Multiple Models for Management in the Chesapeake Bay

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Annapolis, Maryland

Scientific and Technical Advisory Committee

to the Chesapeake Bay Program

Steering committee members

Don Weller (SI-SERC)
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Workshop plan

- Introduction
- Case studies
- Perceptions of modeling & MM by public and decision makers
- Legal issues
- Much discussion

Technical experts

Dom DiToro	Great Lakes phosphorus
Vic Bierman	Gulf of Mexico
Kenneth Reckhow	Neuse River
Ray Najaar	Climate and weather
Marjy Friedrichs	Bay hydrodynamics and DO
Jim Kelly	CMAQ

Legal & social science experts

Rick Day	Role of models in AFB
Ross Pifer	lawsuit
Wendy Wagner	How courts view models
Pasky Pascal	& multiple models
Michael Paoloiso	Public (mis)understanding
Christine Keiner	of models &
Jeremy Trombley	participatory modeling

Concerns addressed

- Costs more
- Highlights uncertainty
- May create legal issues
- May confuse stakeholders

Executive Summary

In early 2012, the Director of the Chesapeake Bay Program (CBP) asked the Program's Scientific and Technical Advisory Committee to consider how the CBP might use multiple models. That request resulted in two workshops. The first detailed a pilot multiple modeling project for the Bay's shallow waters (Friedrichs et al. 2012). The second workshop, summarized here, sought to develop more general recommendations on how the CBP could utilize multiple models in management decisions. The workshop considered case studies of multiple models in environmental regulation, the perception of multiple models by the public and decision makers, and legal issues associated with multiple modeling in regulatory settings. This report presents the Findings (factual conclusions or the consensus of workshop experts about the use and benefits of multiple modeling) and four Recommendations that the CBP could initiate to begin realizing those benefits:

Findings

1. Using multiple models offers many documented advantages over analyzing one model of an environmental system.
2. There are different ways to implement multiple models (multi-model ensembles, using other models to assess a decision model, modular community modeling, and model comparisons in pilot studies or testbed areas). The common principle is that findings are stronger when multiple lines of evidence, multiple data sets, or multiple algorithms agree.
3. Analyzing multiple models increases knowledge and understanding of underlying processes.
4. Average predictions from a set of models typically perform better than those from any single model.
5. Information from multiple models can help quantify model uncertainty, which is critical to sound science and rational decision-making.
6. Modeling is inexpensive compared to the costs of monitoring, implementation, and sub-optimal decisions.
7. Properly framed multiple models can be a legal asset rather than a liability.
8. Managers and the public are poorly informed about modeling, model uncertainty, multiple models, and the value of investments in modeling.
9. Multiple modeling can expand opportunities for additional technical experts and non-technical stakeholders to participate in modeling, fostering greater understanding and acceptance of models and the decisions based upon them.
10. Multiple models of the Chesapeake Bay and its watershed already exist and they could be integrated into CBP modeling to improve knowledge and decision making.

Recommendations

1. The CBP should implement a multiple modeling strategy for each major decision-making model of the Bay (airshed, land use, watershed, and estuary) and analyze the output to quantify skill, advance knowledge, and inform adaptive management.
2. The CBP should exercise the multiple model systems developed under Recommendation 1 to quantify model uncertainty and confidence in key predictions used in decision making.
3. The CBP should estimate and better communicate the appropriate levels of spending on monitoring, modeling, and research relative to the costs of implementation and the cost of sub-optimal decision-making.
4. The CBP should implement ways to better communicate modeling, uncertainty, and multiple model results to partners, decision makers, and the public.

Scientific findings

1. Using multiple models offers many documented advantages over analyzing one model of an environmental system.

Scientific findings

2. There are different ways to implement multiple models

   (multi-model ensembles,

   using other models to assess a decision model,

   modular community modeling, and

   model comparisons in pilot studies or testbed areas).

   The common principle is that findings are stronger when multiple lines of evidence, multiple data sets, or multiple algorithms agree.

Scientific findings

3. Analyzing multiple models increases knowledge and understanding of underlying processes.

4. Average predictions from a set of models typically perform better than those from any single model.

5. Information from multiple models can help quantify model uncertainty, which is critical to sound science and rational decision-making.

Findings on cost & legal issues

6. Modeling is inexpensive compared to the costs of monitoring, implementation, and poor decisions.

7. Properly framed multiple models can be a legal asset rather than a liability.

Findings on communication

8. Managers and the public are poorly informed about modeling, model uncertainty, multiple models, and the value of investments in modeling.

