A total station plan combined with "Chikyu" and DONET: simultaneous observation from seafloor to atmosphere

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DONET (Dense Oceanfloor Network system for Earthquakes and Tsunamis) has been developed and installed around Nankai Trough, which is motivated by the 2004 Sumatra-Andaman Earthquake. DONET contains pressure gauges as well as seismometers, which are expected to detect crustal deformations driven by peeling off subduction plate coupling process. From our simulation results, leveling changes are different sense among the DONET points even in the same science node. On the other hand, oceanic fluctuations such as melting ice masses through the global warming have so large scale as to cause ocean bottom pressure change coherently for all of DONET points especially in the same node. This difference suggests the possibility of extracting crustal deformations component from ocean bottom pressure data by differential of stacking data. However, this operation cannot be applied to local-scale fluctuations related to ocean mesoscale eddies and current fluctuations, which affect ocean bottom pressure through water density changes in the water column (from the sea surface to the bottom). Therefore, we need integral analysis by combining seismology, ocean physics and tsunami engineering so as to decompose into crustal deformation, oceanic fluctuations and instrumental drift, which will bring about high precision data enough to find geophysical phenomena. Since "Chikyu" has a plan of operation to connect borehole observations to DONET, we have to discuss the best way to do simultaneous observation from seafloor to atmosphere by taking advantage of this chance.

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Keywords: subduction zone, megathrust earthquake, ocean current

Intensive XBT measurement reveals short-period gravitational internal wave in the sea: its impact on GNSS/acoustic seafloor geodetic survey

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GNSS/acoustic measurement, consisting kinematic-GNSS monitoring of a sea-surface platform and acoustic ranging to seafloor transponders, is significantly affected by temporal variation of sound speed structure in seawater. In most cases, it can be well approximated with a time-varying laterally stratified structure. Therefore, we usually assume this condition in the GNSS/acoustic analysis. Any violation of this assumption results in apparent fluctuation of horizontal position of transponders. The fluctuation generally shows unstable long-timescale feature (several hours to a day), but sometimes shows clear periodic feature (0.5-1 hour). Such a short-timescale periodic feature can be interpreted by gravitational internal wave. Its quantitative contribution to the GNSS/acoustic analysis highly relies on local horizontal gradient of the field, which is the product of vertical gradient of sound speed, wave amplitude, and inverse wavelength of the internal wave. However, no direct observational evidence of this hypothesis has been available so far.

Then we conducted intensive XBT profiling of water column concurrently with GNSS/acoustic point survey in Kumano-nada, Nankai trough in 2016. Total 12 XBT-based temperature profiles with an interval of 10 minutes (lasting 2 hours), and a single XCTD-based density profile at the end were obtained, which provide fundamental information on the wave period. In the temperature profiles, we clearly identify up to 20 m of vertical oscillation of the water column shallower than 600 m. In the next step, we will estimate horizontal wavelength of this observed internal wave and calculate the local horizontal gradient of the net sound speed structure in order to be compared with apparent horizontal fluctuation observed in the concurrent GNSS/acoustic survey. These fundamental data in the water column will also contribute to understand small fluctuation in pressure at ocean bottom.

This work has been supported by SIP (Enhancement of societal resiliency against natural disasters) and Kakenhi 15H04228, 15K13557.

Keywords: acoustic ranging, GNSS/acoustic, internal gravitational wave, sound speed, seafloor geodesy

Bottom pressure variation associated with 2004-2005 Kuroshio large meander south of Japan

