

Chesapeake Bay Water Quality and Sediment Transport Model (WQSTM) Review

Damian Brady*
Steven Chapra
Marjorie Friedrichs
Thomas Jordan

Joseph DePinto*
Dominic Di Toro
Matthew Gray
Meng Xia



***With extra special thanks to
Bill Ball and Rachel Dixon!***

* Co-chairs

Overview

Objective: Based on the provided “documentation”... determine the model’s scientific credibility and utility for the 2017 Mid-Point Assessment of the Chesapeake Bay TMDL

“Documentation”: Reports and presentations received between May 2017 - Fall 2017

Conclusion: Changes made to the 2010 WQSTM were deemed “*scientifically defensible and appropriate for preliminary application for the MPA*”, but.....

Questions

1. Is the documentation clear?

2.-8. Are the approaches for modeling the following appropriate?

- **Organic matter behavior (G1, G2, G3)**
- **Impacts of Conowingo infill on WQ**
- **Impacts of SLR on WQ**
- **Impacts of warming temperatures on WQ**
- **Impacts of tidal wetland loss on WQ**
- **Shoreline erosion & shallow water dynamics**
- **Impacts of oysters on WQ**

9. How can the WQSTM be improved in the long-term?

Questions

1. Is the documentation clear?

2.-8. Are the approaches for modeling the following appropriate?

- **Organic matter behavior (G1, G2, G3)**
- **Impacts of Conowingo infill on WQ**
- **Impacts of SLR on WQ**
- **Impacts of warming temperatures on WQ**
- **Impacts of tidal wetland loss on WQ**
- **Shoreline erosion & shallow water dynamics**
- **Impacts of oysters on WQ**

9. How can the WQSTM be improved in the long-term?

Q2: Organic Matter (G1, G2, G3)

Panel agrees that the new parameterizations, i.e. including three organic matter (OM) types in water column:

- Improves coupling between pelagic and benthic OM cycling
- Successfully accommodates more refractory sources of OM (shoreline erosion & Conowingo scour loads)

Recommendations (medium term):

- Recommend systematic comparison of model results with and without water column G3
- Recommend analysis of differences between the 2010 model version and this version – how does the new model shift OM cycling spatially in the Bay?

Q3: Impacts of Conowingo infill

Panel agrees with the ideas that:

- Conowingo Reservoir is essentially in “dynamic equilibrium” (on long time scales, sediment in = sediment out)
- Direct nutrient/sediment reduction from the watershed will be more effective than management of reservoir sediments

Recommendation (short term = now):

- Sensitivity analysis should be conducted on impacts of increased loadings of nitrogen that could be associated with once-per-decade scour events

Recommendation (long term):

- Need better approach for modeling temporal variability of net deposition/scour in the reservoir and the bioavailability of the nutrient content of scoured sediments

Q6: Impact of tidal wetland loss on WQ

Panel finds the modeling approach (SLAMM):

- To be simple, but very useful
- Demonstrates that tidal wetland loss does not have large impact on estuarine WQ standard attainment (i.e. main-stem oxygen concentrations)

Recommendations (long-term):

- Perform further analysis as to whether SLAMM accurately simulates net gains/losses of wetlands
 - If wetland loss is of *minor importance*, then SLAMM can continue to be used
 - If wetland loss is of *major importance*, a more mechanistic/dynamic treatment of wetland accretion and erosion may eventually be needed

Q8: Impact of oyster biomass on WQ

Panel finds:

- Approach for parameterizing factors in the model is defensible
- Uses best data available
- Results consistent with other studies (oysters can positively impact clarity but must reduce their N inputs)

Recommendations (long-term):

- Compare results from mechanistic model used here to results from other existing models (e.g. ShellSIM, ShellGIS, FARM)
- Review new literature (Gray & Langdon 2017) that finds issues with mechanistic models, such as that used here

Q7a: Shoreline erosion & nutrient attenuation by tidal wetlands

Panel found:

- Proposed approaches for estimating nutrient loads from shoreline erosion are defensible
- Proposed approaches for estimating nutrient attenuation by tidal wetlands are defensible
- They agree that erosion is negligible source of N, but possibly significant source of P

