Preliminary Estimates of Future Climate Change Influence On Water Quality In Chesapeake Bay Using CH3D-ICM

STAC Workshop: Climate Change Modeling 2.0
September 24, 2018

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Chesapeake Bay Program
Science, Restoration, Partnership

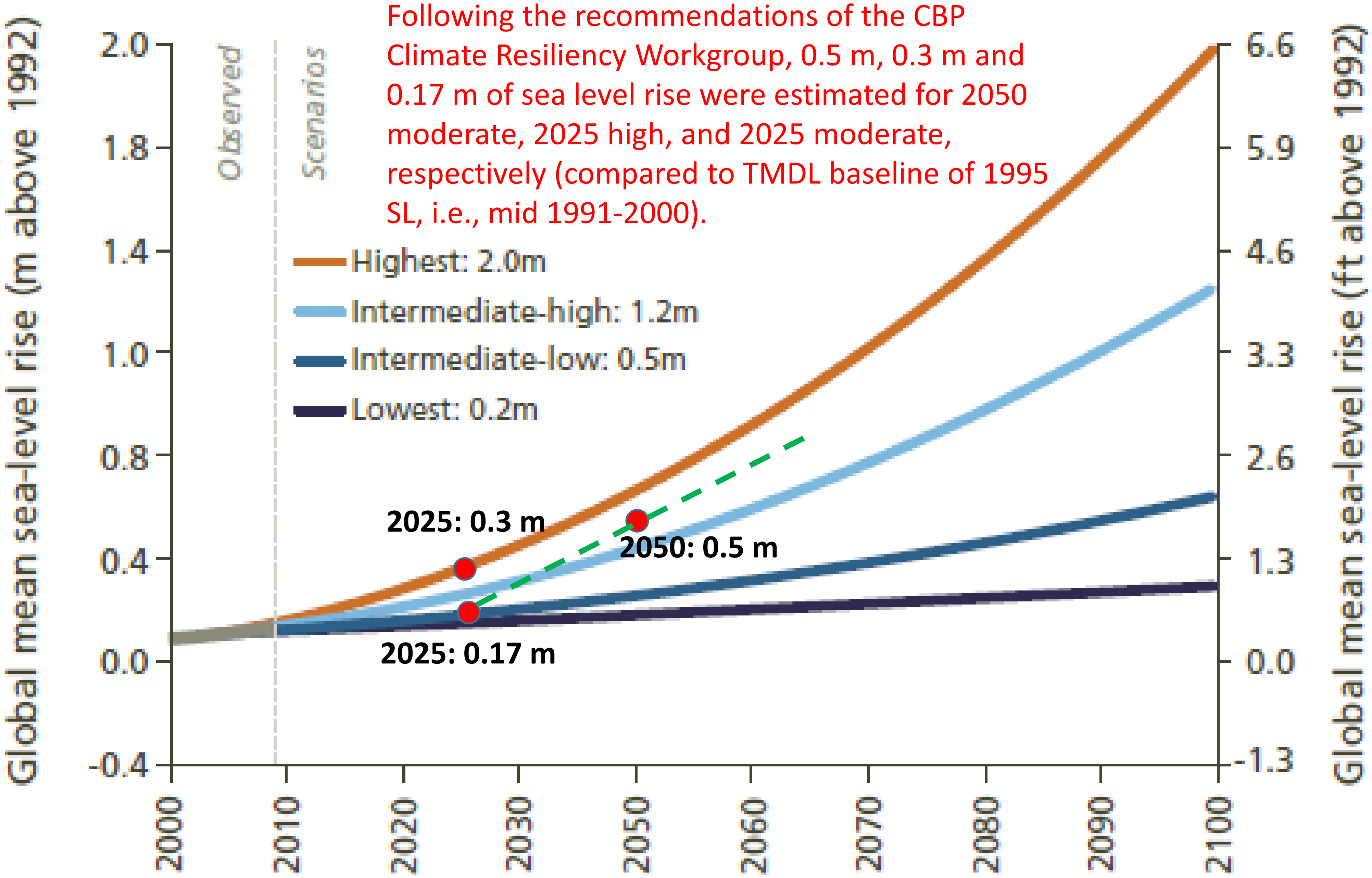
Outline

- Improved sea level rise simulation
- Corrections to air to water heat flux inputs
- Updated nutrient loading from the watershed
- Refinements to open ocean boundary
- Preliminary results

Sea Level Rise Estimates

Linear interpolation and extrapolation for 2035 (0.3 m), 2045 (0.43 m), 2055 (0.57 m) and 2065 (0.7 m).

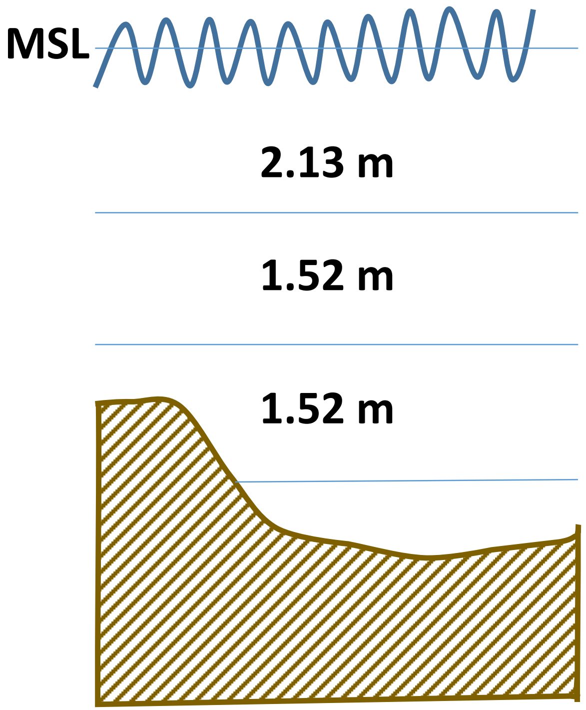
Climate Resiliency Workgroup will provide best CBP estimates of 2035 and 2045 in 2019.



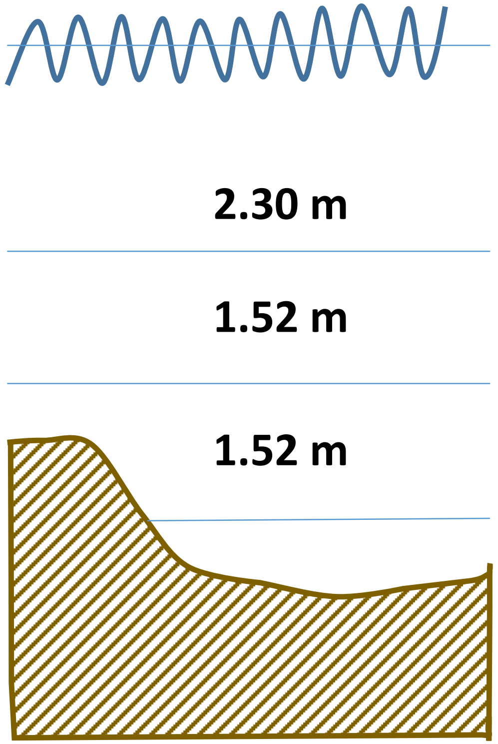
From Parris et al. (2012). *Global Sea Level Rise Scenarios for the United States National Climate Assessment. NOAA Technical Report OAR CPO-1. (1992 used as the starting year)*

