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Layout of buoys and seafloor transponders for next-generation measurement system for ocean floor crustal deformation

Tsuyoshi Sakata[1*], Ryoya Ikuta[2], Keiichi Tadokoro[1]

[1]Environmental Studies,Nagoya University, [2]Faculty of Science, Shizuoka University

We are developing a geodetic method of monitoring crustal deformation under the ocean using kinematic GPS and acoustic ranging. We deployed benchmarks on ocean floor and determine the positions of them by acoustic ranging from vessel whose position is determined by kinematic GPS technique. Ultrasonic signals are generated from the surface vessel drifting over the benchmarks that replies the signals. Both sound speed structure and the benchmark unit positions are determined simultaneously using a tomographic technique from the two way traveltime of the ultrasonic signals.

We repeatedly carried out measurements at several sites around Nankai trough, South eastern part of Japan. Now the horizontal repeatability is about 3 cm. Although a few measurements in one year enable this repeatability to detect stable deformation rate of the crust due to subduction within few years, unstable temporal variations or faint changes cannot be detected. To monitor the focal area of coming plate boundary earthquakes, real-time monitoring is desirable.

Therefore, we are designing a moored buoy-based next generation measurement system, with which we can continuously monitor the ocean floor crustal deformation.

In the new system, buoys have all the functions which the ship has in the present way. But we need to consider that the positions of the buoys are controlled not by us but by current. We can control only the area of drifting by designing the length of the mooring cables and the buoyancy of the buoys. If we want to make the buoy stable around one point, we can make the cable short but we must make the buoyancy large to avoid sinking by the current, which requires more cost. An appropriate designing of length of the cable and buoyancy is very important.

We theoretically investigated the relationship between buoy-transponder geometry and the accuracy of transponder positioning. We assumed a system consisting of combination of three transponders and three buoys. We calculated the joint probability density function (j-pdf) of the weight center location of the benchmarks, which were called from three buoys in half space homogeneous sound structure, from the synthesized travel time. We defined the FWHM for the peak of j-pdf as an accuracy of the positioning, and then calculated this accuracy with various depths of the benchmarks and geometries of the measurement system.

As a result, we understand relationship between the accuracy of benchmark positioning and the configuration as follows:

1. The appropriate expanse of the benchmarks is about square root of 2 times of the depth. 2. The two triangles by benchmarks and the buoys are preferable being staggered. 3. The accuracy of the benchmark positioning can be kept in the range of 10% worse than the best. 4. If the buoy configuration distorts, 30% shortening of the length of the side makes the accuracy of the positioning 40%worse.

The results suggest that the benchmark positioning accuracy is less robust with distortion of the buoy configuration than with simple shift keeping their configuration. We should design the length of the cables and buoyancy of the buoys to keep the horizontal motion of the buoys not to distort the triangle more than 30% to keep the accuracy in the range from 0 to 40% worse than the best one.

In this study, we investigated the accuracy on assumption that the velocity structure is half-space homogeneous. In addition, we should check up the appropriate number and geometries of the buoys in the case which sound structure changes in space as well as in time.

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