Analysis for GNSS/acoustic ocean bottom crustal deformation considering the heterogeneity of sound speed structure in ocean

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Observation for ocean bottom crustal deformation by GNSS (global navigation satellite system) acoustic method is monitoring long-term movements of transponders fixed on seafloor by acoustic ranging. We estimate the transponder position for each observation by vessel with the assumption that the relative position between transponders does not change temporally. Thus, precise estimation of the displacement needs having correct array shape.
The main factor of positioning error is temporal and spatial variation of travel time in ocean. Temporal variation is caused by the tide with a cycle of 12-24 hours and by the inertial gravity wave with a cycle of several 10 minutes. With the assumption that the transponder position is fixed during observation, the long-term variation can be estimated easily and the short-term variation cannot be cause of bias positioning error because its effect is included in the observed travel time as noise. The spatial variation is caused by the temperature, pressure, and salinity. The vertical gradient can be obtained by CTD (conductivity, temperature, depth profiler) measuring. Main factor of horizontal gradient is the temperature gradient which is generated significantly in the area near the Kuroshio current. We considered that the horizontal gradient has largest effect on the positioning. Then, we developed new estimation method considering both temporal and spatial variation of sound speed.
New method assumes that the horizontal sound speed structure has constant gradient. We applied this method to the observation point off the coast of Ashizuri and Kumano and compared the array shape estimated by new method and one considering only temporal sound speed variation. The result shows that the transponders where the sound speed is faster is estimated to be shallower. Making theoretical travel time small for the transponder where the sound speed is faster needs to make the propagation distance short. Since the ranging is operated on the circular route around the array, horizontal position cannot be biased to decrease the average of residual of travel time. That is why the position is estimated to be shallower. Thus, the accurate positioning needs considering the horizontal gradient of sound speed. We also discovered that the ship track has effect on its accuracy.

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