Stability test to apply kinematic Precise Point Positioning to the routine analysis of the GNSS-A seafloor positioning by Japan Coast Guard

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In the Hydrographic and Oceanographic Department of the Japan Coast Guard (JHOD), global seafloor positioning technique using acoustic wave (GNSS-A; Global Navigation Satellite System –Acoustic ranging combined technique) has been developed since the early 2000s and provided geodetic results in the frontal area of the subduction zone (e.g., Fujita et al., 2006 EPS; Yokota et al., 2018 Sci. Data). It revealed the coupling distribution on the plate boundary in the Nankai trough (Yokota et al., 2016 Nature) as well as the postseismic deformation map in the off-Tohoku region (Watanabe et al., 2014 GRL). Just after the 2011 Tohoku-oki earthquake, the GNSS-A observations detected several tens of meters of coseismic seafloor displacements (Sato et al., 2011 Science), which enhanced the researchers’ understandings of this devastating event. Recently, Yokota and Ishikawa (2020 Sci. Adv.) showed the GNSS-A ‘s potential to detect slow slip events. Rapid reporting of the seafloor movements due to events such as interplate earthquake and slow slip event can provide the researchers valuable information to discuss the temporal and spatial variation of crustal activities in their earlier stage.

In the routine GNSS-A analysis in the JHOD, baseline analysis is used to determine the precise track. It requires GNSS observation data at the terrestrial reference sites, whose positions must be solved beforehand. We use the GEONET stations operated by the Geospatial Information Authority of Japan (GSI) as the reference sites, using their 1 Hz data fixed to the F3 solutions (Nakagawa et al., 2009 J. GSI). In addition, precise GNSS products such as satellite orbits are necessary to determine the track. Normally, the vessel’ s track for GNSS-A is determined using the final product which is available after 12-18 days. On the other hand, the rapid products published online within 17-41 hours can accelerate the processing of GNSS-A analysis though it is preliminary. However, since it is necessary to receive data from another institute, we must put in mind that there may be a possibility of delay or failure to make contact with the institute, especially in cases such as emergency observations after a large earthquake.

As an alternative, kinematic precise point positioning (PPP) can be a solution, which realize precise positioning without the reference sites. In these days, we can easily obtain the additional GNSS products, i.e. high rate satellite clocks, for PPP via the internet. Thus, PPP has advantages over baseline analysis when providing rapid GNSS-A solutions.

In this study, we evaluated the dependency of GNSS analysis strategies, i.e., baseline analysis and PPP with final products as well as PPP with rapid products, on GNSS-A solutions. The GNSS-A data after 2008, when the transducer had been mounted on the bottom of the vessel, were processed. Software “IT” (Colombo 1998) version 4.2 and “RTKLIB” version 2.4.2 (Takasu, 2013) were used for baseline analysis and PPP, respectively. The GNSS-A analysis in this study is based on Yokota et al. (2018 Sci. Data). The obtained time series of displacement indicated that PPP achieves stability within the GNSS-A positioning precision equivalent to the conventional method.
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Authority of Japan. The software IT was provided by Dr. O. L. Colombo of the NASA Goddard Space Flight Center. RTKLIB is an open source software developed by Dr. T. Takasu of the Tokyo University of Marine Science and Technology (available at http://www.rtklib.com/).

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