Sensitivity Analysis of Sea Level Rise Simulation To the Ocean Open Boundary Specification Using the 2017 CH3D-ICM

Modeling Workgroup Quarterly Review

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Chesapeake Bay Program

Science, Restoration, Partnership

Initial Estimates of Climate Change Influence On Chesapeake Water Quality Attainment

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In the next eight weeks we need to produce for Chesapeake Bay Program decision makers our best estimate of the influence 30 years of climate change (1995 to 2025) has on Chesapeake Bay water quality.

The findings so far:

- On one hand, increased 2025 temperatures ameliorates the estimated increased precipitation in the watershed through evapotranspiration, but also increases stratification and hypoxia in the tidal Bay.
- However, increases in sea level rise, salinity increases at the Bay mouth, and increased watershed flows all increase estuarine gravitational circulation which in turn decreases estimated hypoxia in the Chesapeake under estimated 2025 conditions of sea level and watershed flows.

(This work uses the Beta 3 Watershed Model and the Beta 4 WQSTM to provide the best estimate available today of 2025 and 20150 conditions compared to the 1995 TMDL conditions. We need to run the analysis on the final Watershed and WQSTM models.)

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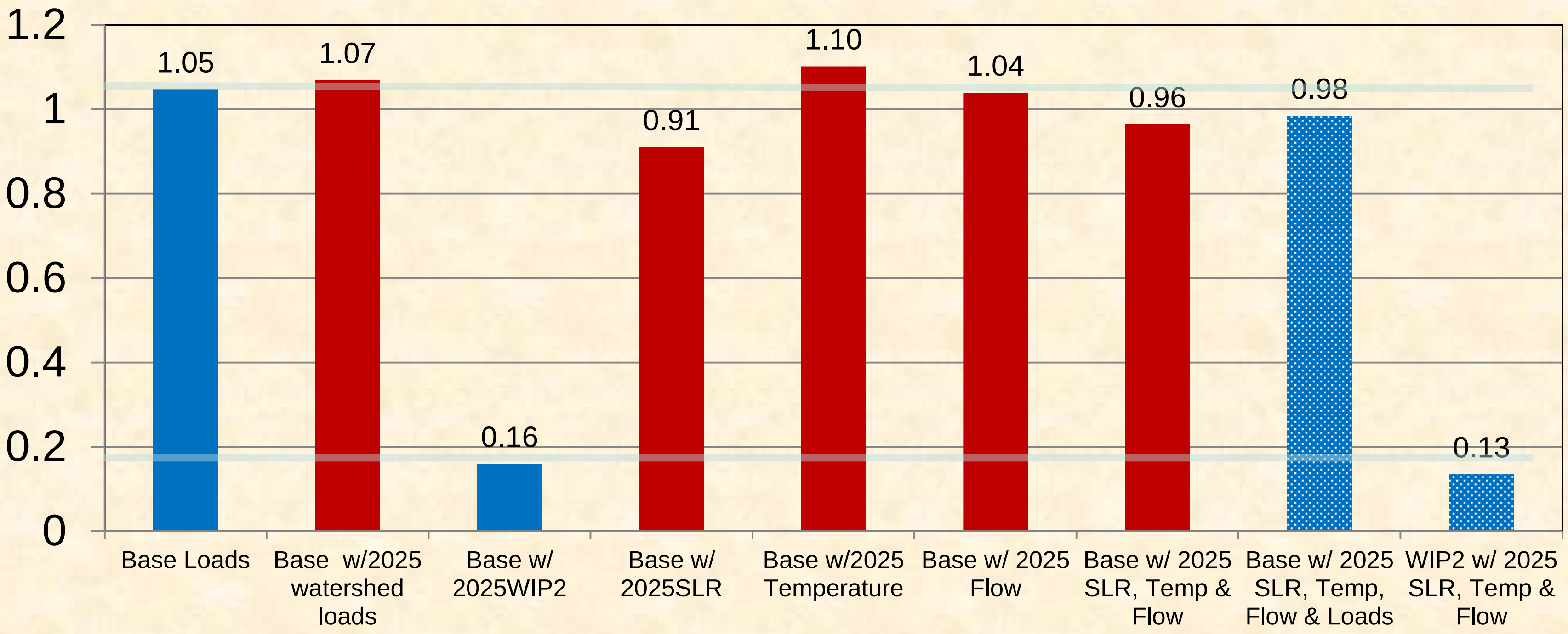
Hypoxic volume (DO <1 mg/l) in CB4MH (Model estimate in summer 1991-2000)