Sea level rise simulation

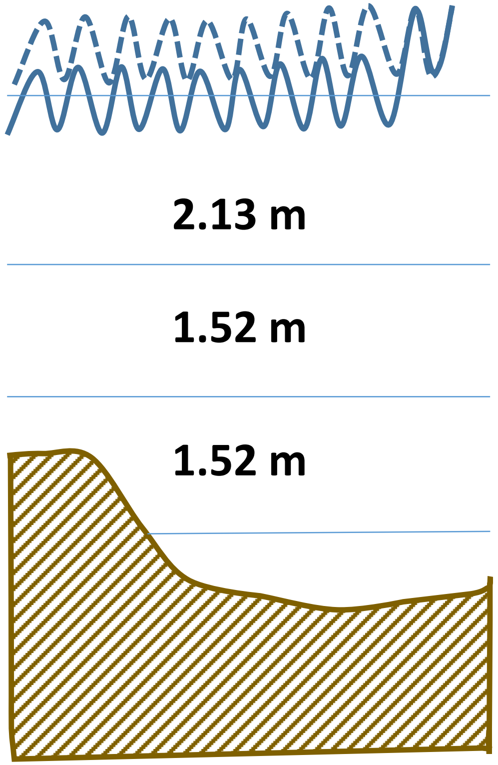
Base



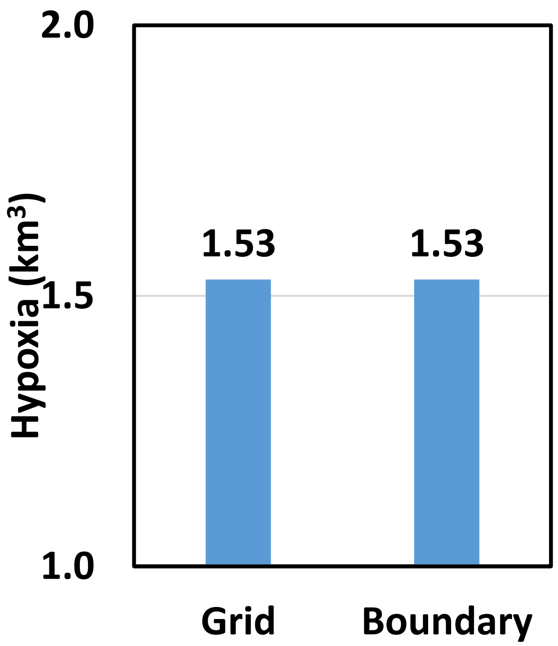
Sea level rise
Change the grid



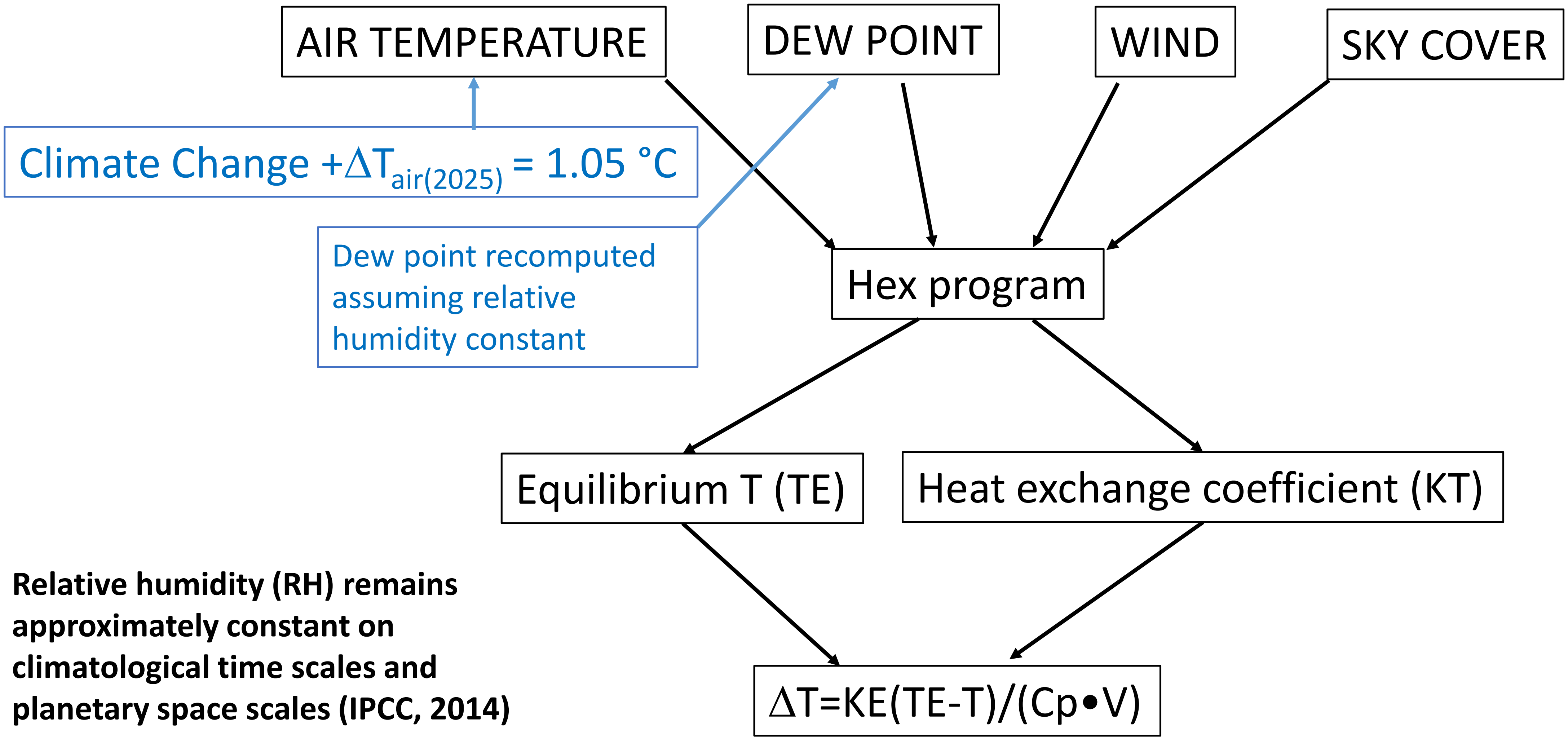
Sea level rise
Change the open boundary



Hypoxia volume
in CB4

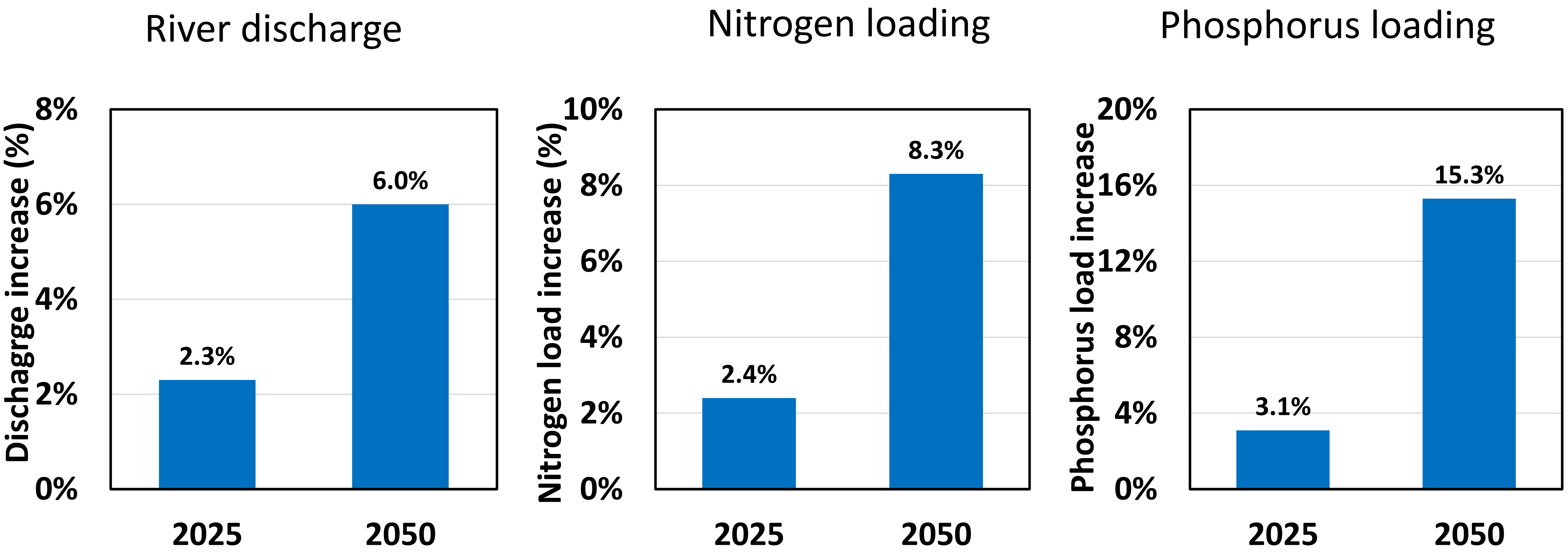


ICM Meteorological Forcing for Heat Transfer From Air to Tidal Waters



Relative humidity (RH) remains approximately constant on climatological time scales and planetary space scales (IPCC, 2014)

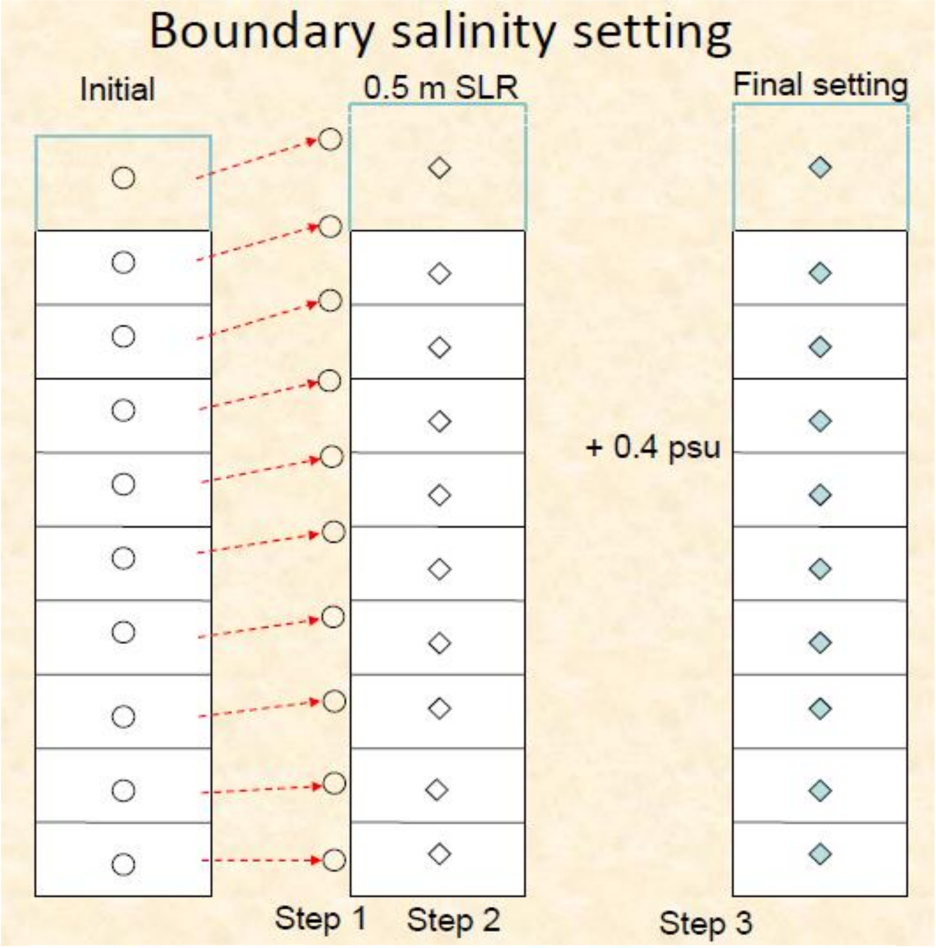
Changes in river discharge and nutrient loading in the 2025 and 2050 climate change scenarios

