Characteristics of tectonic tremor activity along the Japan Trench before the 2011 Tohoku Oki earthquake

*Hidenobu Takahashi[1,2], Ryota Hino[1], Naoki Uchida[1], Ryosuke Azuma[1], Susumu Kawakubo[1], Kazuaki Ohta[3], Masanao Shinohara[4]

1. Graduate school of Science Tohoku University , 2. Central Research Institute of Electric Power Industry, 3. National Research Institute for Earth Science and Disaster Resilience, 4. Earthquake Research Institute, The university of Tokyo

Recently, slow earthquakes have been discovered in Tohoku-oki by using the Seafloor Observation Network for Earthquakes and Tsunamis along the Japan Trench (S-net) (Nishikawa et al., 2019). The characteristics of the slow earthquakes in Tohoku-oki differ from those in the Nankai Trough (Obara and Kato, 2016). Along the Nankai Trough, sources of slow earthquakes are continuously distributed along the deeper and shallower sides of the seismogenic zone, whereas those show complex spatial distribution along the Japan Trench (Nishikawa et al., 2019). In Tokachi-Oki, Tanaka et al. (2019) observed tremors within several kilometers from moderate-sized interplate earthquakes, suggesting small-scaled frictional heterogeneities on the plate interface in the area. Mixed distribution of regular earthquakes and tremors, as well as high regular earthquake activity, make the Japan trench ideal place to study the relationships between tremors and regular earthquakes.

Takahashi et al. (2020, AGU) detected tremors based on the ocean bottom observations from October 2007 to October 2008 along the Japan trench. As a result, tremors occurred before the 2011 Tohoku-Oki earthquake in Iwate-Oki (39.3–40.2˚N), Miyagi-Oki (38.7˚N–39.2˚N), Fukushima-Oki (36.5–37.0˚N), and Ibaraki-Oki (35.5–36.5˚N). In this study, we compare spatio-temporal relationships between tremors and regular earthquakes based on the same data set with those used in our previous study. We focused on if spatial complementarity of tremors and regular earthquakes distributions, and synchronicity of tremors and nearby regular earthquakes activation.
In the depth range between 10–20 km, where tremors are active, most of the regular earthquakes were concentrated in several clusters, like tremors, and these regular earthquake clusters were clearly separated from the tremor clusters. However, tremor and regular earthquake clusters are close to each other, and in many cases, both are adjacent to each other at a distance of a few kilometers or less.

The most active cluster of regular earthquakes during our observation period in Iwate–Oki is located in between two isolated tremor clusters. These regular earthquakes were concentrated in time and its timing is immediately after the nearby tremor episodes. The location of the regular earthquake cluster was located near the end of the tremor cluster where the tremor migration terminated. A similar pattern was observed in Ibaraki–Oki. The cluster of regular earthquakes was observed adjacent to the tremor sources, and this cluster also activated after the cessation of the tremor episode with source migration and was located near the terminal of the migrating. However, not all the tremor activities are accompanied by regular earthquake activity. In the case of tremor activity followed by the regular earthquake activity, tremor distribution tends to be broaden toward the regular earthquake cluster, suggesting variety of interaction between tremor and regular earthquake.

The spatial complementarity of tremors and regular earthquakes suggests that these occur in different conditions on the plate boundary, like other subduction zones, but their spatial closeness indicates that the frictional heterogeneity has a scale of several kilometers on the plate interface in the Japan Trench subduction zone. The observed synchronicity of tremor and regular earthquake activities can be

explained by a common phenomenon, SSEs. The variety of the association between tremors and regular earthquakes can be attributed to the fluctuation in the generation of SSEs: only when the SSEs, initiated from tremor sources, expanded to a nearby seismogenic area, the slip activates regular earthquakes.

Keywords: The Tohoku Oki earthquake, Slow earthquake