Recommendations for future modeling (long-term):

- Need to improve simulation of the bio-availability of shoreline-erosion particulate P; current estimate (14% = inorganic) is too low
- Need to improve simulation of fate of this P (mostly burial)
- Need to improve characterization of the particulate P being buried; must distinguish between erosion of surface soil & subsoil
- Need to incorporate elevation into nutrient attenuation processes (higher marshes have less time for suspended sediments to deposit)

Q7b: Shallow water dynamics

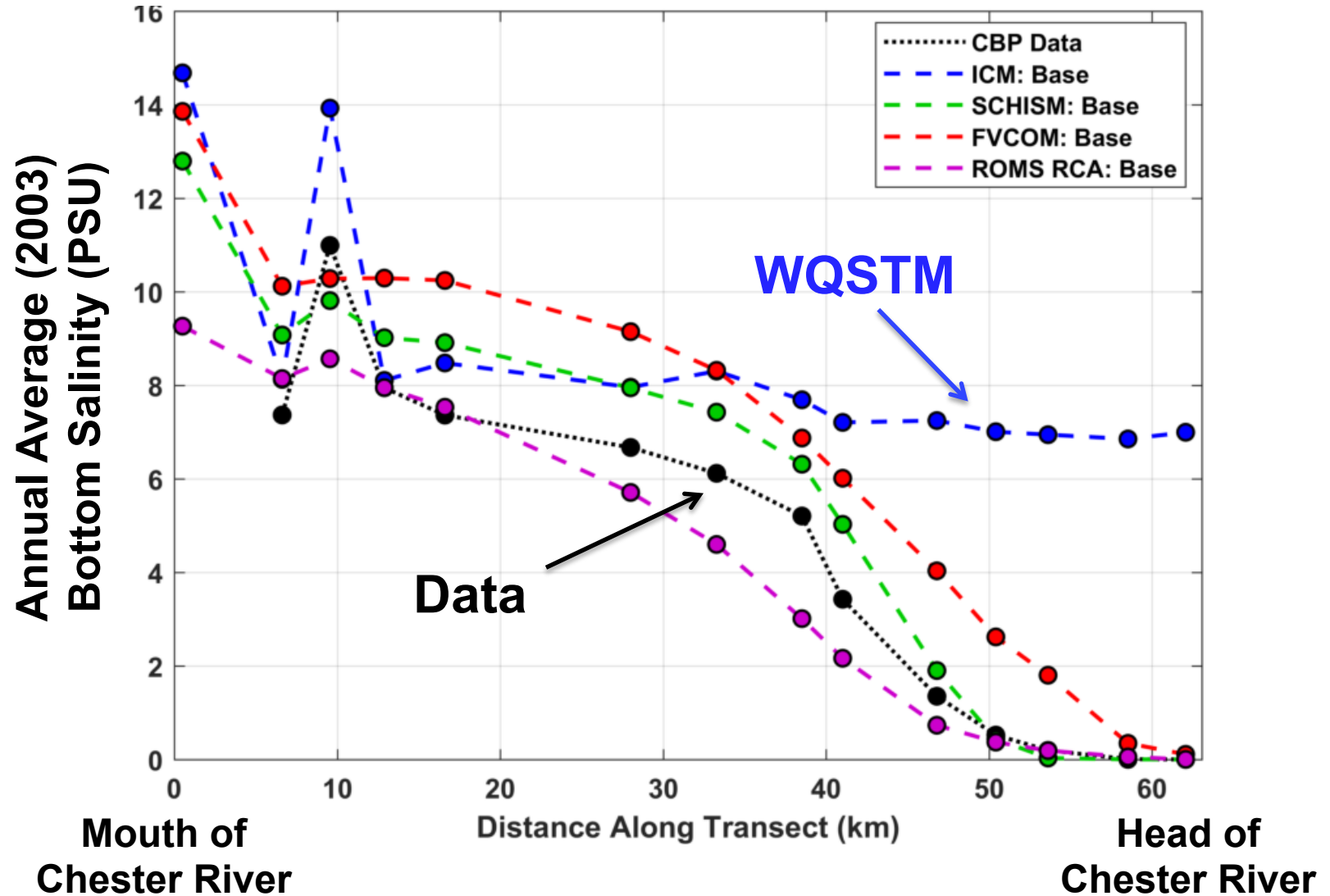
Panel found that:

- Not clear that new approaches represent a significantly improved simulation of shallow water dynamics

Recommendations (long-term):

- A higher resolution model is needed as the current model does not correctly reproduce the upstream salinity gradient in shallows (e.g. Chester River)
- Conservative physical variables such as salinity must be correctly modeled before improving the shallow water quality simulations

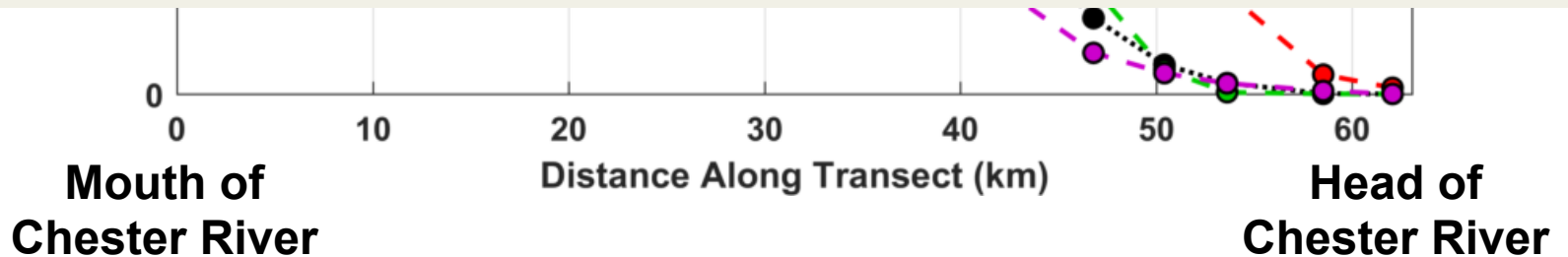
WQSTM does not resolve downstream salinity gradient in shallow water



WQSTM does not resolve downstream salinity gradient in shallow water



**Recommendation:
New hydrodynamic model is
needed, preferably using
unstructured grids or nesting**



Q4 and Q5: Impacts of climate change on WQ (hypoxia)

WQSTM results show :

- Changes in nutrient inputs (due to precip + ET) have small impact
 - SLR substantially reduces hypoxia
 - Warming temperatures slightly increase hypoxia
- Overall, climate change *reduces* hypoxia (???)

Q4 and Q5: Impacts of climate change on WQ (hypoxia)

WQSTM results show :

- Changes in nutrient inputs (due to precip + ET) have small impact
 - SLR substantially reduces hypoxia
 - Warming temperatures slightly increase hypoxia
- Overall, climate change *reduces* hypoxia (???)

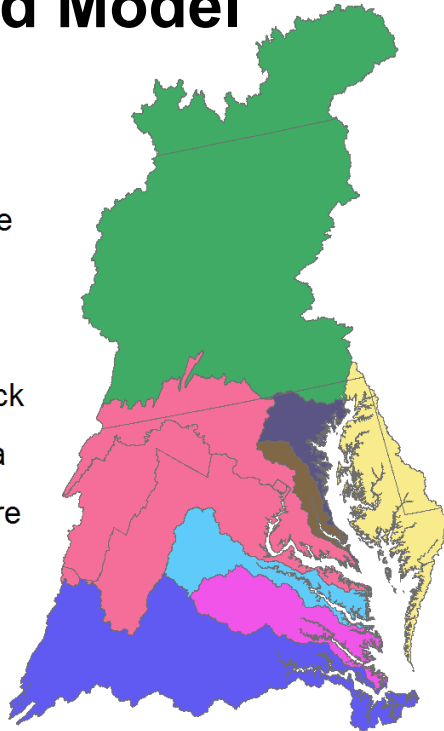
Multiple models!