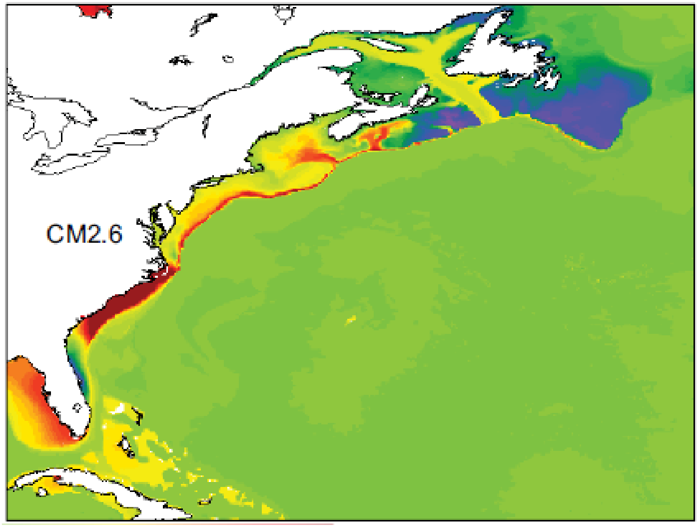


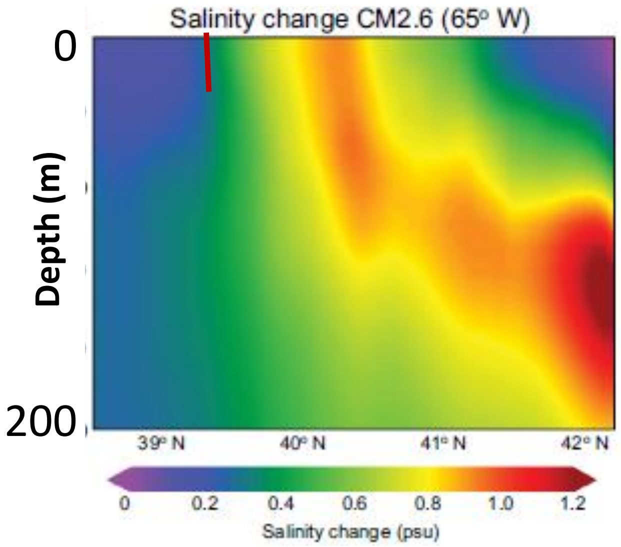
From Gopal Bhatt

2050 salinity adjustment at the the ocean open boundary

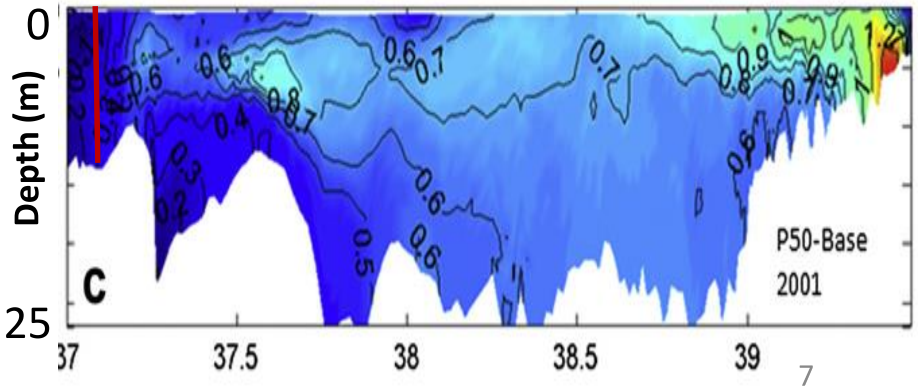
- Constant salinity in vertical profile: +0.4 psu based on Hong and Shen, 2012, supported by Seba et al., 2016 for 2050.
- For 2025 0.14 psu (= 0.4 x 0.17/0.5)







Seba et al. 2016



Hong & Shen 2012

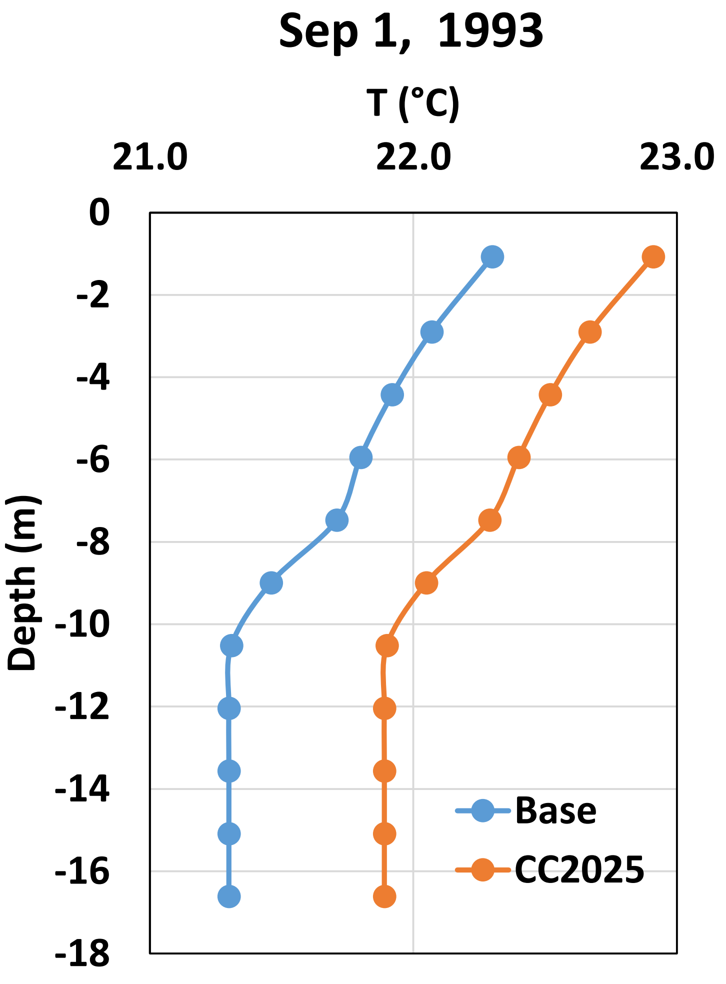
Temperature adjustment at the open boundary

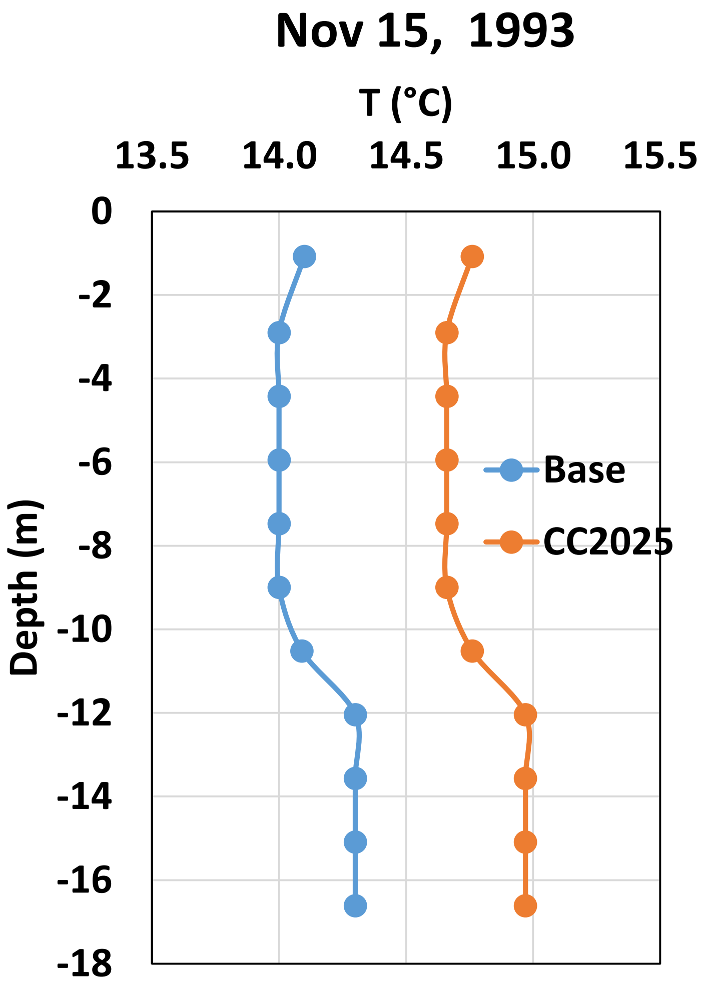
ΔT_{water}=1.0•ΔT_{air} • $T_{water}/T_{surface}$

