論文の内容の要旨

Seismicity Patterns before and after the 2011 Tohoku Earthquake in the Japan Trench Subduction Zone

（日本海溝域における 2011 年東北地方太平洋沖地震前後の地震活動）

氏名　仲谷 幸浩

The 2011 off the Pacific coast of Tohoku Earthquake (the Tohoku earthquake) occurred on March 11, 2011 in the Japan Trench subduction zone with a moment magnitude of 9.0, which was the largest earthquake ever recorded in Japan. Many studies using various types of data, such as teleseismic, geodetic, strong motion, and tsunami data, have proposed generally common source rupture models characterized by a large coseismic slip along an up-dip part of the plate interface and high-frequency ruptures along its down-dip edge. Both onshore and offshore seismic observation data before and after the Tohoku earthquake are available in and around its source area. However, most of previous studies of local seismicity using ocean bottom seismometer data have often focused only on manual relocation of hypocenters listed in the existing earthquake catalogs. Therefore, the location and frequency of offshore earthquakes with small magnitudes have yet to be elucidated especially after the Tohoku earthquake. Such less complete earthquake catalogs need to be improved to discuss frequency-magnitude distributions (FMDs) and the b-value of the Gutenberg-Richter law (G-R law)

which is considered to be related to the differential stress. This thesis contributes to understanding the spatiotemporal variations of the FMD in the Japan Trench subduction zone before and after the occurrence of the Tohoku earthquake and to discussion on possible physical properties that cause such variations.

First of all, I developed an automated method for detection and location of local earthquakes including small-magnitude ones. The method is composed of the amplitude-based trigger algorithm and the waveform coherence analysis. I applied the method to onshore and offshore seismic data in the Japan Trench subduction zone before and after the 2011 Tohoku earthquake and extracted hypocenters as seismic sources of energy release. As a result of application of the newly developed method, I obtained a more complete earthquake catalog whose magnitudes of completeness (Mc) for the pre- and post-Tohoku periods are approximately 2 and 3, respectively, as being derived as minimum magnitudes which can maximize the goodness of fitting test assuming the G-R law within the magnitude range of Mc and above. The resulting detection rate in comparison to a conventional detection and location system is high even for the period immediately after the Tohoku earthquake. Focal depths are constrained around the plate interface and the error of epicenters is about 20 km estimated by comparison to the existing catalog and by experiments using synthetic seismic wavelets.

For the pre-Tohoku period, from October 2007 to June 2008, the results show seismicity boundary along 39°N. Locations of the low seismicity are in agreement with that of the aseismic area where the presence of fluid along the plate interface has been suggested by previous studies. In contrast, the seismic area is observed just south of the aseismic area around 39°N, corresponding to the down-dip side of the coseismic slip zone of the Tohoku earthquake. For the post-Tohoku period, first three months after the Tohoku earthquake, the resulting number of earthquakes is about 1.8 times as many as that of the Japan Meteorological Agency (JMA) catalog data within a band of 5 km on both sides (above and below) of the plate interface. The seismicity distribution shows coincidence between low-seismicity area and the coseismic slip zone, except near the Japan Trench. This relationship is also identified by negative correlation between the cumulative seismic moment release and the amount of coseismic slip. On the other hand, active aftershock clusters are located along the down-dip edge of the coseismic rupture region. It is one of the important contributions of this thesis to constraining the extent of the source area of the Tohoku earthquake in terms of seismicity and indicating the stress increase in its surrounding area.

Finally, I investigated the spatiotemporal variations of FMDs before and after the Tohoku earthquake. The remarkable result is that the b-value, which is the relative amount of small to large earthquakes, is low in wide areas corresponding to low Mc immediately after the Tohoku earthquake, comparing to the previous study using the JMA catalog data. Under the assumption that the frequency of earthquakes is characterized by the G-R law and the magnitude-dependent detection rate, the statistical analysis shows that the breakdown of the G-R law occurs in these areas for the post-Tohoku period. The deviation from the G-R law is confirmed in the magnitude range greater than ~4, where the observed cumulative number of earthquakes shapes a convex curve. This thesis first reveals such breakdown of the G-R law for aftershocks of the 2011 Tohoku earthquake by including small-magnitude offshore earthquakes. In the area that experienced high frequency radiation at the coseismic slip, a substantial decrease in the b-value from 1.16 to 0.64 is observed from before to after the Tohoku earthquake. Such change in the fraction of earthquakes with a magnitude of ~2 might be occurred due to changes in the stress field and/or frictional properties along the plate interface. The areas adjacent to the northern and southern limits of the coseismic slip zone show low b-value for the post-Tohoku period or decrease in the b-value from before to after the Tohoku earthquake. Such feature can be explained by increase of differential stress originated from the main shock in its surrounding area. This thesis revealed the regionalities of the FMDs using entire range of magnitudes, and the results provide constraints on relationship between the FMDs and source region and its rupture process of the 2011 Tohoku earthquake.