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Seafloor movements associated with the 2011 Tohoku Earthquake detected by GPS/acoustic geodetic observation

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The Hydrographic and Oceanographic Department, Japan Coast Guard, have been developing precise seafloor positioning systems using the GPS/acoustic combination technique under technical cooperation with the Institute of Industrial Science, the University of Tokyo and carrying out campaign observations along the major trenches in the Pacific Ocean, such as the Japan Trench and the Nankai Trough. The primary purpose of these observations is to detect and monitor the crustal deformation caused by the subduction of the oceanic plate near the plate boundary where huge earthquakes repeatedly occur.

On 11 March 2011, a large interplate earthquake [Mw = 9.0] occurred at the plate boundary off Miyagi Prefecture, northeastern Japan. Various studies have been under way to understand the mechanism of occurrence of this earthquake. For example, the Geospatial Information Authority of Japan (GSI) has reported coseismic displacements on land, on the basis of the dense GPS network. The largest displacement has been detected at the Oshika peninsula, amounting to about 5 m toward ESE and about 1 m downward.

Because the Oshika peninsula is located about 130 km away from the epicenter of the earthquake, it is preferable to measure crustal movements closer to the focal regions, that is, on the seafloor, to better constrain the focal mechanism of the event.

In order to monitor crustal movements offshore, we have been carrying out seafloor geodetic observations. Five sea-floor reference points were installed off the Tohoku region between 2000 and 2004 with campaign observations carried out three times a year on average. After the event, we conducted observations at these sites. Comparison between before and after the event yielded coseismic displacements of 5 to 24 m toward ESE and ?0.8 to 3 m upward. In particular, at reference point near the epicenter, we detected a huge coseismic displacement of about 24 m toward ESE and about 3 m upward. This is more than four times larger than that detected on land.

These results suggest that slip on the plate boundary near the trench exceeded the 20- to 30-m level estimated as a maximum by the terrestrial data, because slip on the plate boundary should be much larger than displacement of the sea floor.

With only five observation sites, we may not be able to constrain the detailed feature of focal mechanism, but we believe that the coseismic displacements obtained offshore in this study will provide far better constraints than only the terrestrial data in inferring a fault model for this event.

Keywords: Seafloor geodetic observation, the 2011 Tohoku earthquake