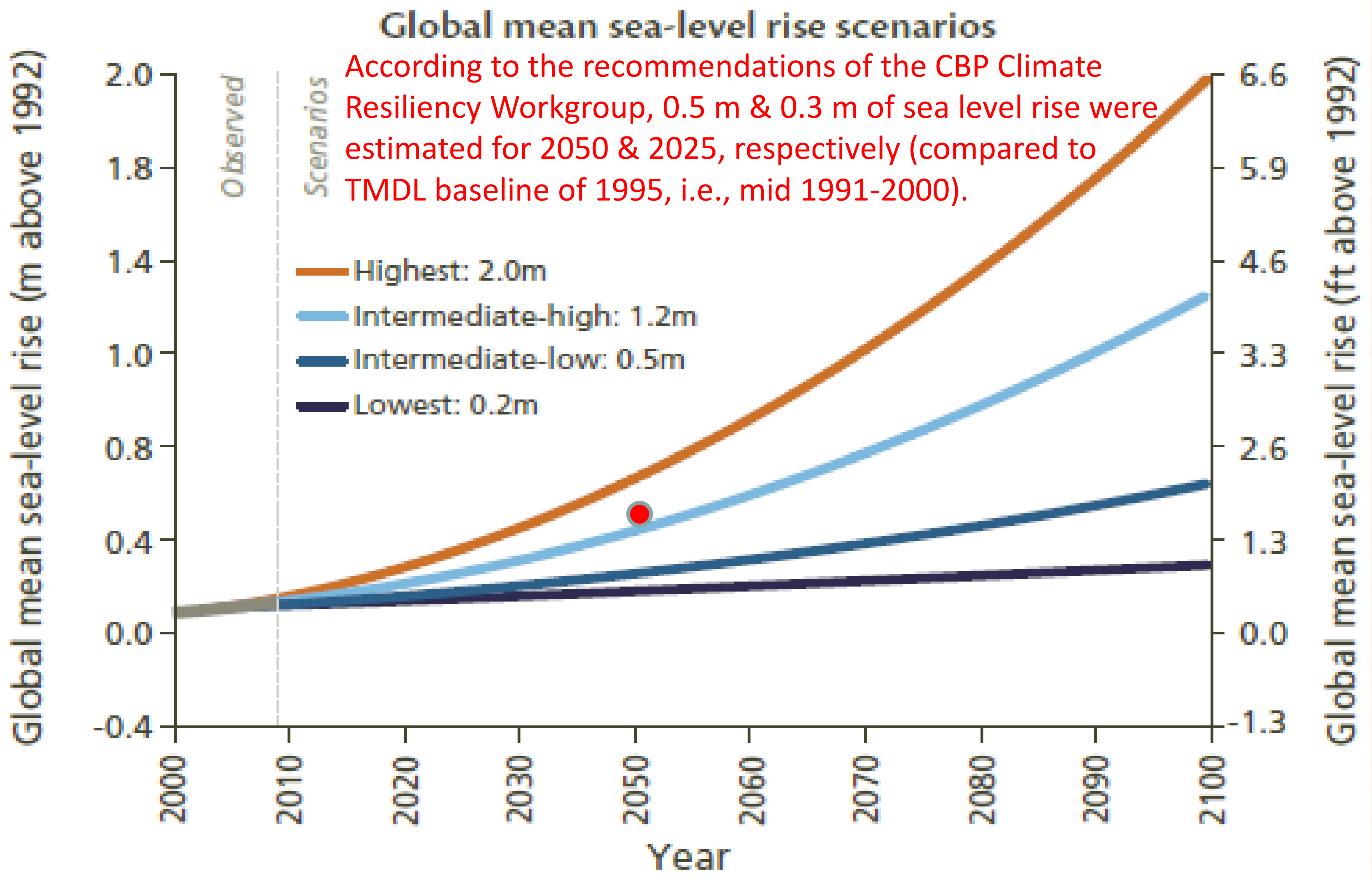


DO <1 mg/l annual average daily hypoxia from 1991 to 2000 over the summer hypoxic season of May through September.

solid blue = key scenario, solid red = sensitivity scenario, stippled blue = 2025 climate scenario

