Analysis of the source process of the 2016 Off Fukushima, Japan, crustal earthquake using land and seafloor observation data

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The 2016 off Fukushima earthquake (Mjma 7.4) occurred off Fukushima, northeast Japan on November 22, 2016 (JST). The moment tensor solution of F-net and the spatial distribution of the mainshock and its aftershocks indicate that this event was a shallow crustal normal-fault-type earthquake. Seismic and geodetic data for this earthquake were recorded not only by land observation networks but also by a seafloor observation network. In this study, we investigate the source process of this earthquake using seismic and geodetic data of land and offshore observation networks.

First, we estimate a rectangular fault model using land and seafloor geodetic data. For land geodetic data, we use two horizontal components of static displacements at stations of GEONET of GSI, which were obtained by differencing the preseismic and postseismic positions. For seafloor geodetic data, we use the uplift and subsidence spatial distribution, which was estimated from pressure waveform data at stations of S-net of NIED in Kubota et al. (2021, JpGU). Using these data, we estimate a rectangular fault with a uniform slip by the MCMC method. Unknown parameters are the spatial location of the rectangular fault (latitude, longitude, and depth), the fault mechanism (strike, dip, and rake), the fault length and width, and the slip value. For the geodetic Green’s functions, we calculate the theoretical static displacements assuming a homogeneous elastic half-space.

This analysis suggests the SE-dipping normal-fault-type fault model with a fault length of ~18 km, a fault width of ~13 km, and a slip of ~4 m. The top and bottom depth values of the estimated rectangular fault are ~3 km and ~9 km, respectively.

Then, we conduct the joint source inversion of near-field seismic and geodetic data. The spatiotemporal rupture history was estimated using the fully Bayesian multiple-time-window source inversion (Kubo et al. 2016). For near-field seismic data, we use velocity waveforms at stations of K-NET, KiK-net, and F-net of NIED. Their Green’s functions were calculated using the discrete wave number method and the reflection/transmission matrix method, with a 1-D layered velocity structure model. The 1-D velocity structure models were obtained for each station from the three-dimensional velocity structure model. For geodetic data and Green’s functions, we use the same ones as the investigation of the rectangular fault model. The assumed fault model in the source inversion is constructed by extending the rectangular fault model to cover the distribution of aftershocks. The horizontal location of the rupture starting point is set to the epicenter determined by JMA. The depth of the rupture starting point is set to the depth of the fault model at the epicenter of JMA.

The preliminary result of the source inversion suggests that large slips are found south-west of the rupture starting point and this large slip region is consistent with the rectangular fault model. These large slips were caused by the main rupture at 10-16 s after the rupture initiation, which propagated toward the southwest direction. The synthetic static displacements well match the observations, although the data fit of strong-motion waveforms is not good.

Keywords: The 2016 off Fukushima earthquake, Earthquake source process, Strong motion waveforms, Geodetic data, Seafloor observation network

