GPS/ACOUSTIC COMBINATION TECHNIQUE

Seafloor Geodetic Observation

A system for precise seafloor positioning using GPS/Acoustic Combination Technique has been developed by the Hydrographic and Oceanographic Department, Japan Coast Guard, in close collaboration with the Institute of Industrial Science, University of Tokyo. Accuracy of this positioning achieves several centimetres. Based on the system, seafloor reference points have been deployed on the landward slope of major trenches such as the Japan Trench and Nankai Trough to monitor crustal movement caused by subduction of the Oceanic Plate. Observations of undersea crustal movement will provide invaluable information on the physical state of the rupture zones of huge earthquakes distributed around the plate boundary. Efforts to improve the described system are still ongoing.

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Primary Objective
To know which area of the plate boundary plane is sticking and to what degree is very important. This information is theoretically present in observed crustal movement around the focal region. In Japan, the dense land GPS network deployed by the Geographical Survey Institute, which consists of more than a thousand GPS stations, renders a significant proportion of observed data for this purpose. However, because there is no data in the offshore area, resolution on the undersea rupture zone of huge earthquakes is quite poor. The primary objective of our project is to compensate for this important blank area of observations with our technique.

Observation System
The GPS antenna and the transducer on board, which are above and in the seawater, are installed at the top and the bottom respectively, of an observation pole with the length of about 8m fixed at the stern of the vessel. An acoustic signal is transmitted from the onboard transducer and the seafloor station called the mirror transponder (Figure 3) receives the signal and sends it back after a certain time interval. The onboard transducer receives the returned signal and records it together with the transmitted ones. In order to measure the precise relational position between the GPS antenna and the transducer, information on the tilt and azimuth of the pole is measured with a motion sensor. Other than these, the temperature and salinity of the seawater are measured with a CTD and XBT at the proper time interval to get acoustic velocity for transforming a travel time into a range.

Coast Guard Observation
Figure 4 shows the distribution of the seafloor reference points already deployed. We have now set up more than ten reference points, mainly on the landward slope of the major trenches. For each point, four mirror transponders were installed in a square with their corners pointing to north, east, south and west. Water depths of these points range from about 400 to 2,400 metres. Japan Coast Guard survey vessels are used in the observation. Acoustic observation is carried out whilst vessel drifting to avoid noises coming from a driving engine. This makes it difficult to control a geographical distribution of observation lines. On board observers should try to make the geographical distribution of data most favourable, considering the direction of wind and water flow.

Major Error Sources
Although an accuracy of several centimetres level has been attained, this technique has many error sources, which may make the result unstable. We here expand upon two major ones. First, long-baseline kinematic positioning often carries substantial errors, like a drift of several tens of centimetres. Satisfactory results can be obtained in many cases where observation conditions are fairly good but our practical observation on-board sometimes degrades the data quality. Another error source stems from the acoustic velocity structure. The performances of observation instruments such as CTD and/or XBT do not come up with our required accuracy of centimetres level. Moreover, it is practically impossible to cover spatial and temporal variations of the acoustic velocity structure by observations. Therefore, making some reasonable estimation and correction of the effective velocity from observed data is necessary, which is a key issue in improving accuracy of the seafloor positioning. Additionally, in marine observation we suffer from many practical problems such as a deformation of the observation pole and data insufficiency due to ill weather conditions, requiring our further patient efforts.