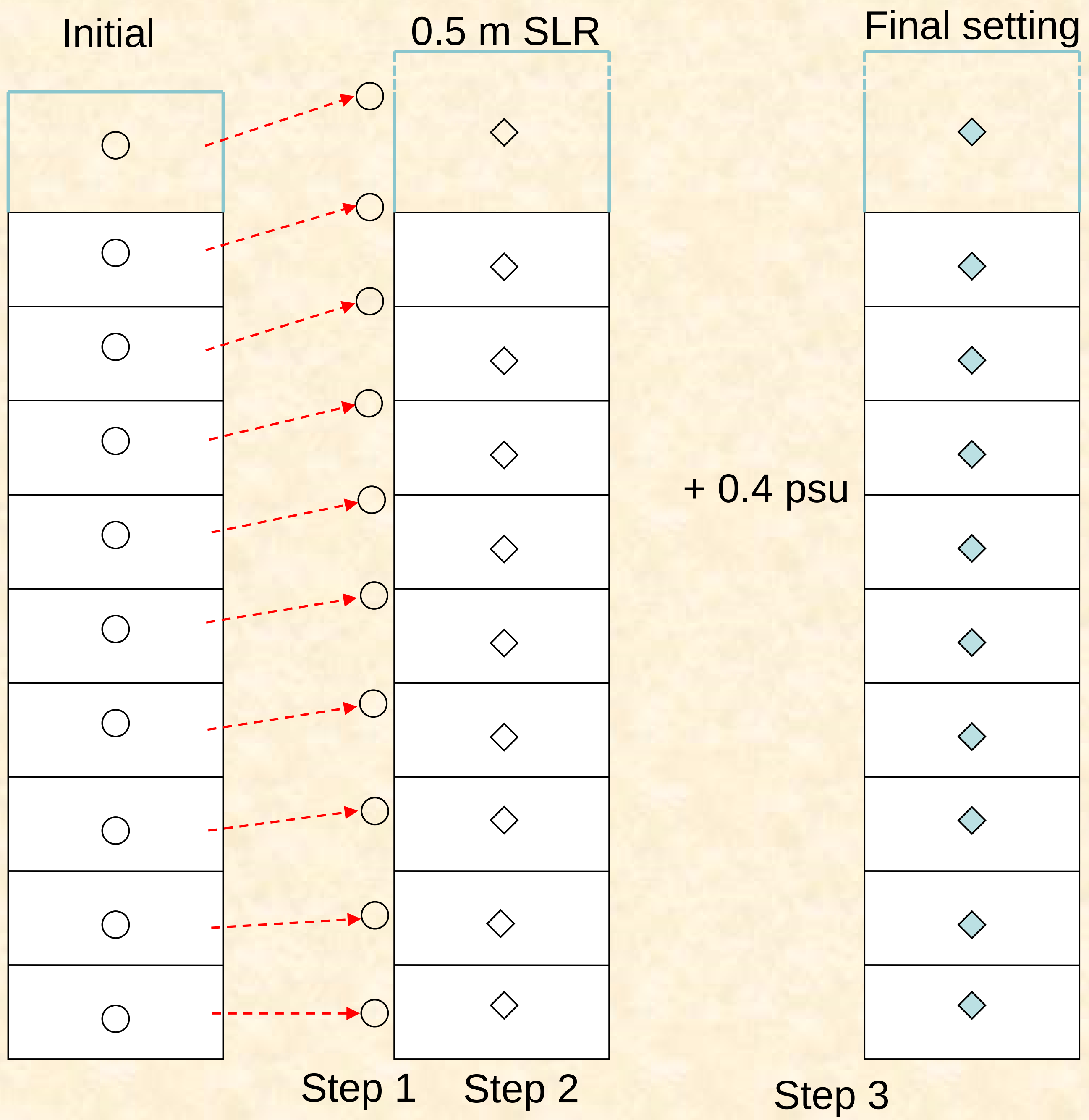
Overview:

Review the sensitivity scenarios of estuarine circulation with estimated 2050 sea level rise (SLR). The sensitivity scenarios used the 1993-1995 WQSTM simulation period to compare scenarios of 1) Base Case w/ out SLR or boundary salinity increase, 2) SLR only w/out salinity boundary increase, and 3) SLR w/ salinity boundary increase. In the case of both (2) and (3) there is an expectation from theory of an increase in gravitational circulation.



From 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.*

Boundary salinity setting

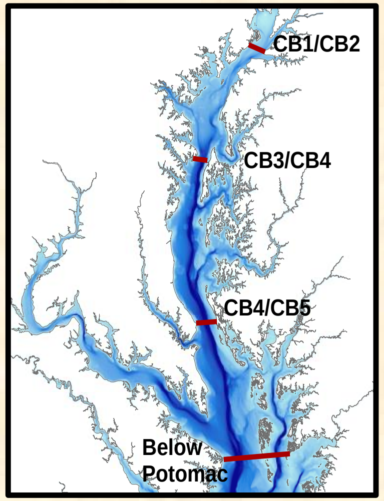


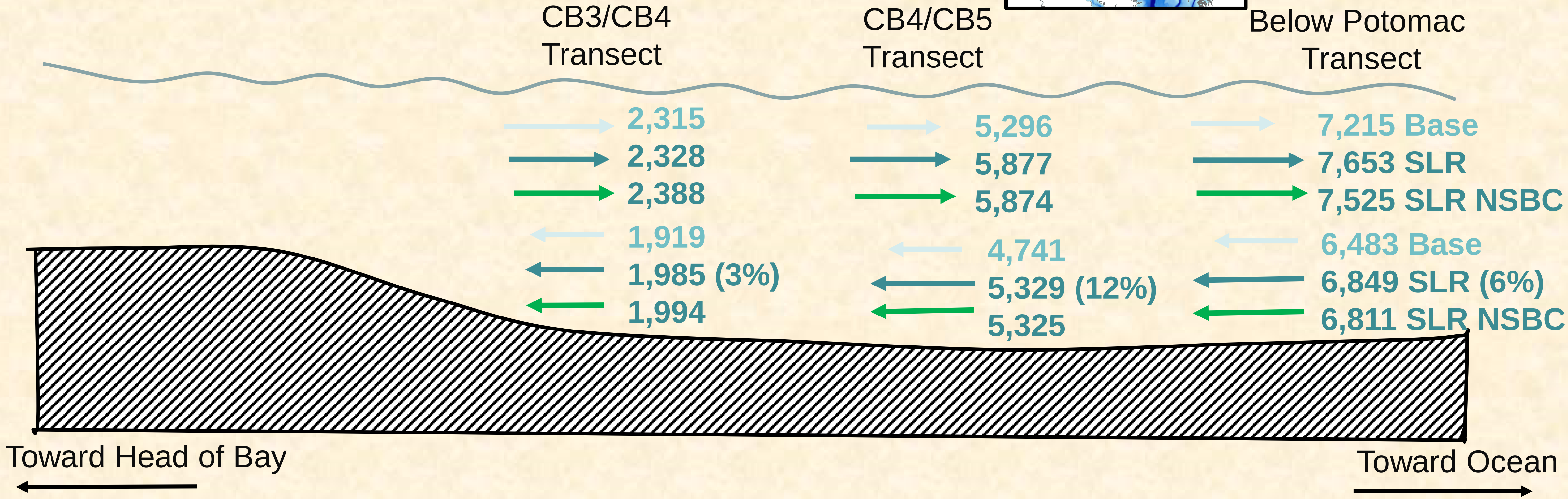
Does salinity adjustment influence water quality simulation and to what extent?

