Estimation of the early afterslip location of the 2011 Tohoku-Oki earthquake using onshore GNSS and offshore pressure data

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Understanding of spatial and temporal development of the early afterslip just after the large earthquake is extremely important to characterize the frictional properties vicinity of an earthquake. Widely installed onshore geodetic data has been utilized to estimate the frictional properties along the plate interface (e.g. Miyazaki et al., 2004). One of the opportunity to study for early afterslip of the large event is 2011 Tohoku-Oki Earthquake. Dense continuous GNSS was installed nationwide, which had captured whole time period for this event successfully. Thus, we focus on the early afterslip of the 2011 Tohoku-Oki event in this study using both of onshore GNSS and offshore pressure data.

For the onshore GNSS data, we estimated the every 30 seconds kinematic time series until 18 hours after the mainshock. To enhance the signal-to-noise ratio of kinematic time series, we applied the principle component analysis (PCA) for kinematic PPP time series. We removed the lower contribution components from raw time series. For the offshore pressure data, we used the data-set by Hino et al. (2014). The raw OBP time series was sampled into 1 minute, after taking 1 minute average of raw data. Next, the resampled pressure data were de-tided, de-drifted and corrected by the ocean model to detect the seafloor deformation (Inazu et al, 2012). The time series of corrected OBP showed a strong signal of tsunami wave propagation. To clearly showed the tectonic deformation of the seafloor, we applied moving average of a window of (time with of windows) in length. The amount of displacement was estimated based on logarithmic functions fitted to the filtered pressure records.

To estimate the spatial and temporal development of early afterslip, we applied a conventional network inversion filter (NIF) (Segall and Matthews, 1997). We assumed an elastic half-space model (Okada, 1992) to calculate green functions of surface displacement due to slips on subfaults. We assumed local benchmark motions in unknown state vectors. To reduce the number of unknown parameters, we assumed pure reverse faulting. We omitted 10 minutes parts just after the mainshock from both onshore and offshore data because of the large disturbance caused by the seismic wave passage.

We estimated the early afterslip distribution using two different data sets for comparison. First one is the result from the onshore GNSS data only. Second one is the result both from the onshore GNSS and the offshore pressure data. Using only the onshore data, the estimated afterslip mainly concentrate on the deeper extension of the coseismic slip distribution. Spatial pattern of the estimated afterslip consistent with previous study (e.g. Munekane et al. 2012). In contrast, obtained early afterslip distribution completely difference when we included the offshore data. The estimated afterslip mainly concentrated in the shallower part of the subducting plate interface. Estimated moment release amount reached 2.37×10^{21} Nm (correspond to Mw 8.24) after the 18 hours from the mainshock. It clearly larger than the previous studies such as Munekane et al [2012]. It may be caused by the offshore pressure data. Just after the 2011 Tohoku-Oki event, all of the ocean bottom pressure time series indicate the clear subsidence signal. To explain this subsidence, afterslip cannot locate in the deeper part of the subducting plate interface because the afterslip in the deeper part generate the upward displacement in the ocean bottom pressure sites.

We will discuss the more detail characteristic of the estimated early afterslip distribution. We also try to estimate the afterslip distribution using L1 regularization inversion (e.g. Evans et al., 2012) approach to illuminate the location of the afterslip just after the mainshock.

Keywords: Early afterslip, Ocean Bottom Pressure, GNSS, Network Inversion Filter