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Coseismic slip distribution of the 2011 Off the Pacific Coast of Tohoku Earthquake estimated based on GPS data

Takeshi Iinuma[1*], Mako Ohzono[2], Yusaku Ohta[1], Satoshi Miura[3]

[1]Graduate School of Science, Tohoku Univ., [2]Graduate School of Sci., Hokkaido Univ., [3]Earthq. Res. Inst., Tokyo Univ.

The 2011 Off the Pacific Coast of Tohoku Earthquake (M9.0) occurred on 11 March 2011 off the Pacific coast of Tohoku district, northeastern Japan, where the Pacific plate is subducting at a rate of about 8 cm/year beneath the overriding continental plate. Various studies on major interplate earthquakes around this area have revealed that some of those events can be regarded as recurrent ruptures of asperities, which are defined by distributed patches showing large coseisimc slip. The rupture area of the 2011 earthquake includes several asperities M ˜ 7 earthquakes.

Earthquakes with magnitudes of about 7.5 or larger have repeatedly occurred on the plate boundary east off Miyagi Prefecture (Miyagi-oki) with an interval of about 37 years. The most recent one took place in 1978 (M7.4). Based on historical records of these recurrent earthquakes, the Headquarters for Earthquake Research Promotion stated that the next Miyagi-oki earthquake will occur with a probability of about 70 % in the next 10 years from 1 January 2011.

On August 16, 2005, an interplate earthquake with magnitude 7.2 occurred. Okada et al. (2005) carried out the relocation of aftershocks of the 1978 and 2005 events to reveal that the aftershock area of the 2005 event is overlapped only with the southeastern part of the 1978 source area. Yaginuma et al. (2006) performed the seismic waveform inversion for the 2005 event to estimate the coseismic slip distribution and found that it also corresponds to the southeastern part of the 1978 rupture area. The northern and southwestern parts of the rupture area of 1978 earthquake did not slip aseismically after the 2005 earthquake (Miura et al., 2006; Iinuma et al., 2011). Therefore, we had regarded that the remaining asperities of the 1978 Miyagi-oki earthquake had not been ruptured and had been accumulating strain energy since 1978 for the next Miyagi-oki earthquake, until the 2011 M9.0 earthquake occurred.

Thus, we tackled the problem whether the remaining asperities of the 1978 Miyagi-oki earthquake were ruptured with the 2011 off the Pacific Coast of Tohoku Earthquake or not based on land GPS observation data. In the present study, we applied GPS data to estimate coseismic slip distributions on the plate boundary by means of a geodetic inversion method.

The results show that the significant large slip area is divided into two areas. One is the main rupture area on the plate interface shallower than 30 km in depth where the subducting plate contacts with the crust of the continental plate. Another one locates at Miyagi-oki region where the asperities that caused the 1978 Miyagi-oki earthquake are distributed. We can conclude that tremendous slip in the crust-crust contact zone on the plate boundary mainly caused the 2011 off the Pacific coast of Tohoku Earthquake, and that the boundary between the continental crust and mantle on the hanging wall side of the plate interface fault might prevent the main shock rupture from propagating into the crust-mantle contact zone along the plate interface. Miyagi-oki, however, is an exceptional region where the coseismic slip also occurred on the plate interface under the continental mantle. The material heterogeneity of the mantle wedge might control this slip distribution.

Whole estimated slip distribution suggests that the main shock rupture did not propagate into the brittle-ductile transition zone along the plate interface. Igarashi et al. (2001) pointed that there is a clear boundary of the distribution of the interplate earthquakes in this region, and no slip is estimated at the plate interface deeper than this border. However, week interplate coupling is estimated in the deeper plate boundary based on interseismic crustal deformation data. Thus, postseismic slip is expected to occur in the plate interface deeper than this border in order to release the cumulative strain energy due to the interplate coupling.

Keywords: The 2011 Off the Pacific of Tohoku Earthquake, Miyagi-oki Earthquake, Coseismic Slip Distribution, GPS