From the Literature: Expectations of the Chesapeake Bay Response to Sea Level Rise:

- Increased salinity in Bay
- Increased up-estuary salt intrusion
- Increased vertical mixing (increased tidal currents)
- Changes in stratification
- Increased gravitational circulation
- Increased salinity at ocean boundary

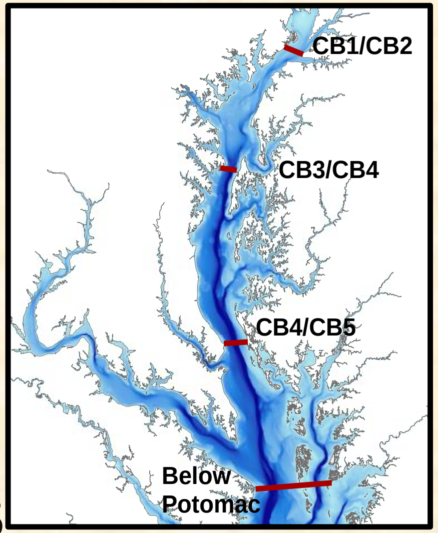
Cross-transect water fluxes (m^3/s) Base case versus sea level rise (SLR) of 0.5m. Summer 1993-1995

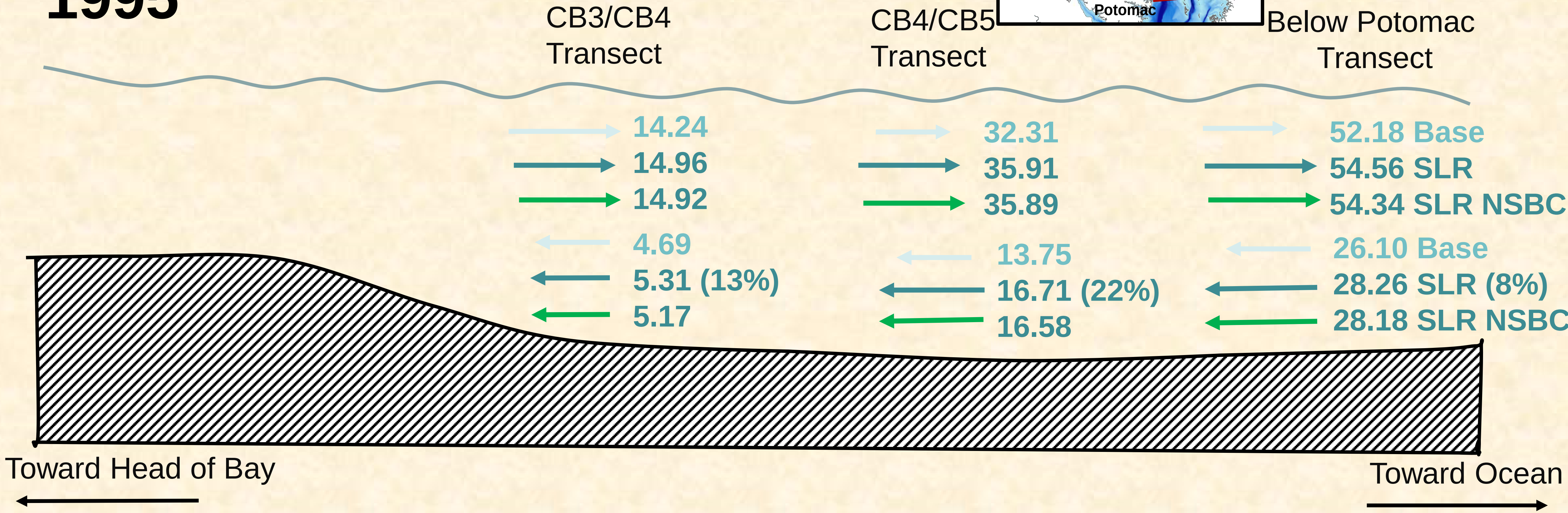




Base = Beta 4 WQSTM, SLR = 0.5m representing relative Chesapeake sea level rise from 1995 to 2050.
Units in mean m^3/s for summer (Jun-Sept) 1993 to 1995; NSBC: No Salt Boundary Change.

