On dynamic rupture modeling of megathrust earthquakes based on estimated coupled regions in the Nankai Trough

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In the Nankai Trough subduction zone, various types of slip events occur (Obara and Kato, 2016). Short-term slow slip events (SSEs) with low-frequency tremors occur at depth. Long-term SSEs with long recurrence intervals and durations also occur. In addition, very low-frequency earthquakes (VLFEs) are occurring in shallower areas. Recently, how stresses accumulate in the coupling zone has also been clarified by inversion analysis using GNSS data (Noda et al., 2021; Saito and Noda, 2022). Based on recent studies, how megathrust earthquakes propagate should be investigated using dynamic rupture models. In particular, the following are important issues for estimating seismic and tsunami hazard caused by Nankai trough megathrust earthquakes: how the rupture propagates in the shallow part of the Nankai Trough subduction zone and causes tsunamis, how far the rupture propagates in the deeper part of the subduction zone, and how strong ground motions are generated. This presentation introduces the results of a preliminary dynamic rupture simulation by Tsuda et al. (2024) and discusses future subjects in modeling dynamic rupture propagation.

Tsuda et al. (2024) performed dynamic rupture simulations of megathrust earthquakes in the Nankai trough subduction zone based on the three-dimensional spectral element method (e.g., Galvez et al., 2014), incorporating plate boundary structures (Iwasaki, 2015) and using the slip-weakening friction law (Ida, 1972). The distribution of stress drop was obtained by the product of the stress accumulation rate estimated by Noda et al. (2021) and the recurrence interval (100 years). Strength excess (SE) was assumed to be 1.5 times the stress drop. In shallow and deep areas, the friction law of slip strengthening was given, whereas, in other areas where the stress accumulation rate was not positive, both the stress drop and SE were set to zero. In the SSE regions surrounding the coupling zone, both stress drop and SE are considered to be small because pore fluid pressure is considered to be high, and normal stress is considered to be low (Shibazaki and Shimamoto, 2007; Matsuzawa et al., 2010). Under these conditions, Tsuda et al. (2024) were able to reproduce a megathrust earthquake (Mw 8.6) that ruptures three segments of the Nankai, the Tonankai, and the Tokai with the rupture initiation point set off the Kii Peninsula. The model by Tsuda et al. (2024) reproduced a large slip from off Shikoku to off Hyuga-nada. This is due to the coupled rupture of the Shikoku-oki asperity and the Hyuga-nada earthquake (1968) asperity. The rupture of the Nankai Trough earthquake may extend to the asperity of the rupture of the 1968 earthquake.

Several issues that should be considered when modeling megathrust earthquakes in the Nankai Trough are discussed. The first issue is whether dynamic rupture propagates to the regions where long- and short-term SSEs occur at depth; although strain is released in the SSE regions, the strength is low due to high pore pressure, and slow rupture may propagate. In the model by Tsuda et al. (2024), the SE is assumed to be zero, but finite values must be used. In this case, the slip must be very small in the shallow and deep regions. There is also a possibility that thermal pressurization (TP) may occur. In this case, a stress drop may occur even in the region where the stress accumulation rate is not positive, and a large slip may occur.