

Short Note

A brief overview of recent activities and approaches for investigating shelf-basin exchange processes and coastal sea circulation around Japan

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Abstract — Recent activities and approaches for investigating shelf-basin exchange processes and coastal sea circulation around Japan are overviewed briefly in terms of physical oceanography.

Key words: shelf-basin exchange processes, coastal sea circulation, around Japan

1. Introduction

Coastal sea environment is strongly influenced by physical oceanographic processes. This overview is intended, in terms of physical oceanography, to summarize recent activities and approaches for investigating shelf-basin exchange processes and coastal sea circulation around Japan.

2. Research Activities on Shelf-Basin Exchange Processes

There are some important issues which are crucially influenced by the shelf-basin exchange processes. The Kuroshio large meander is an example. The Kuroshio, a western boundary current in the North Pacific, often takes the large meander path (Taft 1972, Kawabe 1995). In idealized theoretical models, as well known, behavior of the boundary current is strongly controlled by viscosity and nonlinearity in the vicinity of the western boundary (Munk 1950, Veronis 1966, Pedlosky 1996). Perhaps similarly, the Kuroshio large meander in the real ocean is also controlled by viscosity and nonlinearity in the shelf/slope area south of Japan. According to numerical studies, viscous vorticity flux from the coast (Akitomo et al. 1991) and enhancement of instability by bottom topography (Endo et al. 2011) play essential roles in formation of the Kuroshio large meander. However, because of difficulty in detailed observation (both in time and space), observational evidence for these mechanisms has not been provided so far.

Another example is export of dense shelf water into the

intermediate and deep ocean. There are three export areas around Japan. In the East China Sea, shelf water intrudes into subsurface and intermediate layers of the Kuroshio (Isobe et al. 2004), which has important potential role in transporting a large volume of CO₂ from the shelf to the deep ocean (Tsunogai et al. 1999). In the Okhotsk Sea, descent of shelf water in the slope region contributes to formation of the Okhotsk Sea Intermediate Water (Fukamachi et al. 2004), which leads to formation of the North Pacific Intermediate Water (Yasuda 1997). In the Japan Sea, descent of dense shelf water controls abyssal environment and climate (Gamo 1999, Tanaka 2014). Details of these processes such as exact quantity and interannual variability, however, are not well understood.

3. Research Activities on Coastal Sea Circulation

Needless to say, the coastal marine environment is very strongly influenced by coastal sea circulation, and it is very closely related to fishery in Japan. It should be noted that the 2011 Great East Japan Earthquake (and Tsunami) strengthened the linkage between coastal oceanography and fishery. As an example, a research program “Tohoku Ecosystem-Associated Marine Sciences (TEAMS)” was launched after the 2011 Earthquake, aiming to investigate physical, chemical, and biological factors controlling the ecosystems in the devastatingly damaged areas. A point worthy of note is that in the program, a great deal of importance has been attached to synergistic cooperation with local fishermen. This is because the hydrographic observation over the inshore fishery areas,

where many fishing implements are placed, cannot be made without support from fishermen. At the same time, there are many fishery problems that cannot be solved without academic approaches; for example, the physical oceanography is needed to reveal the seawater circulation that conveys nutrients into the “non-feeding” sea farming areas. In other words, the other aim of the program (still ongoing) is to develop practical ways to perform state-of-the-art physical oceanography together with local communities (Tanaka et al. 2016). Similar approaches to synergistic cooperation with local fishermen, focusing on higher trophic level species (fish and cephalopods), are ongoing in various parts of Japan (Nakada et al. 2014, Morioka et al. 2017).

