A Visualization Study of Vortexes Extracted from the Tremendous Ocean Simulation Data: An Application in Funka Bay

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1 Introduction

International activities toward realizing smart fishing [1] are evolving to reduce their operational risks, greenhouse gas emissions and energy loss in response to recent hikes in the price of crude oil [2]. The state-of-the-art ocean simulation with spatiotemporally high resolutions can provide the detailed and accurate now/forecast of ocean currents, temperature and sea-level, and so on, which might help to improve the fishing efficiency [3]. The helpful information has to be correctly informed to the fishermen in order to achieve the smart fishing even if the now/forecasts of ocean states are perfectly accurate. However, the tremendous data of ocean states is daily produced by the operational forecast simulation aided by data assimilation system. Therefore, it is necessary that the beneficial information for good fishing operations is promptly extracted from deluged data sources of the ocean states and showed to the fishermen in time.

In this study, we prove a comprehensive visualization method to effectively show the fruitful information using realistic ocean datasets produced by a land-sea coupled model with spatiotemporally high resolution. We select Funka Bay located in Northern Japan, Hokkaido (Figure 1) as a pilot study area from a viewpoint of aquaculture. Funka Bay is a typical enclosed bay and produces vast production of scallops and kelps around the coastal ocean every year, and Alaska pollack in the inner region of the bay. It is known that their production is closely related to the flow fields or seasonal eddies formed in the bay. We visualize the characteristics of the eddies using the three-dimensional visualization technique [4,5] to examine the flow pattern, spatial scale, lifespan, three-dimensional structure, and so on.

2 Methodology

2.1 Data sets

The datasets used in this study are calculated by a coupled land-oecan model consisting of both hydrometeological model [6] and a three-dimensional OGCM developed at Kyoto University [7]. The coupled model was used to reproduce more realistic land-ocean forecasts using the initial condition and the spun-up calculation from beginning of 2006 following Nakada et al. (2012) [5].

The analysis period of 2008–2009 was selected since a significant contrast in summer-time vortexes associated with the surface salinity was found then which should be influenced by the runoffs into the bay; the summer-time salinity in 2009 was much less than in 2008.

Re-analysis and predicted meteorological datasets GPV-MSM were used to be input to the coupled model, which are mean hourly air temperature, precipitation, cloud cover, relative humidity, and wind speed. The data were interpolated onto grids at an interval of 500×500 m in the land computational domain and ~1.5 km in the ocean domain using the spline method on the watershed. The coupled model was validated by using observational data and showed both quantitative and qualitative reproducibility of the temporal variations in the bay after several calibrations.

2.2 Visualization

To detect an important flow feature, vortices, in the ocean, we employ a vortex detection algorithm depicting streamlines around vortex cores coupled with the entire vortex area [5]. According to [5], approaches for detection of a typical oceanographic feature, in particular, a vortex were evaluated in terms of accuracy, clarity and usability.

The vortex detection algorithm consists of two parts. The first part is vortex core detection. A geometry-based vortex core detection method is used to detect vortex cores. The second part is closed streamline detection around vortex cores. Finally, the combinations of vortex core regions and their surrounding closed streamline regions form the entire vortex regions.

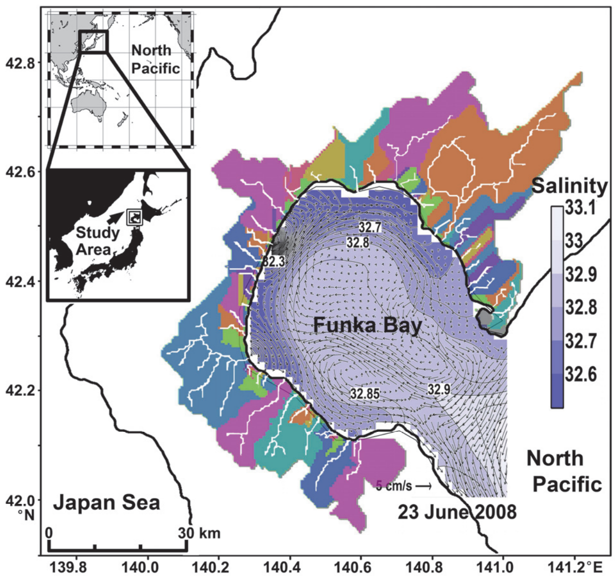

Figure 1 Map of the study area showing watersheds around Funka Bay. The typical summertime eddy is shown with the simulated salinity field in 23 June 2008.

3 Results and Discussions

Figure 2 shows a good example of the flow field in the bay, indicating the asymmetric twin vortex simulated by the coupled model. The northern vortex corresponds to the summertime clockwise circulation indicated by the surface current velocity indicates (Figure 1). The twin vortex is drawn by the surrounding streamlines that starts from vortex cores. The extension and density of the streamlines indicates the spatial scales of the vortexes and their strength of divergence and convergence, respectively (Figure 2a). The northern vortex is big and shows the high-density streamlines suggesting the weak divergence or nearly circulation. On the other hand, southern vortex is small and strong divergence because of low density of the streamlines. The big vortex exhibiting shape of a mushroom (Figure 2b) indicates the deep structure (~100 m) and the shear flow field representing the typical baloclinic structure.

