Earthquake swarm detection along the Hikurangi Trench, New Zealand: insights into the relationship between seismicity and slow slip events

*Tomoaki Nishikawa[1], Takuya Nishimura[1], Yutaro Okada[2]

1. Disaster Prevention Research Institute, Kyoto University, 2. Graduate School of Science, Kyoto University

Earthquake swarms, which are anomalous increases in the seismicity rate without a distinguishable mainshock, often accompany aseismic transients, such as fluid migration and episodic aseismic slip along faults. Investigations of earthquake swarm activity can provide insights into the causal relationship between aseismic processes and seismicity. Furthermore, earthquake swarms can be used as potential indicators of aseismic transients that have previously escaped detection. For example, attempts have been made to detect offshore SSEs by examining the earthquake swarm activity in subduction zones, such as the Aleutian and Japan trenches (e.g., Reverso et al., 2015; Nishikawa et al., 2019).

Slow slip events (SSEs) along the plate interface in the Hikurangi Trench, New Zealand, are often accompanied by intensive earthquake swarms. However, the detailed spatiotemporal distribution of these earthquake swarms is still unclear. Here we apply the earthquake swarm detection method published in Nishikawa and Ide (2018) to seismicity along the northern and central Hikurangi Trench and create a new earthquake swarm catalog. We then compare our new earthquake swarm catalog with Global Navigation Satellite System (GNSS) time series data, and existing SSE and tectonic tremor catalogs, to both elucidate the causal relationship between aseismic transients and seismicity and detect new aseismic transients.

We extracted M3.0 or larger earthquakes from the GeoNet earthquake catalog for the 1997–2015 analysis period. We selected the location of our study region to encompass the source regions of shallow SSEs along the northern and central Hikurangi Trench. We then applied the earthquake swarm detection method published in Nishikawa and Ide (2018) to the seismicity. This method objectively distinguishes earthquake swarms from ordinary mainshock–aftershock sequences using the epidemic-type aftershock sequence model (Ogata, 1988; Zhuang et al., 2002). As a result, we detected 119 earthquake swarm sequences along the Hikurangi Trench. Most of the detected earthquake swarm sequences were intraplate events, and their epicenters were mainly distributed along the east coast of the North Island, with a sparse inland distribution.

We then compared the new earthquake swarm catalog with GNSS time series data, and existing SSE (Wallace & Beavan, 2010; Wallace et al., 2012; Wallace & Eberhart-Phillips, 2013; Wallace et al., 2016) and tectonic tremor (Todd & Schwartz, 2016; Todd et al., 2018; Romanet & Ide, 2019) catalogs. We detected eastward GNSS displacements caused by SSEs following the method published in Nishimura et al. (2013) and Nishimura (2014). We found that 14 of the detected earthquake swarm sequences occurred within 14 days of the SSE occurrence periods and were located either within or on the periphery of the SSE source regions. Furthermore, the detected earthquake swarms often occurred close in time to transient eastward GNSS displacements potentially due to SSEs that have previously escaped detection. The earthquake swarms sometimes preceded or succeeded the GNSS displacements by more than a week, suggesting the earthquake swarm seismicity rate in the Hikurangi Trench is not correlated with SSE slip or stress loading rates. Similar to earthquake swarms, tectonic tremor bursts were sometimes delayed by more than a week with respect to the transient GNSS displacements.

SSE-induced stress loading is not a plausible triggering mechanism for these pre-SSE and post-SSE earthquake swarms. We instead propose that high fluid pressure within the slab, which accumulated before the SSEs, may have caused intraplate fluid migration, which in turn triggered the pre-SSE earthquake swarms (see Figure). Using an earthquake focal mechanism analysis, Warren-Smith et al. (2019) inferred that there was a build-up of fluid pressure within the subducting slab before SSEs in the Hikurangi Trench. Such an accumulation of pressurized fluids may break a low-permeability seal, allowing fluid migration along preexisting intraplate faults prior to an SSE, which reduces the shear strength of the faults (e.g., Raleigh et al., 1976; Yamashita, 1998) and potentially triggers pre-SSE earthquake swarms. Furthermore, the occurrence of an SSE along the plate boundary enhances the permeability of the surrounding rocks via strain-induced fracture opening (Rivet et al., 2011). This may induce fluid movement/drainage from intraslab faults to the plate boundary and overriding plate after an SSE has occurred (Warren-Smith et al., 2019). Such post-SSE fluid migration may trigger post-SSE earthquake swarms and delayed tremor bursts.