Evaluation of the error propagation in GPS/A measurement using a moored buoy

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Tohoku University, Japan Agency for Marine Earth Science and Technology (JAMSTEC), and Japan Aerospace Exploration Agency (JAXA) have co-developed a continuous observation system for horizontal and vertical crustal deformation and tsunami using a moored buoy (Takahashi et al., 2014). The third sea-trial has been carried out in the supposed source region near the Nankai Trough. A seafloor transponder array is installed on the depth of 3 km which consists of six transponders forming a ~3 km-wide triangle. The target accuracy in horizontal positioning of this system is on the order of 1 m to detect the seafloor deformation associated with a M8-class earthquake.

The buoy in the system (1) has difficulty to keep a fixed point and (2) is often located along the circumference of 4 km-radius due to the mooring cable is longer than the water depth by 1.5 times. These factors are thought to have an influence to the array positioning as (1) the systematic error due to an error in array geometry (relative positions of individual seafloor transponders) and (2) the larger error than those near the array center. However, the error propagation in the buoy system has not been ever clarified quantitatively. Therefore, we examined the error propagation in GPS/A measurement using a moored buoy through numerical experiments. Then we proposed how to improve the accuracy of the system based on the result of the experiments.

Possible error sources in the buoy system are a vertical buoy position error in kinematic Precise Point Positioning (PPP, Zumberge et al., 1999), an attitude error, which is equivalent to a horizontal buoy position error, traveltime error, and array geometry error. We estimated the array position with the above error and synthetic data on the grid in 10 km square every 100 m. We assumed the errors as following.

1. A vertical buoy position error in post processing kinematic PPP: normal distribution (1 σ: 4 cm, Ohta et al., 2006)
2. Travel time error (false picking by 1 peak and picking resolution): uniform distribution (±0.1 ms) and normal distribution (±0.01 ms).
3. Array geometry error: normal distribution (1 σ: horizontal 15 cm, vertical 25 cm)

The largest errors in array positioning amount to 1. 10-20 cm, 2. 30-40 cm and 3. 50-~150 cm for each error source. Amount of the propagated error is linearly proportional to the error sources. The numerical experimental results generally agree with the array position error in the second trial. Array geometry error is found to be most significant. The array geometry must be determined with a few cm-accuracy to achieve the final positioning accuracy on the order of 1 m in the future.

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