Estimation and correction for the effect of sound speed variation on GPS/Acoustic seafloor positioning

Yukihito Osada[1]; Hiromi Fujimoto[2]; Satoshi Miura[3]; Aaron Sweeney[4]; Toshihiko Kanazawa[5]; Shigeru Nakao[6]; Shin'ichi Sakai[7]; John A. Hildebrand[8]; C. David Chadwell[9]

[1] ERI, Univ. Tokyo; [2] AOB, Tohoku Univ.; [3] RCPEV, Graduate School of Sci., Tohoku Univ.; [4] RCPEVE,Tohoku Univ.; [5] ERI, Tokyo Univ; [6] ERI, Univ of Tokyo; [7] Earthquake Research Institute, Univ. of Tokyo; [8] MPL, SIO, UCSD; [9] UCSD, SIO, MPL

We from three institutions jointly developed a precision, digital acoustic ranging system for deep seafloor. Scripps institution of Oceanography, University of California, started a GPS/A experiment for monitoring crustal deformation on the southeastern slope of Hawaii Island by using the same acoustic system, and deployed 7 precision acoustic transponders. The area is on a long submarine slope, and ocean tide may bring about daily variations in sound speed structure. These features are similar to those of subduction zone. We therefore jointed the first cruise of the experiment in 2000 to examine the newly developed acoustic system and the effect of sound speed variations. We added one PXP (DJ-1) and carried out GPS/A observation by using 3 PXPs (deepest triangle included DJ-1) deployed at the depth 2500 - 4500m.

A system for the GPS/A observation consists of three components: GPS component, underwater component, and an interface between them. We set 3 GPS antennas on the ship and a reference on land at Hivalt at an altitude of about 1250m. The baseline length for kinematic GPS positioning was ca. 50km. We calculated a three dimensional position of an under-hull acoustic transducer based on the positions of GPS antennas and measurements of relative positions with a total station.

GPS / Acoustic positioning is carried out in two steps; the first step is to estimate the location of horizontal position of each PXP. We collected GPS/A data along a circle around each PXP with a fixed sound speed profile obtained from CTD observation. We calculated an acoustic range between the under-hull transducer and a PXP along a ray path based on the speed structure. Difference between the observed and calculated two-way travel time is attributed to an error in the 3-dimensional position of the PXP. The most probable position of each PXP was so estimated as to minimize the difference.

The second step is GPS/A observation to get a precise horizontal position of PXP array center. Considering the different water depths of the PXP, we tried to keep the ship position near the point where the ray angle to each PXP was the same. Then the ray path to all the PXPs have the same range within the time-varying surface layer of the ocean. The residuals of the travel time to each PXP amounted to +/- 0.7m with a fixed sound speed structure. The speed structure was updated with the CTD observations, and the residuals decreased to +/- 0.4m. The large residuals were fairly well canceled in the position of the array center of three PXPs.