The 2011 great Tohoku-Oki (Mw9.0) earthquake and its seismological significance

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The 2011 great Tohoku-Oki earthquake is one of the most devastating earthquakes in Japanese history and is the greatest earthquake in its modern history. Mainly because of the extremely large and widespread tsunami, it caused severe damage to northeastern Japan especially near the Pacific coast; the number of death and missing amounts to about 20,000.

In northeastern Japan, the Pacific plate subducts beneath the North American plate at a rate of 8-9 cm/yr. This subduction of the Pacific plate causes extremely high seismic activity there. Many large destructive earthquakes with magnitudes of 7.5-8 have occurred repeatedly along the plate interface beneath the Pacific Ocean. Seismic waveform inversion studies have shown that large slip areas of the 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). The Headquarters for Earthquake Research Promotion of the Japanese government released a statement that there is a very high probability of occurrence of M7.5-class earthquake along the plate interface off Miyagi Prefecture by the long-term forecast of earthquake occurrence based on the records of large earthquakes for the last 100 years or so. Seismic coupling coefficient at the plate interface east of northern Tohoku was estimated to be approximately 25 %, while that east of southern Tohoku-Kanto approximately 10 % or less (e.g., Kanamori, 1977; Seno, 1979; Peterson and Seno, 1984; Pacheco et al., 1993). However, both back-slip 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 so showed much higher interplate coupling of about 70-80 % for these areas.

The 2011 great Tohoku-Oki earthquake occurred along this plate boundary zone. The rupture started at a point on the plate interface off Miyagi Prefecture, the area of very high probability of earthquake occurrence, but it did not stop within the anticipated earthquake source areas. As a result, the rupture area of the earthquake extends about 500 km long and about 200 km wide with the largest slip exceeding about 50 m. The earthquake ruptured about two thirds of the seismogenic plate interface east of the entire Tohoku-Kanto area. In addition to the dense nationwide seismic and GPS networks installed in the inland of the Japanese Islands, intensified ocean bottom observations have been done in the area off Miyagi Prefecture

because of high probability of earthquake occurrence there. Data from these high-resolution dense observation networks together with those from global observation networks provide a unique opportunity for deeper understanding of this great megathrust earthquake. For example, data from the ocean bottom crustal deformation observations provide evidence for an anomalously large slip at the shallow plate interface near the trench axis, suggesting the need to revise a widely accepted conceptual model that the shallow part of the subduction plate boundary is a stable-sliding zone, not a seismogenic zone.

It is particularly important for the mitigation of earthquake hazards to understand how and why such a great megaturust 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 long-term forecast by the Japanese government. In this presentation, general features of seismic observations in Tohoku, the characteristic of the Tohoku-Oki earthquake and its seismological significance will be discussed.