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A simple model reproducing complex behavior of a giant earthquake cycle

MITSUI, Noa[1*], SAGIYA, Takeshi[2]

[1]Earthquake and Volcano Research Center, Nagoya Univ., [2]Disaster Mitigation Research Center, Nagoya Univ.

The 2011 off the Pacific coast of Tohoku Earthquake is giant earthquake estimated as M9.0 and the source region is expanded from off-Miyagi to off-Fukushima. The magnitude is larger than expected one which is M7-M8 (e.g., The Headquarters for Earthquake Research Promotion, 2002). Some possible causes for reaching M9.0 are proposed in order to understand the mechanism of the earthquake occurrence. They are different on the points: 1) whether the moment of M9 is accumulated before the earthquake occurred, 2) what is the main cause of M9.0 (e.g., spatio-temporal change of frictional parameters, coseismic linkage of several asperities). However some interpretations are misled from the method of data analysis or numerical simulations.

Thus we propose a model based on a simple idea that earthquakes occur frequently at the boundary between asperity and non-asperity area because the incresting rate of the strain energy is large. From this point of view, off-Miyagi M7 source regions can be considered as the boundary not only in the depth direction but also lateral one, considring several data (past and 2011 seismic sources, interseismic activity including repeating earthquake, seafloor geometry, crustal structure, and interseismic slip deficit distribution estimating from GPS data). On the other hand, the source region of the 2011 off the Pacific coast of Tohoku Earthquake (mainly off-Fukushima region) can be assumed at lower incresing rate than that at off-Miyagi. We express this model based on the rate- and state-dependent friction law (Dieterich, 1979). The boundary between asperity and non-asperity in the depth direction is modeled changing the value of A-B from negative to positive, and we set smaller L (characteristic slip distance) at the off-Miyagi M7 source regions than the other surrounding regions in order to reproduce the reccurence of M7 earthquakes.

As the results, we reproduce the recurrence times, the source region, and the rupture propagation of M7 and M9 earthquakes. We analyze the spatio-temporal distribution of slip and shear stress change, and we understand that the moment release rates of M7 earthquakes are comparable to expected one from the plate convergence rate at the final stage of M9 cycle. This suggests that the slip deficit of the area seems to be completely canceled by only M7 events, and it can mislead understanding the whole image of the earthquake cycle using only the data in the last stage of the earthquake cycle. Moreover we analyze afterslip of the M7 events, and we find the area and the cumulated magnitude of the afterslips become larger at the later stage of M9 cycle. In the presentation, we will report the numerical simulation of crustal deformation using this earthquake cycle model.