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

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We are developing a geodetic method for 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.Both sound speed structure and the benchmark positions are determined simultaneously from the two way travel time of ultrasonic signals.

We repeatedly carried out measurements at several sites around Nankai trough, South western part of Japan. Now the horizontal repeatability is about 1-5 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 slight changes cannot be detected. To monitor the focal area of anticipated plate boundary earthquakes, lower repeatability error is desirable. The most effective factor of that is a temporal-spatial variation of sound speed structure. In the measurement system we are taking, we can average spatial variations of sound speed structure, though, it also includes temporal variations. We are planning to install a moored buoys-based next generation measurement system using tomographic technique as a method of dividing temporal and spatial variations of sound speed structure completely.

Therefore, we are designing a moored buoy-based next generation measurement system.But we need to consider that the positions of the buoys are controlled 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 composed of three transponders installed at a depth of 1000 m and three buoys and also set buoy-transponder geometries were equilateral triangles. The length of a side of them was 2000m.We assumed the sound speed structure as two layers.We defined 'initial sound speed structure (ISSS)'on which the value of sound speed in first layer (0-100 m in depth) was 1523 m/s and it in second layer (100-1000 m in depth) was 1486 m/s.Then we also set another sound speed structure with 99.98% of the value of sound speed on ISSS to consider horizontal spatial variations of sound speed structure. We calculated travel-time using these two structures depending on positions of buoys.We calculated the joint probability density function (j-pdf) of the weight center location of benchmark from the synthesized travel time.We calculated the positioning accuracy, the FWHM for the peak of j-pdf, with various geometries of the measurement system.We also evaluated this accuracy in X, Y, and Z components.

The results show the following relationship between the accuracy of benchmark positioning and the configuration:

(1) If the weight center location shifts 1000 m from the best position, the accuracies in X and Y components can be kept in the range of 25 % worse than the best solution.

(2) If the buoy configuration distorts, 40% shortening or lengthening of the length of side makes worse the accuracy by 10 %.

(3) In both simple horizontal shifts of buoys and the distortion of the buoy configuration, the ratio of the deterioration of accuracy in Z component is larger than that in another two components.

Taking the accuracy in Z component into account, the results suggest that the benchmark positioning accuracy is less robust with simple shift keeping their configuration than with distortion of the buoy configuration. And (3) also agrees with the fact that our real measurements show the horizontal error is better than the vertical error.

Keywords: Buoy, Ocean floor crustal deformation, Acoustic ranging, GPS, Tranceducer