Lateral heterogeneity of sound speed in sea water for accurate location of ocean-bottom positions

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1. Introduction

We have developed a system for observing seafloor crustal deformation. This system combines GPS and acoustic ranging techniques. In this system, we first determine the position of an observation ship by kinematic GPS ; next, we locate an ocean-bottom transponder by measuring its distance to the seafloor transponder by ultrasonic ranging method. The location of the seafloor station is thus located eventually relative to onshore reference sites. In this talk we discuss effects of lateral heterogeneity of the sound speed in sea water onto the location of a seafloor station.

2. Simultaneous CTD measurements with two ships

We evaluated lateral heterogeneity of the sound speed in sea water for accurate determination of an ocean-bottom position. If we carry out CTD measurements with a single ship, we cannot distinguish spatial and temporal variations from the measurement results. We therefore made simultaneous CTD measurements with two ships, Asama of Mie Prefecture Science and Technology Promotion Center, and Wakashio Maru of the Nippon Salvage Co., Ltd., at the Kumano Basin on July 16th and 17th 2003. The distances between two ships are 2, 1, 0.6, 0.3, and 0.15 nautical miles. The two ships were aligned parallel or orthogonal to the direction of ocean current. The CTD instruments used are SBE-19 & SBE-911plus of Sea-Bird Co., Ltd.

3. Spatial and temporal changes

The spatial variation is large at depths above 600 meters. It increases with the distance between two ships. It is negligible when the distance between two ships is 0.15 nm. The spatial change is up to 3 m/s when two ships were aligned parallel to the direction of ocean current, and up to 7 m/s for orthogonal direction.

The daily variation in sound speed reaches up to 8 m/s even for a distance 0.15 nm between the two ships, which is significantly larger than 5 m/s observed in the Suruga Bay [Tadokoro etc, 2002].

4. Mislocation of ocean-bottom position caused by variations of the sound speed

The data used in this calculation are eight simultaneous CTD measurements and a pair of the data set measured at the two sites with the separation of 0.15 nm. Also CTD measurements at twenty-three sites in the north Kumano Basin from July 14th 2003 to July 18th 2003 are included in the above dataset. We obtain 1-D and 3-D models of sound speed of the sea water from the above dataset. We calculate arriving points of ray path at the ocean bottom for a pair of sound speed models. The differences in arriving points between the two models are 10-80cm and 100-150 cm. On the basis of the results we evaluate the effects of the temporal and spatial variations on the location error of a sea-floor position.

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