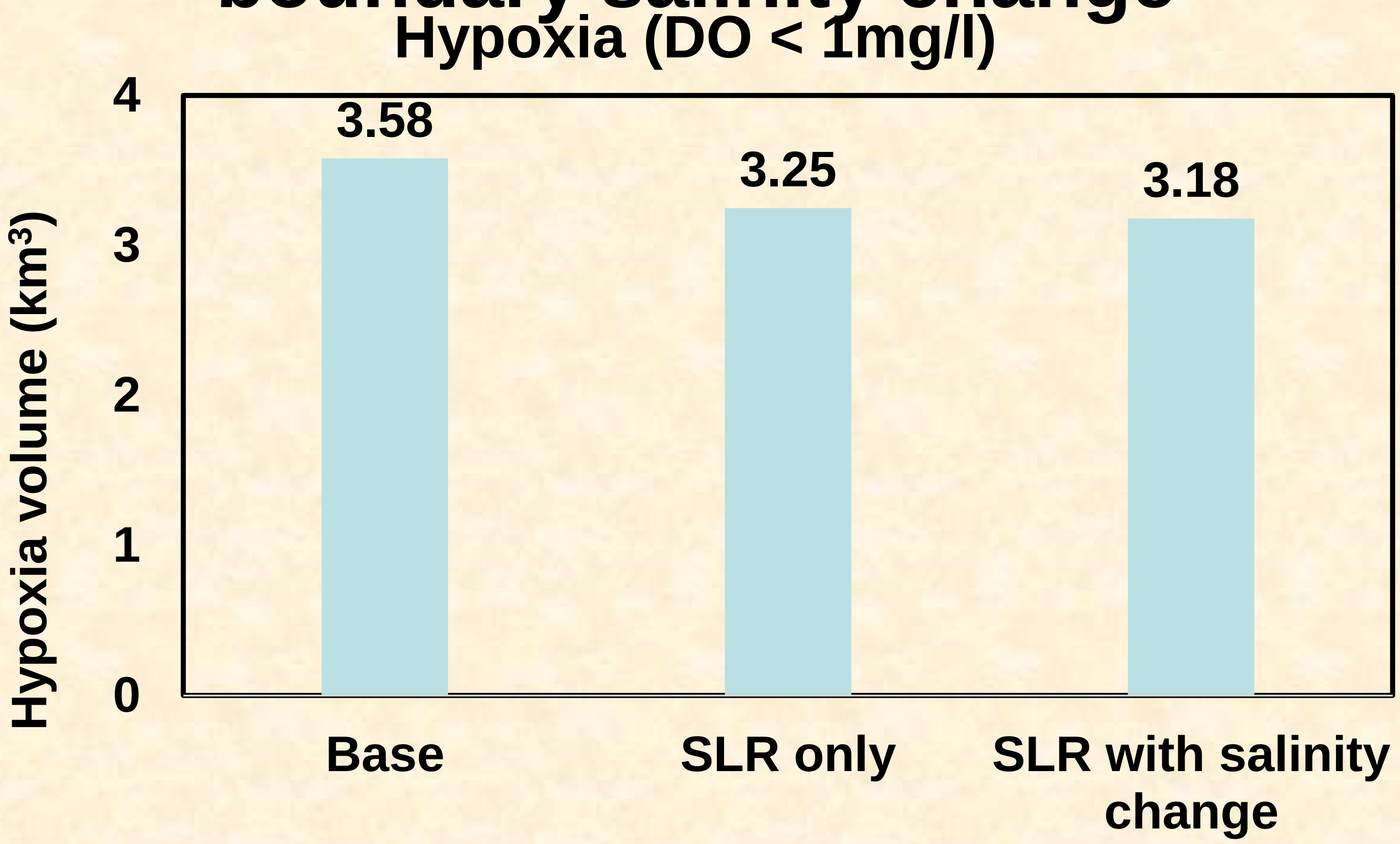
Cross-transect DO fluxes (kg/s) Base case versus sea level rise (SLR) of 0.5m. Summer 1993 - 1995



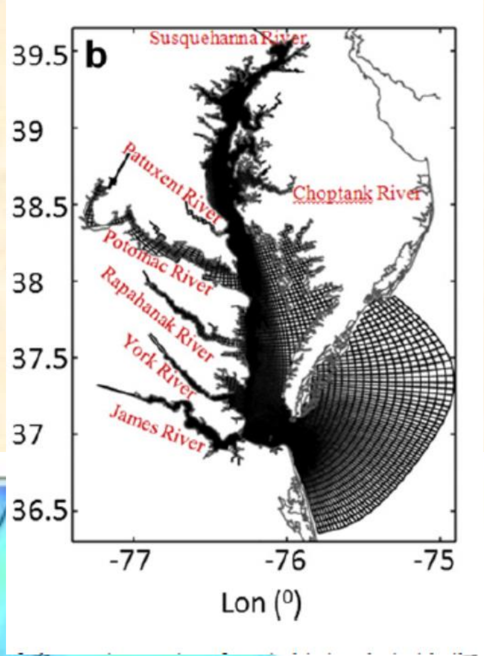


Base = Beta 4 WQSTM, SLR = 0.5m representing relative Chesapeake sea level rise from 1995 to 2050.
Units in mean kg DO per second (kg/s) for summer (Jun-Sept) 1993 to 1995; NSBC: No Salt Boundary

