2017 Midpoint Assessment Management Needs: Estimated Influence of 2050 Climate Change on Chesapeake Bay Water Quality Standards

STAC Workshop: Development of Climate Projections for Use in Chesapeake Bay Program Assessments

March 7, 2016

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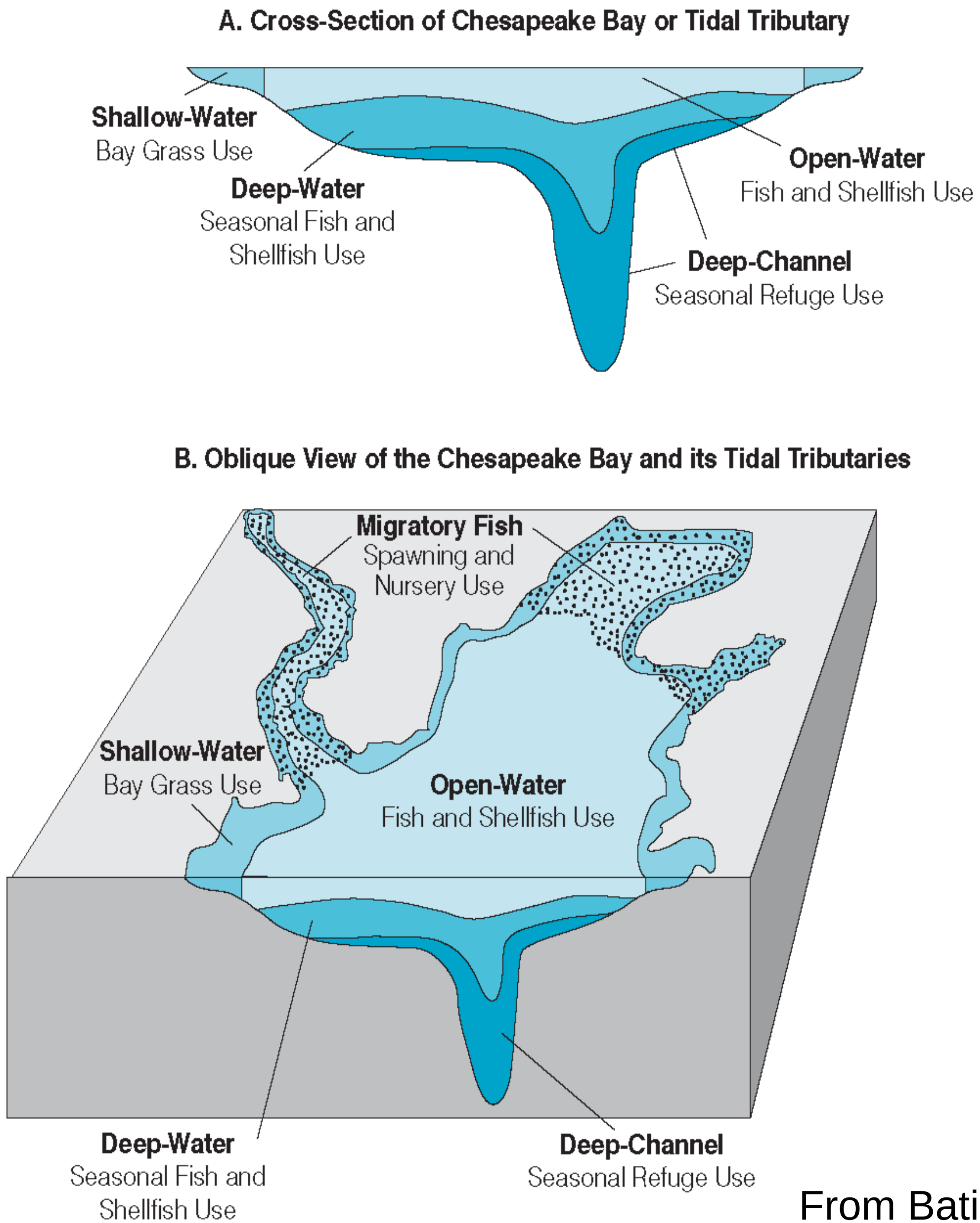
Chesapeake Bay Program
Science, Restoration, Partnership

Motivation

- The Chesapeake Bay Program partners are developing the tools to quantify the effects of climate change on watershed flows and loads, storm intensity, increased estuarine temperatures, sea level rise, and ecosystem influences including loss of tidal wetland attenuation with sea level rise, as well as other ecosystem influences.
- Current efforts are to frame initial future climate change scenarios based on estimated 2025 (potential TMDL application) and 2050 conditions (scoping scenario application).
- In 2017 the CBP partnership will need to decide if, when, and how to incorporate climate change considerations into the Phase III WIPs.

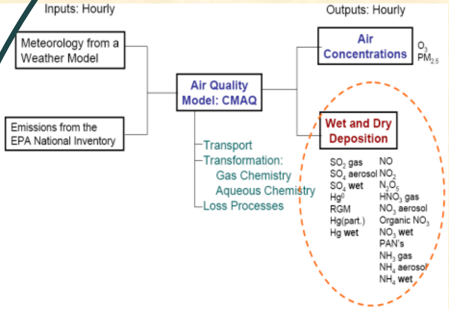
Water Quality Standards of Deep Water, Deep Channel, Open Water, and Shallow Water Dissolved Oxygen (DO) are key for protection of living resources. Chlorophyll and SAV/clarity standards are also designed to protect living resources.

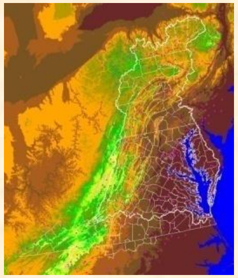


From Batiuk (2003)

Nutrient Allocation Decision Support System

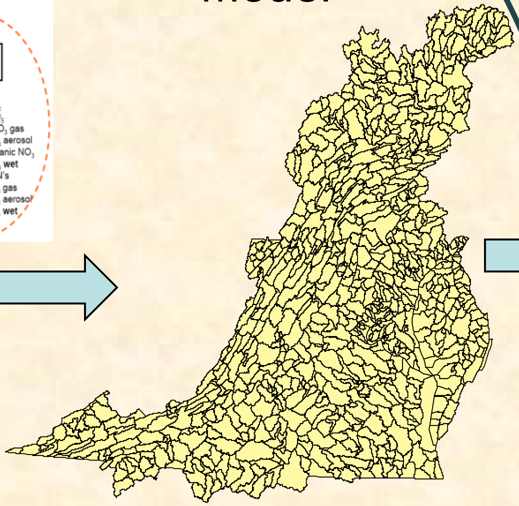
Airshed Model





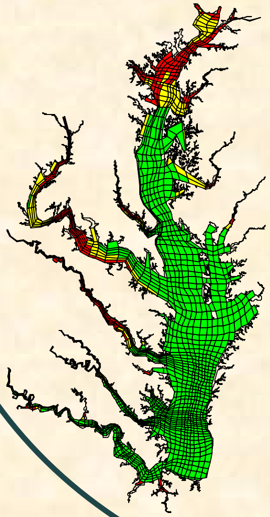
Land Use Model

Watershed Model

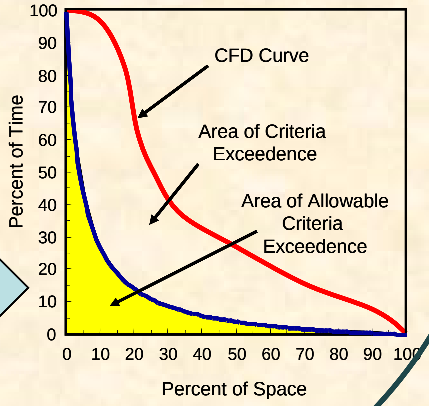


Used to Assess Air-Water Exchanges

Bay Model



Criteria Assessment Procedures



Used to Assess TMDL Achievement

Effects

Allocations

With the CBP Analysis Tools We're Examining….