Redo WQSTM climate change experiments with another modeling system (ChesROMS-ECB) forced with identical WSM outputs (part of NOAA CHAMP project)

Methods: Modeling Framework

Chesapeake Bay Program's Watershed Model

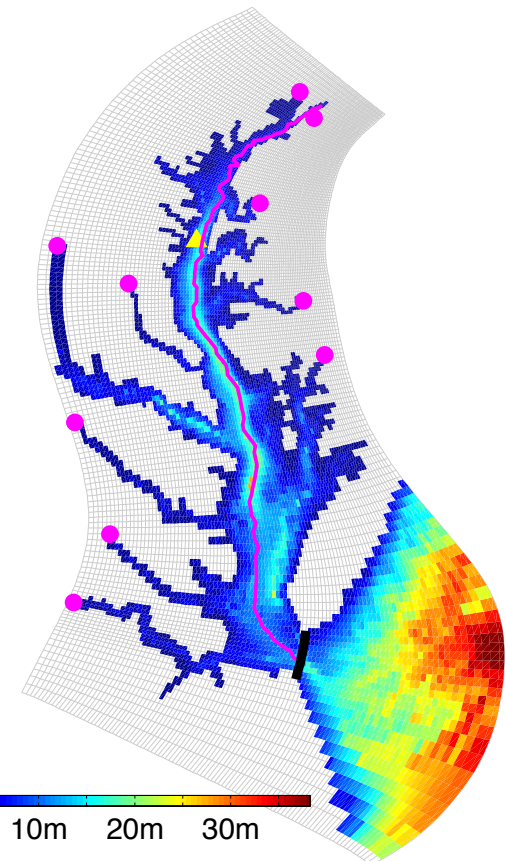
Major Basin



(Shenk and Linker, 2013)

- **Base Run (realistic 1993-1995 nutrients)**
- **TMDL Run (reduced nutrients)**

ChesROMS-ECB



(Feng et al., 2015; Irby et al., 2016)

Methods: 2050 climate change

In 2050, relative to 1990s, we assume:

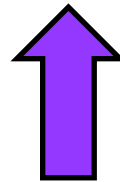
**Water
Temperature**



1.75°C

Everywhere in
water column

Sea Level Rise



0.5m

At open
boundary

Rivers



~15% flow

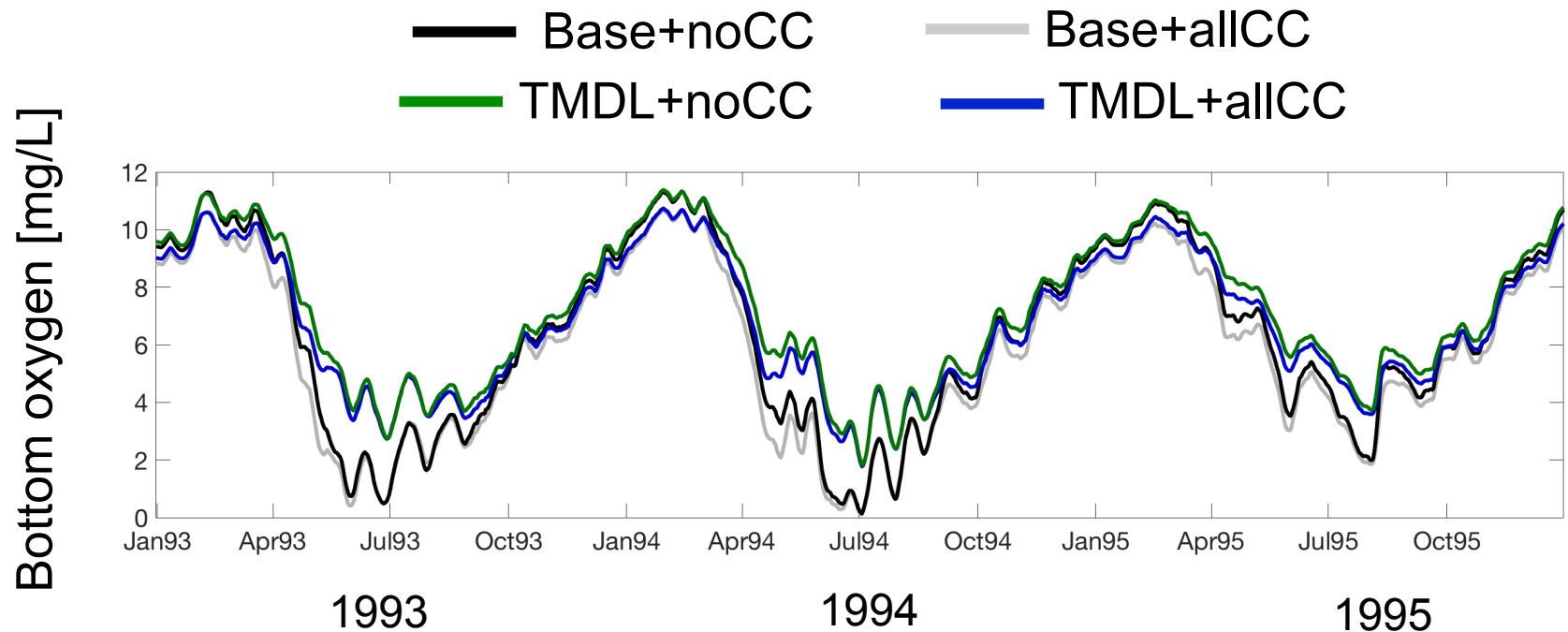
In winter
only

*(Bhatt et al. and
Hinson et al.)*

Climate Change Scenarios:

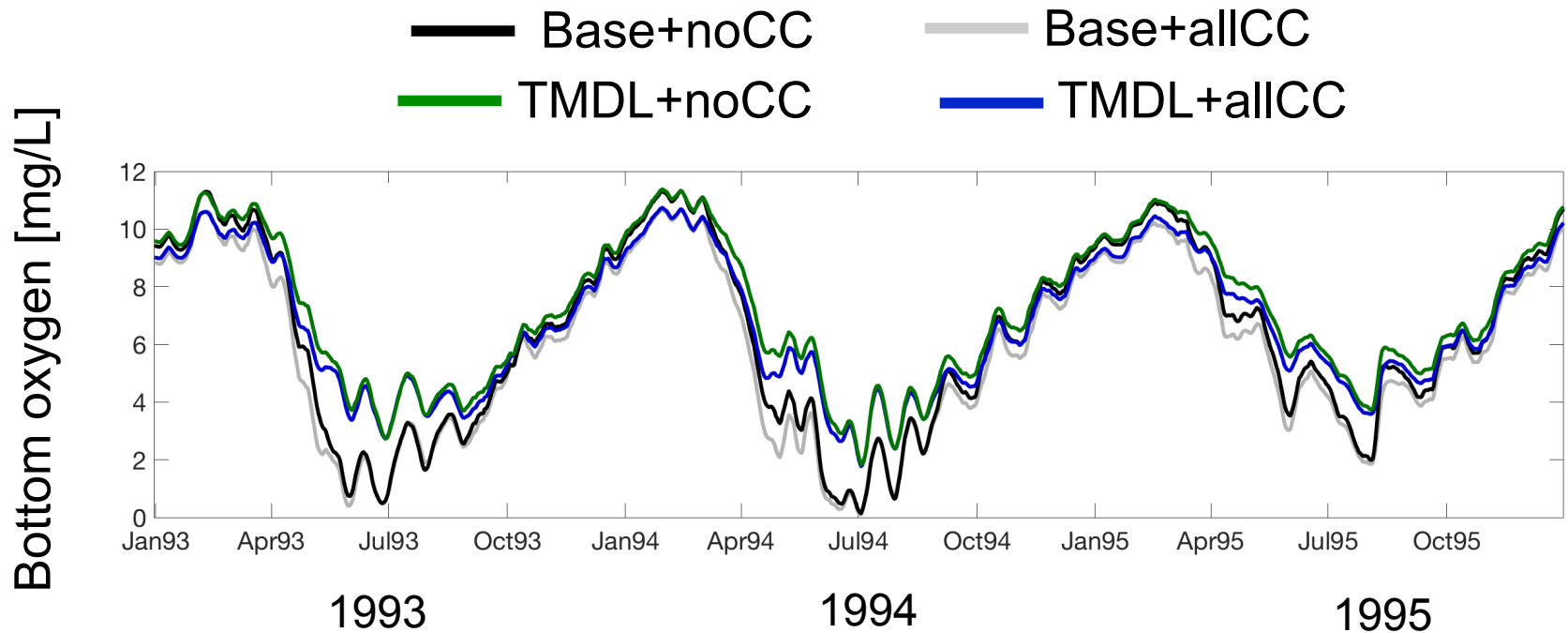
- Temperature
- Sea Level Rise (SLR)
- Rivers (precip/temperature/evapotranspiration)
- All

