×10^{22} Nm (Mw9.0). Large slip area extends from hypocenter to the shallower part of the fault plane. The maximum slip amount exceeds 30 m. We get 3 asperities, which have almost the same temporal and spacial distribution obtained by teleseismic waveform analysis. The comparison of observed and synthetic waveforms at the stations is quite well.

3. Discussion and Conclusion

We get almost consistent results by teleseismic waveform and regional strong motion waveform analysis. But slip distribution in southern part is not identical with teleseismic and regional analysis. This suggests the larger location error compared to that in northern part, but the slip amount is necessary to explain the strong waveform peaks at stations in Kanto area. The sources of high frequency energy radiation were roughly estimated using the modified Source-Scanning Algorithm [Aoki et al., 2011]. Five high-frequency radiation sources (HFS) were imaged during this event. The HFSs are generally located just rim of the slip patch. The moment release by 2nd stage is very large and maximum slip amount exceeds 30m. It is relatively large value compared to the maximum slip for another huge earthquake such as the 2004 off Sumatra event and the 2010 Chile event, which is about 15m [USGS, 2004, 2008]. The rupture duration is long (˜80 s) at the hypocentral region. This long duration produces very large slip amount and may generate large tsunami. This large asperity coincides with the large co-seismic slip area obtained by GPS analysis [GIJ, 2011] except near trench area, where small co-seismic slip is estimated by GPS. The difference is partly because the resolution near the trench is poor in GPS analysis. The region, where tsunami back propagation curves of initial crests were concentrated [Hayashi et al., 2011], is just above the large slip area obtained by this study.

Acknowledgement

Strong motion seismograms of K-NET and KiK-net deployed by NIED, and of JMA network are used in this study. Teleseismic seismogram are distributed by IRIS DMC. We use teleseismic body-wave inversion program developed by Kikuchi and Kanamori (2003).

Keywords: source process, the 2011 off the Pacific coast of Tohoku Earthquake, teleseismic seismogram, strong motion seismogram