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Off the southern coast of Japan, a Kuroshio large meander occurred in late July 2004 and continued to exist until about August 2005. Before the formation of the large-meander (LM) path, a Kuroshio path disturbance, called a small meander, occurred to the southeast of Kyushu. The propagation and development of the small meander were observed by bottom pressure sensors installed on inverted echo sounders (PIES) off Ashizuri-misaki and a seismic observing system off Muroto-misaki. The variations in bottom pressure, sea surface height (SSH), and the PIES-derived geopotential distance were examined focusing on the formation of the LM path. The bottom pressure was found to be depressed presumably due to a deep cyclonic eddy associated with the small meander, and this depression led the SSH depression by up to about two months. The phase shift between the surface and deep layers was significantly greater than those of other small meanders that did not develop into large meanders. This is evidence that baroclinic instability is an important process for the development to the large meander. After the formation of the LM path, the bottom pressure beneath the Kuroshio increased with a lag of about two months behind the SSH elevation. The high bottom pressure continued until about February 2005 when the LM path began to decay. The bottom pressure increase suggests that due to the stronger near-bottom current in the LM period than the non-LM period, the topographic steering is effective in the LM period and stabilizes the path. This is consistent with the fact that no small meanders occurred in the early LM period from late July 2004 to early February 2005.

Keywords: Kuroshio, Large meander, Bottom pressure, Inverted Echo Sounder, Seismic observing system

Microscale ocean disturbance that affects the GPS-A seafloor geodesy

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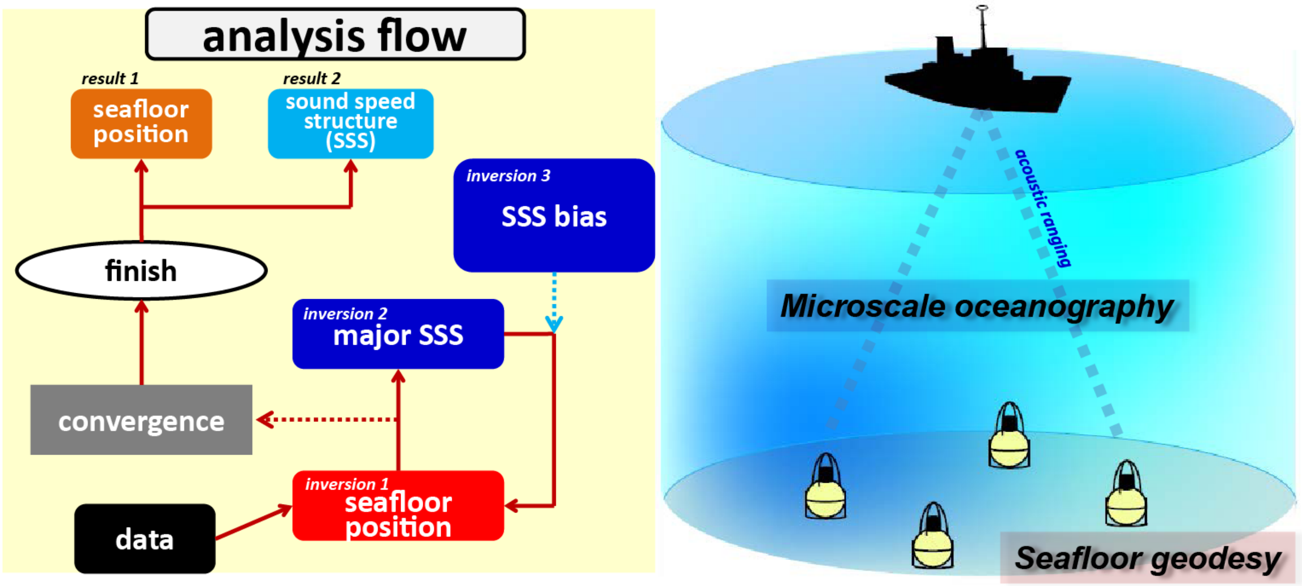
Seafloor geodetic observations accomplished several monumental works in the fields of seismology and geodesy. Many seafloor geodetic works were performed using the GPS-Acoustic ranging combination technique (GPS-A) [e.g., Gagnon et al., 2005, Nature; Sato et al., 2011, Science; Kido et al., 2011, GRL; Yokota et al., 2016, Nature]. In this technique, we observe using vessels (or buoys) on the sea around the seafloor acoustic mirror-type transponders set within the range of 1 - 3 km. Seafloor absolute positions were determined using this acoustic data, the attitude data and the GPS data on the vessels. Although the GPS-A technique achieved establishment of the stable and sophisticated seafloor observation network, an observation precision (1 σ = 2 - 3 cm: horizontal) remains lower than other geodetic observation techniques.
The observation precision is affected by ocean disturbances strongly. We have reduced this effect using analytical approaches in this decade (Figure). In that process, spatial and temporal changes of undersea sound speed structures (SSS) were approximated as fields modelled using high-order temporal functions [Fujita et al., 2006, EPS]. In the recent study, we found out a possibility that spatial biases of the SSS were also able to be modelled by using the similar method. These methods could make contributions to upgrade the precision of the GPS-A data. In this presentation, we'd like to review our current analysis flow and discuss effects of these analytical approaches.
Additionally, we remark the SSS modelled in our analysis. Although it was just noise for us, it is able to be considered as an important parameter visualizing an ocean event. The obtained SSS has very small spatial and temporal scales, a km-scale and an hour-scale, and is difficult to be acquired in other observations. Therefore the GPS-A may have possibility to open a new window to see a microscale ocean event.

