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The role of tectonic tremor in slow earthquake

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Since the discovery of the slow earthquake, tectonic tremors, very low frequency earthquakes (VLFs), and slow slip events (SSEs) are thought to have close relation. Although the tremor activity is often regarded as a proxy of SSEs, the degree of proximity is yet unclear due to the lack of detailed quantitative comparison between them, especially for tectonic tremors. Here, we develop a method to estimate the seismic energy of tremors and apply it to tremors in four subduction zones (Nankai, Japan; Cascadia, USA-Canada; Jalisco, Mexico; South Chile). This method estimates the seismic energy of tremors, after evaluating the regionally averaged seismic attenuation and the site amplification factors, which has not been considered enough in previous studies estimating the seismic energy of tectonic tremors. Then the catalog of the energy rate, which is the seismic energy divided by the tremor duration, is compared with some characteristics of tremors, VLFs, and SSEs.

We have observed three types of spatial distributions in terms of energy rate; heterogeneous, homogeneous, and isolated. In regions where the energy rate is heterogeneously distributed on the plate interface, such as Nankai and northern Cascadia, tremor activities almost always initiate from where the energy rate is low. Sometimes the initial tremors trigger more energetic tremors nearby, which are further followed by a long-distance tremor migration along the strike of the subducting plate. These energetic tremors tend to have longer recurrence intervals, and seem to control the onset of a large-scale tremor migration, which probably corresponds to a SSE. In Nankai, the energy rate of tremors estimated between 2-8 Hz is large where VLFs have been detected in the frequency range of 0.02-0.05 Hz. These observations suggest that the characteristics of tremors are regionally various, but similar in different frequency ranges. In the region where tremor activities are isolated, such as East Shikoku, Jalisco and South Chile, each tremor activity has occurred independently, and the relations between the energy rate and the recurrence intervals cannot be seen. In the region where the energy rate is homogeneously distributed on the plate interface, such as a part of southern Cascadia, tremor activities have occurred spontaneously in the entire tremor zone.

Our observation suggests a possibility that the spatial distribution of the energy rate of tectonic tremors might control the behavior of slow earthquakes in the region. When the energy rate is distributed heterogeneously, some energetic tremors seem to control the activity of SSEs, as a switch that ignites a large-scale migration. When tremor patches are isolated, they are passively controlled by the tectonic loading. When it is homogeneously distributed, minor tremor activities, which rupture the only part of the tremor zone, cannot occur.

Keywords: Slow Earthquake, Tectonic Tremors, Seismic wave energy