Microseismicity prior to the 2011 Tohoku-Oki earthquake around the mainshock hypocenter

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It has been pointed out that slow earthquakes driving intense foreshock activities cause stress concentration on the epicenters of eventual large earthquakes and trigger mainshocks (e.g. Obara and Kato, 2016). In the 2011 Tohoku-oki Earthquake, foreshock activity thought to be accompanied by a slow earthquake was observed from about one month before the mainshock on March 11 (Kato et al., 2012). At that time, ocean bottom seismometers (OBSs) were installed in this area. In the seismic waveform records obtained by this observation, many events that seemed to be small earthquakes that were not the subject of the previous research were observed. By inspecting such numerous micro earthquakes, it is expected that we will be able to deepen our understanding of the spatiotemporal distribution of foreshock activity and clarify new features of processes preceding large earthquakes. Here, we detected foreshocks and estimated their hypocenter distribution prior to the Tohoku-oki earthquake including tiny events, to discuss the characteristics of the spatiotemporal development of the foreshock activity.

In this study, the waveforms obtained from the OBSs installed around the epicenter of the Tohoku-oki earthquake were used to detect the earthquake and estimate the epicenter by the envelope correlation method (Obara, 2002). As a result, 1963 events were detected during the three days of the analysis period, from March 9 to March 11, and about 70% of them were located with epicenter errors within 10 km. Using this result, the spatial distribution of foreshock activity was investigated in detail. It was found that microearthquakes were concentrated into two regions, separated by the coseismic rupture area of the largest foreshock (M 7.3, March 9 11:45 JST), on the northeastern and southwestern sides, respectively. This is in good agreement with the general picture pointed out for aftershock distributions of many large earthquakes, in which aftershock activities become low in the main coseismic slip area of mainshocks.

The onset timing of seismicity is different between these two active areas. On the northeastern side, activity began immediately after the occurrence of the largest foreshock, showing temporal expansion from the epicenter of the largest foreshock. On the southwest side, activity began about 9 hours after the occurrence of the largest foreshock. This activity expanded from the west side (down-dip side), and the second largest foreshock (M 6.8, March 10 06:24 JST) occurred on the east side (up-dip side).

The number of earthquakes in each active area showed a temporal variation; several increases associating large earthquakes (M> 6) occurrences. However, a sudden increase of the seismicity without any large earthquakes was observed in the northeastern active area. With this activation, the activity of the small repeating earthquakes (Kato et al., 2012) seem to have reactivated. It is suggested that there is a temporal fluctuation in the aseismic process behind the foreshock activity.

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