ΔT_{water}=0.6•ΔT_{air} • $T_{water}/T_{surface}$

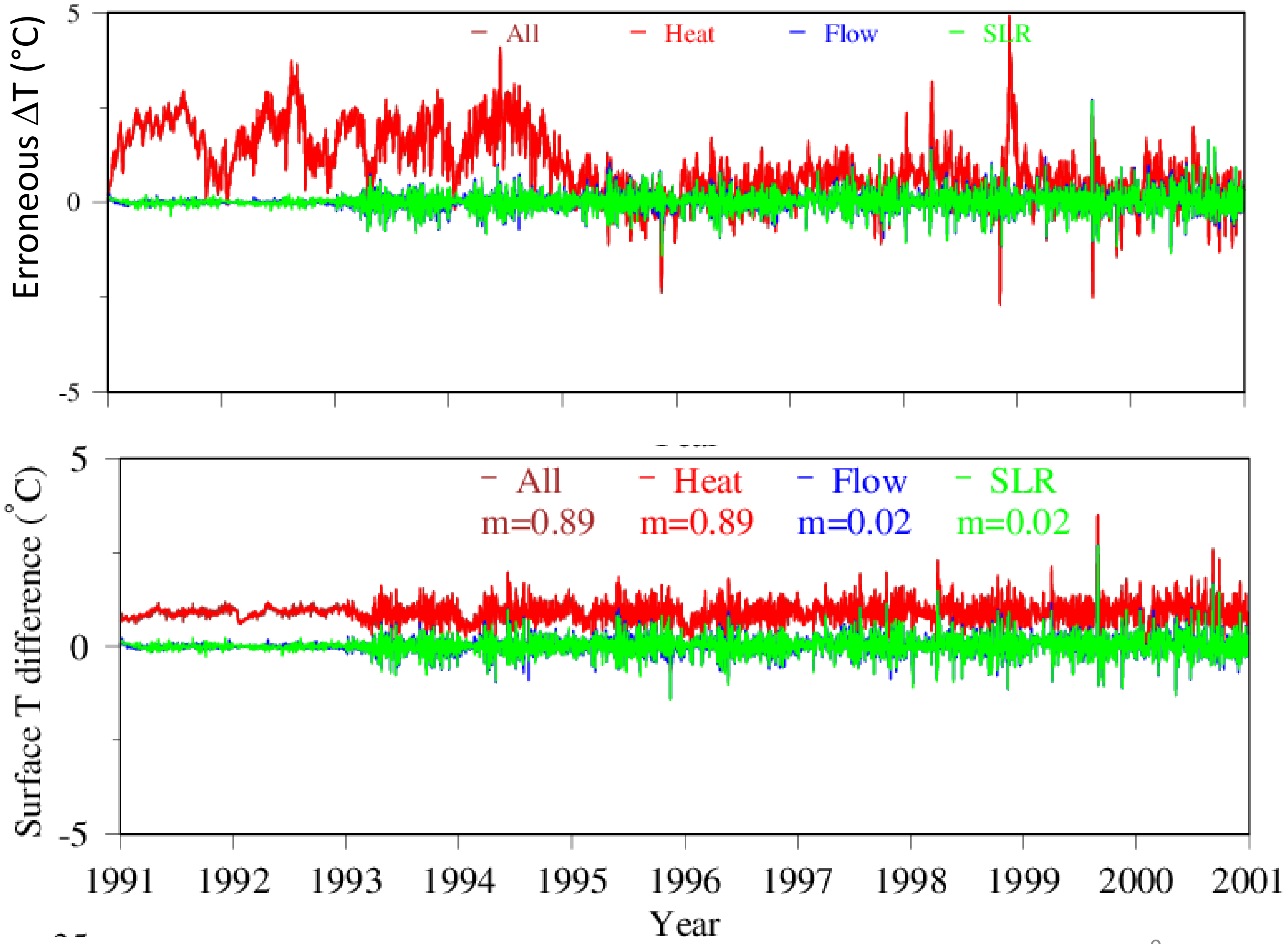
Morrill et al 2014:

- **An increase in water temperature of about 0.6-1.0°C for every 1°C increase in air temperature.**





Surface temperature difference between climate change scenarios and the base case, Station CB4.3C.

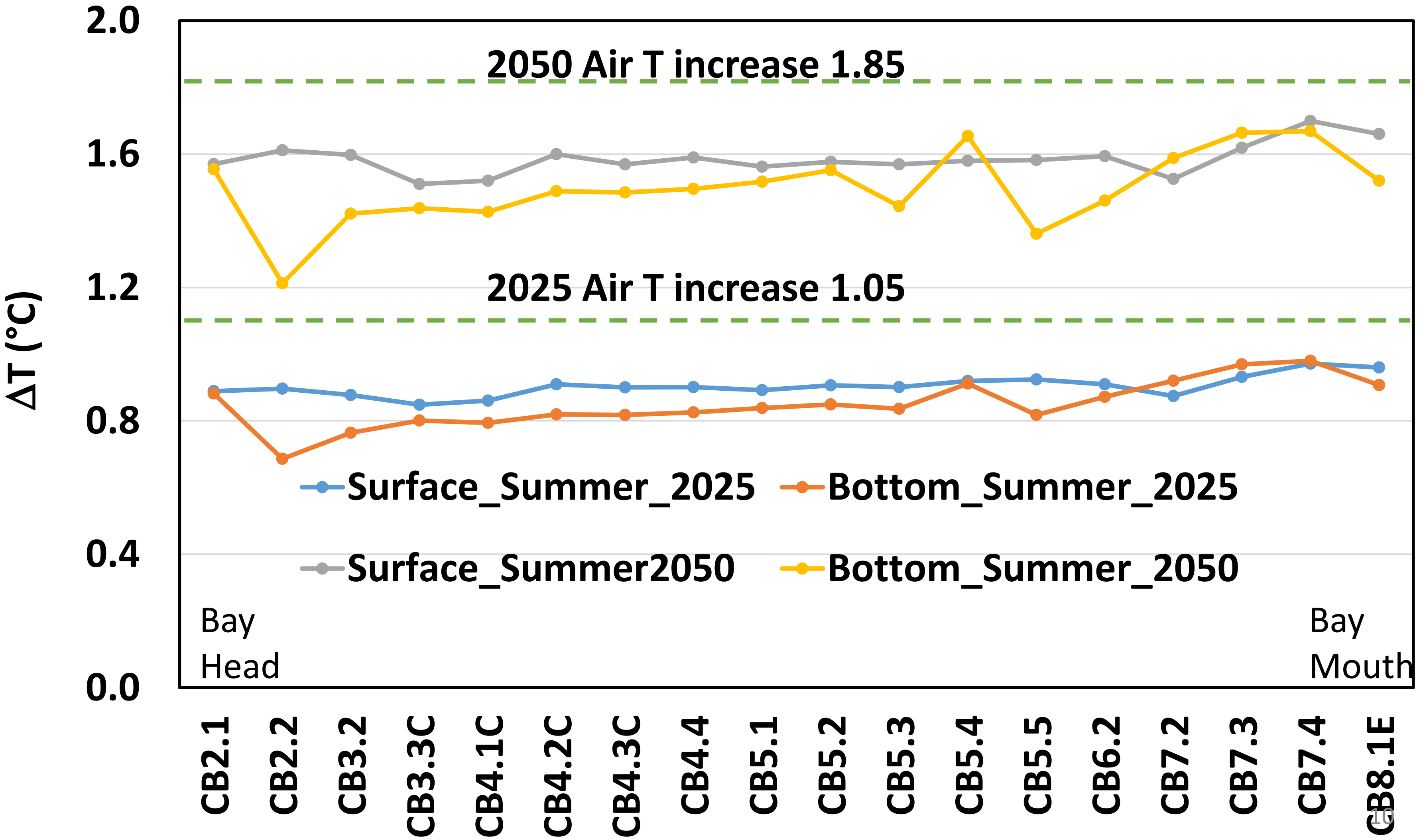


Surface water T change under 2025 and 2050 CC

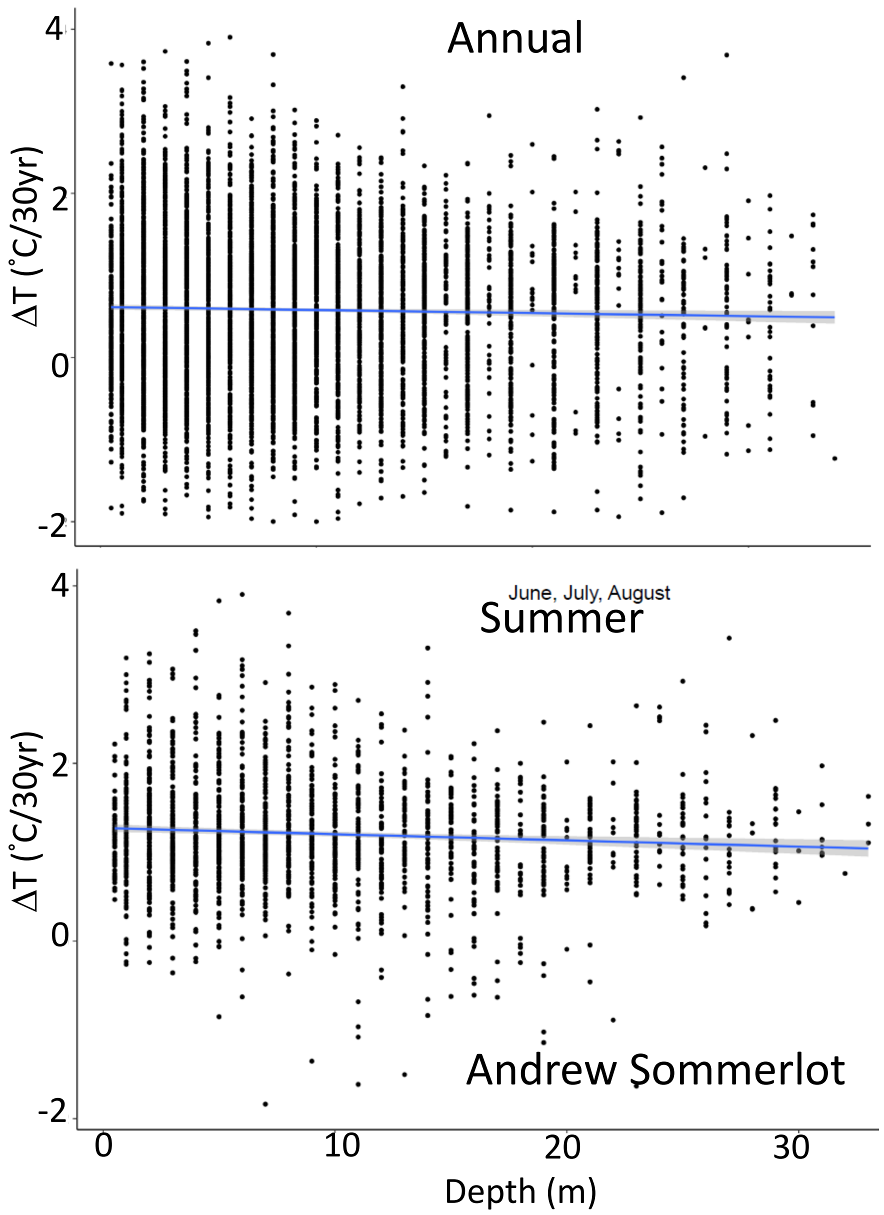
Thomas et al 2017: data 1982-2014, 0.3 °C per decade;