These characteristics of twin vortex are important information associated with the transportation of scallops eggs and/or leave and actually required for aquaculture management instructed by fishery researchers of prefectural institutes. In the case of understanding the characteristics using conventional approaches, we generally need some graphics such as maps of flow fields at each depth and vertical section. However, employing our visualization method, one three-dimensional graphic can intuitively exhibit the qualitative spatial structure of the vortex structure. It is also found that our simulated results were well consistent with the observational data derived by R/V Ushio-Maru, Hokkaido University. This fact confirms that our visualization and simulation can satisfactorily provide the useful information for the good fishing or aquaculture grounds.

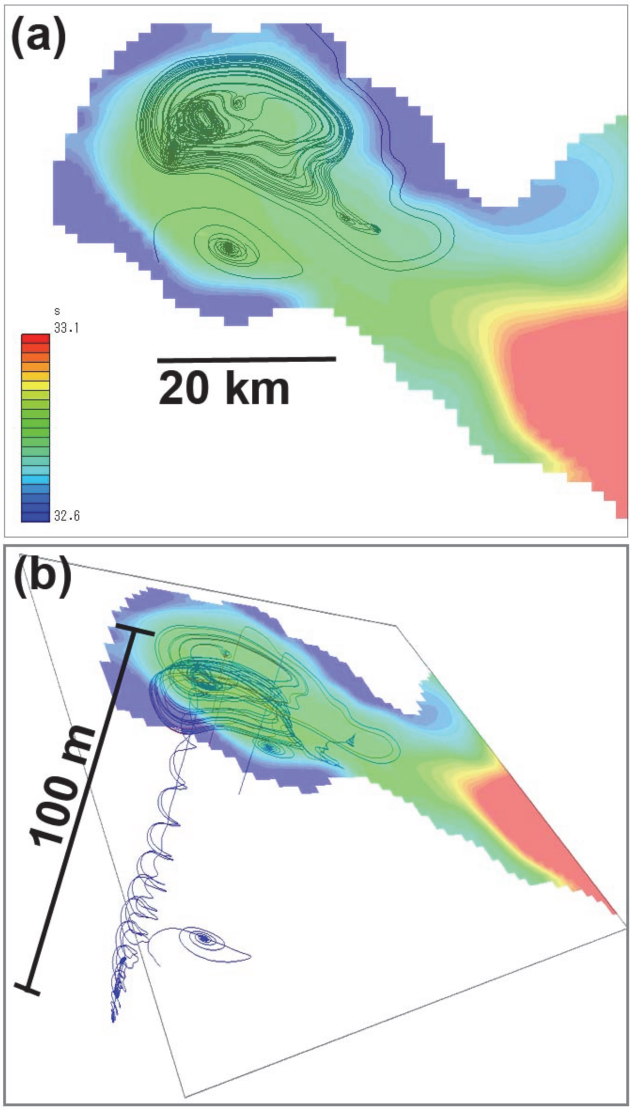

Figure 2 (a) An example of visualization of the simulated eddies depicted by stream lines and colored salinity field in Funka Bay. (b) Overhead views of the eddy in 23 June, 2008.

4 Conclusion

This study showed that a comprehensive visualization may effectively provide the helpful information toward the smart fishing using tremendous data of the daily ocean states produced by a land-sea coupled model with spatiotemporally high resolution. The information can contain the spatial structures and characteristics of the vortex and be effectively extracted from the simulated data representing many ocean properties. Our results underline that the development of visualization of the operational simulation data is essential as same as the increase of the simulation ability in order to achieve the prompt and accurate transmission of the information.

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References

[1] Aps, R., Fetissov, M., Lassen, H., Smart management of the Baltic Sea fishery system: Myth or reality?, Baltic International Symposium (BALTIC), 2010 IEEE/OES US/EU, 1-9, 2010.

[2] Driscoll, J. & Tyedmers, P, Fuel use and greenhouse gas emission implications of fisheries management: the case of the New England Atlantic herring fisher, Marine Policy, 34, 353–359, 2010.

[3] GODAE Coastal and Shelf seas Working Group, Towards the assessment and demonstration of the value of GODAE results for coastal and shelf seas models and forecasting systems, 79pp, 2007.

[4] Globus, A., C. Levit and T. Lasinski, A Tool for Visualizing the Topology of Three-Dimensional Vector Fields, Proceedings Visualization '91, San Diego, California, October 22–25, pp. 33–40, 1991.

[5] Guo, D., Evangelinos, C., Patrikalakis, N.M., Flow feature extraction in oceanographic visualization. In: Computer Graphics International Conference, IEEE Computer Society Press, Greece, pp. 162–173, 2004.

[6] Nakada, S., Y. Ishikawa, T. Awaji, T. In, S. Shima, T. Nakayama, T. Isada, S. Saitoh, Modeling Runoff into a Region Of Freshwater Influence for Improved Ocean Prediction: An Application in Funka Bay, Hydrological Research Letter, 6, 47–52, 2012.

[7] Ishikawa Y, Awaji T, Toyoda T, In T, Nishina K, Nakayama T, Shima S, Masuda S, High-resolution synthetic monitoring by a 4-dimensional variational data assimilation system in the northwestern North Pacific, Journal of Marine Systems, 78, 237–248, 2009.