Skill assessment of multiple hypoxia models in Chesapeake Bay and implications for management decisions

I. D. Irby  
*Virginia Institute of Marine Science*

M. A.M. Friedrichs  
*Virginia Institute of Marine Science*

C. T. Friedrichs  
*Virginia Institute of Marine Science*

R. Hood

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**INTRODUCTION**

Chesapeake Bay and its surrounding watershed play host to an extensive suite of commercial, agricultural, shipping, and tourism industries that have a value upwards of one trillion dollars and home to 16 million people. Ensuring the health of the Bay has become a priority for the six states that make up the watershed. Together they have committed to reducing nutrient input to the Bay to improve water quality. A multiple community model implementation approach can be used to gauge uncertainty and elevate confidence in regulatory model projections.

**OBJECTIVE**

Statistically compare a set of estuarine models of varying biological complexity to the regulatory model in terms of reproducing the mean and seasonal variability of hypoxia related variables in the Chesapeake Bay (Fig. 1).

**METHODS**

- Simulations from the regulatory model (R) and three community-based models (A, B, C) based on the Regional Ocean Modeling System (ROMS) were analyzed (Table 1):
  - Biological Complexity

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>N, P, Si</th>
<th>N, P, Si</th>
<th>C, N, N</th>
</tr>
</thead>
<tbody>
<tr>
<td>BGC Sed</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Algal Groups</td>
<td>3 2 1 1</td>
<td>3 2 1 1</td>
<td></td>
</tr>
<tr>
<td>Vertical Grid</td>
<td>0.25 km</td>
<td>1 km - 1 km</td>
<td>1 km - 1 km</td>
</tr>
<tr>
<td>Surface</td>
<td>0.7 0.5 0.2</td>
<td>0.2 0.2 0.2</td>
<td></td>
</tr>
</tbody>
</table>

**ANALYSIS**

- Model output was compared to Chesapeake Bay Program monitoring data using a best time match system for roughly 34 cruises at 10 main stem stations in 2004 and 2005 (Fig. 2).
- Model ability to reproduce the mean and seasonal variability of each variable was evaluated via Target Diagrams (Fig. 3).

**RESULTS**

- All models consistently underestimate both the mean and standard deviation of stratification but perform well in terms of surface and bottom temperature, salinity, and DO (Fig. 2).
- All models consistently perform better in the southern portion of the Bay (Fig. 4).
- The skill of all four models are similar to each other in terms of temperature, salinity, stratification, and DO (Fig. 5).
- Model skill for Chl-a and nitrate is inconsistent between the models (Fig. 6).
- All models reproduce bottom DO better than the variables generally thought to have the greatest influence on DO: stratification, Chl-a, and nitrate (Table 2).

**CONCLUSIONS**

- Overall, models with lower biological complexity and lower resolution achieve similar skill scores as the regulatory model in terms of seasonal variability along the main stem of the Chesapeake Bay.
- All four models do substantially better at resolving bottom DO than they do at resolving its stratification, Chl-a, and nitrate due to DO’s sensitivity to temperature as a result of the solubility effect.
- Modeled DO simulations may be very sensitive to any future increases in Bay temperature. In terms of nutrient reduction regulations, these findings offer a greater confidence in regulatory model predictions of DO 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 variation of DO.

**FUTURE WORK**

- Examine the skill of these models in terms of interannual variability for a 25 year period.
- Generate a multiple model ensemble from model B.
- In cooperation with the US Environmental Protection Agency, evaluate regulatory nutrient reduction scenarios in parallel with the model R.
- Utilize the suite of projected water quality simulations to define the uncertainty in regulatory estimates of estuarine response to reduced nutrient loads.

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