Results: Mesohaline Bay



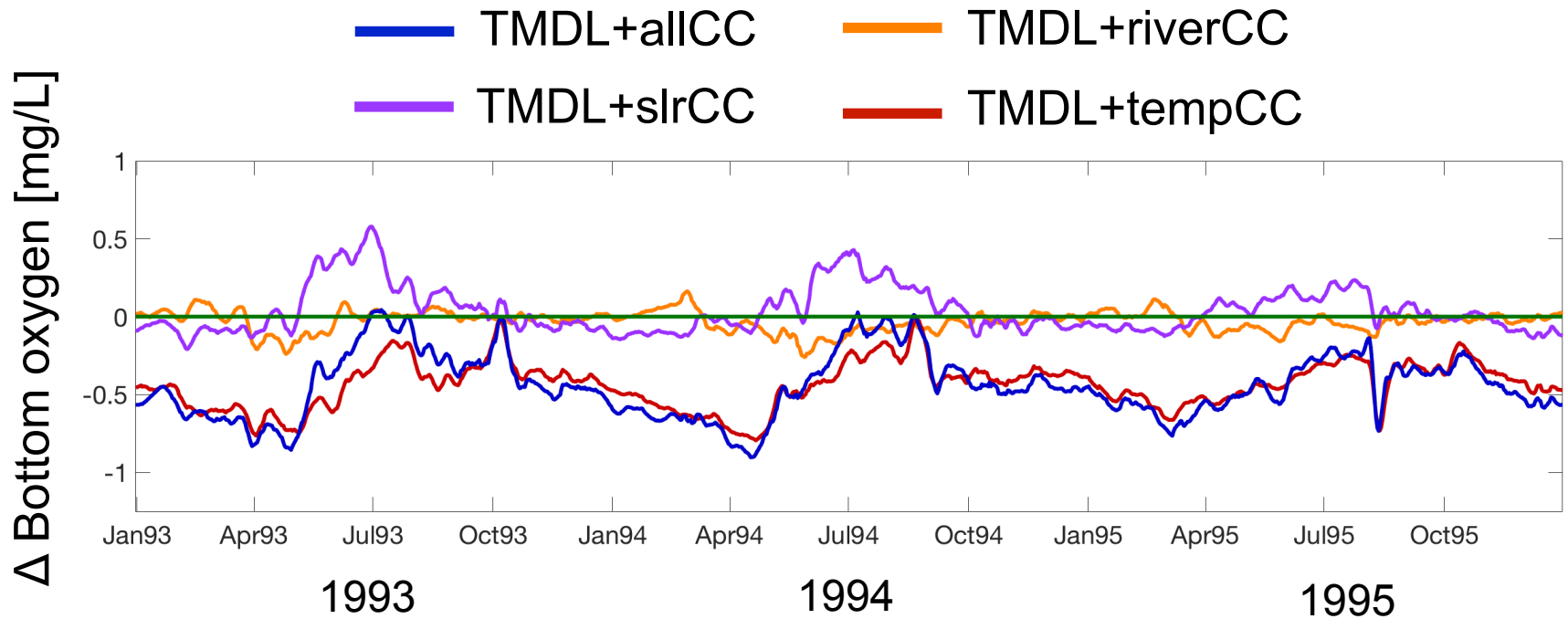
- Climate change exacerbates hypoxia (opposite to WQSTM results)
- Climate change impact on bottom DO \ll impact of TMDL nutrient reductions (same as WQSTM results)

Results: Mesohaline Bay



What causes hypoxia to get worse?
Temperature? SLR? Rivers?