Acknowledgements: We thank the Geospatial Information Authority of Japan (GSI) for high-rate GPS data for kinematic GPS analysis, and for daily coordinates of the sites on the GSI website.

Keywords: Microscale oceanography, GPS-Acoustic ranging combination technique, Seafloor geodetic observation


analysis flow
result 1
seafloor position
result 2
sound speed structure (SSS)
inversion 3
SSS bias
finish
inversion 2
major SSS
convergence
inversion 1
seafloor position
data
acoustic ranging
Microscale oceanography
Seafloor geodesy

Ocean Current Prediction for Deep-Sea Scientific Drilling Vessel CHIKYU

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We conducted predictions of the ocean currents during 3 cruises of the Deep-Sea Scientific Drilling Vessel CHIKYU in 2016. In this presentation, we discuss the ocean situations during the cruises, potentials of the CHIKYU as an observation platform, and the current skills and future developments of the ocean current predictions.

Keywords: ocean current prediction, Chikyu, Kuroshio

Impact of explosive cyclones on the deep ocean in the North Pacific: Simulations and observations

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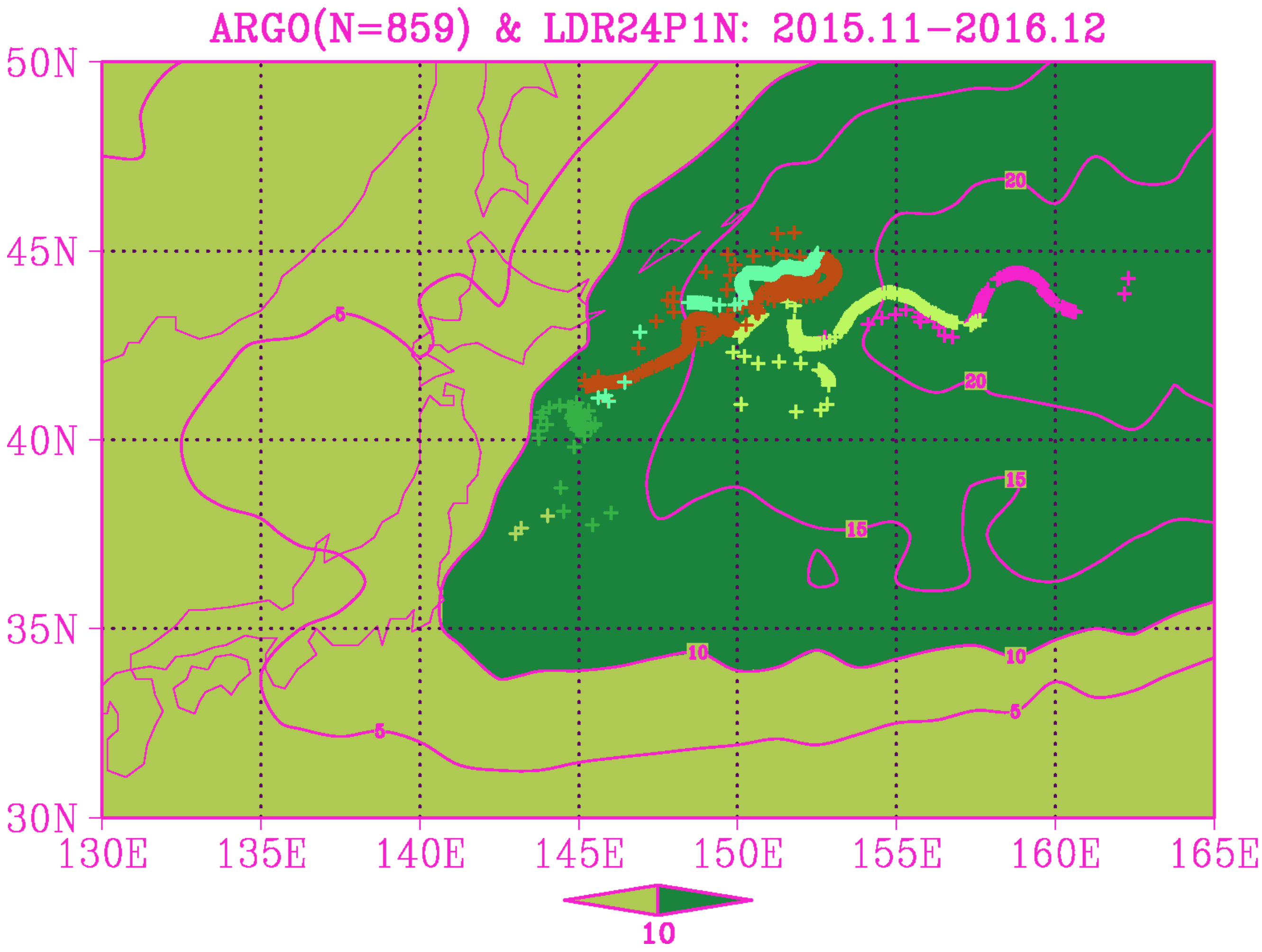
The Northwestern Pacific Ocean is the deepest ocean above which explosive cyclones frequently develop in winter. Composite analysis using eddy-resolving 34 year hindcast simulation of quasi-global ocean by OFES shows that explosive cyclones induce large horizontal divergence within the surface-mixed layer and upward flow that reaches 2000 m depth. In