GPS-A measurement considering the existence of internal gravity wave

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In the GPS-A analysis, the traditional “Layered Model”, in which sound speed in ocean is assumed to be stratified, was widely adopted by research groups. However, the “Gradient Model”, dealing with large scale horizontal spatial inhomogeneity as a linear slope, is recently in progress. Persistent horizontal inhomogeneity was proved to be solved as a time-invariant gradient using moving survey for the site of 3 or more transponders or point survey for 5 or more transponders. For the latter case, even time-varying gradient can be solved for every ranging shot in theoretical, however, the theory cannot be applicable in actual observed data. We consider that the time-varying inhomogeneity is caused by internal gravity wave (IW) for its periodical fluctuation in apparent positioning.

In this study, we first explored the critical wavelength of IW that violates the gradient approximation using a synthetic test. The critical wavelength is found to be comparable to the horizontal extent of seafloor transponder array, which roughly corresponds to the depth of the site. Next existence of such short wavelength IW around our observation site was examined by realistic numerical simulation. We employed 2-D transection that intersect from the Izu-Bonin ridge (main excitation source of IW) to the Kumano-nada (one of our observation site), where local tidal current is nearly parallel to its transect. IWs excited by the interaction between barotropic tidal current associated with the four major constituents and seafloor topography were computed. Although long wavelength IW (~100 km) due to the M_2 constituent was dominant, non-negligible amount of short wavelength IWs were also observed, which were generated through cascade-down process with non-linear interaction. We conducted synthetic tests of GPS-A positioning with time-varying sound speed field that constructed from the computed IW field with a given reference potential density profile and found that the obtained time series of apparent position has quite similar frequency and amplitude to those observed in real data. We also found that the most significant cause of the systematic error in GPS-A positioning comes from relatively longer period (~3 hours) IW in the deep portion, while IW in the shallow part can be removed by time average due to its short enough time period (~1 hour).
In order to model such feature in the GPS-A analysis beyond the Gradient Model, we proposed “Disturbance Model” that assigns individual anomalous sound speed in the deep portion for each transponder rather than assuming a simple geometry in the perturbation field. In the Disturbance Model, additional surface platform is needed to balance the increase of unknowns describing sound speed field. Autonomous surface platforms are developed recently, which will help multi-surface-platform observation. We are now investigating the optimum configuration of the multi-surface-platform using both analytical and numerical approaches.

Keywords: GPS-Acoustic, sound speed in ocean, internal gravity wave, seafloor crustal deformation

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