Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

U03-02 Room:301A Time:May 20 09:30-09:55

Generation mechanism of the 2011 Tohoku-oki earthquake - what are resolved and what are left unresolved

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Beneath northeastern Japan, the Pacific plate subducts west-northwestward at a rate of ~8 cm/yr along the Japan Trench, which causes extremely high seismic activity mainly along the plate interface. Many large destructive earthquakes with M7.5-8 have occurred repeatedly along the megathrust beneath the Pacific Ocean. Seismic waveform inversion studies have shown that large slip areas of repeating large interplate earthquakes overlap each other, supporting the asperity model for the generation of earthquakes in this subduction zone (e.g., Yamanaka and Kikuchi, 2004). Long-term forecast of earthquake occurrence by Earthquake Research Committee of the Headquarters for Earthquake Research Promotion based on the records of large earthquakes for the last 100 years or so released a very high probability of occurrence of M7.5 class earthquake along the plate interface in the off Miyagi region. Seismic coupling coefficient at the plate interface east of northern Tohoku estimated from the last ~70 years data is ~25 %, while that at the plate interface east of southern Tohoku is ~10 % or less (e.g., Kanamori, 1977; Seno, 1979; Peterson and Seno, 1984; Pacheco et al., 1993). However, both backslip inversions of GPS data (e.g., Suwa et al., 2006) and small repeating earthquake analyses (Uchida et al., 2011) based on data for the last 10 years or more show much higher interplate coupling coefficients of about 70-80 %.

It is along this plate interface that the 2011 M9.0 Tohoku-oki earthquake, the greatest earthquake in the modern history of Japan, occurred. Its slip area extends about 500 km long and about 200 km wide with the average slip of roughly about 10 m, rupturing about two thirds of the megathrust east of the entire northeastern Japan arc. It caused severe damage to northeastern Japan; especially tsunami excited by this earthquake was huge and killed many people near the Pacific coast of northeastern Japan. It is particularly important for the mitigation of earthquake hazards to understand how and why such a great earthquake with magnitude 9.0 did occur along this plate boundary, since the occurrence of such a great earthquake there was not predicted in the report of the long-term forecast of earthquake occurrence by Earthquake Research Committee of the Headquarters for Earthquake Research Promotion.

In this presentation, I will try to discuss 1) what are resolved and what are left unresolved, 2) what were not known before the earthquake, 3) what were lacking in earthquake research, and 4) what sort of investigations and studies we need to do from now, in order to understand the generation mechanism of this great earthquake and to develop research on earthquake forecast.

Keywords: 2011 Tohoku-oki earthquake, generation mechanism of earthquake, interplate coupling, earthquake research