Results: Mesohaline Bay



- **SLR** reduces hypoxia – **same as WQSTM**
- **Rivers/precip** increase hypoxia – **same as WQSTM**
- **Temperature** causes large increase in hypoxia – **different from WQSTM**

→ **Of three climate impacts, here T is greatest**

Why opposite results?

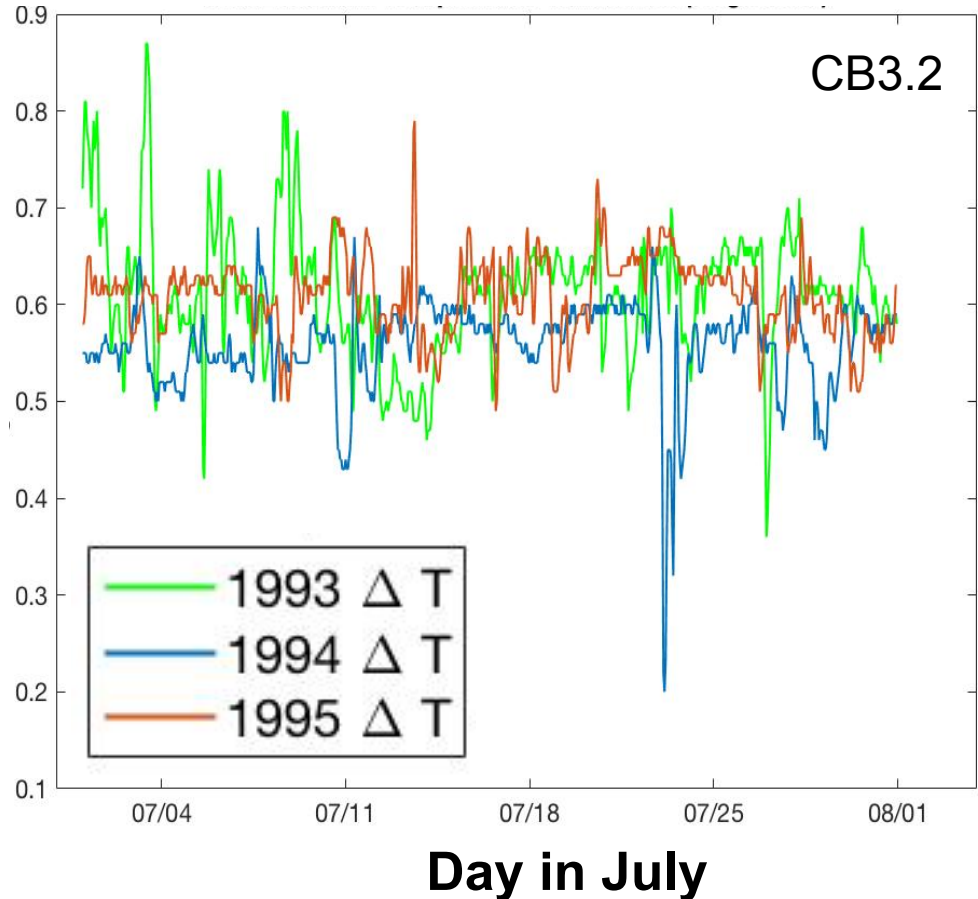
WQSTM:

$\Delta T_{\text{bot}} \sim 0.6^\circ\text{C}$
(other stations
are $\sim 0.7\text{-}0.8^\circ\text{C}$)

ChesROMS:

$\Delta T_{\text{bot}} = 1.75^\circ\text{C}$

**WQSTM summer bottom
 ΔT between 1995 & 2050**



- ChesROMS: $\Delta T_w = 1.75^\circ\text{C}$ throughout water column, based on literature
- WQSTM: $\Delta T_w \sim 0.6^\circ\text{C}$ at the bottom, based on realistic ΔT_{atm} (**but ΔT_{rivers} and ΔT_{OBC} may need to be re-examined**)

Q4: Impacts of SLR on WQ

Panel agrees that:

- Model results demonstrating SLR slightly reduces hypoxia are reasonable (albeit surprising!)

