Abstract

[Project Information]

Project Title :	Realization of a digital twin of water environment in closed water: Establishment of data assimilation method for ecosystem model and development of long-term water quality reanalysis database
Project Number :	JPMEERF20221R01
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[Abstract]

This research project aimed to establish data assimilation techniques for aquatic ecosystem models and develop long-term reanalysis datasets for enclosed coastal waters, with a focus on Ise Bay and Tokyo Bay. Despite significant improvements in regard to wastewater treatment technologies, issues such as red tides and bottomwater hypoxia persist in these regions. To address these challenges, this project has promoted the concept of a “digital twin” of the aquatic environment by integrating observations and ecosystem models using data assimilation methods. Two main data assimilation frameworks were employed. The first utilized the Ensemble Kalman Filter (EnKF) with the in-house ecosystem model EcoPARI applied to Ise Bay. The second framework applied a Four-Dimensional Ensemble Variational method (4D-EnVar) to the Regional Ocean Modeling System (ROMS) of Tokyo Bay. A 12-year physical quantity reanalysis dataset covering 2011–2023 was successfully created for Ise Bay. The EnKF system assimilated observations (temperature and salinity), resulting in significant improvements in the simulation accuracy. In particular, the root mean square error (RMSE) for temperature and salinity was reduced by more than 30% compared to runs without assimilation. For Tokyo Bay, a 7-month reanalysis experiment was conducted from April to October 2020 using 16 ensemble members in the 4D-EnVar system. The results showed an improved accuracy in the simulation of biogeochemical variables, especially for chlorophyll-a and dissolved oxygen, although slight tradeoffs were observed in regard to the physical variable accuracy. Sensitivity experiments revealed the need to balance variable weights in order to avoid the overcorrection of specific parameters. Field campaigns were also conducted in Mikawa Bay to estimate the observation error characteristics. These analyses confirmed that most measurement errors were random and within acceptable ranges, although the vertical and horizontal variabilities due to stratification and freshwater input were notable. This project has demonstrated the feasibility of creating high-resolution, long-term reanalysis datasets using data assimilation in aquatic ecosystem models. The developed methodologies are expected to support coastal environmental policies and management by

providing scientific insights into the spatiotemporal dynamics of water quality and ecosystem processes.

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