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Comparison of Hydrodynamic and Water Quality Models of the Chesapeake Bay: Results of the IOOS Coastal Ocean Modeling Testbed

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ABSTRACT

The Environmental Protection Agency (EPA) has developed a set of Total Maximum Daily Load (TMDL) allotments of nutrients and sediments for the six states that make up the Chesapeake Bay Watershed in order to elevate the health of the Bay, primarily in regards to dissolved oxygen concentrations. In developing the TMDLs, the EPA employed several water quality-based model outputs from multiple numerical modeling system together with an extensive set of monitoring data. Utilization of a multiple model approach when evaluating the status and recovery of the Bay system could enhance the overall confidence in model projections and better define model uncertainty. Open-source modeling systems such as the Regional Ocean Modeling System (ROMS) offer a cost effective way of utilizing the knowledge base of a large group of people form multiple institutions to address management issues within a single system. This study compares the relative skill of a set of ROMS-based models to the EPA regulatory model in terms of the seasonal variability of the Chesapeake Bay. Throughout the main stem of the Bay both model types achieve a similar model skill score in regards to dissolved oxygen (DO), the primary indicator of Bay health by the EPA, but vary significantly in terms of their ability to reproduce chlorophyll and nitrate.

METHODS

- Simulations from the EPA regulatory model and three ROMS-based models were analyzed (Fig. 1, Table 1):
  - CH3D – ICM: EPA
  - ROMS – RCA: UMCES
  - ChesNENA: VIMS
  - ChesROMS – BGC: UMCES
- Model output was compared to Chesapeake Bay Program monitoring data using a best time match technique. Analyses included surface and bottom temperature, salinity, dissolved oxygen, chlorophyll-a, and nitrate.
- Model output was compared to Chesapeake Bay Program monitoring data using a best time match technique. Analyses included surface and bottom temperature, salinity, dissolved oxygen, chlorophyll-a, and nitrate, as well as stratification.
- Model ability to reproduce the mean and seasonal variability of each variable was evaluated via Target Diagrams (Fig. 3).

RESULTS

- The skill of all four models are similar to each other in terms of temperature, salinity, stratification, and DO, but the models vary significantly in terms of their chlorophyll and nitrate. (Fig. 4, Table 2).
- All models consistently underestimate both the mean and standard deviation of maximum stratification, particularly at the northern stations (Fig. 5a).
- Despite the models’ inability to resolve stratification, the models reproduce the mean and variability of DO quite well. All models perform better at the southern stations than the northernmost stations (Fig. 5b).
- Model skill for surface chlorophyll varies significantly between models, with the regulatory CH3D – ICM model performing best (Fig. 5c). ROMS – RCA is particularly challenged at the southern stations.
- Model skill for surface nitrate varies significantly between models, with two of the ROMS-based models performing as well or better than CH3D – ICM (Fig. 5d). ChesROMS is particularly challenged at the southern stations.

CONCLUSIONS

- Overall, models with lower biological complexity and lower resolution achieve similar skill scores as the EPA regulatory model in terms of seasonal variability along the main stem of the Chesapeake Bay. Multiple variables exhibit latitudinal dependence of model skill that is consistent throughout all four models, e.g. mean stratification is underestimated most and model skill for DO is lowest in the north.
- All four models do substantially better at resolving bottom DO than they do at resolving three variables that are primary influences on DO: stratification, chlorophyll, and nitrate. This follows because DO’s variability is sensitive to temperature as a result of the solubility effect, and the models reproduce temperature very well.
- In terms of TMDL development, these findings offer a greater confidence in CH3D – ICM predictions of seasonal variability since a model does not necessarily need to perform well in terms of stratification, chlorophyll, or nitrate in order to resolve the mean and seasonal variability of DO.

FUTURE WORK

Examine the skill of these multiple models in terms of interannual variability, with the goal of formulating a ROMS-based model that performs as well as the EPA regulatory model for both seasonal and interannual variability of DO and hypoxic volume.

ACKNOWLEDGEMENTS

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ANALYSIS

- Model skill of the ROMS-based models (Fig. 6): CH3D – ICM: EPA, ROMS – RCA: UMCES, ChesNENA: VIMS, ChesROMS – BGC: UMCES
- Model output was compared to Chesapeake Bay Program monitoring data using a best time match technique. Analyses included surface and bottom temperature, salinity, dissolved oxygen, chlorophyll-a, and nitrate, as well as stratification.
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