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Numerical experiments to figure out the cause of positioning error in measurements of ocean crustal deformation.

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We have developed a seafloor positioning system for observing seafloor crustal deformation using combination of acoustic ranging and kinematic GPS techniques. This system consists of an observation vessel and seafloor transponders. In each observation site, three transponders are deployed on the seafloor, which positions are measured using travel time of acoustic signals which generated and received by the surface vessel. Using this system, we have achieved an accuracy of about 3-5 cm of horizontal positioning in each observation. We solve the equation system for travel time of acoustic signal and get the position of the transponders as well as temporal variation of sound speed structure. The accuracy of the positioning is affected by sound speed variation as well as other observation errors in kinematic GPS, vessel's attitude measurement, and detection error of acoustic signals.
To estimate how and to what degrees these errors affect to the positioning results, we conducted some numerical experiments as follows.
First we gave the positions of the three transponders and trails of surface vessel. Then we made several variation patterns of sound speed structure. Some were designed to reproduce actual structure and others to be expanded members to understand the relationship between the variation manners and the positioning errors. Next, we calculated travel-times of the acoustic signals between the given transponders and the vessel trails. These numerical observations were done for evaluating the contribution of following four elements.
(1) Temporal scales of sound speed variation
(2) Amplitude of the temporal variation
(3) Coherence between temporal variation and the trails
(4) Difference from horizontal layered structure
Next we solved the synthetic data to get the transponder positions. As a result, first we found that short term variations affect to the result more than long term ones do. Next we found that the coherency between the temporal variation of the sound speed and the ship position does not make the solution worth. This is because the variation coherent to the ship position had a very long time scales than the compared temporal variation.
The most important thing in the result of numerical experiment is that the lateral variation (difference from horizontal layered structure) of the sound speed affected to the accuracy more seriously than any temporal variations. Sound speed variation of 0.05 % by lateral change made solution as 5 times uncertain as the solution for the data with same degree of variation by horizontal layered.
In the real ocean observations, we know that the sound speed structure changes laterally and the amplitude of the variation cannot be neglected. It suggests that we should modify the analysis model more fit to the nature of the sound speed structure. This will lead us to achieve better accuracy.

Keywords: acoustic ranging, sound speed structure, numerical experiment, temporal variation, spatial variation