沿岸海域モデルへの境界条件の影響

Exploring the influence of the boundary conditions in a coastal ocean model

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In the area of numerical simulation, the problem of open boundary conditions can be considered one of the most significant and challenging research topics of coastal modeling because it has a great impact on the solution within the model domain. It is widely known that the open boundary conditions could lead to ill-posed problems (Orlanski, 1976), however, the prescribed open boundary conditions scheme doesn't exist.

Tokyo Bay is a semi-enclosed bay, the freshwater discharge from rivers and offshore seawater from the bay mouth drive the estuarine circulation in the bay. There have been many ocean models applied in Tokyo Bay to predict the hydrodynamic process and water quality. However, nowadays, in most studies applying coastal ocean models in Tokyo Bay, the open boundary conditions are either an artificial algorithm related to water depth and the period of a year, or a profile function deduced from a period of observation data or even a fixed constant or a rough time resolution dataset predicted by some ocean models. These methods are not accurate enough and cannot provide the real-time change of the connection exchange between the seawater inside the bay and the seawater outside the bay. Moreover, no study compares and combines the data measured at the observation station with the open boundary data provided by other ocean models.

HYCOM is an eddy-resolving, real-time global and basin scale ocean prediction system. One of the most important capabilities of HYCOM is to provide boundary conditions for the higher-resolution regional and coastal models. Most of the existing studies using the HYCOM ocean model to provide open boundaries have focused on the Atlantic coast, while the open boundary conditions for coastal models along the North Pacific coast are very limited.

TEEM model is an integrated, layer-resolved, process-based, sediment-water coupled, long-term robust, and three-dimensional ecosystem model applied in Tokyo Bay (Amunugama & Sasaki, 2018). It is an important coastal ecosystem model in Tokyo Bay. However, the open boundary conditions of water temperature and salinity set in TEEM model at the mouth of the bay are assumed artificial open boundary conditions, which cannot reflect the real-time influence of the seawater inside Tokyo Bay by the seawater outside the bay. This limits the authenticity and accuracy of the simulation results of the water temperature and salinity in the bay and further affects the accuracy of the simulation results of other variables in water and sediment. The location of Tokyo Bay is shown in Figure 1.

In this thesis, the water temperature data provided by the observation station at the mouth of Tokyo Bay and the water temperature and salinity data predicted by the ocean model HYCOM were combined and compared to explore the possibility of different sources of datasets and their combination to provide open boundary conditions for a coastal model TEEM in Tokyo Bay. The functionality of coastal model TEEM was improved by replacing the artificial open boundary conditions with real-time changing water temperature and salinity datasets

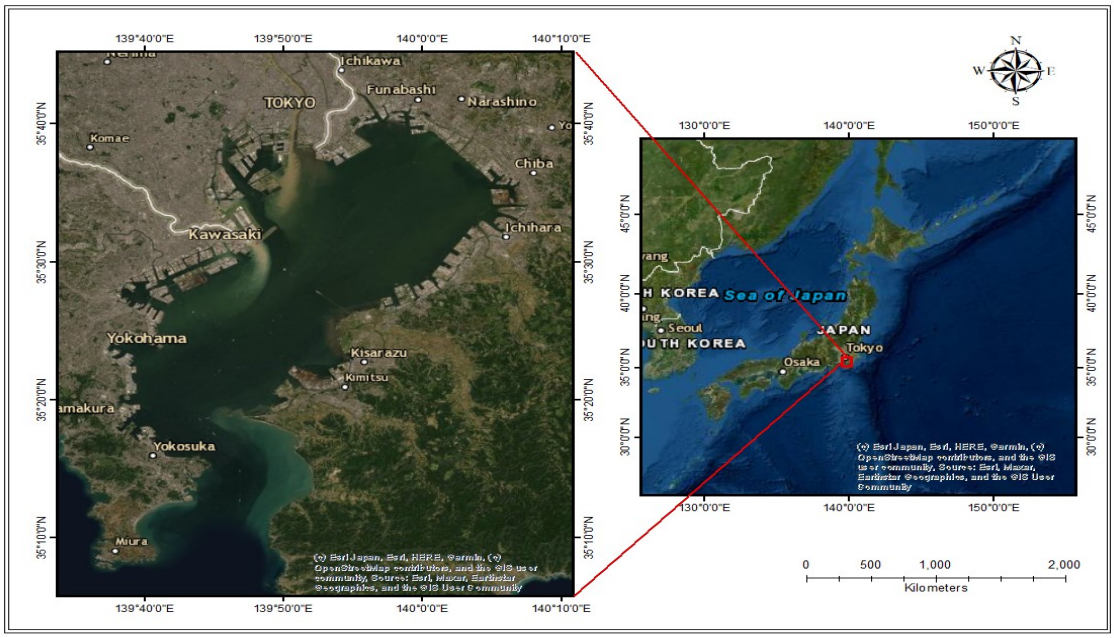

Figure 1 The research area

in high time resolution. In addition, the uncertainty caused by different embeddings of the coastal model and data obtained from the ocean model at the open boundary to the result accuracy in Tokyo Bay was also figured out.

Error analysis of observed and modeled water temperature and salinity from 2018.03.15 to 2019.04.30 were conducted at Kawasaki station (35°29′25" N,139°50′02" E) which locates at the center of Tokyo Bay. The statistical variables used to calculate the accuracy of the simulation results are the mean value of the observation data, the mean value of the modeled results, the mean absolute error, the root mean square error, RRE, and R square.