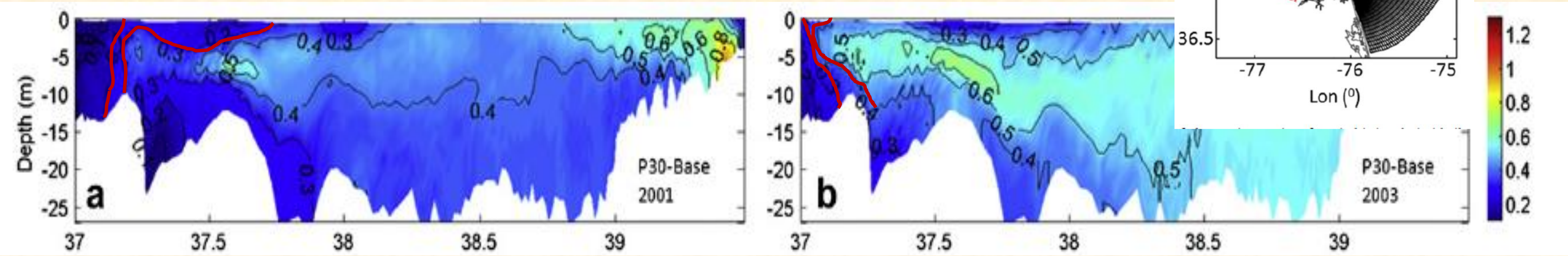
Sea level rise 2050 (0.5m) with open boundary salinity change (SLR) and SRL without open boundary salinity change



Origins of the 0.4 ppt Ocean Boundary Condition



Model estimates of delta June average salinity in 2001 (dry year) and 2003 (wet year) relative to base calibration under conditions of a 0.3 m sea level rise.

