Relation Between Focal Mechanism Changes and Moment Release for the 2011 off Pacific Coast of Tohoku Earthquake

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Abstract

An analysis of the rupture process of earthquakes is one of the most fundamental studies in seismology. A moment release distribution can be directly obtained from seismic waveform inversion. The obtained moment release distribution can be transformed to the slip distribution, by assuming the rigidity of the medium. Because of the uncertainty of the rigidity, the estimate of the moment release distribution is commonly more accurate than that of the slip distribution.

Numerous studies have estimated the slip distribution of the 2011 off the Pacific coast of Tohoku Earthquake using various datasets and methods. One problematic point on the estimates of the slip distribution is the location of the large slip; some models estimated a large slip near the trench axis off the Miyagi Prefecture, whereas other models estimated a large slip around the mainshock hypocenter. This disagreement seems to be primarily attributed to the heterogeneity of the rigidity around the source region, because different assumptions on the heterogeneity of the rigidity have been adopted in these studies.

I tried to estimate the reliable moment release distribution of this earthquake in this study.

Another problematic point is the location of the lower limit of large moment release in the down-dip region from the mainshock hypocenter.

However, the location of the lower limit of large moment release in the down-dip region shows variation in previous studies. Clarifying the lower limit of the large moment release of the Tohoku earthquake is important in terms of seismic risk assessment, because the asperity that caused the 1978 Miyagi-oki earthquake (M-7.6) is located around there.

In Chapter 2, I introduced the datasets used in this study and an overall feature of the distributions of focal mechanisms before and after the mainshock. It is reported that the focal mechanisms have drastically changed due to the Tohoku earthquake. Since such a change of focal mechanisms gives a clue to the addressed problems, I precisely analyzed focal mechanisms in the focal region of the Tohoku earthquake and found two characteristic focal mechanism distributions.

In Chapter 3, I focused on the characteristic focal mechanism distributions after the mainshock in the footwall from the mainshock hypocenter to the trench axis off the Miyagi Prefecture, which are many strike-slip events with the P-axes in the NS direction in the footwall from the mainshock hypocenter to the trench axis off the Miyagi Prefecture. I firstly calculated the static stress change due to the Tohoku earthquake in the up-dip region from the mainshock hypocenter. The static stress change should be essentially calculated from the moment release assuming the heterogeneous elastic properties. However, since it is shown that stress states are less affected by the heterogeneous elastic properties, I calculate the static stress change due to the moment release distribution under the assumption of an elastic half-space with constant elastic properties. Here, I employed the two end members of moment release models with a peak of moment release near the mainshock hypocenter and near the trench. It was found that the model with a large moment release near the hypocenter well explains the focal mechanism distribution with the P-axes in the NS direction in the footwall of the region from the mainshock hypocenter to the trench axis off the Miyagi Prefecture. The extremely large surface displacements observed in the hanging wall near the trench axis is considered to be resulted from small rigidity in this region.

In Chapter 4, I focused on a drastic spatial change of focal mechanisms, from almost vertical to much smaller dip angles $(30^{\circ}-60^{\circ})$ in P-axes, in a very narrow area in the hanging wall in a deeper part near the mainshock hypocenter; thrust type events with the P-axes almost parallel to the plate boundary are also observed in the footwall of this region. I investigated where the lower limit of the large coseismic moment release is extended, on the basis of the stress changes by the model with a large moment release near the mainshock hypocenter discussed in chapter 3 and the characteristic spatial distribution of focal mechanisms after the mainshock in the hanging wall around the lower limit of the large moment release. I compared the characteristic focal mechanism distribution in the hanging wall in the deeper part near the mainshock hypocenter with the static stress changes calculated by some representative moment release models. It was found that the characteristic focal mechanism distribution could not be explained only by the stress change calculated from the models, if the after slip was included. Thus, I analyzed the characteristic focal mechanisms by considering the effect of the initial stress, which is the sum of the stress change due to the mainshock including the after-slip and the initial stress. It is inferred that the spatial change in the differential stress before the mainshock is about 5 - 10 MPa in the region deeper than the narrow area where the characteristic P-axis distributions are seen and about 0 - 2 MPa in the shallower region, and that the lower limit of nearly the flat moment release distribution (the upper limit of the large moment release gradient) is located in the same region as or in the deeper region than the location of the characteristic P-axis distribution. The estimated stress magnitudes are partly examined quantitatively by utilizing the results of stress tensor inversion before and after the mainshock.

The region where the relatively higher differential stress was estimated corresponds to the asperity of the 1978 Miyagi-oki earthquake, suggesting that the strength of the asperity of the 1978 Miyagi-oki earthquake is higher than that of the surrounding region. The latter result about the moment release distribution suggests that the lower limit of the large moment release of the Tohoku earthquake extended to the asperity that caused the 1978 Miyagi-oki earthquake.