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Research on improved observation of seafloor crustal movement under the DONET program - progresses and problems -

Hiromi Fujimoto[1*], Motoyuki Kido[1], Yukihito Osada[1], Ryota Hino[1], Satoshi Miura[1]

[1]RCPEV, Grad. Sch. Science, Tohoku Univ.

1. Introduction

A seismic network Hi-net and a geodetic network GEONET, extended in Japan after the 1995 Kobe Earthquake, are epoch-making geophysical networks for monitoring crustal activities. Most of large earthquakes, however, are subduction-induced earthquakes and occur in the offshore area outside of the networks. Therefore, alternative seismic and geodetic networks are necessary over the focal area of the coming large earthquakes. The DONET program is an important step for the marine seismic network. A similar forward step is necessary for a marine geodetic network. GPS/Acoustic seafloor positioning is the most probable method for observation of seafloor crustal movement in a wide area. Progresses attained by the Tohoku group under the DONET program and key problems will be reported.

2. Results

The Tohoku group used a buoy towed from a ship for the GPS/A observation, trying to keep the buoy above the center of the precision acoustic transponder (PXP) array. The following results have been attained.

(1) Scientific results

Large crustal movement associated with 2004 earthquake off Kii Peninsula was detected by seafloor geodetic observation for the first time (Kido et al., 2006). Crustal movement off Miyagi Prefecture is also estimated.

(2) Improvement in data analysis

Assuming a layered velocity structure, Kido et al. (2007) developed a scheme of seafloor positioning for GPS/A observation using a buoy whose position is difficult to precisely control. Vertically averaged acoustic velocity estimated by the scheme agrees well with oceanographic observation. Results of seafloor positioning show, however, that velocity structure varies laterally. Then Kido (2007) proposed a method with 5 PXPs to estimate the horizontal gradients, but a preliminary experiment could not demonstrate the validity of the method.

(3) Improvement in the hardware system

a) Sampling frequency of GPS positing was increased to 10 Hz from 1 Hz (Osada et al., 2008), and then the effect of motion of the buoy was accurately corrected with additional data from a motion sensor (Kido et al., 2008).

b) Revised models of the buoy for GPS/A observation were developed for future moored-buoy observation, and examined through sea trials (Fujimoto et al., 2008).

c) We selected three types for the moored buoy, and evaluated them considering the effect of water currents of 1 to 3 knots.

d) Three PXPs were successfully recovered with an acoustic release mechanism for an ocean bottom seismometer about 4.5 years after their deployment (joint research with ERI, Univ. Tokyo). The success suggests the probability of recycled use of PXPs.

e) By using an ROV, we visually confirmed stable attitude of 10 PXPs that had been deployed near the focal area of 2004 M7-class earthquakes off Kii Peninsula (jointly with Nagoya Univ. and

Japan Coast Guard).
f) A method for monitoring local crustal movement was also examined. Results of horizontal acoustic ranging on the seafloor at distances shorter than 1 km showed long term stability of 1 cm (RMS) for about four months.

3. Key problems
Comparing the GPS/A observation with GPS observation with the GEONET, the following serious differences exist: more than one order in the precision of positioning, about two orders in the number of observation sites, and sampling intervals, continuous and real-time observation versus once or twice in a year. Considerable improvements are required in repeatability of positioning, reduced observation time for positioning, continuous observation, and reduced time for data analysis.
Lateral variation in the velocity structure in the ocean degrades the seafloor positioning and results in long observation time for averaging out the effect. A breakthrough in the problem is a key to cope with the problems mentioned above. Important points will be systematic observation of the lateral variation and modeling of the ocean dynamics combined with the DONET.

Keywords: Observation of seafloor crustal movement, seafloor geodesy, GPS/A, DONET, Tonankai-Nankai, Kumano-nada