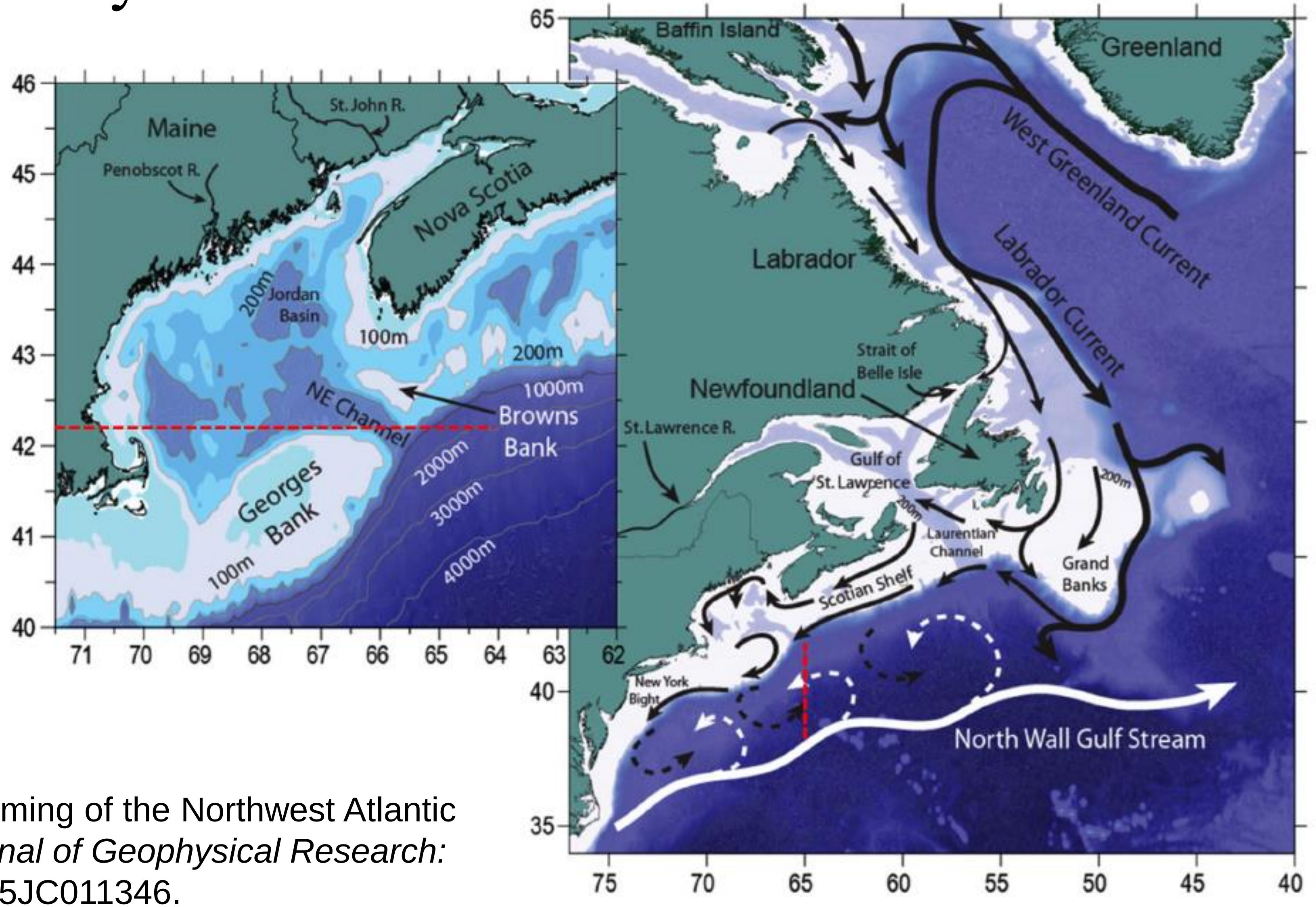


“The mean salinity at the Bay mouth would increase with rising sea level, which could alter the along-Bay pressure gradient. Meanwhile, the water depth in the Bay also increases. These changes will result in the variations of gravitational circulation. According to the classical estuarine circulation theory ….given a sea-level rise of 1.0 m, [in Chesapeake Bay] gravitational circulation will increase by a factor of 1.5.”

Hong and Shen, *Estuarine, Coastal and Shelf Science* 104-105 (2012) 33-45 (page 40)

Bringing us to….why?

“Northwest Atlantic Ocean and Labrador Sea bathymetry and major current systems. Black arrows are colder, fresher water associated with the Labrador Current. White arrows are warmer, saltier water associated with the Gulf Stream. Dashed arrows indicate mixing of waters (not currents) in the Slope sea. Inset shows location of the Northeast Channel (NEC; sill depth ca. 220 m) where a mix of these Slope and Shelf Waters enter the Gulf of Maine.”



Saba, V. S., et al. (2016), Enhanced warming of the Northwest Atlantic Ocean under climate change, *AGU Journal of Geophysical Research: Oceans*, 121, 118–132, doi:10.1002/2015JC011346.