addition, interannual variability of explosive cyclone activity affects the amplitude of vertical motion and the daily-scale temperature variations in the deep ocean. However, normal observations of ocean cannot capture the oceanic response to explosive cyclones. Sea-surface temperature observations from satellite are not sensitive to explosive cyclones because of deep mixed layer in winter. The time interval of ARGO floats, usually 10 days, is too long to observe rapid change associated with explosive cyclones within 1 day. To observe the oceanic response, high-frequency observations using ARGO floats has been conducted in two winters in 2015/2016 and 2016/2017 in the Northwestern Pacific. The ARGO floats used for the special observations allow real-time change of observation mission including time interval and depth of profile observation through satellite communication. The mission change was operated based on medium-range ensemble forecast data by Japan Meteorological Agency. When an explosive cyclone was predicted with high probability by the forecast, 6-hourly observations with 650 m depth were conducted. Otherwise daily observations with 2000 m depth were conducted between November and March in each winter. 859 profiles were observed until December 2016 under the region where explosive cyclones were active.

References: Kuwano-Yoshida, A., H. Sasaki, and Y. Sasai, *Geophys. Res. Lett*, 44, 320-329 (2017).

Keywords: explosive cyclone, ARGO float, OGCM


ARGO(N=859) & LDR24P1N: 2015.11-2016.12
50N
45N
40N
35N
30N
130E
135E
140E
145E
150E
155E
160E
165E
5
10
15
20
10