Increased Estuarine Temperature

- Direct warming of tidal water
- Indirect warming from watershed inputs
- Indirect warming from ocean boundary inputs

Sea Level Rise

- Influence on hydrodynamics
- Influence on tidal wetland loss and associated loss of nutrient attenuation
- Increased organic loading from wetland erosion

Watershed Hydrologic and Loading Changes

- Changes in precipitation volume
- Changes in precipitation intensity
- Changes in land use

With CBP Analysis Tools We're Examining *(continued)*

Ecological Changes

- Temperature ranges and optima (*Zostera*)
- Other ecological changes

Changes in Airshed

- Changes in precipitation volume
- Changes in precipitation intensity
- Changes ground level ozone with temperature increases

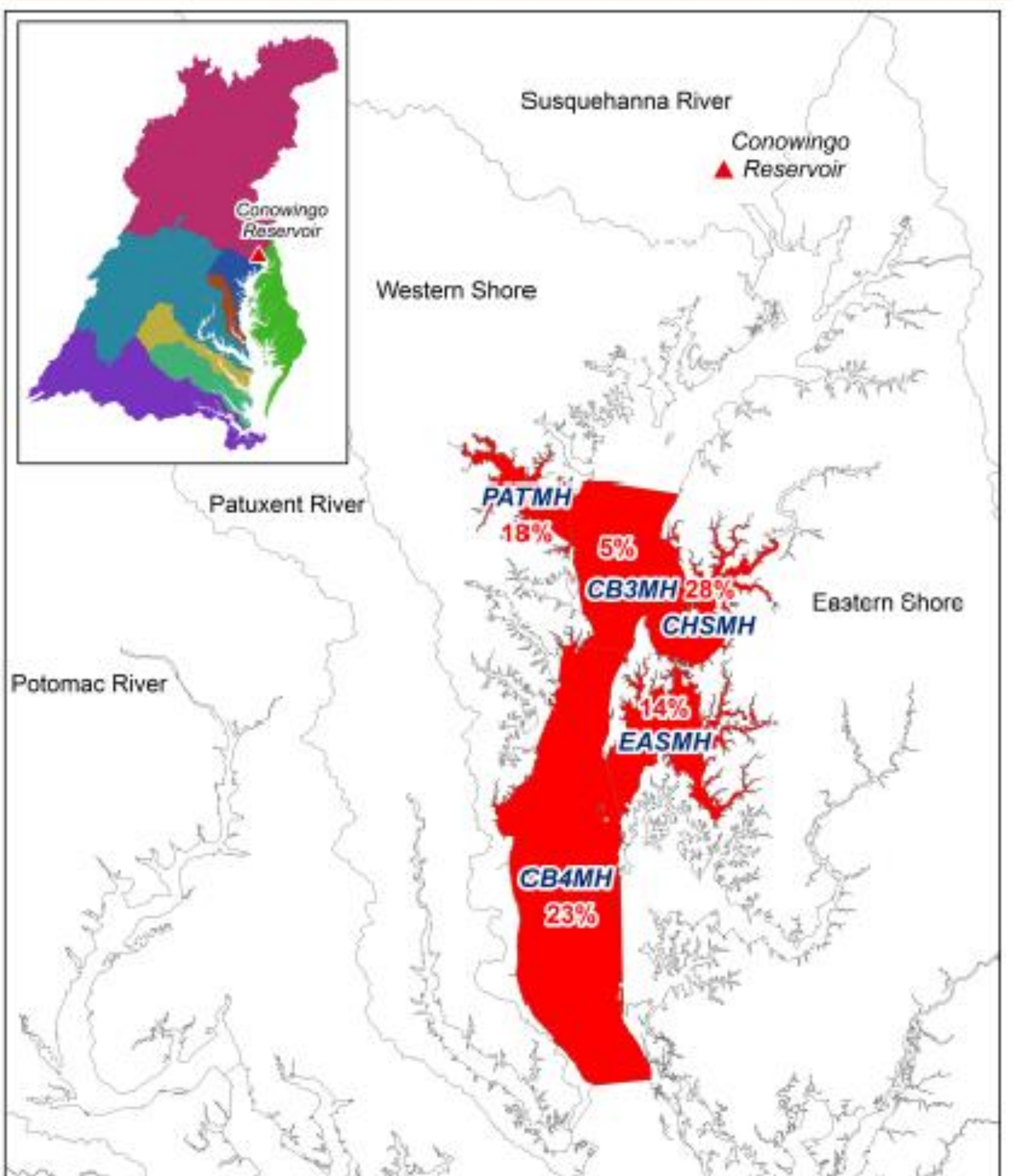
Additional Inputs To the CBP TMDL Climate Change Decision:

- Historical studies of climate change
- GCM models downscaled for the Chesapeake watershed
- Intercomparison of coastal systems
- Other relevant climate change research, monitoring, and observations (a lot!)

The Key Point of Influence on the Chesapeake TMDL is…

….CB4MH and the adjacent contiguous region of deep-channel and deep water habitat.

Figure shows Chesapeake hypoxia under estimated current (2010) conditions represented by deep channel DO standard nonattainment. Insert shows the major basins of the Chesapeake watershed.

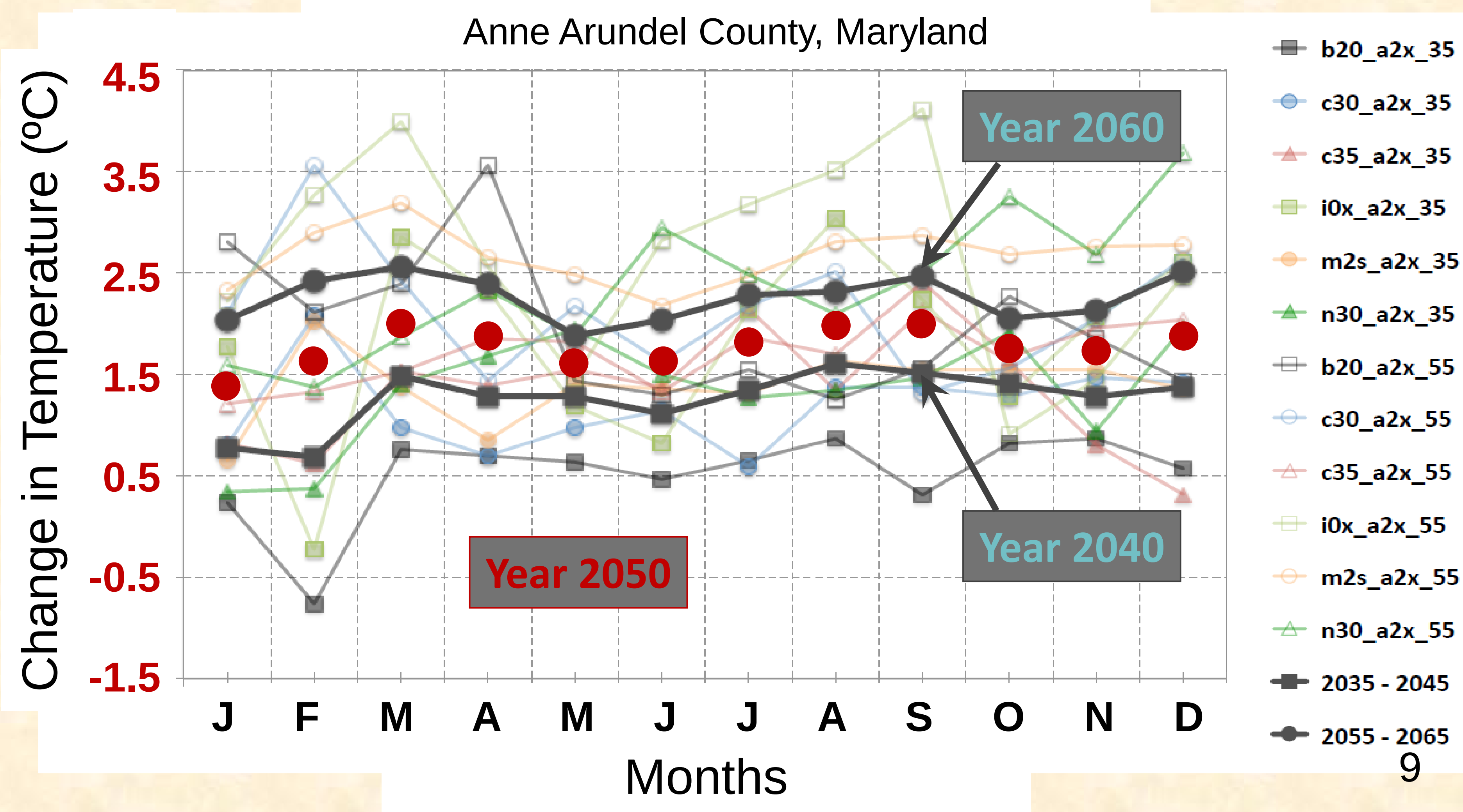


Assessing Water Quality Standard Impacts of:

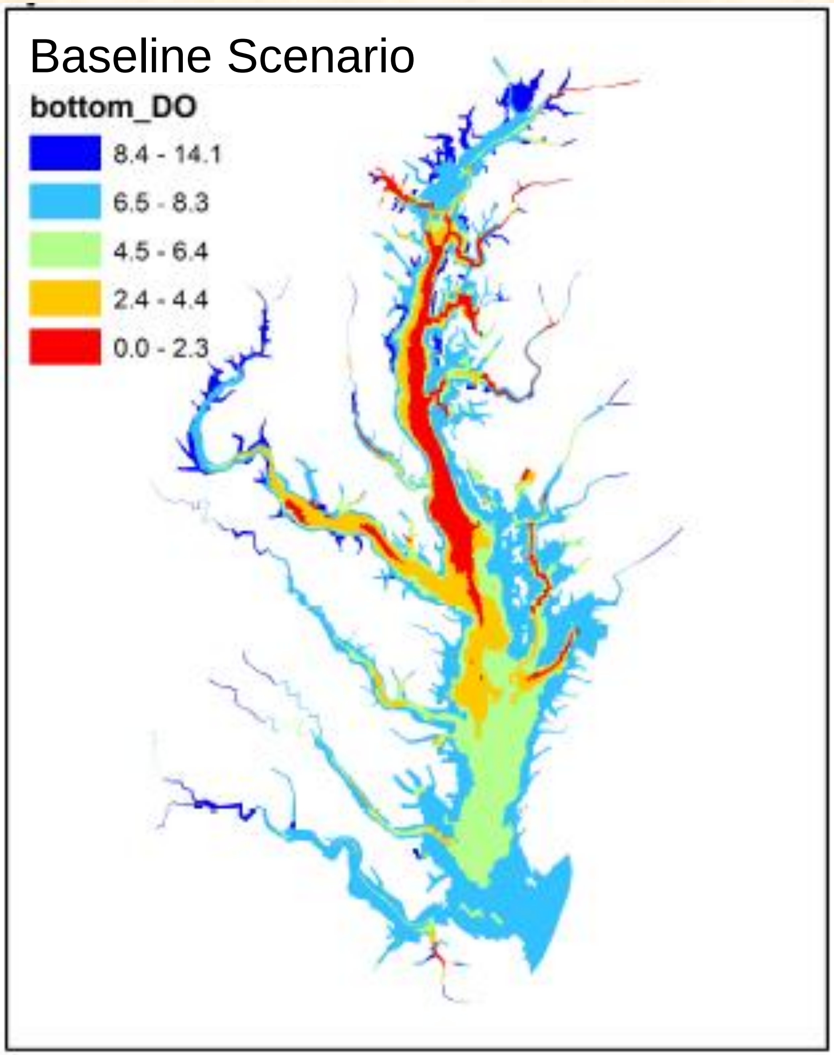
- Estimated 2050 increate in temperature
- Estimated 2050 increase in sea level rise
- Estimated 2050 increase in watershed loads
- Estimated 2050 loss in tidal wetland attenuation

2050 Temperature Increase Scenario

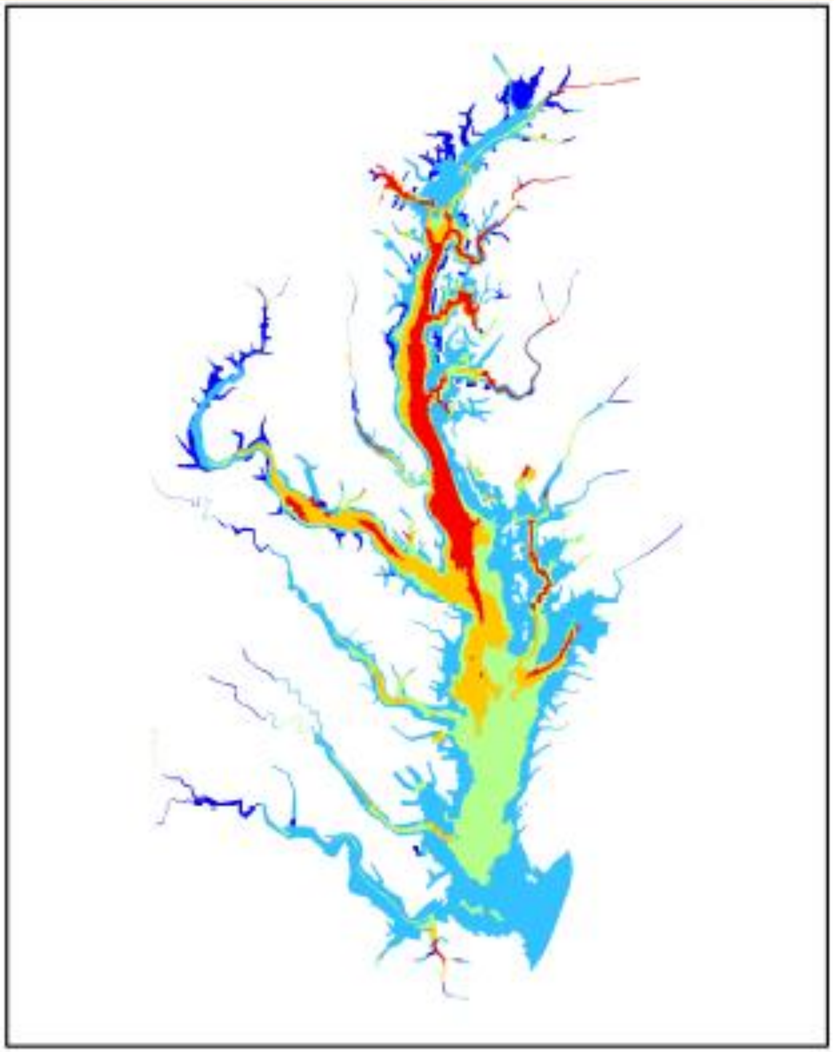
Projections of downscaled ***mean monthly change in temperature*** were obtained from multiple global climate models. Estimated overall increase in watershed-wide annual average temperature was 1.75°C.