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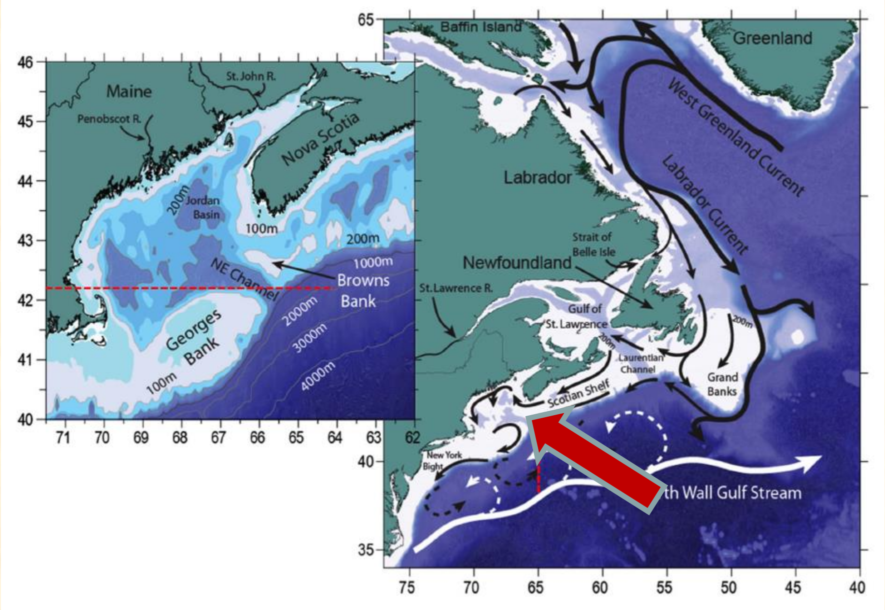
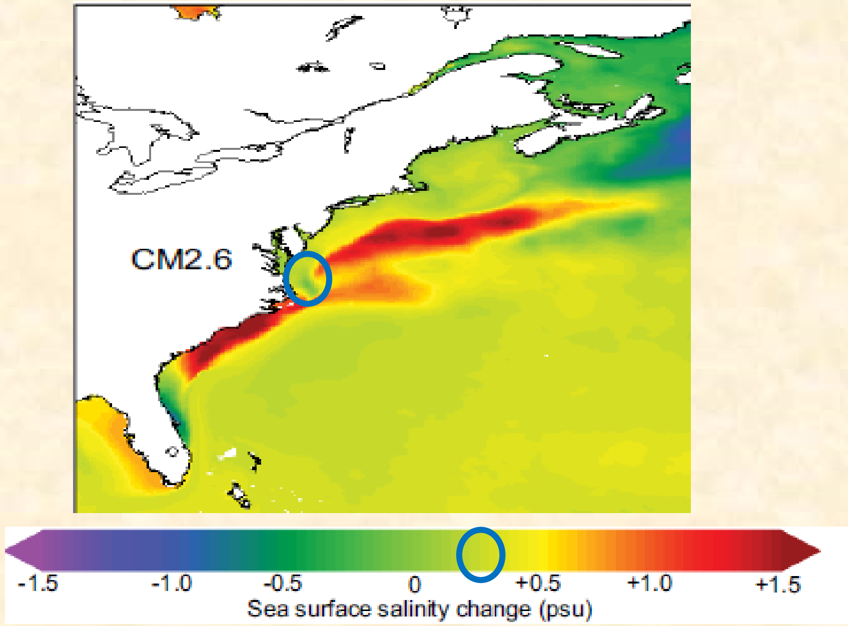
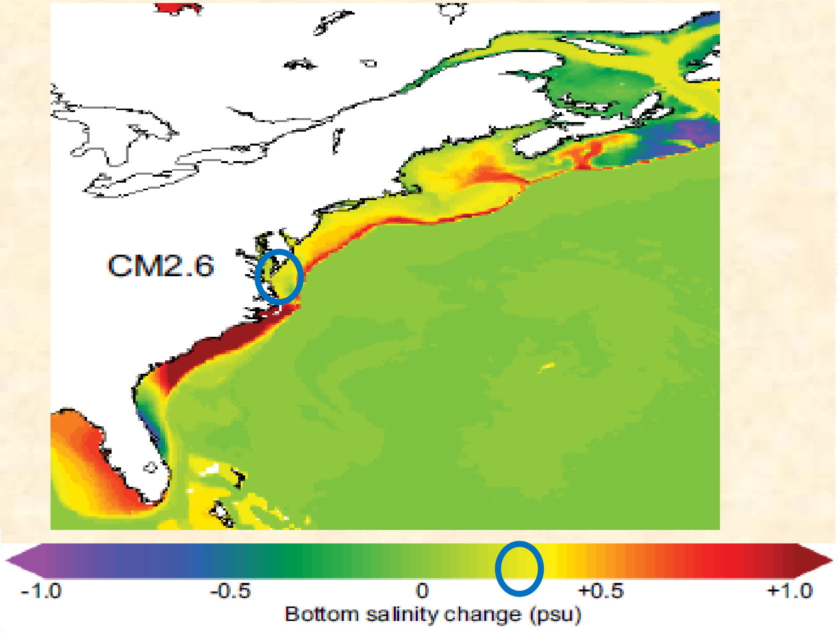
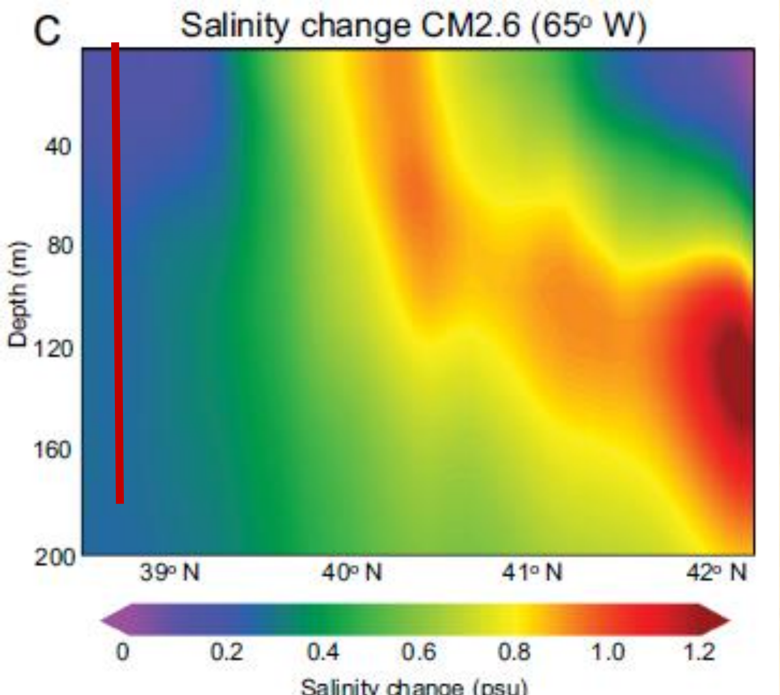


"Examining the ocean change in CM2.6* in more detail, we find an enhanced warming and a more substantial increase in salinity in not only the surface waters of the Northwest Atlantic Ocean but also in the bottom waters of the Northwest Atlantic Shelf. The increase in both temperature and salinity is associated with a northerly shift of the Gulf Stream, a retreat of the Labrador Current, and the replacement of cold Labrador Slope Water by warm Atlantic Temperate Slope Water along the Shelf Slope. This water mass replacement leads to a higher proportion of warmer and saltier Atlantic Temperate Slope Water entering the Shelf via the Northeast Channel."

CM2.6 is a climate model from NOAA Geophysical Fluid Dynamic Laboratory w/ a highly spatially resolved ocean simulation.







Conclusions:

- **Sea level rise (SLR) is estimated to be a major influence in increased gravitational circulation in the Chesapeake.**
- **Increased salinity at the ocean boundary condition also increases gravitational circulation in the Chesapeake.**
- **The 0.4 ppt salinity adjustment at the ocean boundary is consistent with literature and provides a better simulation of the salinity distribution within the Chesapeake under estimated 2050 SLR conditions.**