

The slow earthquake spectrum in the Japan Trench illuminated by the S-net seafloor observatories

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Investigating slow earthquake activity in subduction zones provides insight into the slip behavior of megathrusts, which can provide important clues about the rupture extent of future great earthquakes. In the Japan Trench, which is a subduction zone located off the Pacific coast of eastern Japan, a pioneering study by Kawasaki et al. (1995) observed a M_w 7.3–7.7 aseismic slip transient accompanied by an earthquake swarm (seven M_j 6.0–6.9 events) far off the coast of Iwate Prefecture in July 1992. Furthermore, Kato et al. (2012) and Ito et al. (2013) revealed that one month before the March 2011 M_w 9.0 Tohoku-Oki earthquake, a slow slip event (SSE) accompanied by an earthquake swarm (four M_j 5.2–5.5 events) containing repeating earthquakes had occurred inside the Tohoku-Oki earthquake rupture area off Miyagi Prefecture. However, the distribution and activity of slow earthquakes across the entire Japan Trench have been unclear because the slow earthquakes occur far offshore and because ocean-bottom seismic or geodetic observations have been conducted only in limited areas and periods.

In 2016, the National Research Institute for Earth Science and Disaster Resilience (NIED) started the operation of the Seafloor Observation Network for Earthquakes and Tsunamis along the Japan Trench (S-net). The S-net consists of 150 seafloor observatories equipped with ocean-bottom seismometers and pressure gauges that are distributed over the Japan Trench and southern end of the Kuril Trench. Here, we used the S-net seismograms to map a detailed distribution of tectonic tremors from August 2016 to August 2018. The observed tremors coincided with very-low-frequency earthquakes (VLFs) and an SSE. Compiling these and other related observations, including earthquake swarms containing repeating earthquakes, we found that the slow earthquake distribution is complementary to the Tohoku-Oki earthquake rupture. We then used our observations to divide the megathrust in the Japan Trench into three along-strike segments characterized by different slip behaviors: the northern (off Iwate Prefecture) and southern (off Ibaraki Prefecture) segments are characterized by a frequent occurrence of slow earthquakes, whereas the central (off Miyagi Prefecture) segment hosted the Tohoku-Oki earthquake and is characterized by a sparse distribution of slow earthquakes.

Very recently, there has been further progress in the study on the slow earthquake activity along the Japan Trench. Onshore seismic and geodetic observations have revealed the VLFE distribution across the entire Japan Trench (Baba et al., 2020) and the detailed SSE distribution in the southern segment (Nishimura, 2020) before and after the 2011 Tohoku-Oki earthquake. Moreover, Kubo & Nishikawa (2020) have pointed out the complementarity between the slow earthquake distribution and rupture areas of M_w -7-class interplate earthquakes that occurred before or after the 2011 Tohoku-Oki earthquake in the northern and southern segments.

Integrating the results of the S-net observations and these very recent studies, we suggest that the along-strike variation of the slow earthquake activity is a persistent feature that has existed since before the Tohoku-Oki earthquake. The VLFE distribution before the Tohoku-Oki earthquake well correlates with

the tremor distribution after the Tohoku-Oki earthquake, with sparse VLFE and tremor distributions inside the largest coseismic slip area of the Tohoku-Oki earthquake. Slow earthquakes and rupture areas of large interplate earthquakes are distributed in a complementary manner, although the SSE one month before the Tohoku-Oki earthquake in the central segment is a notable exception. On the basis of these integrated observations, we propose that the slow-earthquake-prone areas impede the rupture propagation of great earthquakes along the Japan Trench and limit their sizes. This insight may help us better estimate the rupture extent of future great earthquakes along the Japan Trench.

Keywords: The 2011 Tohoku-Oki earthquake, Slow earthquake, Subduction zone, Megathrust earthquake, S-net, The Japan Trench