

Projecting marine ecosystem changes with state-of-the-art numerical models

*Michio Kawamiya¹

1. Japan Agency for Marine-Earth Science and Technology

It is becoming more and more important to quantitatively understand the relationship between ocean environmental changes and productivity. For example, the recent spate of poor catches of Pacific saury has been attributed to the occurrence of warm water masses off the coast of Sanriku, and there are concerns about climate change impacts as a background. However, it is still unclear whether these changes in the marine environment are long-term trends caused by anthropogenic warming or short-term events that occur within the range of natural variability.

The existence and changes of medium-scale eddies found throughout the ocean including the coasts off Sanriku are affecting the marine ecosystem. Other factors may also be playing roles, such as typhoons, ocean heat waves that have been occurring frequently in recent years, and disturbances in the physical environment such as the Madden-Julian Oscillation. What specific effects do they have on the marine ecosystem and how do they lead to the maintenance and change of productivity?

Understanding the mechanisms and predicting how these disturbances affect marine ecosystems and lead to changes in productivity is essential for humans to maintain the bounty of the ocean and to further enrich our lives in the future. Furthermore, it is an urgent issue to clarify the feedbacks of the cycling and emission of various greenhouse gases (CO₂, N₂O, etc.) and aerosols in and over the ocean through the marine ecosystem, on the surface environment. Theme 3 of the Advanced Institute for Marine Ecosystem Change (AIMEC) will research these issues.

AIMEC will adopt a high-resolution ocean general circulation model (OGCM), and an Earth system (ESM) model that incorporates atmosphere and biogeochemical process, as tools to address these issues. The Japan Agency for Marine-Earth Science and Technology (JAMSTEC) has realized a simulation with a horizontal resolution of 0.1° (about 10 km) that covers the entire ocean and can represent medium-scale eddies to a certain degree using the Earth Simulator, a large computer system operated by JAMSTEC. The ESM that JAMSTEC has been collaboratively developing has contributed to the latest assessment report of the Intergovernmental Panel on Climate Change.

By equipping such a high-resolution OGCM with the latest marine ecosystem module, a comprehensive understanding of the physical environment and ecosystem of the oceans and the material cycles will become possible. By combining the information obtained from the ESM and the environmental DNA studies, another important tool adopted in AIMEC, with the phytoplankton distribution reproduced by the latest high-resolution marine ecosystem model, it is expected that scientists can map the distribution of marine organisms into their functions in terms of material cycles, fishery production, and climate formation. Such mapping will lead to improved accuracy in predicting changes in ocean material circulation and productivity in response to changes in the physical environment, including their feedback to climate. Artificial intelligence (AI) may be a powerful tool in this regard.

Toward the grand goal of understanding the factors and dynamics that bring society the bounty of the ocean, the "ocean digital twin" can be constructed by further improving the accuracy of the

high-resolution OGCM under development, coupling it with a cutting-edge marine ecosystem module with high reproducibility, and incorporating data assimilation technology to integrate observation data. Using the ocean digital twin possibly combined with AI, it will be possible to understand and predict the functions of marine ecosystems in various areas, and to assess the impacts on, and to navigate the responses of human society.

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