2050 Temperature Increase Scenario

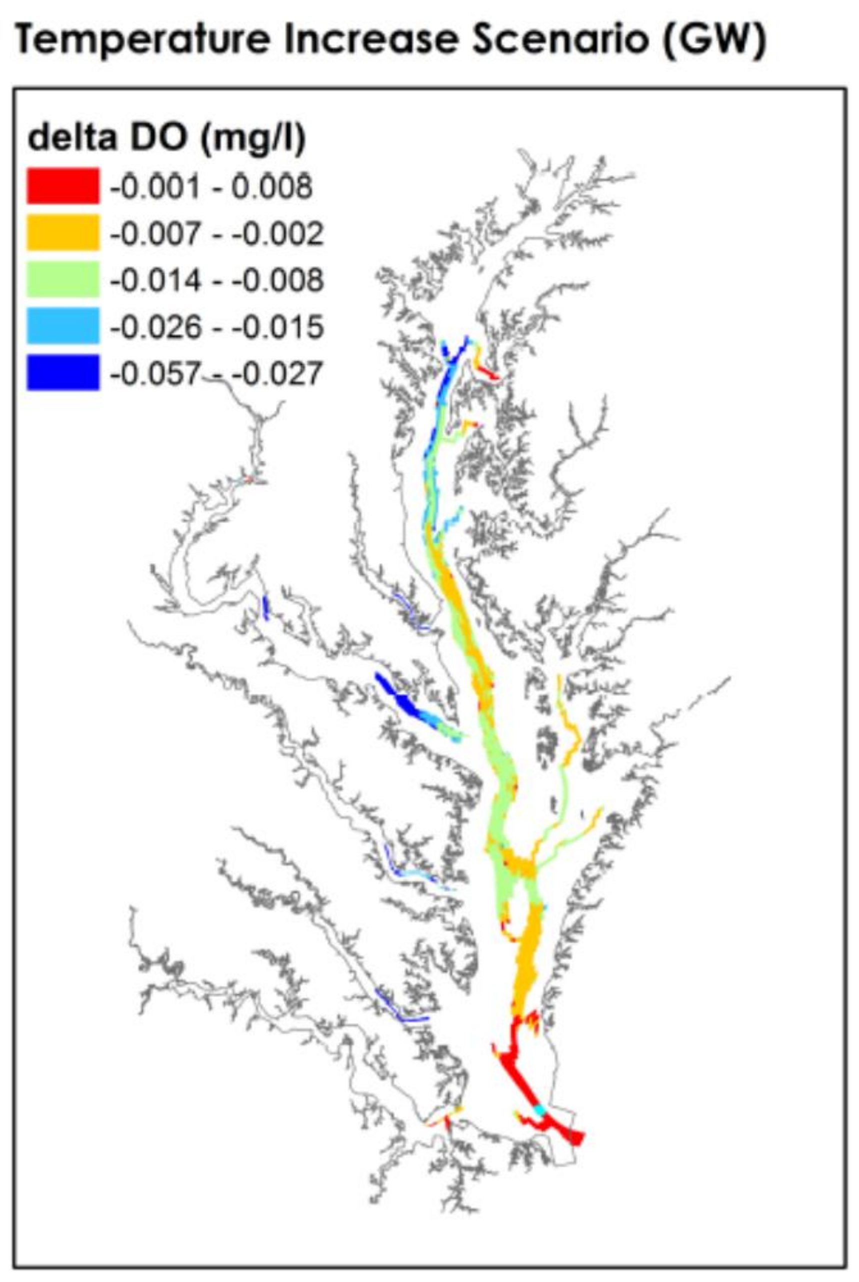


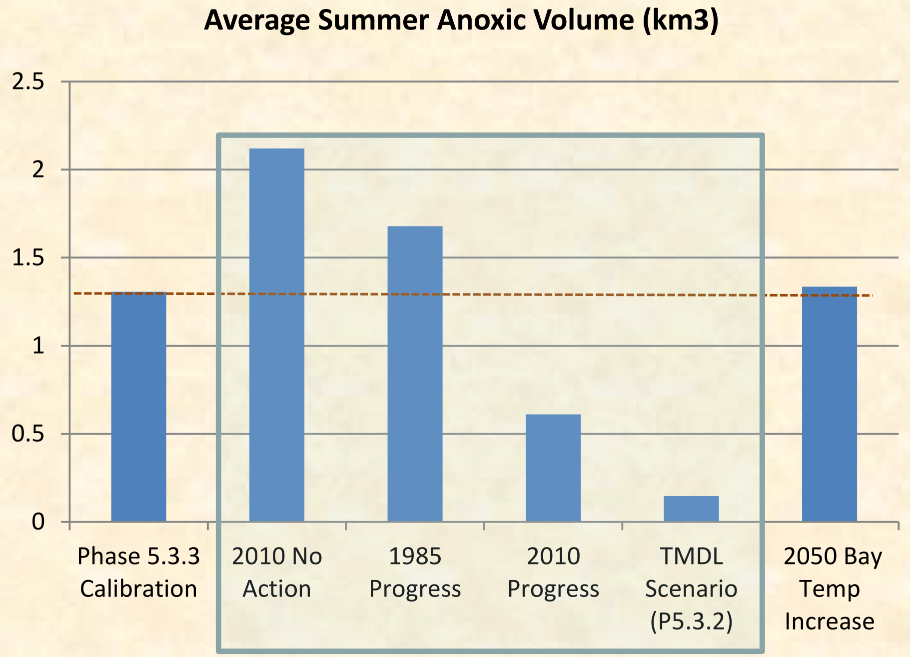
Average of 1991-2000 bottom cell DO



2050 Temperature Increase Scenario

Influence of Estuarine Temperature Increases on Bottom DO



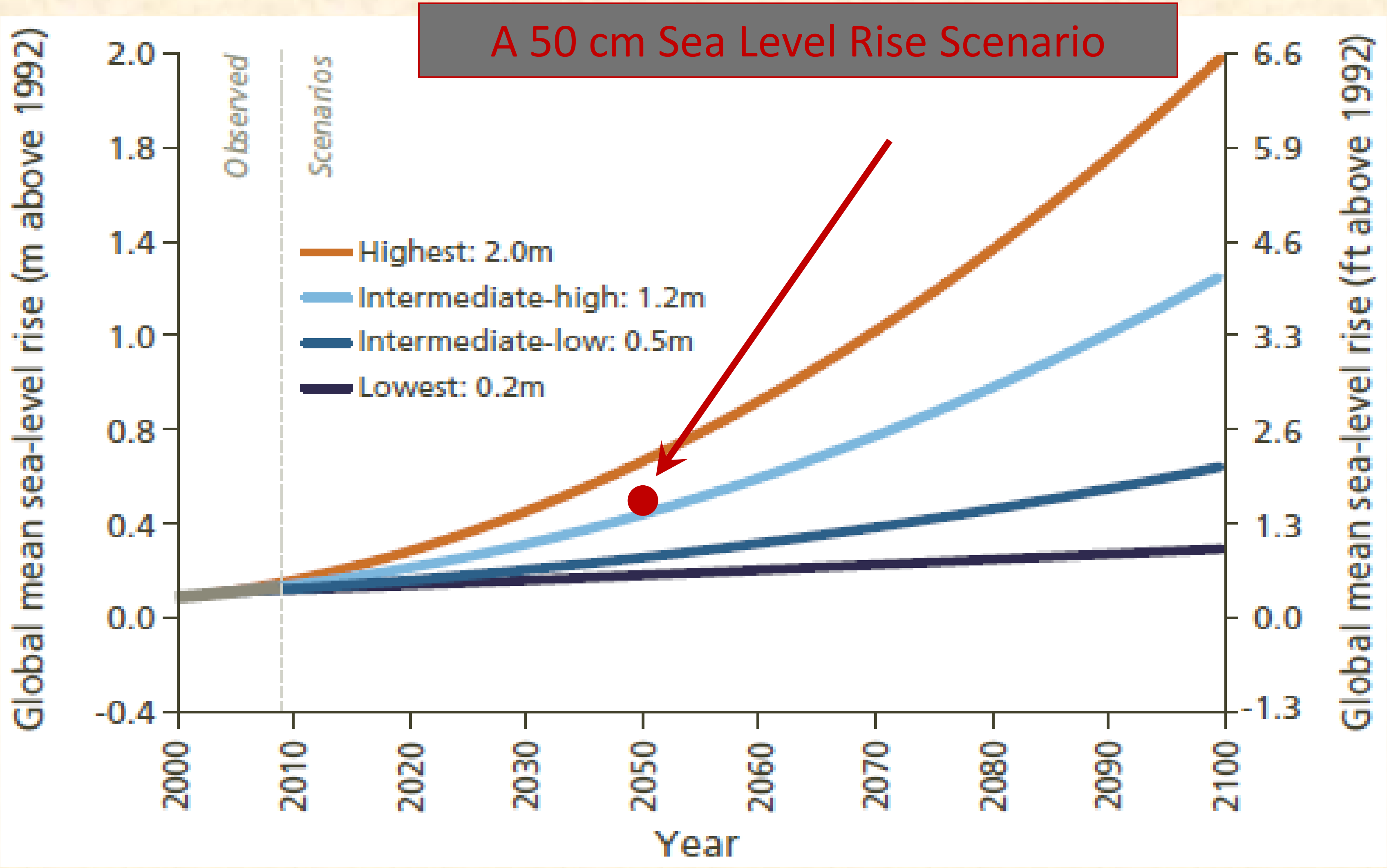


The influence of an 2050 estimated temperature increase on Chesapeake hypoxia is small.

But we can measure in infinitesimal with our models. The estimated delta increase in Chesapeake hypoxia due to 2050 estimated temperature increases ranges from 0.008 to -0.06 mg/l.

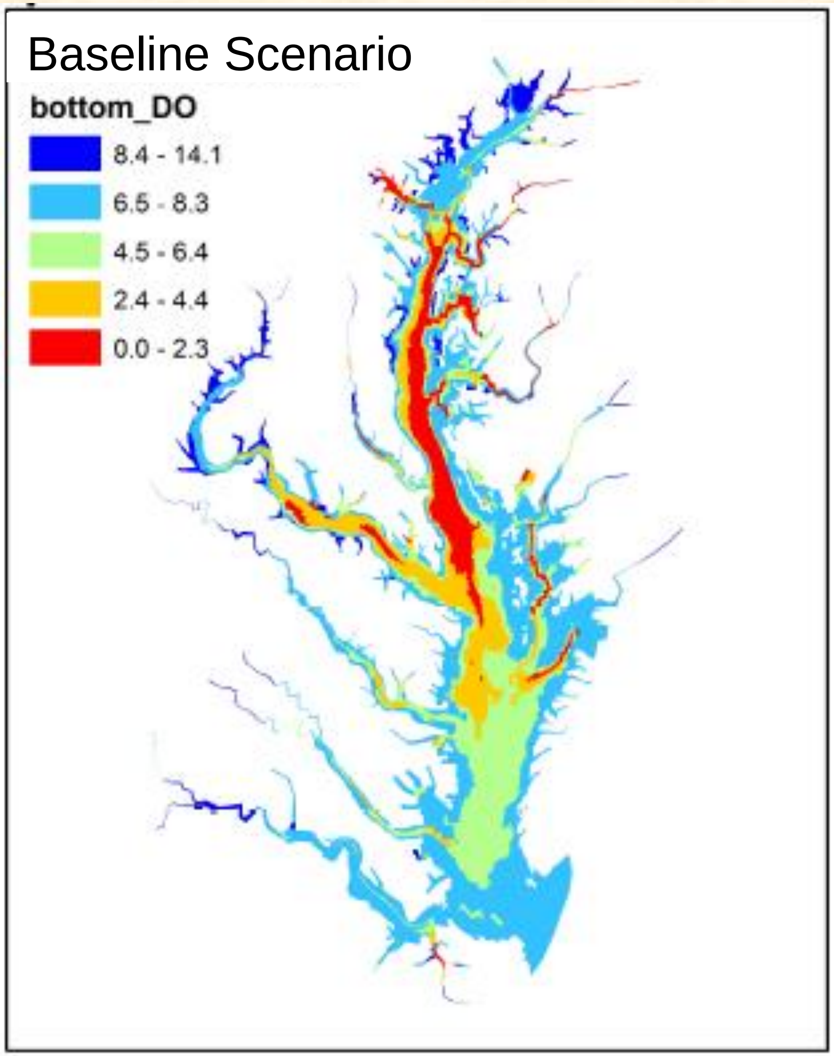
Hypoxia increases are due to the increase in vertical stratification due to the increased thermocline and because of increased respiration.