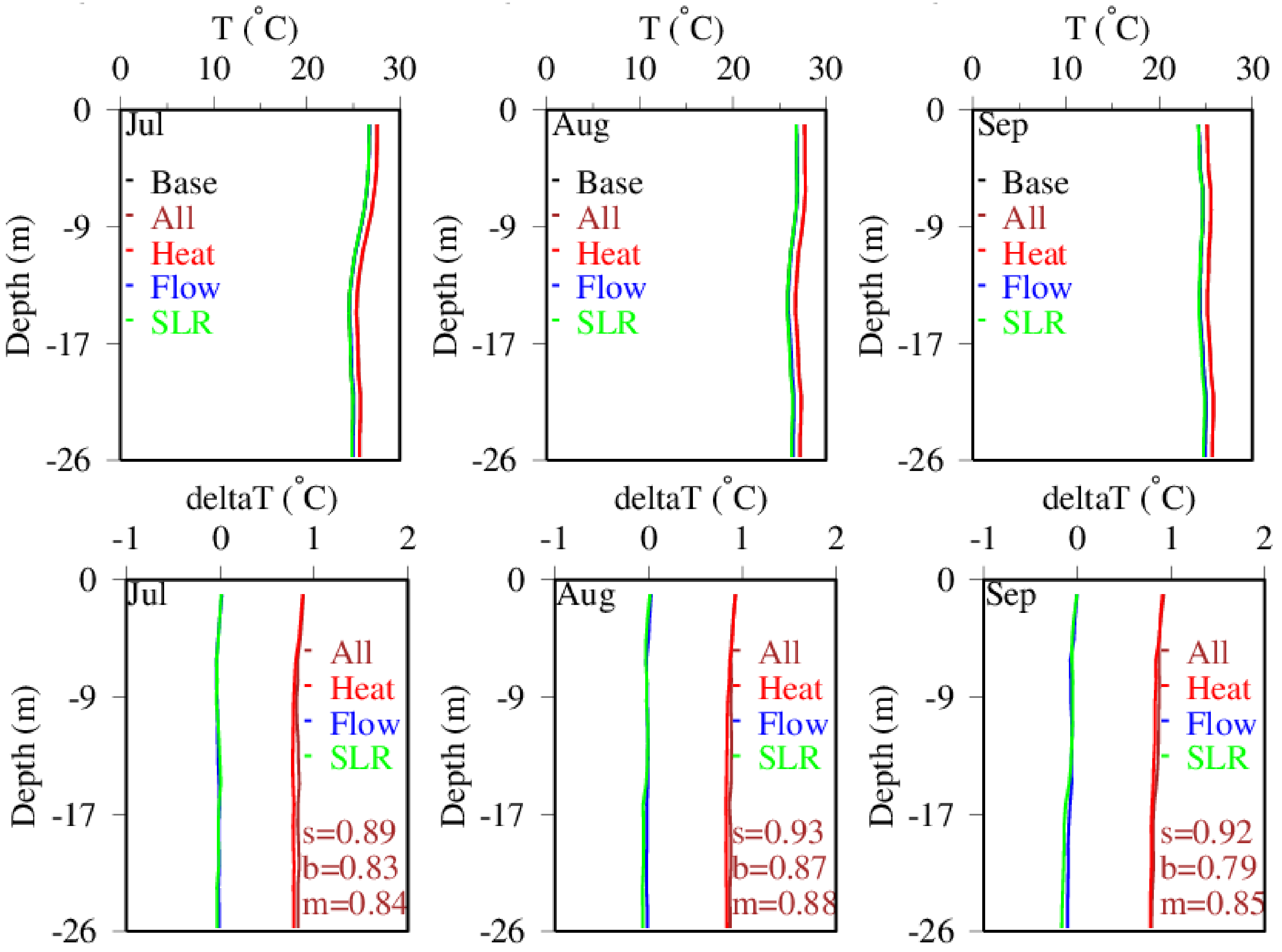
Preston 2004: Data 1949-2002: 0.185 °C per decade;

Irby et al., 2018: 1.75 °C for 2050.



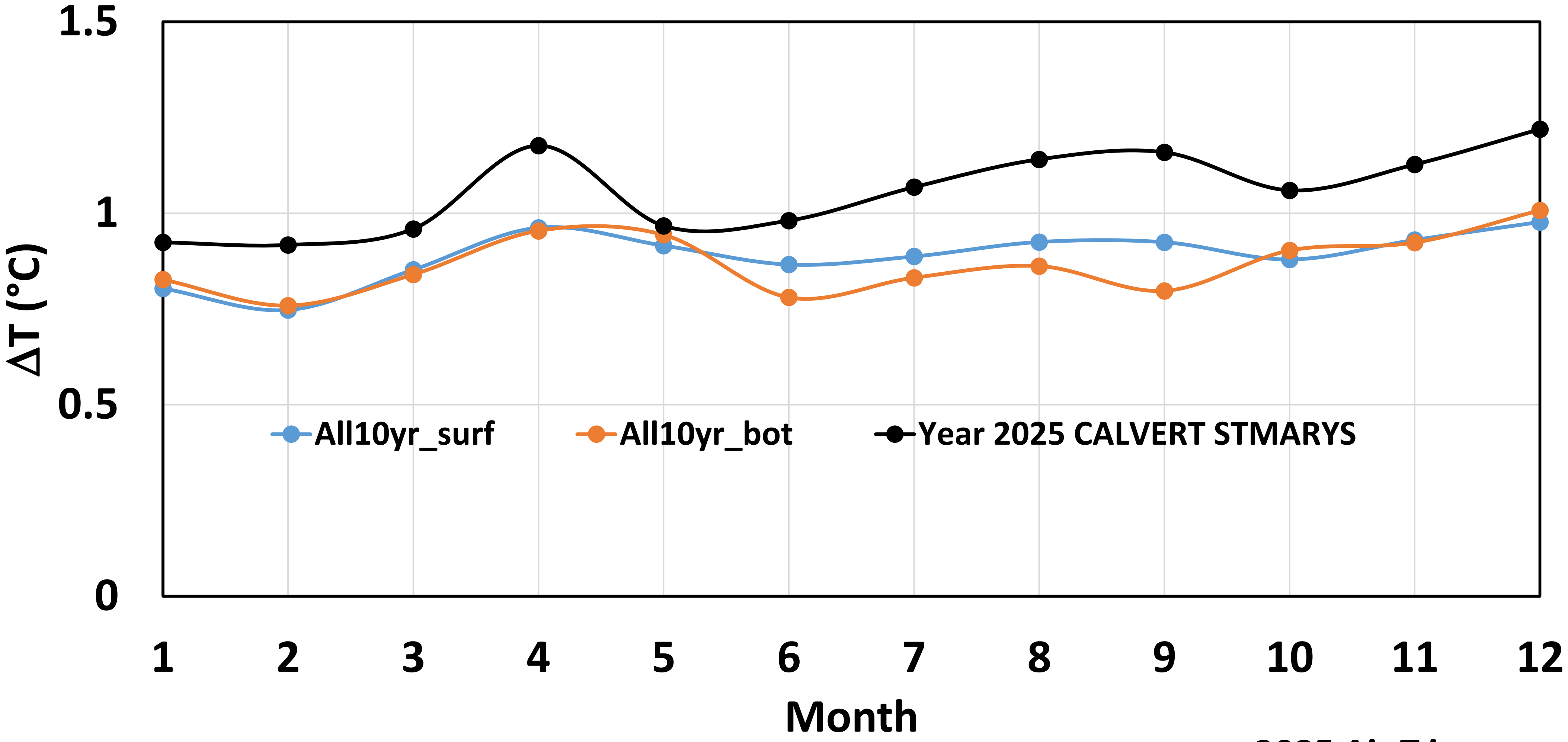
T and ΔT profile at CB4.3C under 2025 CCC





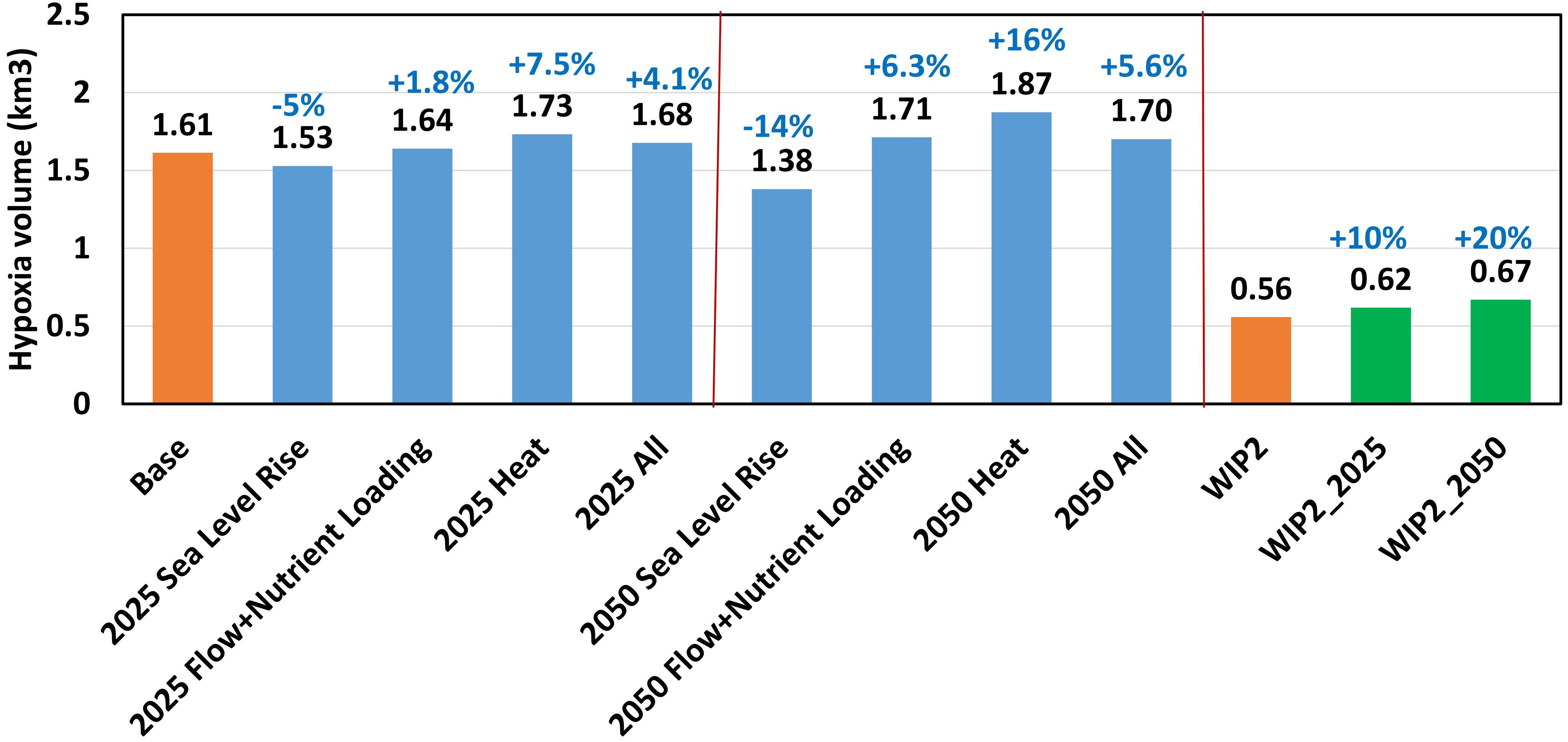
S: surface; b: bottom; m: vertical average over 10 years.

