Method of data analysis and error estimations in the GPS/Acoustic seafloor geodetic observation

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We have been developing a system for precise seafloor geodetic observation with the GPS/Acoustic combination technique and deploying about fifteen seafloor reference points on the land-ward slope of the major trenches around Japan, such as Japan Trench and Nankai Trough. The primary purpose of our observation is to detect and monitor the crustal deformation caused by the subduction of the oceanic plate near the plate boundary. At each point, we carry out a campaign observation with several days using a survey vessel and revisit it once or twice a year. In this presentation, we summarize the methods of data analysis in this technique and present some positioning results with error estimations.

Method of data analysis

The procedure of data analysis consists of following three different stages as a whole: (1) kinematic GPS (KGPS) analysis, (2) acoustic wave analysis to obtain round travel time between the transducer on board and seafloor transponder, (3) a combination of results from (1) and (2) to get the precise seafloor station position.

The KGPS analysis is made by the software IT developed for the long baseline positioning by Dr. Colombo of NASA/GSFC. The acoustic wave analysis is carried out for determining precisely the onset time of the received signal by applying the M-series cross-correlation technique. The final analysis to get positions of seafloor stations is performed by a linear inversion method based on the least squares estimation.

Error sources and their estimations and corrections

In the last analysis (3), undersea acoustic velocity structure must be given to convert travel times of acoustic wave into travel ranges. However, it is difficult to get the acoustic velocity structure in the seawater from observations such as CTD and XBT measurements with accuracy sufficient to our purpose, which is one of major error sources in this technique. Therefore, we are trying to estimate the acoustic velocity errors from the travel time residuals in the positioning analysis. By taking a proper strategy, the correction of acoustic velocity errors based on this estimation improves the final positioning result significantly.

Errors included in the KGPS results are another major error sources in the seafloor station positioning. A useful index, though not rigorous, on the amount of errors included in the KGPS positioning is the low frequency time variation of the height solution after correcting the geoidal and tidal height variations of the sea surface. Because the height of the GPS antenna on the vessel is basically bound to the sea surface in the long period range, the corrected height variation as above should be close to flat in time if the positioning is accurate. With this method, we sometimes find temporary drifting height errors with several tens of centimeters in our KGPS results. The KGPS results including such errors should be removed from input into the final positioning analysis.

Repeatability of the seafloor station positioning

Repeatability of the seafloor station positioning was examined using observation data acquired at the Off-Miyagi reference point. For this purpose, we divided the data from a campaign epoch into subsets with one or multiple observation days. We then compared the coordinates of the seafloor stations determined from different subsets. The result shows a repeatability of several centimeters in the horizontal components of the obtained positions. However, there found a case where the comparison shows discrepancies of several tens of centimeters between determined coordinates from the different subsets. Examination on the cause of the error is being carried out. The comparison between determined coordinates from different campaign epochs at the Off-Miyagi reference point shows a temporary position variation consistent with the expected intraplate deformation in this region. In the presentation, results from other seafloor reference points are also reported.