9. Multiple modeling can expand opportunities for additional technical experts and non-technical stakeholders to participate in modeling, fostering greater understanding and acceptance of models and the decisions based upon them.

A *convenient* truth

10. Multiple models of the Chesapeake Bay and its watershed already exist and they could be integrated into CBP modeling to improve knowledge and decision making.

Recommendation

1. The CBP should implement a multiple modeling strategy for each major decision-making model of the Bay (airshed, land use, watershed, and estuary) and analyze the output to quantify skill, advance knowledge, and inform adaptive management.

With this, CBP would:

- Begin to realize many benefits of multiple modeling
- Satisfy repeated STAC recommendation
- Demonstrate skill of CBP models
- Foster effective adaptive management
- Build scientist, management, and stakeholder confidence
- Support the claim of using the best possible science

Caveat

Recommending greater use of multiple models in the CBP does *not* undermine the current application of the existing CBP models or provide a rationale for delaying or halting TMDL implementation.

Recommendation

2. The CBP should exercise the multiple model systems developed under Recommendation 1 to quantify model uncertainty and confidence in key predictions used in decision making.

- Lack of uncertainty estimates is a limitation of the current modeling suite
- Balancing risk and uncertainty is critical to making good decisions

Recommendation

4. The CBP should implement ways to better communicate modeling, uncertainty, and multiple model results to partners, decision makers, and the public.

Need to educate stakeholders about:

- The utility and risks of using the models as decision/management tools.
- The need to quantify uncertainties associated with the models and the modeling results.
- The need to account for those uncertainties in decision making.
- The advantages of having multiple models contributing to an overall assessment and understanding of the Chesapeake Bay ecosystem.

Recommendation

3. The CBP should estimate and better communicate the appropriate levels of spending on monitoring, modeling, and research relative to the costs of implementation and the cost of poor decisions.

Part of a larger science challenge

- Persuading the public of the value of information and the cost of ignorance.

Implementation

Research
modeling
monitoring

The cost of restoring the Bay is far greater than needed investments in modeling, monitoring, and research.

Subtext

- Significant, on-going outreach is needed to explain modeling and its value if stakeholders are expected to provide funding to support modeling, to contribute effectively to developing models, and to have confidence in the model and the results.
- That outreach could be implemented through current outreach and education programs and through participatory modeling.

Need to educate stakeholders about:

- The advantages of having multiple models contributing to an overall assessment and understanding of the Chesapeake Bay ecosystem.

Need to educate stakeholders about:

- The fact that knowledge is always incomplete, so targets and recommendations may change as understanding improves.
- The value of adaptive management as a path forward in the face of incomplete knowledge and uncertainty.

Need to educate stakeholders about:

- The development and structure of the models used to quantify pollutant loads to the Bay and to assess the water quality in the Bay.
- The critical assumptions implicit in the models.
- The strengths and limitations of the models.
- The utility and risks of using the models as decision/management tools.

Possible applications

- Estuary
  - Shallow water pilot project
  - Extend past model comparisons
  - Bayes-net model as implemented in Neuse estuary
- Watershed
  - Formal comparisons of existing watershed-wide models (CBP watershed model, USDA-CEAP, SPARROW, RIM data)
  - Comparisons for particular watersheds or BMPs
  - Make CBP model more modular
- CBML could provide funding, personnel, & collaborative environment

Suppose multiple models and adaptive management could provide even modest (2 to 5%) reductions in the Blue Ribbon panel's restoration cost estimate of $28 billion.