2050 Sea Level Rise Scenario

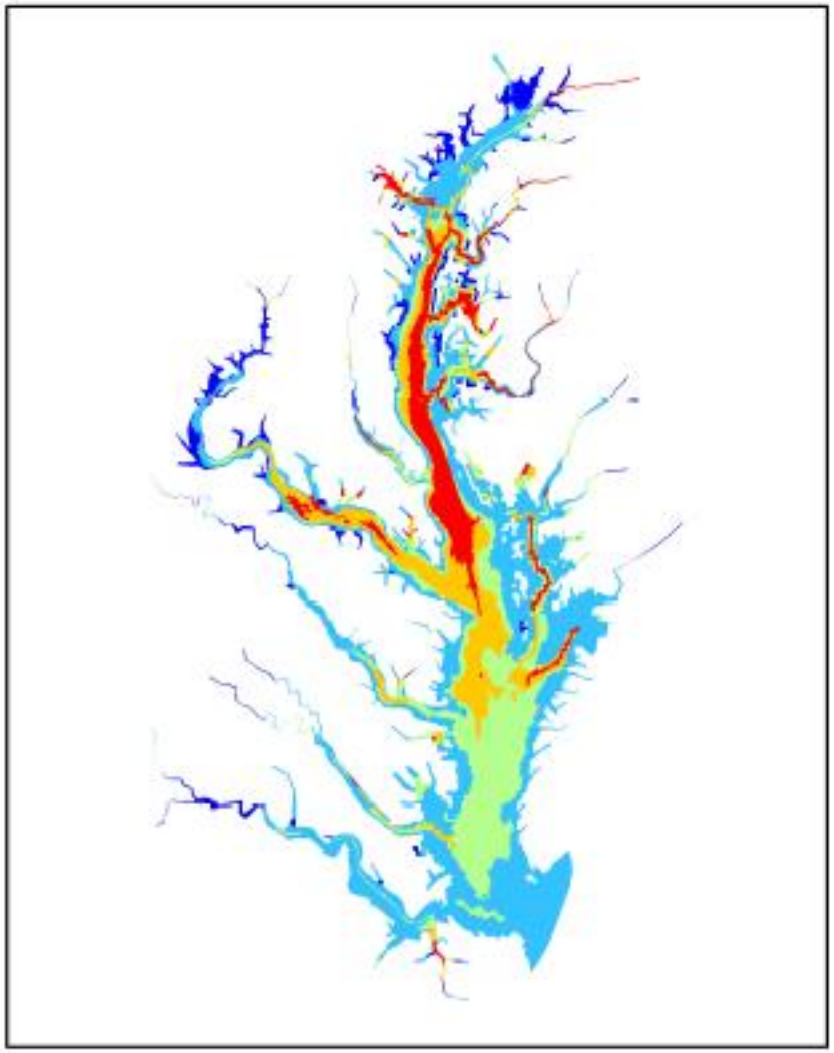


Parris, A. et al. 2012. Global Sea Level Rise Scenarios for the United States National Climate Assessment. NOAA Technical Report OAR CPO-1. National Oceanic and Atmospheric Administration, Silver Spring, Maryland.

