Multiple Model Comparisons in the Chesapeake Bay: Hydrodynamics and Dissolved Oxygen

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• Lessons learned from the U.S. IOOS Estuarine Hypoxia Testbed model comparison project in the Chesapeake Bay

• Recommendations from the STAC sponsored M3.1 workshop, concerning the multiple shallow water model pilot project
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The U.S. IOOS Testbed Project

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Coastal Inundation Team
Shelf Hypoxia Team (Gulf of Mexico)
Estuarine Hypoxia Team (Chesapeake Bay)
The U.S. IOOS Testbed Project

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The U.S. IOOS Testbed Project

Overarching Goal of EH Component:

To help improve operational modeling of hypoxia in Chesapeake Bay

Methods:

• Compare relative skill of various Bay models
• Compare strengths/weaknesses of various models
• Assess how model differences affect water quality simulations

What should a “Next Generation Bay Model” entail?
Five Hydrodynamic Models Configured for the Bay

CH3D
Cerco & Wang
USACE

UMCES-ROMS
Li & Li
UMCES

EFDC
Shen
VIMS

CBOFS (ROMS)
Lanerolle & Xu
NOAA

ChesROMS
Long & Hood
UMCES
Five Biological (DO) Models Configured for the Bay

- **ICM**: CBP model; complex biology
- **BGC**: NPZD-type biogeochemical model
- **1eqn**: Simple one equation respiration (includes SOD)
- **1term-DD**: depth-dependent respiration (not a function of x, y, temperature, nutrients...)
- **1term**: Constant net respiration
Coupled hydrodynamic-DO models

Six combinations:

- CH3D + ICM $\leftrightarrow$ CBP model
- EFDC + 1eqn
- CBOFS2 + 1term
- ChesROMS + 1term
- ChesROMS + 1term+DD
- ChesROMS + BGC

Physical models are similar; biological/DO models differ dramatically.

All models (except CH3D) run using same forcing/boundary conditions, etc...
Model Skill

How well do the models represent the mean and variability of *stratification* and *dissolved oxygen* at ~40 CBP stations in 2004 and 2005?

● = ~40 CBP stations used in this model-data comparison
Relative model skill: Target diagrams

Model skill (RMSD) = Distance from Origin
symbol at origin → model fits observations perfectly

Jolliff et al., 2009
Relative model skill: Target diagrams

Model skill (RMSD) = Distance from Origin symbol at origin $\rightarrow$ model fits observations perfectly

- $y > 0$: overestimates mean
- $x > 0$: overestimates variability

Jolliff et al., 2009
CH3D, EFDC reproduce bottom salinity best
CH3D reproduces hydrodynamics better than the ROMS models: the multiple model comparison has increased our confidence in the CBP model.
CBP model does well, but other models do equally well, even though they were not as skillful in terms of stratification
Again, CBP model does well, but other community models are rapidly improving; some now do equally well.
Multiple model comparison demonstrates that improving the physical model can be just as important as improving the biological model.
What about other years, besides 2004?
By adjusting the advection scheme in ROMS, the HVs now agree better with the data; maybe an adjustment to the advection in CH3D could result in a similar improvement?
15-year time series (1991-2005) mean bottom DO
All models do well at many of the CBP stations
1-term Scully models overestimate annual mean bottom DO in north and underestimate in south.
CBP model underestimates in east; overestimates in west
What have we learned from the U.S. IOOS multiple modeling effort? Specifically...

- Multiple hydrodynamic+DO models exist for the Bay
- CBP model does very well!
  - Increased academic confidence in and support for the CBP model
- Other models do nearly as well, especially in terms of reproducing DO
  - Even though they are not reproducing stratification as well as CBP model, they can still reproduce DO fields
- Simple constant net respiration rate models reproduce mean and variability of DO surprisingly well
- Averaging output from multiple models provides better hypoxia hindcasts than relying on any individual model alone
- New ROMS with improved advection scheme shows great promise
What have we learned from the U.S. IOOS multiple modeling effort?

More generally…

**Critical importance of:**
- quantitatively assessing model skill
- multiple open source, community models
- large group of people from multiple institutions, all collaborating on CB modeling issues

**Recommendation for CBP modeling program (from STAC):**
- use a multiple modeling strategy
- begin with a multiple shallow water model pilot project
• Lessons learned from the U.S. IOOS Estuarine Hypoxia Testbed model comparison project in the Chesapeake Bay

• Recommendations from the STAC sponsored M3.1 workshop, concerning the multiple shallow water model pilot project
Overall Recommendation:

A multiple shallow water model pilot project is key to the advancement of the CBP modeling program and should begin as soon as possible.

Workshop report (Friedrichs, Sellner & Johnston, 2012) available online at:
Pilot Project Rationale

- Need for **multiple modeling efforts**:
  - Help determine whether the regulatory model is as skillful as other models of the Bay
  - Build scientist, management and stakeholder confidence in the model at a time when confidence in the regulatory model is low
  - Excellent opportunity for the CBP to heed recommendations suggested in several recent CBP reports and reviews
Need for new shallow water modeling efforts:

- Modeling WG has identified limitations to existing model in the shallowest, most productive part of Bay
- Because DO & water clarity are criteria that must be met to delist the Bay, the Modeling WG has suggested that additional modeling approaches need to be considered in these waters
Pilot Project Outcomes

- **Project Outcome:**
  - Identification of new model for the shallow waters and/or suggested improvements to existing model
  - Confidence estimates for CBP shallow water simulations
  - Demonstration of utility of using multiple CB models, in response to recommendations of previous NRC/STAC reports/reviews
Pilot Project Methods

Methods:

- Shallow water hydrodynamic+water quality modelers will be sought for participation in a 1-2 yr pilot project.

- Each modeling team will:
  - Use common forcing to implement 3-5 year base case runs at specified times and sites.
  - Provide daily distributions of variables relevant for SAV (T, S, DO, light, nutrients).
  - Provide results as above after forcing model with specified nutrient reduction scenarios.
Pilot Project Methods

Methods (cont.):

- A separate model comparison team will:
  - Use daily distributions from each model as input to a specified empirical SAV model
  - Use state-of-the-art metrics to assess the relative skill of the participating simulations
  - Compare results of the modeled nutrient change scenarios
  - Analyze causes and impacts of differences among models
Overall Recommendation:

A multiple shallow water model pilot project is key to the advancement of the CBP modeling program and should begin as soon as possible.