Monthly air T change and surface T simulation at CB4.3C



2025 Air T increase 1.05
2050 Air T increase 1.85

Hypoxia volume (<1 mg/l) in summer (Jun-Sep) 1991-2000 in CB4MH



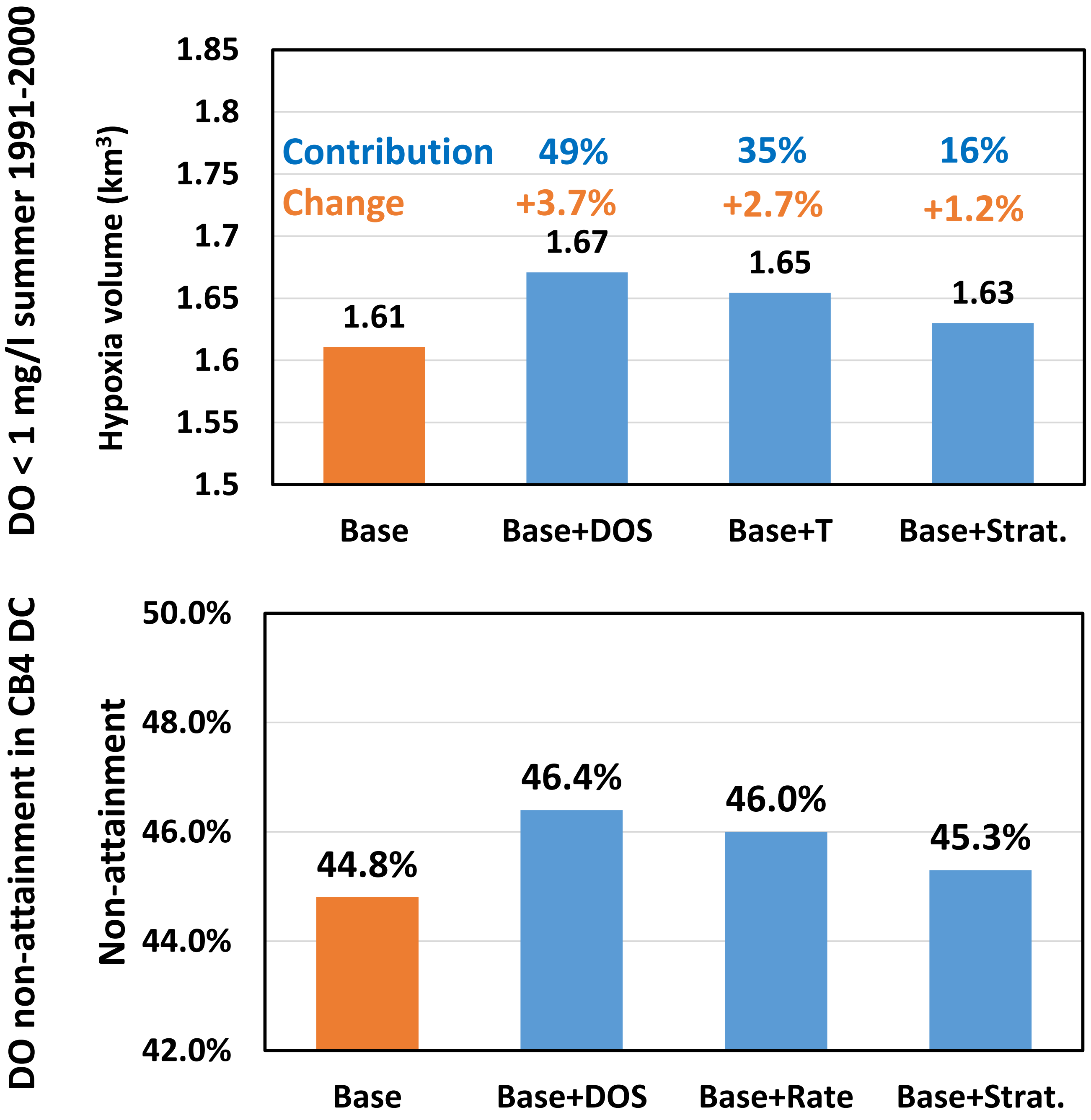
Temperature effects

- **Dissolved oxygen solubility: a 0.9 °C increase in temperature decreases dissolved oxygen solubility by 0.13 mg/l, or 1.7%.**

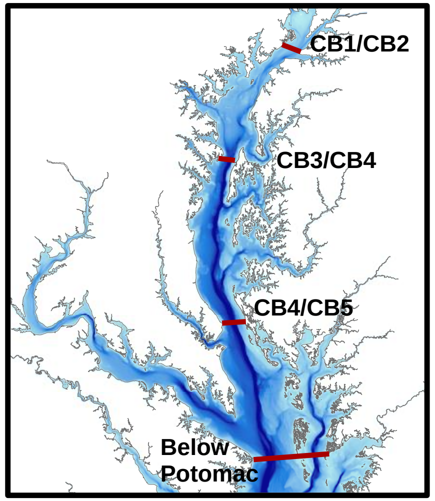
- **Biological rates: increase 6% over 0.9 °C (Q_{10}=2)**

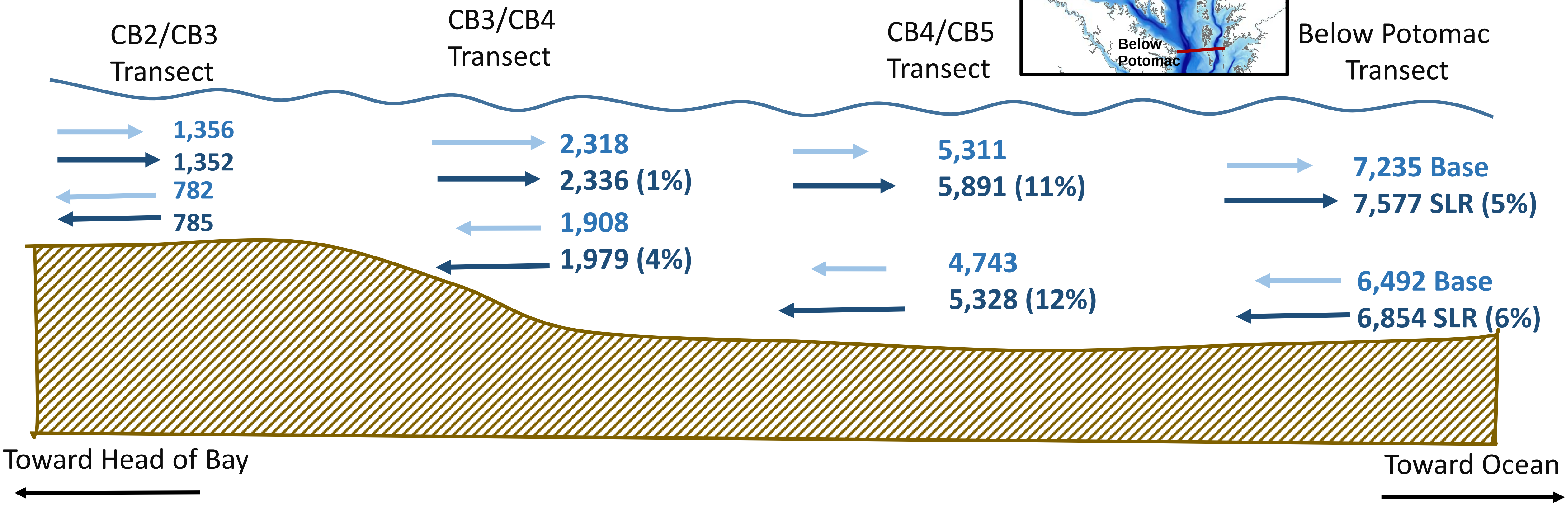
- **Stratification (physics)**

Sensitivity analysis of T modified DO-saturation and biological rate and stratification on water quality, CB4MH, deep channel