2050 Sea Level Rise Scenario

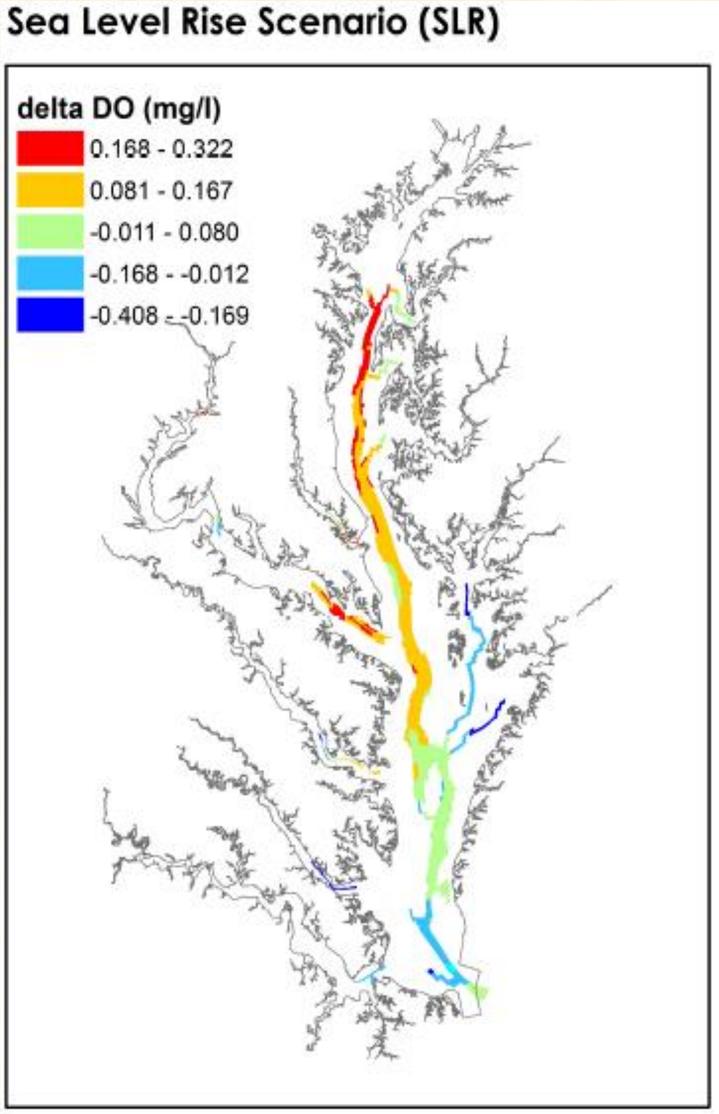


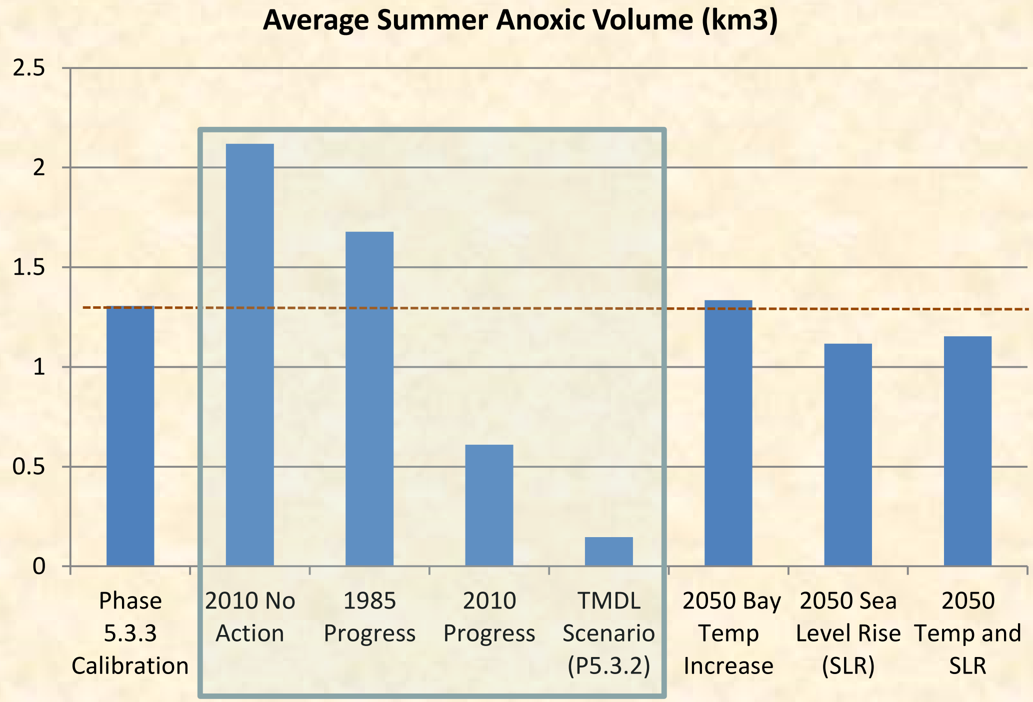
Average of 1991-2000 bottom cell DO



2050 Sea Level Rise Scenario

Changes in Hydrodynamics due to Sea Level Rise

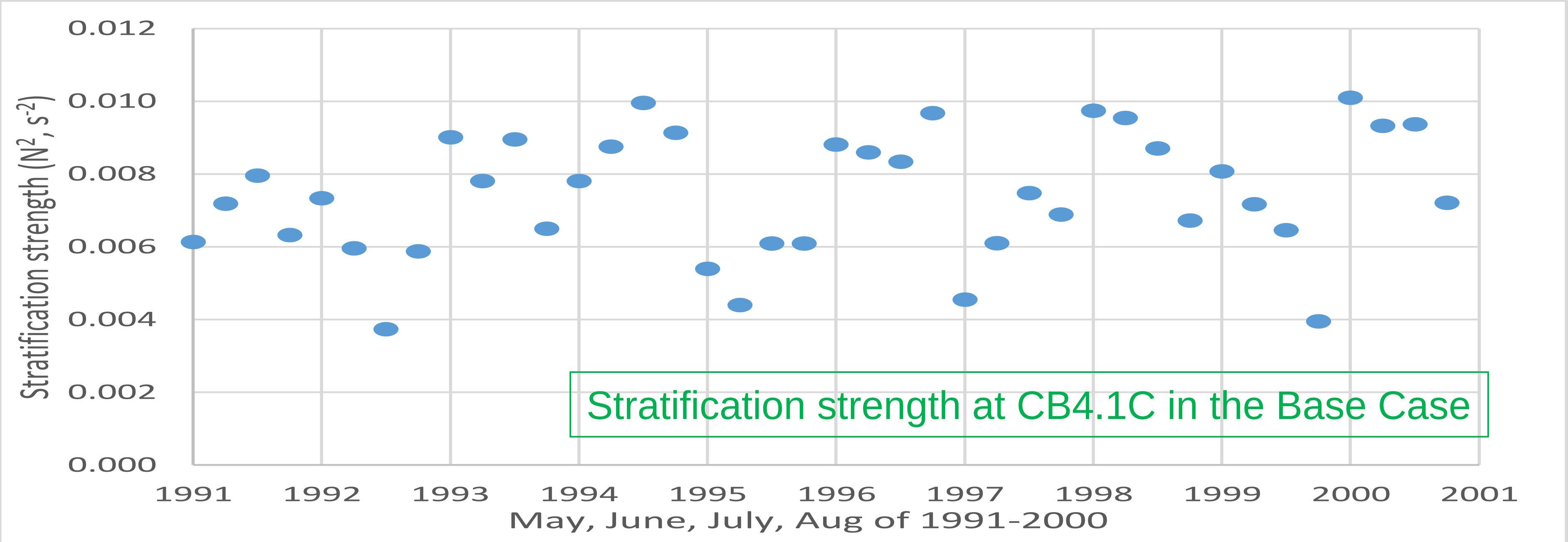




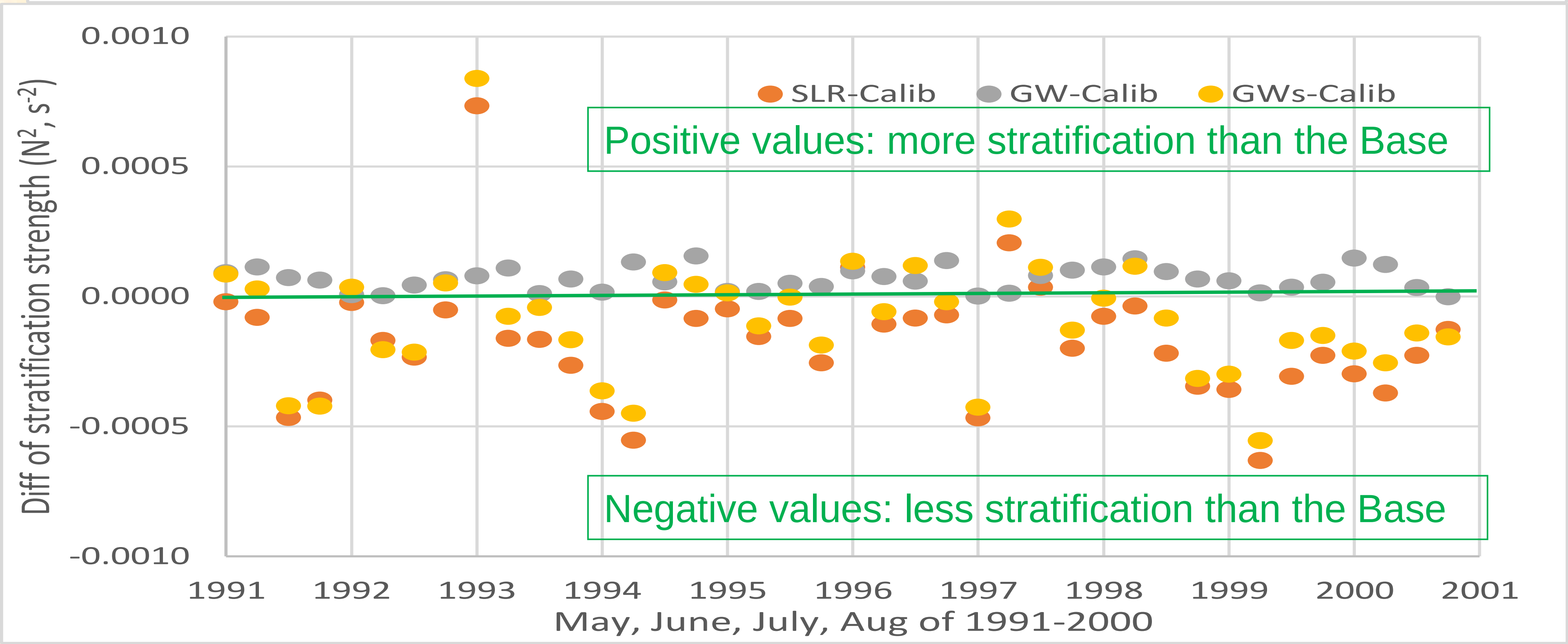
The influence of an 2050 estimated sea level rise on Chesapeake hypoxia is also relatively small.

The estimated delta in Chesapeake hypoxia due to 2050 estimated sea level rise ranges from 0.3 to -0.4 mg/l.

Hypoxia decreases in the mid-Bay are due to increased ventilation of deep Chesapeake waters by high DO ocean waters and also to changes in vertical stratification.

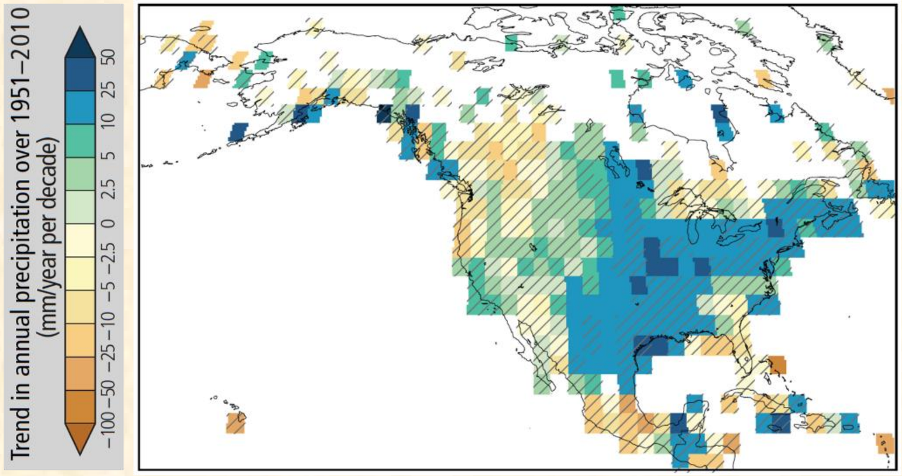


Stratification strength (N^2, s^{-2})
0.012
0.010
0.008
0.006
0.004
0.002
0.000
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
May, June, July, Aug of 1991-2000
Stratification strength at CB4.1C in the Base Case



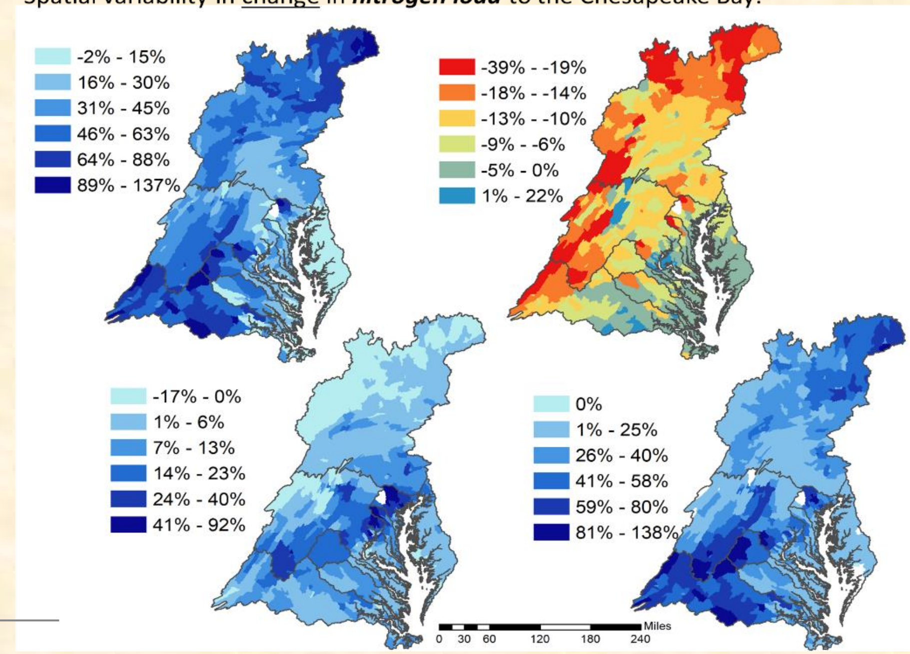
Diff of stratification strength (N^2, s^{-2})
0.0010
0.0005
0.0000
-0.0005
-0.0010
SLR-Calib
GW-Calib
GWs-Calib
Positive values: more stratification than the Base
Negative values: less stratification than the Base
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
May, June, July, Aug of 1991-2000

