GPS/Acoustic submarine positioning using a small buoy in the subduction zone off northeastern Japan

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GPS/Acoustic positioning is combination of kinematic GPS (KGPS) positioning between land and sea surface, and acoustic ranging between the sea surface and the seabed. To cancel the influence of the sound velocity variation, 3 precision acoustic transponders (PXPs) are deployed for one GPS/acoustic positioning site forming an equilateral triangle, then the location of the center of the PXP array is measured above the center.

We developed precise underwater acoustic ranging system for medium water depth that is simple enough to use a signal with a single frequency of 10kHz. We calculate the two-way travel time between the sea-surface transducer and a PXP by taking correlation between the transmitted and the received signals. The acoustic signal consists of a set of pseudorandom noise code, and a unit of the code is six waves of 10kHz sine waves with a phase shift of 0 or 180 degree according to the code. This system is hardly influenced by the Doppler effect according to vertical motions of the transducer. We use the software GIPSY-OASIS II for KGPS analysis. Although we plan to use acoustic transducers equipped on the hull of low noise research vessels in the future, there are some difficulties for the moment. Therefore, we developed a towed buoy with 3 or 4 GPS receivers and an acoustic transducer. During the experiments, we deployed XCTD probes to measure vertical distribution of salinity and temperature.

We carried out GPS/Acoustic positioning off Miyagi Prefecture in August and October, 2003, and in August 2004. Ship time was limited in 2003, and we allotted time mainly to estimate the position of each PXP with the buoy shifted around each PXP. In all the experiments, we determined the center of the PXP array using the data collected near the pre-defined center.

When we estimated the position of a PXP array in 2004, it became clear that the travel time residuals were dependent on the distance of the buoy from the array center. We corrected for this by multiplying a coefficient to the sound velocity obtained from XCTD data. Since this correction was committed only in the direction which decreases the velocity by 0.1-0.2%, the acoustic velocity from XCTD may have a systematic offset of 0.1-0.2%. In positioning observation in the Miyagi offing in 2003 and 2004, the positioning accuracy based on arrays is 9-13cm, when it calculates for every shot. If the error is random, an error can be reduced by increasing observation time. However, since the error by sound velocity change is changing systematically in about 2 hours, it is necessary to suppress the influence. If the average in every hour which is the half-wavelength of the cycle of a system error is taken, positioning accuracy will be set to 6-11cm, and will approach a normal distribution. The accuracy of the average value of two observations in 2004 is 2-3cm, and both are in agreement. We confirm displacement for northwestward from 2003 to 2004. This is roughly corresponding to the displacement vector of one year calculated from the model of Suwa et al., (2004).

A future improving point is a method of correcting the sound velocity which changes systematically. From an analysis side, sound velocity is corrected based on the common trend of range residual when observing on the center of the array, and it is possible to remove the systematic error by a buoy shifting from the array center. It is possible by shifting the position of a buoy fixed time from a center periodically during observation at the center from an observation side to estimate sound velocity from the relation between an apparent array position and the position of a buoy.