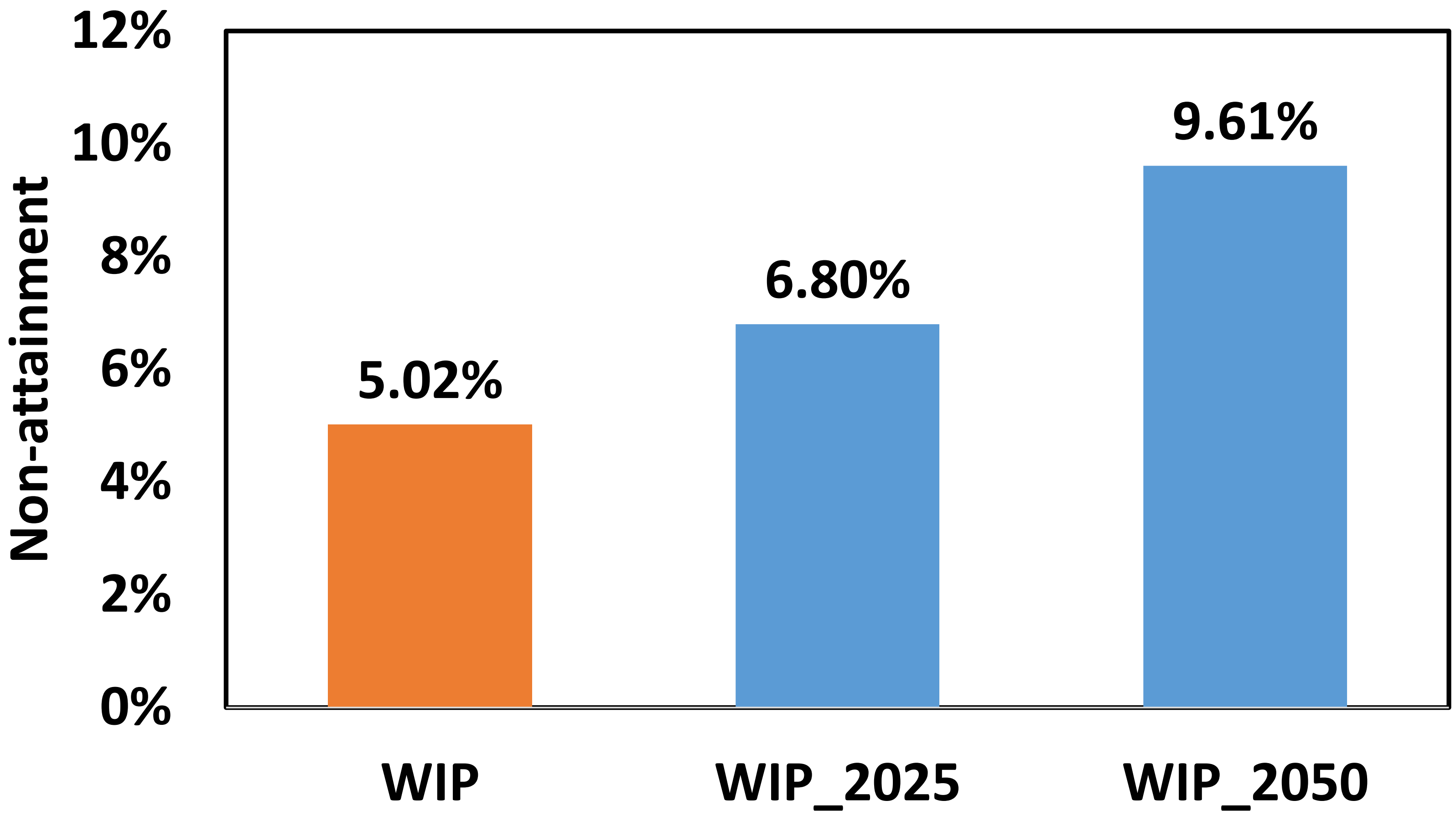
Cross-transect water mass fluxes
Base case versus sea level rise (SLR)
Summer 1993-1995





Base = Beta 2 Calibration. SLR = 0.5m Sea Level Rise Scenario representing relative Chesapeake sea level riser from 1995 to 2050. Units in mean cubic meters per second (m^3/s) for summer 1993 to 1995 hydrodynamics.

Estimated DO water quality attainment in the Deep Channel CB4MH under the WIP condition



Conclusions:

- **Temperature is the most sensitive variable in controlling hypoxia under estimated 2025 and 2050 climate change conditions, followed by sea level rise and nutrient loading.**
- **Increased temperature increases hypoxia whereas sea level rise improves DO in the Deep Channel, with the combined effect of an increase in 1.8% non-attainment in CB4 Deep Channel under the WIP condition with estimated 2025 future climate risk.**
- **Sea level rise magnitude: linear interpolation for 2035 and 2045; Waiting for final recommendation from Climate Change Resiliency WG.**
- **Investigation of air to water factor for temperature at the open ocean boundary ongoing.**

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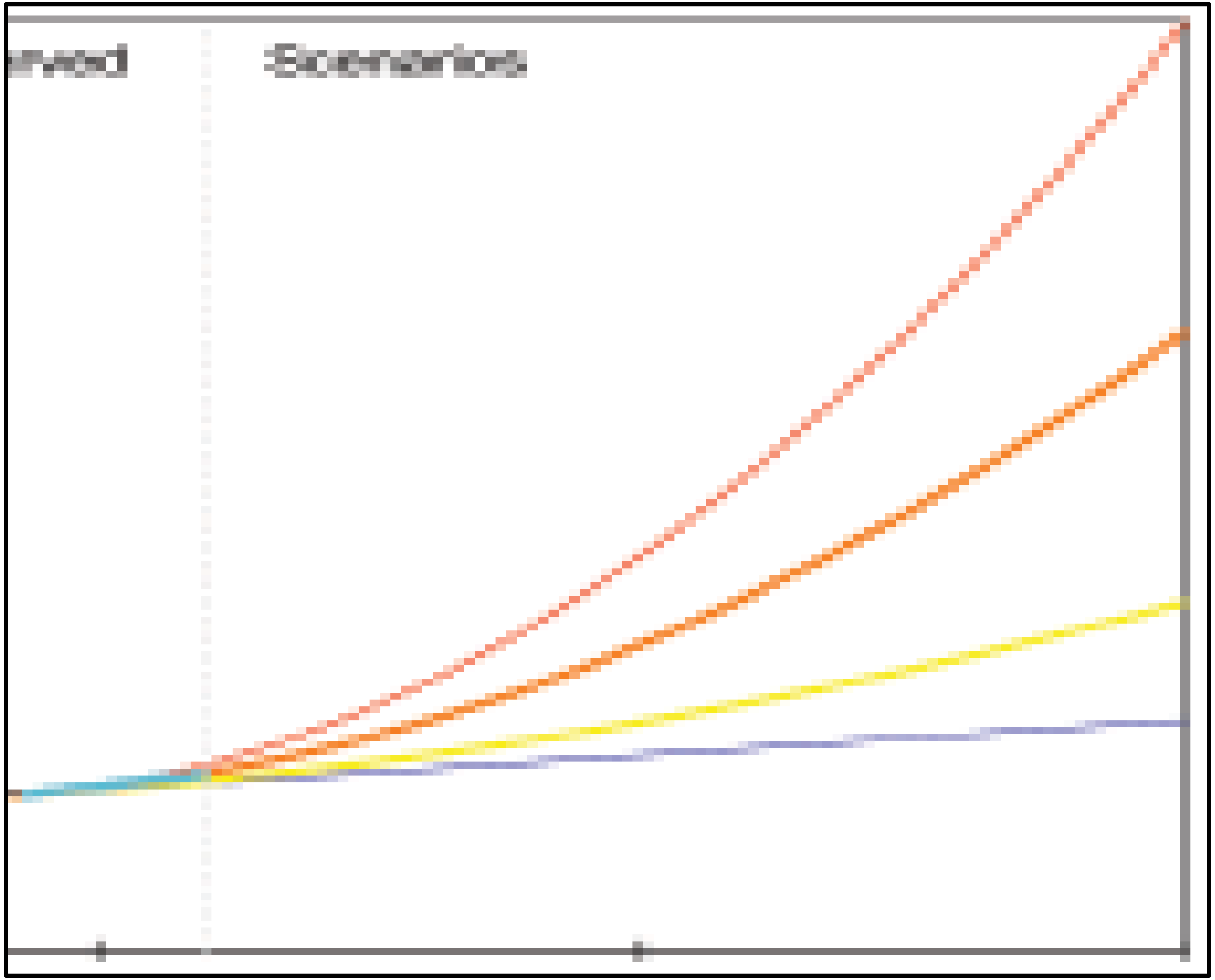
Annex