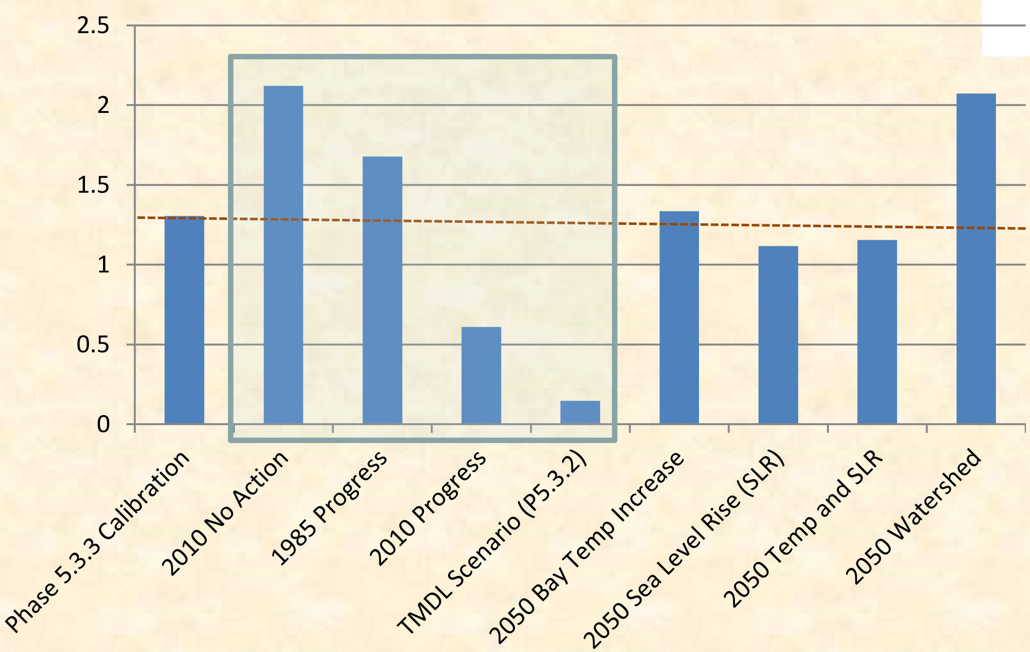
Watershed Hydrologic and Loading Changes



Romero-Lankao and others, North America. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B:

Spatial variability in change in ***nitrogen load*** to the Chesapeake Bay:

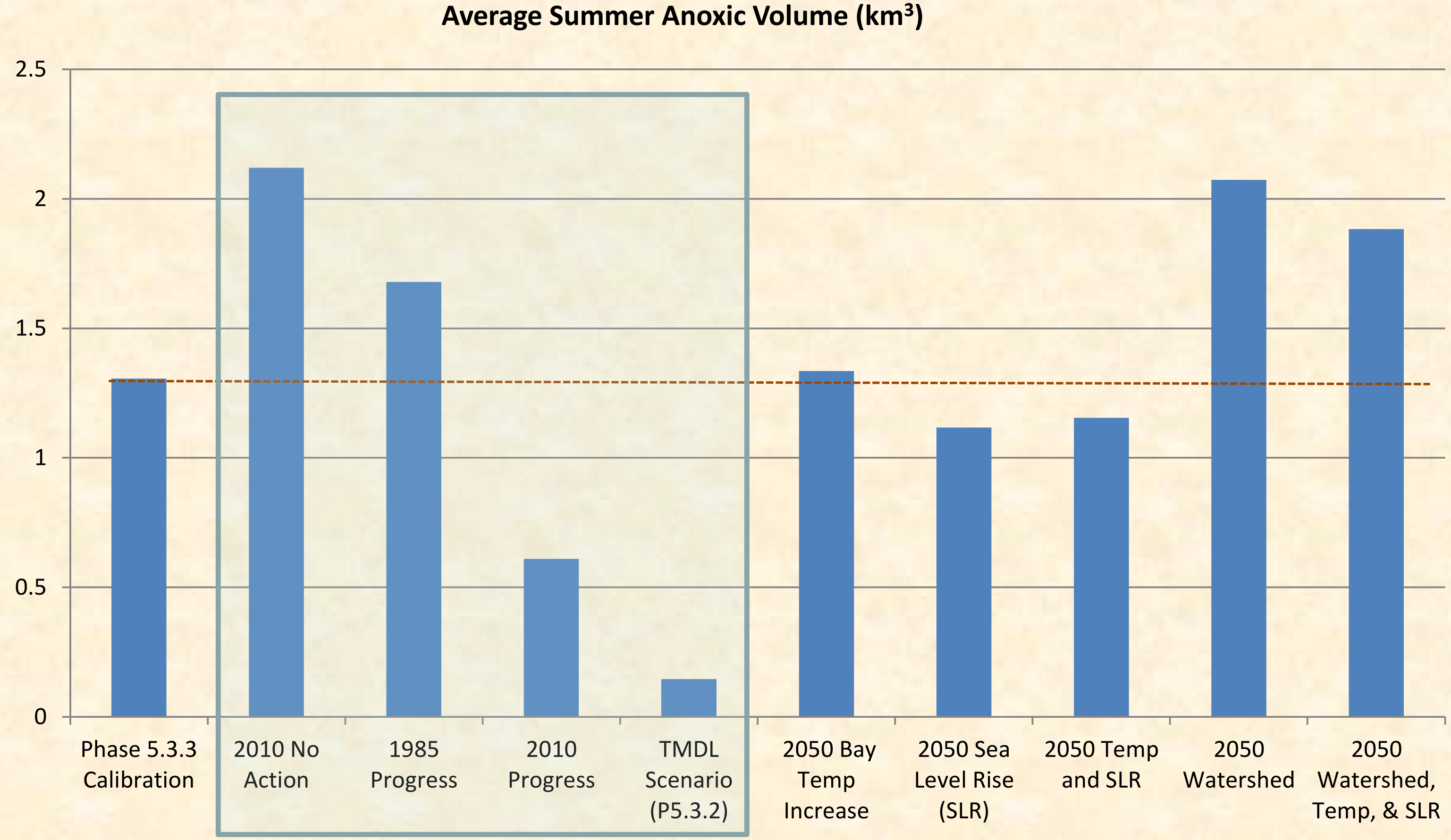




Maloney and 31 others, 2014: North American Climate in CMIP5 Experiments: Part III

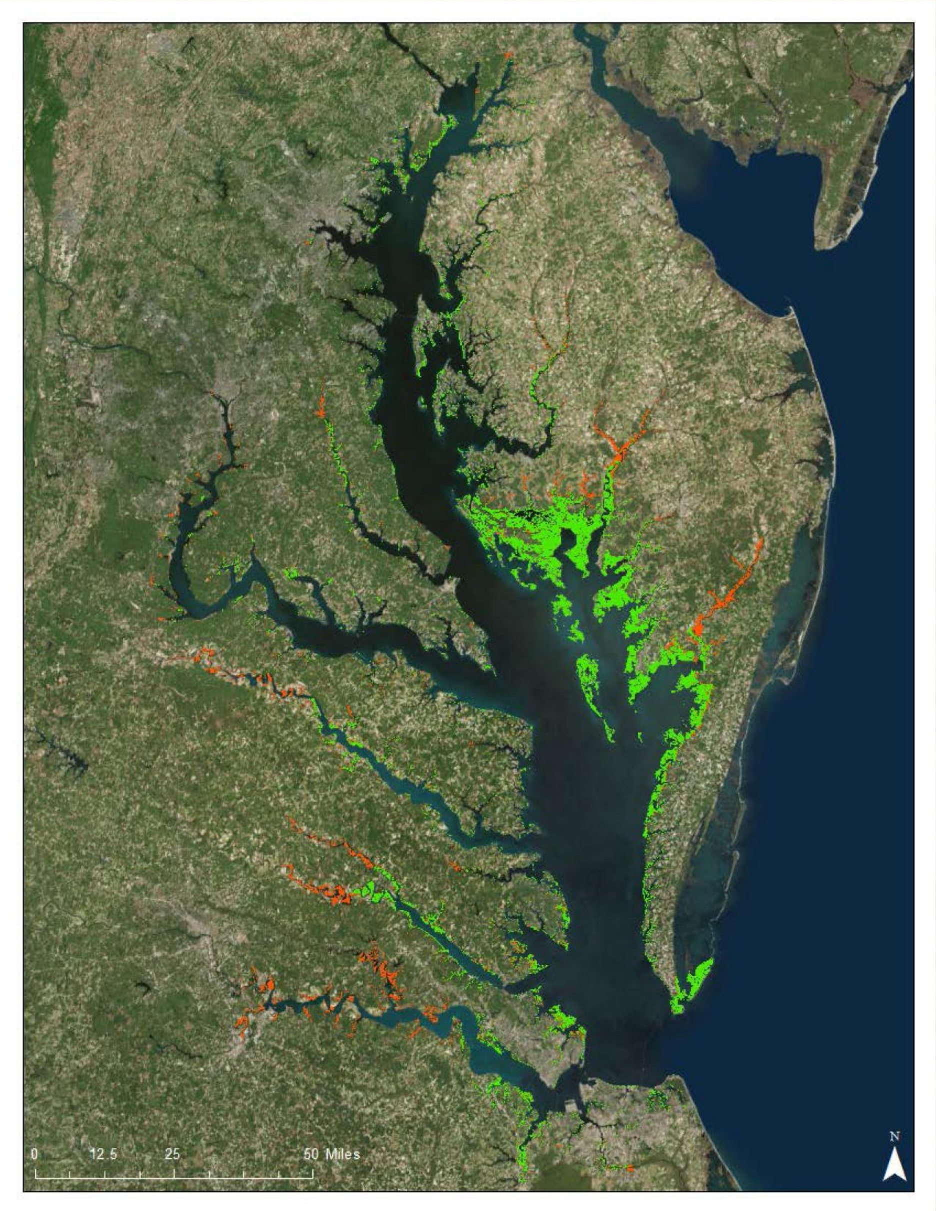
"For early twenty-first century the precipitation increases 5%-10% (10-30mm) over the northeast US…..Over the northeast US, the mean precipitation increases by 15%-25% by the late twenty-first century. The number of relatively heavy precipitation events (>25mm day-1) over the northeast US increases by 50% by the early twenty-first century and increases 4-5 times by the late twenty first century."

