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A plate boundary earthquake model with consideration on submarine active faults

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Active faults observed on seafloor along Japan Trench are resultants of repeated large earthquakes. We discuss on the relation between large earthquakes and their source faults based on a detailed active fault map along Japan Trench. Judging from the location and continuation of active faults in the earthquake source area, we consider that one of the extensive thrust faults which extends from off-Sanriku to off-Ibaraki for about 500km, is directly related to the source fault of the 2011 off the Pacific coast of Tohoku Earthquake.

The 2011 off the Pacific Coast of Tohoku Earthquake (Mw9.0) generated large tsunami with massive pulsating pattern of waves (Maeda et al. 2011). A leading hypothesis believed among many seismologists is that rupture of two extensive asperity patches surrounded by stable sliding area on the plate boundary generated the earthquake. One of the asperity patches in depth caused the strong motion and the other near the surface caused fault rupture along the axis of Japan Trench and generated gigantic tsunami. Large displacement ˜50m eastward and ˜7 to ˜10m upward was estimated from comparison of data obtained before and after the earthquake in 2004 and 2011 by multi-narrow beam bathymetric surveys across the trench (Fujiwara et al. 2011). Satake et al. (2011) explained the large tsunami height by simultaneous faulting on two different fault planes that fit with the above-mentioned asperities. Since most of the workers hypothesized without any doubt believed that the earthquake was caused by the fault ruptured up to the trench axis, existence of submarine active fault is rather overlooked so far. However, we consider the large displacement is due to landslide and do not find any extensive fault scarp on the trench axis.

We simulated pattern of seafloor deformation associated with the earthquake using a simple dislocation model for a single fault plane with uniform slip that dips 14 degree in depth and 33.6 degree beneath the tectonic bulge related to the extensive active fault. A result shows that an area of large uplift agrees more or less with the location of tectonic bulge with width of about 20km.

The record of tsunami first wave obtained by the GPS wave gage set on about 200m deep seafloor off Kamaishi on southern Sanriku Coast (Port and Airport Research Institute, 2011). The record suggests that after gradual sea-level rise of 2m during 6 minutes, acute sea-level rise of 4m took place within 4 minutes, and then sea-level abruptly dropped by 4m within 2 minutes. The length of pulsating tsunami wave is estimated about 17km from tsunami propagation velocity at 200m deep sea and total duration of pulsating pattern of tsunami, i.e. 7 minutes. This tsunami wave pattern resembles the pattern of seafloor deformation we calculated above.

We also simulate crustal movement and tsunami height along the Tohoku coast by an earthquake source fault model based the location of the submarine fault with fault-slip deduced from tectonic scarp height that is regarded as cumulative fault-slip. Our simulation explains the observed co-seismic subsidence and large tsunami height along the coast better than many other simulations based on various inversion models.

Based on these observations, we propose active fault model for plate boundary earthquake that large earthquakes are characteristically caused from submarine active faults in the island arc crust that overlap each other above the plate boundary in the narrow sense.

Keywords: plate boundary earthquake, asperity model, active fault model