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Development study of sea-bottom crustal deformation measurement system: Main results and problems

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Our group has developed a system for observing sea-floor crustal deformation through combining the kinematic GPS positioning and acoustic ranging techniques. We have already started repeated observation of sea-floor crustal deformation with the system. Followings are the main results of the development study of this system:

Result-1) Horizontal displacement caused by off-shore earthquakes
We successfully observed the co-seismic displacement at the 2004 Off-kii peninsula earthquake (M 7.1 and 7.4). We observed also a significant co-seismic displacement caused by the 2009 Suruga Bay earthquake (M6.5). It is, however, difficult to derive any scientific discussion, for instance fault model of this earthquake.
Result-2) Steady horizontal displacement
We observed steady crustal deformation caused by the plate subduction at the Kumano Basin and the Suruga Bay.
Result-3) Temporal variation in sound speed structure
We acquire travel-time data of the acoustic signal through our system, and we need sound speed structure in the ocean for converting the travel-time to distance. We performed a moored observation with a temperature-depth sensor at the Suruga Bay, and found relatively short period temporal variation in water temperature. We, therefore, developed an algorithm which can estimate the correction coefficient of sound speed in the positioning procedure to correct the temporal variation in water temperature.
Result-4)
We simultaneously performed CTD measurement at two points in the Kumano Basin. The result shows that the sound speed has spatially varied up to 0.034 % per 2 nautical miles on the line perpendicular to the Kuroshio. We also performed acoustic ranging test with two sea-surface acoustic instruments on both an observation vessel and a small moored buoy in the Suruga Bay. We found that the spatial variation in sound speed was up to 0.01 % in the region of half nautical miles. In addition, positioning accuracy tens to be low when the surface water temperature gradient becomes large. We, therefore, develop an algorithm which can be estimate also the spatial variation in sound speed with acoustic ranging data recorded with two sea-surface acoustic instruments. It is confirmed that the algorithm works well through a numerical simulation.

The following integrations are necessary for our system: shortening observation and time for analysiss, and integration of positioning. We need the observation period for 2-3 days to average the temporal variation in sound speed. It is necessary to be shortening the observation period to half to one day. The positioning accuracies for each epoch, which depends on the condition of sound speed variation, are 1-5 cm in the present status; the accuracy of displacement velocity is 2 cm/year trough the repeated observation for 2-3 years. We need to integrate the accuracy to 1cm for each epoch in any condition, and to about 1cm/year for displacement velocity estimation through one year repeated observation to undertake the sea-bottom crustal deformation measurement at multi stations for wide ocean area. We need to estimate and/or correct the spatial variation in sound speed structure. For this purpose, it is necessary to develop a new system with multi, about five or more, sea-surface acoustic instruments. It is also necessary to test usefulness of kinematic GPS positioning using the ultra-rapid ephemeris to be shortening the time for analysis.