Recommendations:

- Resolve inconsistency in SLR impact on upper Bay bottom salinities (other models show higher salinities)
- Formulate a plan for having SLR increase area of Bay (wetting & drying), not just volume of Bay

Q5: Impacts of warming on WQ

Panel agrees that:

- Warming will exacerbate hypoxia

Panel is not convinced that:

- Improvement in hypoxia due to SLR >> degradation of hypoxia due to warming

Panel recommends re-evaluation of:

- Solubility equation (*done, summer 2017*)
- Impacts at DO ~2 - 5 mg/L (*done, summer 2017*)
- Temperature dependence of phytoplankton growth (growth does not increase with increasing T)
- Underestimate of bottom water temperature in 2050 (0.5-0.8°C warming rather than 2°C warming)
- Warming of shelf waters and riverine waters

Q1: Documentation

Panel found that:

- Documentation received in May 2017 was not well organized and was incomplete; subsequent information trickled in over the summer, filling in the gaps (not all reviewers received same information)

Recommendation:

- Combine all information into a single updated/improved document
- Include missing information (*e.g. how was the oyster module updated?*)
- Need to explicitly justify the simplifications made in the model (*e.g. removing zooplankton*); do these changes impact management decisions? WQSA?
- Transparently provide model output in a common data format (netCDF, THREDDS) so it can be used by research community

Q9: Overview of model improvements needed (before 2025!)

Specific Model Recommendations:

- Modeling of decadal-scale loading events into and out of the Conowingo reservoir should be re-examined and improved
- Outer boundary of the model should be moved onto continental shelf, to improve fluxes into/out of Bay, especially during SLR experiments
- Technological advances in modeling such as unstructured grids (nested grids?) need to be implemented
- Wetting/drying needs to be included to allow SLR to inundate the coastline/wetlands
- Modeling of phosphorus dynamics should be refined (PIP no longer treated as inert particulate matter)

Panel thoughts on CBP modeling

- CBP should finalize sensitivity analyses and calibrations before subjecting models to external review
 - (Conducting further analyses during review results in confusion/frustration by committee)
- Earlier review (before 2024) of new model components is encouraged in regard to scientific review of the fundamental principles, technical details, and model skill assessment
- Separate smaller reviews/panels of individual model processes would be a productive approach
 - To assist with these analyses, the CBP could assemble a small advisory group to focus specifically on the estuarine component system
 - The advisory group can assist the modelers in making minor model modifications to better address CC and in developing adequate model scenarios that go well beyond merely prescribing an assumed air temperature rise

Panel thoughts on CBP modeling

- The Review Panel also recommends that the CBP establish a plan for the continuing development and improvement of the WQSTM over the next several years
- With recent retirements, it is not clear how future WQSTM analyses will be conducted
- Panel notes importance of having the next generation WQSTM recalibrated and revised in the next few years (2018-2020) and that it be subjected to a follow-up technical review well in advance of 2025

Final Notes on this Review

- The panel found this review especially challenging, because the finalized full 2017 MPA WQSTM system had not been completed at the time of the review.
- Most of review panel were unable to give full consideration to the final WQSTM calibration results, which included new WSM assumptions about land use changes and Conowingo Pond performance. Such calibrations are relevant to “appropriateness of model application to management” that the Panel was asked to assess. *(However the panel largely feels that the final calibration results probably wouldn't impact their judgment on the appropriateness of the model.)*
- Within the above context, the Panel emphasizes that the review would have been far more efficient and complete if the full effort (including final calibration) and documentation had been completed in advance of the review, and if more time had been given for the review after the final presentation of modeling results.

Questions?

