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The possibility of seismic slip in the shallow and deep extensions of the seismogenic zone in the Nankai Trough

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In the 2011 Tohoku earthquake, it is generally accepted that the strong shakings and large tsunamis are excited by large slip near the trench axis from the analysis of various observation data (e.g. Fujiwara et al., 2011). Also along the Nankai trough, deposits of huge tsunami have been found from the coastal lakes (Okamura, 2011). However, such tsunamis were considered to be caused by concurrent ruptures of asperities laterally located in the seismogenic zone so far.

Recently, deep sea vessel, Chikyu obtained core data which implies the seismic slip might propagate to the up-dip end of the subduction interface off Kumano along the Nankai trough (Sakaguchi et al., 2011). This suggests that have occurred in the Nankai trough, not only the Showa-type eqs., great eqs. similar to the 2011 Tohoku. While, from model calculations of seismic cycle, by nesting asperity with different fracture energy (hierarchical asperity), both the massive earthquake ruptures up to the trench axis, and the normal earthquake which ruptures only seismogenic zone, may occur in different seismic cycles (Hori et al., 2009). From the above, in order to reconsider the seismic potential along the Nankai trough, we must reevaluate the possible variation of earthquakes there.

We apply the hierarchical asperity model to Nankai trough. To regard the conventional seismogenic zone as a small fracture energy zone, L=5cm is assumed at 10-20km depth. While due to large L=10m in the shallower region, the shallow plate boundary near the trough is modeled as large fracture energy zone.

As results, two types of earthquake with the different value of 0.4 in moment magnitude occur alternately. Hereafter we refer smaller earthquake as S eq., and larger one is L eq.. The interval between S eq. and L eq. is about 170 years, and next S eq. occurs 203 years after the occurrence of L eq..

The S eq. has large slip along the conventional seismogenic zone from Tokai to Hyuga-nada region, and becomes almost similar slip distribution to previously proposed Hoei model (Furumura et al., , 2011). In contrast, during L eq., coseismic slip extends to near the trough axis, and also extends to deeper region until 35km depth where the interpolate coupling is generally considered to be released by occurrences of VLF tremors.

As for vertical deformation expected from slip distributions, for both types of earthquake, the coast of Tosa Bay subsides about 1m similar to historical earthquake. In other regions, hinge line is also placed almost along the Pacific coastline for both eqs.. In Osaka Bay and Setouchi regions, the amount of subsidence in L eq. reaches several meters, since large slip area is extended to deeper than S eq. as mentioned above.

According to the calculations of the tsunami propagation which take the coseismic uplift and subsidence into account, in the case of L eq., tsunami heights of several meters are expected at Setouchi. These amounts of expected tsunami height are comparable to those of the historical records for Hoei event collected by Matsuura (personal communication). On the other hand, in S eq. with a slip distribution similar to the conventional Hoei model, significant tsunami does not reach the Setouchi and Osaka Bay, contradictory to Hoei tsunami data. In addition, the L eq. also predicts a large tsunami at Ryujin pond in Oita Pref. where deposits have been found due to a giant tsunami.

Accordingly, L eq. is consistent with the several observed data which implies the occurrence of huge earthquake along the Nankai trough. However, in L eq., large slip area is distributed from the trench to deeper VLF tremor zone. Hence, it is still unclear whether tsunamis in the pond Ryujin and the Setouchi areas are excited only by local slips such as near the trough, or by large slips over the entire plate interface. We should conduct additional studies to detect the origin of large tsunami and limit the possible models of Hoei type earthquake.

Keywords: Tohoku Earthquake, Nankai Trough, hierarchical asperity, crustal deformation, tsunami