At 14:46:18 on March 11 2011 (JST; 05:46 on 11 March, UTC), the Tohoku earthquake (Mw 9.1) occurred off the Pacific coast of Northeastern Japan (off Tohoku region, Japan). Approximately 29 minutes after this event (at 15:15:34), the Ibaraki-Oki earthquake (Mw 7.9) occurred off the coast of Kanto region (off Ibaraki region, Japan). In this study, we estimate the rupture process of the joint inversion of teleseismic body waves and GPS data. We adopt the maximum slip duration of each subfault (Tsd) and the propagation velocity of the first time window (Vftw). We also estimate the rupture process of the 2011 Ibaraki-Oki earthquake that caused large after-slip and fault rupture with the subducted seamount and the Philippine Sea plate (PHS). Then, we discuss the relationship between the 2011 Tohoku earthquake and the 2011 Ibaraki-Oki earthquake.

**Abstract**

At approximately 70 km east-southeast from the epicenter of the 2011 Ibaraki-Oki earthquake, Mochizuki et al. (2008) found a subducting seamount (Purple broken circle). In addition, the plate overlying PAC changes from NA in the north off Kanto to the Philippine Sea plate (PHS) in the south. Uchida et al. (2009) estimated the border between the PHS-PAC contact zone: i) Uchida et al. (2009) suggested that the coupling rate in the PHS-PAC contact zone are lower than that in the NA-PAC contact zone. ii) The large afterslip area has been made on this topography, e.g., Scholz and Small (1997); Mochizuki et al. (2008); however, only few attempts regarding how seamount works during fault rupture have so far been made on this topic.

**Result & Discussion**

**At 10 s, the rupture propagates to the up-dip direction ( Orange).**

At 20 s, the rupture expands towards the up-dip direction ( Orange and Green). The slip in the shallow part reaches its peak at 70 s, and continues up to approximately 100 s.

**Comparison with the spatial distribution of teleseismic slip before and after the 2011 Ibaraki-Oki earthquake.**

**Spatial distribution of CMG of the interface earthquake (Mw=3.5) with a rake 180°.**

**The SMGA model is used to explain the source process of large afterslip.**

**Conclusion**

In this study, we analyzed the maximum slip duration of each subfault (Tsd) and the propagation velocity of the first time window (Vftw). We also estimate the rupture process of the 2011 Ibaraki-Oki earthquake that caused large after-slip and fault rupture with the subducted seamount and the Philippine Sea plate (PHS). The spatial resolution of seamount is significantly improved by using seafloor crustal deformation data (Sato et al., 2011) in addition to terrestrial GPS data.

**References**

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**Acknowledgement**

The strong-motion data recorded by K-NET, KiK-net, and F-net of NIED, the GPS data recorded by GSI, the F-net CMT solution catalog, and the JMA unified hypocenter catalog were used for this study. The program package by Kikuchi and Kanamori (2003), the program package by Snoke (2009), the program package by Okada (1992), and RTKLIB Ver. 2.4.1 (Takasu, 2011) were also used.

**Modified figure from GCMT web page**
The 2011 Tohoku earthquake

Inversion Detail

Data
Teleseismic body waves
We use the vertical-component waveforms at 42 IRIS stations with epicentral distances in period of 10-100 s containing not only P-phase (where P-phase means direct P-wave and depth phases such as pP and dp) but also PP-phase in this study. The time length of the dataset in the source inversion is 300 s (starting 10 s before the P-wave arrival).

GPS data
We use two horizontal components of static displacements at 83 GEONET stations. The static displacements of this event were obtained by differencing its preseismic and postseismic positions.

Seafloor crustal deformation data
We use three components of five seafloor static displacements (Sato et al., 2011).

Green’s function
Teleseismic Green’s function
P and PP-theoretical waveforms are calculated after Kikuchi and Kanamori (2003) with six one-dimensional velocity structure models for subfaults with different locations along the dip direction referring to Miura et al. (2005). Theoretical P and PP-phase onsets are set to observed ones for each station.

Geodetic Green’s function
Theoretical static displacements were calculated assuming a homogeneous elastic halfspace after Okada (1992).

Method
We use the kinematic linear waveform inversion with multiple time windows (Hartzell and Heaton, 1983). The slip time history of each subfault is represented by the superposition of 24 time windows with 4.0 s width, each of which is put with 2.0 s lag. The maximum slip duration at each subfault (Tsd) of 100 s was determined by semblance analysis of the near-source small-aperture seismic array data of the strong ground motion waveforms to estimate the wave-radiation duration from the area around the hypocenter. We assume a realistic curved fault surface model considering the three-dimensional shape of the plate boundary (Mura et al., 2005; Nakajima and Hasegawa, 2006; Nakajima et al., 2009; Kita et al., 2010). Relative weights among different kinds of data-set were determined by theoretical tests. The propagation velocity of the first time window (Vftw) of 2.2 km/s was selected so as to minimize the residual of strong-motion data fitting.

Data Fitting
The fitting in both of the teleseismic and geodetic data is quite well. The variance reductions of the teleseismic data and the geodetic data are 67.2% and 99.4%, respectively.

The 2011 Ibaraki-Oki earthquake

Inversion Detail

Data
Strong-motion data
We use three components of time-series data from the 17 stations (K-NET, KiK-net, and F-net) in period of 5-50 s. The time length of the dataset in the source inversion is 50-80 s (starting 10 s before the S-wave arrival).

GPS data
We use two horizontal components of static displacements at 83 GEONET stations. The static displacements of this event were obtained by differencing its preseismic and postseismic positions.

Green’s function
Teleseismic Green’s function
Theoretical strong-motion waveforms were calculated using the discrete wavenumber method (Bouchon, 1981) and the reflection/transmission matrix method (Kennett and Kerry, 1979) using one-dimensional velocity structure models for each station referring Japan Integrated Velocity Structure Model Version 1 (Koketsu et al., 2012).

Geodetic Green’s function
Theoretical static displacements were calculated assuming a homogeneous elastic halfspace after Okada (1992).

Method
We use the kinematic linear waveform inversion with multiple time windows (Hartzell and Heaton, 1983). The slip time history of each subfault is represented by the superposition of 7 time windows with 4.0 s width, each of which is put with 2.0 s lag. We assume a simple planar fault model (120 km along strike × 120 km along dip) with a strike of 206° and a dip of 10° which refers to the spatial distribution of earthquakes deduced from ocean bottom seismographic observations (Yamada et al., 2011). In this study, the relative weights between different kinds of data-set and the relative weight of the smoothing constraint are determined by a trial-and-error process considering the fitting in each data and the agreement between the seismic moment estimated by this analysis and GCMT. The first time window triggering velocity (Vftw) of 2.2 km/s was selected so as to minimize the residual of strong-motion data fitting.

Data Fitting
The fitting in both of the strong-motion and GPS data is quite well. The variance reduction of the strong-motion data and the GPS data are 84.4% and 97.4%, respectively.

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