Besides, there are many issues related to the coastal marine environment other than fishery. The coastal marine environment of the Seto Inland Sea, a semi-enclosed coastal sea with a length of 500 km, has been significantly affected by industrialization and urbanization around the sea over decades. Serious environmental issues resulting from anthropogenic development in the region, therefore, have attracted attentions of Japanese coastal oceanographers (Takeoka 2002, Chang et al. 2009). In the Ariake Sea, a huge dike was constructed in 1997 for reclamation and disaster prevention, and it reduced tidal currents to cause serious anthropogenic impacts, such as hypoxia and anoxia, on the marine ecosystem (Yamaguchi and Hayami 2018). More recently, an issue of microplastics (plastic particles 5 mm or less in size) is rapidly growing in Japan (Isobe et al. 2015), because they are easily but mistakenly ingested by fish, resulting in marine pollution of the marine ecosystem. An important common feature in these environmental issues is that observational data is definitely insufficient because of difficulty in hydrographic observation over the inshore fishery areas.

4. Approaches to Observation and Numerical Modeling

Then, we will discuss technological innovation to approach the above issues. There are certainly difficulties in observation over coastal seas, especially in Japan where fishery is prosperous. However, rapid innovation of measurement instruments and sensors and of numerical simulation models, which increases efficiency of the observation greatly, seems to be breaking through the difficulties.

For example, current meters have been reduced in size, by which it has become easier to mount them on board boats or aquaculture rafts (Tanaka et al. 2017). Moreover, some CT (conductivity-temperature) loggers have been equipped with a mechanical wiper, which periodically sweeps the sensor surface to avoid biofouling: Without the wiper, a long-time mooring (more than two weeks) is usually impossible in eutrophic shallow seas.

Remote sensing has also advanced to become available for coastal oceanography. HF (high-frequency) ocean radars are powerful tool, because they can clearly capture distribution of surface coastal currents in both space and time (Ebuchi et al. 2009, Ichikawa et al. 2013). The Korean geostationary satellite COMS (Communication Ocean and Meteorological Satellite), which is the world’s first geostationary ocean color satellite launched in 2010, covers the Northeast Asia area (including Japan) with high-resolutions of about 500 m and an hour (Nakada et al. 2018). Moreover, new instruments for remote sensing, such as vessel-towed balloons and drones (unmanned aerial vehicles) equipped with a variety of cameras and sensors, are developing rapidly (Miyao and Isobe 2016).

Meanwhile, numerical simulation has also made remarkable progress: the COCO, the ocean general circulation model developed by Tokyo University and JAMSTEC (Japan Agency for Marine-Earth Science and Technology), successfully reproduced wind- and buoyancy-driven and tidal circulation in a small bay (Sakamoto et al. 2017). A point worthy of note is that the model had the very fine high-resolution of 14 m in the bay, but it was connected to outer Pacific models multiply by the use of a nested-grid system. A similar approach is ongoing by the MRI.COM model, developed by the JMA (Japan Meteorological Agency), toward forecasting coastal sea conditions throughout the country (Sakamoto et al. 2016). It should also be pointed out that high-resolution simulation with FVCOM (Isobe et al. 2010) and ROMS (Uchiyama et al. 2017) is also active in Japan. Moreover, a new attempt has begun to reproduce shallow sea circulation by using a fully non-hydrostatic model (Matsumura and Hsumi 2008, Yamagishi and Matsumura 2016).

Finally, data assimilation has to be mentioned. The JCOPE model, which has been developed by JAMSTEC, has a 3DVAR scheme and a horizontal resolution of less than 8 km (Miyazawa et al. 2017). This model is widely used not only for scientific study on mesoscale variability such as the Kuroshio path variation, but also used for ship routing of oil tankers, fishery and drilling ships. The FORA-WNP30 with a 4DVAR system, which has been developed on the basis of the MRI.COM, produced the first-ever reanalysis dataset covering the western North Pacific over the last three decades (1982–2014) at eddy-resolving resolution (Usui et al. 2017). The FRA-ROMS with a 3DVAR, by the FRA (Japan Fisheries Research and Education Agency), has been specialized for systematic conduct of fisheries in the Kuroshio-Oyashio region (Kuroda et al. 2017).

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