By replacing the artificial open boundary conditions of water temperature and salinity set in TEEM with the high time resolution water temperature data measured by the observation station and the high time resolution salinity data predicted by HYCOM, the accuracy of the simulated water temperature and salinity inside Tokyo Bay was greatly improved, with the RRE of simulated water temperature decreased from 0.1207 to 0.0873, and the RRE of simulated salinity decreased from 0.2177 to 0.1943. Compared with only using open boundary datasets provided by HYCOM, the combination of the water temperature data measured by the observation station and the salinity data predicted by the ocean model can provide more accurate open boundary conditions. When the open boundary conditions provided by HYCOM are embedded with the model in the bay, attention should be paid to the way the two models with different water depth settings are coupled at the open boundary. When the HYCOM data is compressed in all depths and inserted into each layer of TEEM, compared with the water temperature and salinity datasets of HYCOM at 100 meters within the sea surface, the water temperature at the open boundary becomes colder, and the salinity increases.

Error analysis of observed and modeled water temperature and salinity from 2018.03.15 to 2019.04.30 were conducted at Kawasaki and Kemegawa station. The RMSEs and RRE of different groups of open boundary conditions for water temperature and salinity are shown in Figure 2.1.1, Figure 2.1.2, Figure 2.1.3 and Figure 2.1.4.

This study provides a way for the

combination of the observation dataset and the dataset predicted by other ocean models to provide the open boundary conditions for the coastal model applied in Tokyo Bay, which can reflect the real situation of the seawater in the bay varied with the seawater outside the bay.

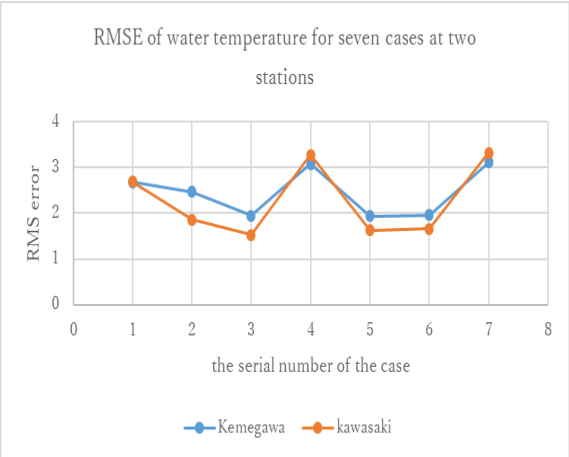

Figure 2. 1 RMSE of water temperature for seven cases at two stations

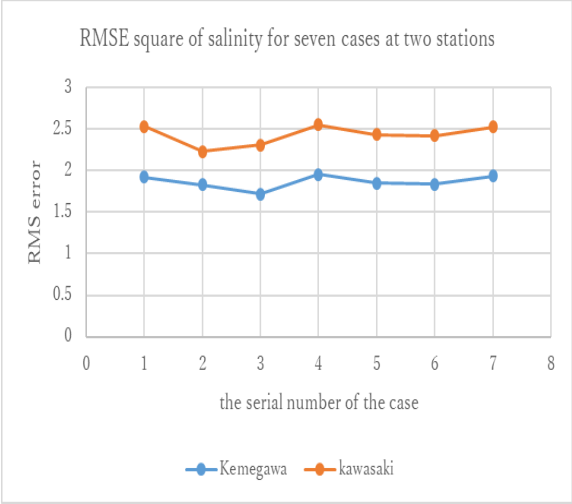

Figure 2. 2 RMSE square of salinity for seven cases at two stations

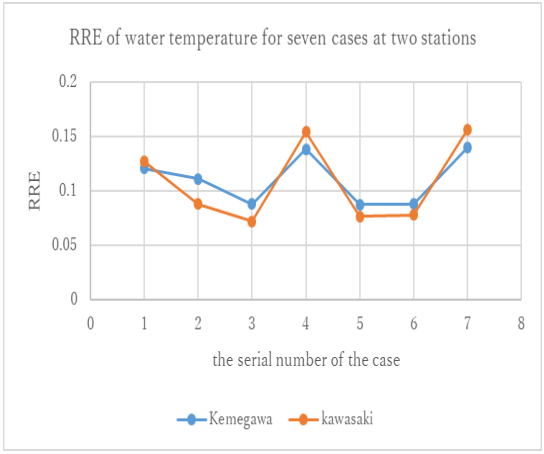

Figure 2. 3 RRE of water temperature for seven cases at two stations

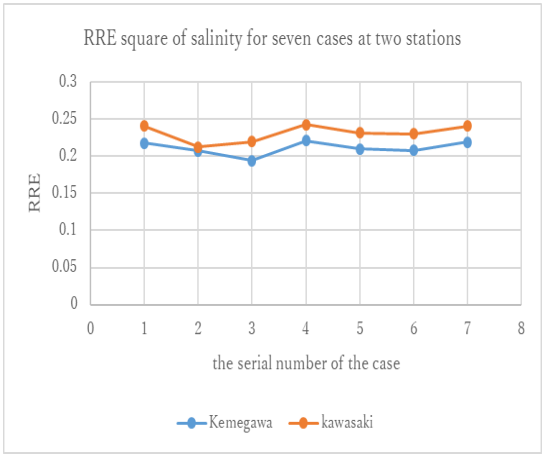

Figure 2. 4 RRE square of salinity for seven cases at two stations

Reference

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Orlanski, I. (1976). A simple boundary condition for unbounded hyperbolic flows. Journal of Computational Physics, 21(3), 251–269.https://doi.org/10.1016/0021-9991(76)90023-1