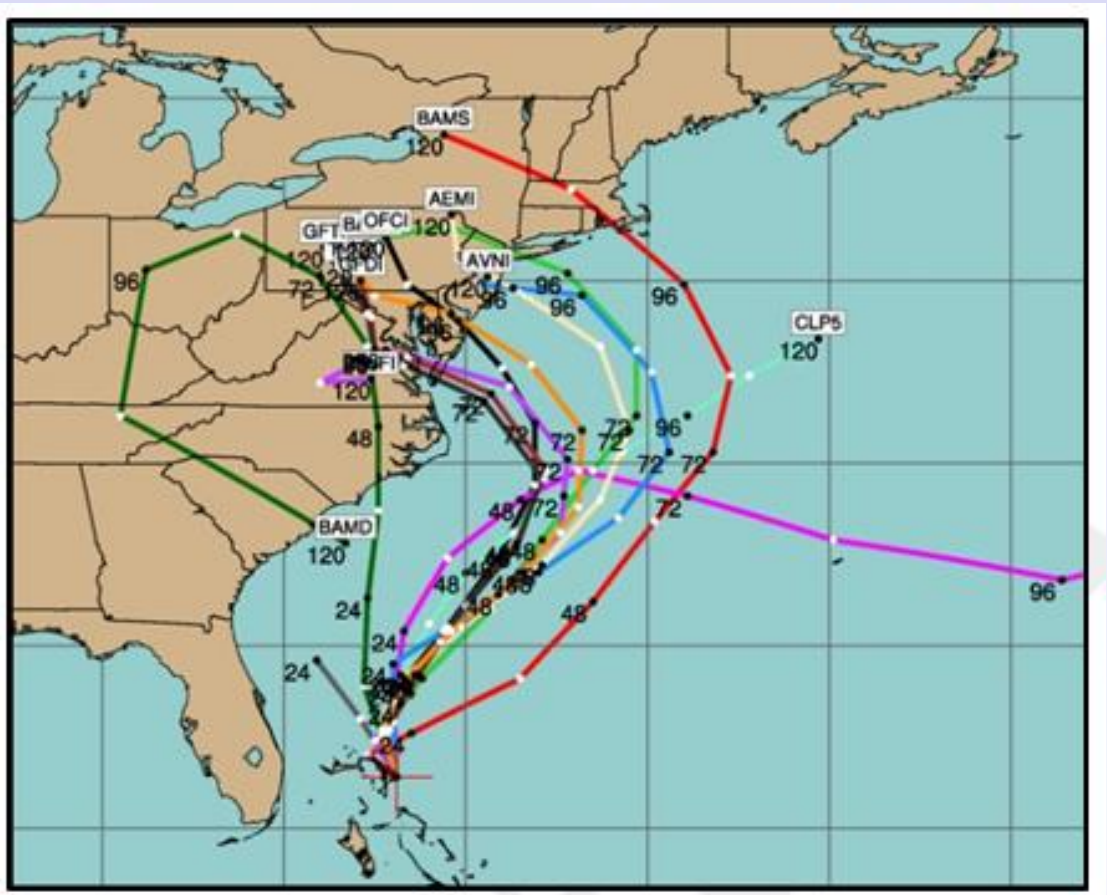
How much would it be worth to have information that could save between $560 million and $1.4 billion in initial costs plus between $54 million and $135 million in annual maintenance costs thereafter?

Concerns addressed

- Costs more

  - Highlights uncertainty
  - May create legal issues
  - May confuse stakeholders

Communications tools

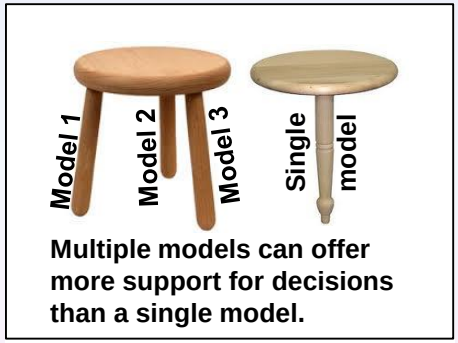


Multiple models are already widely accepted for some issues. In October 2012, television weather broadcasts informed millions of anxious coastal residents with multiple-model projections ("spaghetti plots") of tropical storm Sandy. The same forecasts guided critical decisions by governments and emergency managers.

Communications tools

It is hard to imagine weather and climate prediction without multiple models.

Models are cheap, data are expensive, and implementation is really expensive.

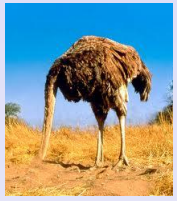


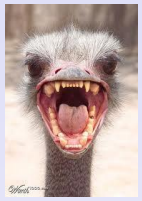
Multiple models can offer more support for decisions than a single model.

Communications tools

If multiple modeling is acknowledged to provide the best science and we do not use multiple modeling, then we cannot claim to be using the best science.

We should not hide from model uncertainty. . .





…instead, we must acknowledge it, quantify it, and use the information to make better decisions.

Communications tools

The cost of restoring the Bay is far greater than needed investments in modeling, monitoring, and research.

Suppose multiple models and adaptive management could provide even modest (2 to 5%) reductions in the Blue Ribbon panel's restoration cost estimate of $28 billion. How much would it be worth to have information that could save between $560 million and $1.4 billion in initial costs plus between $54 million and $135 million in annual maintenance costs thereafter?