Combined 2050 Watershed, Temp, and SLR



Estimated combined effects so far are about half what it took to get from average 1991-2000 conditions (calibration) to the TMDL.

Chesapeake Bay Tidal Wetlands



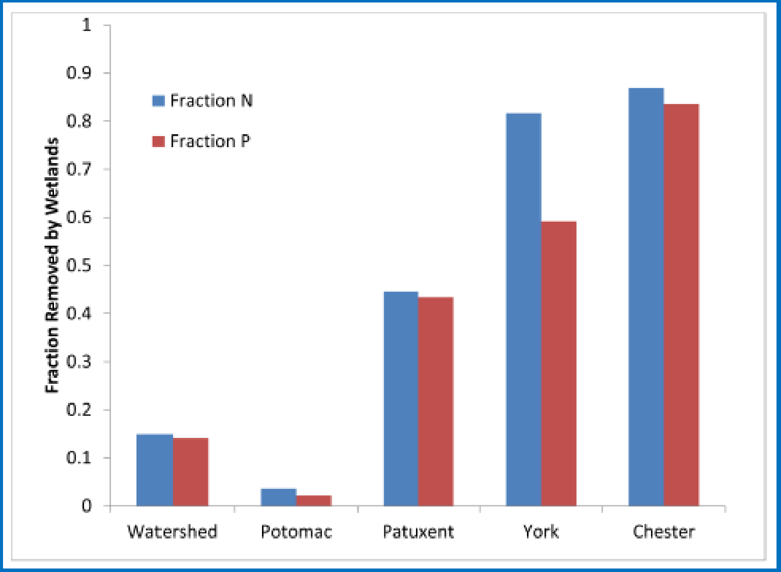
- Extent from National Wetlands Inventory.
- Determined largely from vegetation perceived via aerial photography.
- 190,000 hectares of estuarine (green) and tidal fresh (red) wetlands.
- We are working on a wetlands function module. We will incorporate functions (solids removal and burial, nutrient removal and burial, denitrification, respiration, etc.) into present model. Loss of wetlands functions will be accounted for explicitly.

The Shoreline Management Expert Panel estimated credits for wetlands restoration of 85 lbs N/acre/yr-removed through denitrification and 5.3 lbs P/acre/yr-removed through burial.

Wetlands and 1991-2000 Loads

Loads (kg/d)

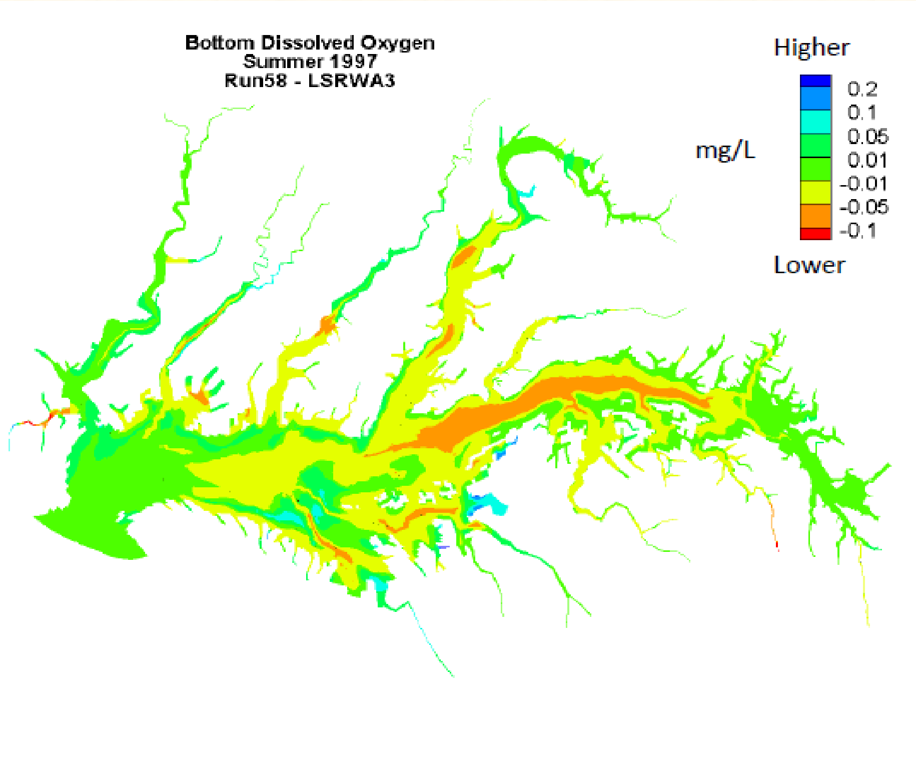
	N Load	Denit	P load	Burial
Watershed	332,445	49,663	22,010	3,102
Potomac Fall-Line	56,311	2,034	5,765	127
Patuxent Fall-Line	2,023	902	130	56
York Fall-Line	3,906	3,189	337	199
Chester Fall-Line	719	625	47	39

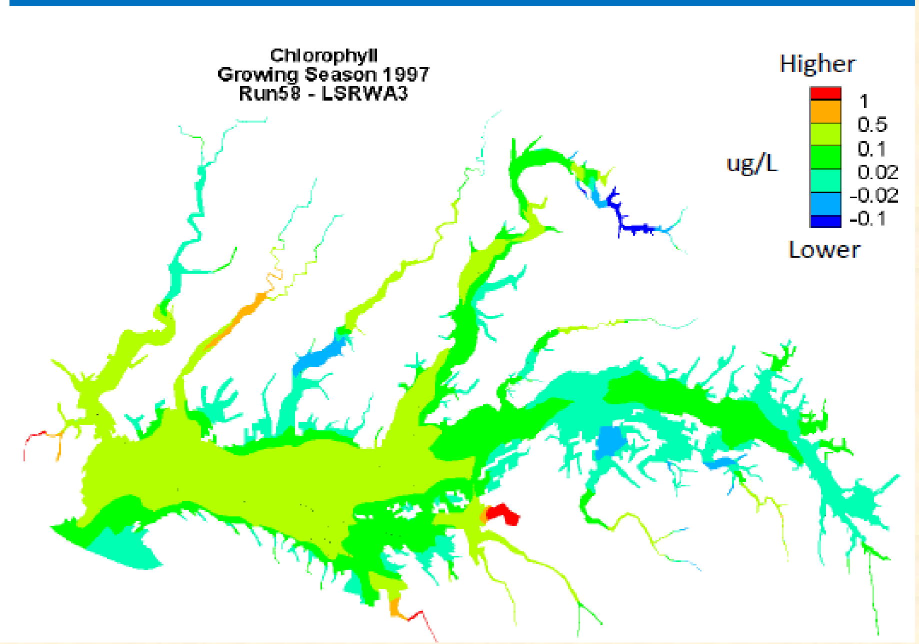


"The tidal marsh-oligohaline estuary removed about 46% and 74% of total annual upland N and P inputs" (Boynton et al., 2008, Nutrient budgets in the Patuxent River estuary)

Marginal Effect of Wetlands Loss on TMDL Conditions

A 40% loss in estuarine wetlands combined with 25% loss in tidal fresh wetlands corresponds to a load increase of 18,219 kg N/d, 1,138 kg P/d.





Currently estimating about a 1% increase in Deep Channel DO nonattainment under conditions of 40% loss in estuarine wetlands combined with 25% loss in tidal fresh wetlands.

Conclusions

- 2017 is a year of decision for the Chesapeake Bay Program (CBP) for incorporation of climate change considerations into the Phase III WIPs.
- The analysis for the 2017 decision will be with the best available information, but climate change impacts are wide-ranging, long-term, and uncertainties are high.
- Adaptive management needs to be applied along with the key strengths of the CBP which include the living resource based water quality standards that must be met regardless of challenges.

Conclusions (continued)

- On the other hand, we know how to deal with the challenge at hand. After all, we have full and complete documentation of a century of temperature increases, sea level rise, precipitation intensity increases, precipitation volume increases, and wetland loss in the Chesapeake region. What does climate change look like? It looks a lot like what we've experienced over our entire careers in coast and watershed science.
- Separation of the different elements of water quality influences that are due to climate change allows more targeted management responses toward tidal marsh loss, stormwater management, or other CBP management responses to climate change.