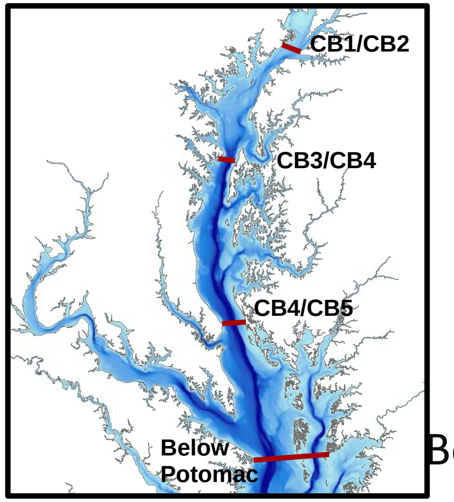
ICPP AR5 2014

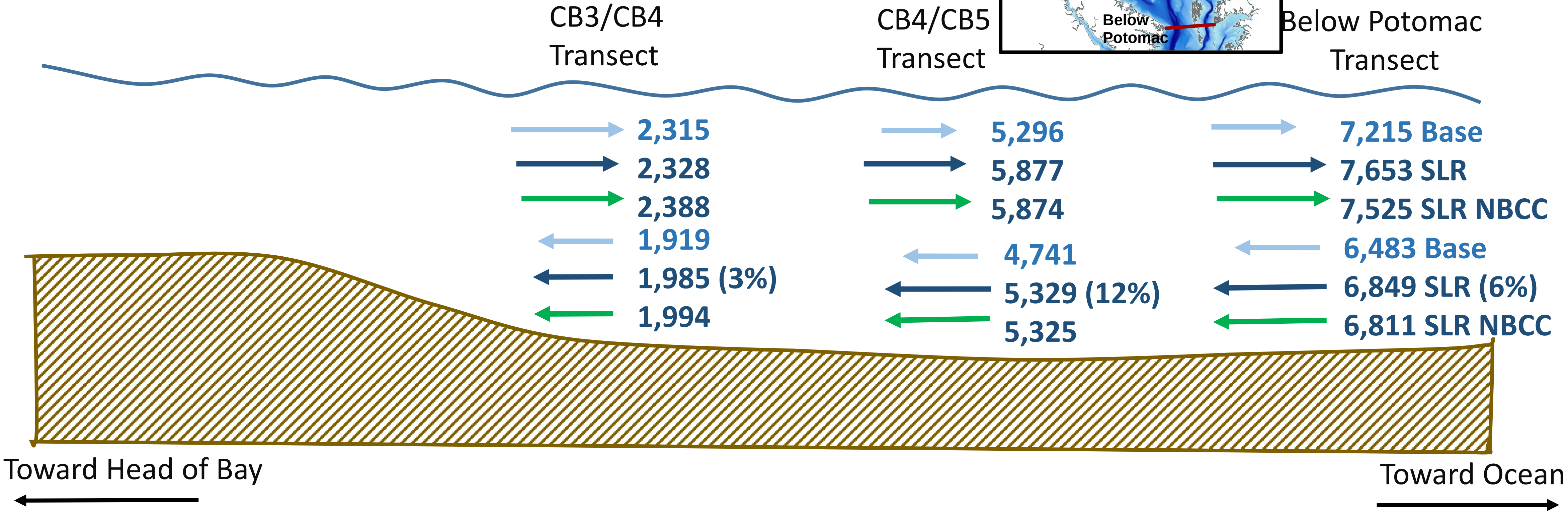
AR5 global mean sea level (m) increase projections[7]		
Scenario	2046–2065 Mean and likely range	2081–2100 Mean and likely range
RCP2.6	0.24 (0.17 to 0.32)	0.40 (0.26 to 0.55)
RCP4.5	0.26 (0.19 to 0.33)	0.47 (0.32 to 0.63)
RCP6.0	0.25 (0.18 to 0.32)	0.48 (0.33 to 0.63)
RCP8.5	0.30 (0.22 to 0.38)	0.63 (0.45 to 0.82)

AR5 global warming increase (°C) projections[7]		
Scenario	2046–2065 Mean and likely range	2081–2100 Mean and likely range
RCP2.6	1.0 (0.4 to 1.6)	1.0 (0.3 to 1.7)
RCP4.5	1.4 (0.9 to 2.0)	1.8 (1.1 to 2.6)
RCP6.0	1.3 (0.8 to 1.8)	2.2 (1.4 to 3.1)
RCP8.5	2.0 (1.4 to 2.6)	3.7 (2.6 to 4.8)


rved
Scenarios

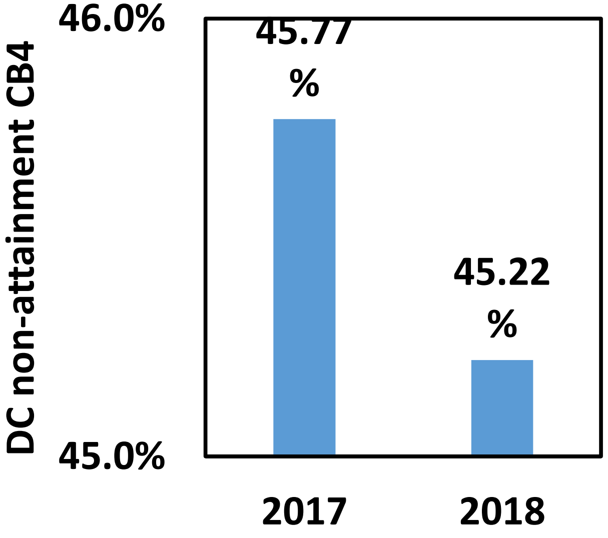
Cross-transect water fluxes (m3/s) Base case versus sea level rise (0.5m) Summer 1993-1995

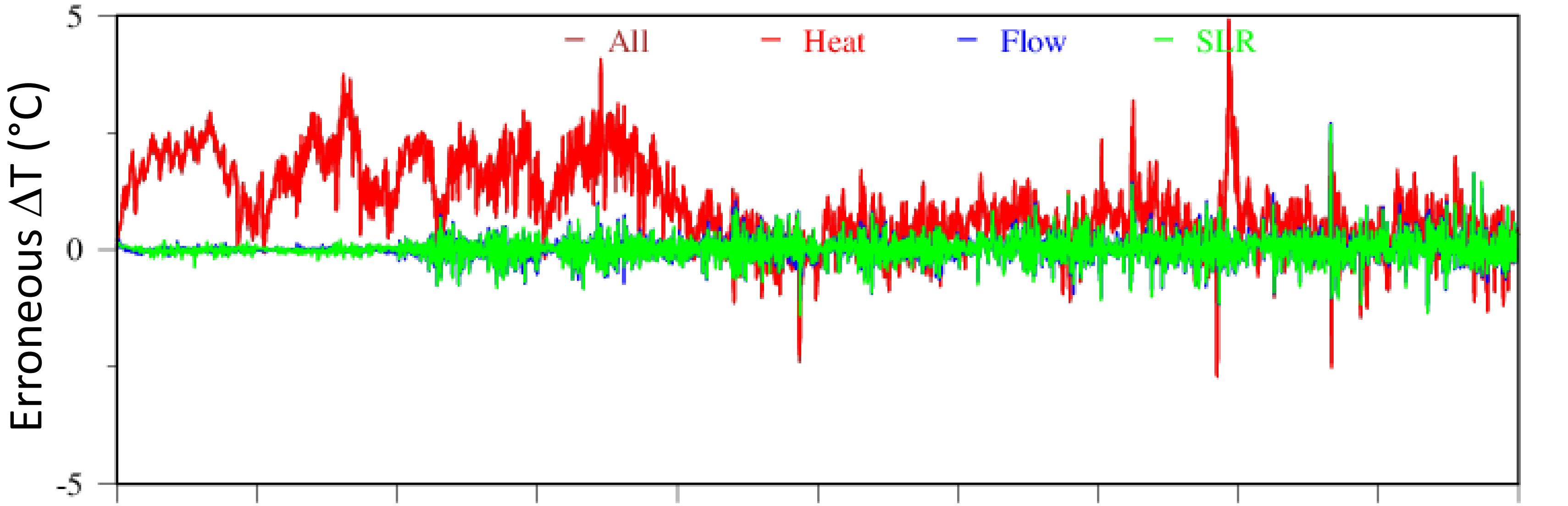


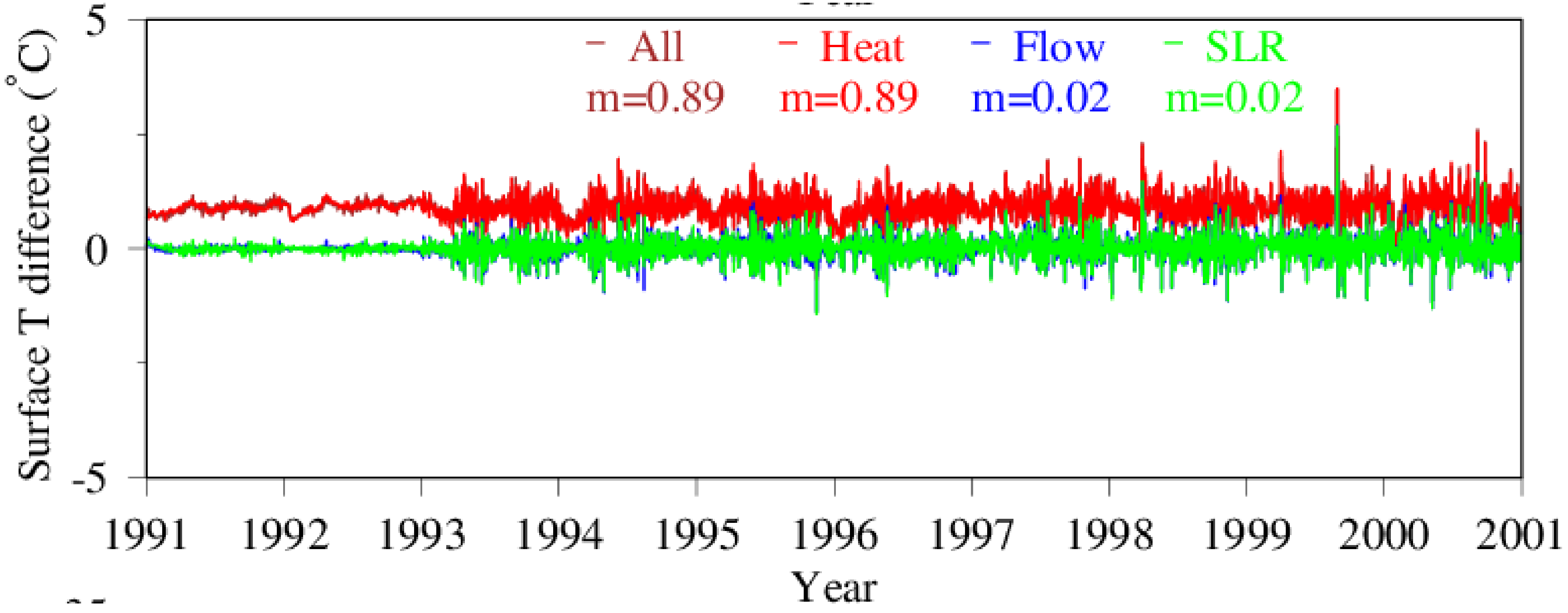


Base = Beta 4 TMDL SLR = 0.5m Sea Level Rise Scenario representing relative Chesapeake sea level rise from 1995 to 2050. Units in mean kg DO per second (m^3/s) for summer ()Jun-Sept) 1993 to 1995; NBCC: No Boundary Change.

Surface temperature difference between climate change scenarios and the base case, Station CB4.3C.



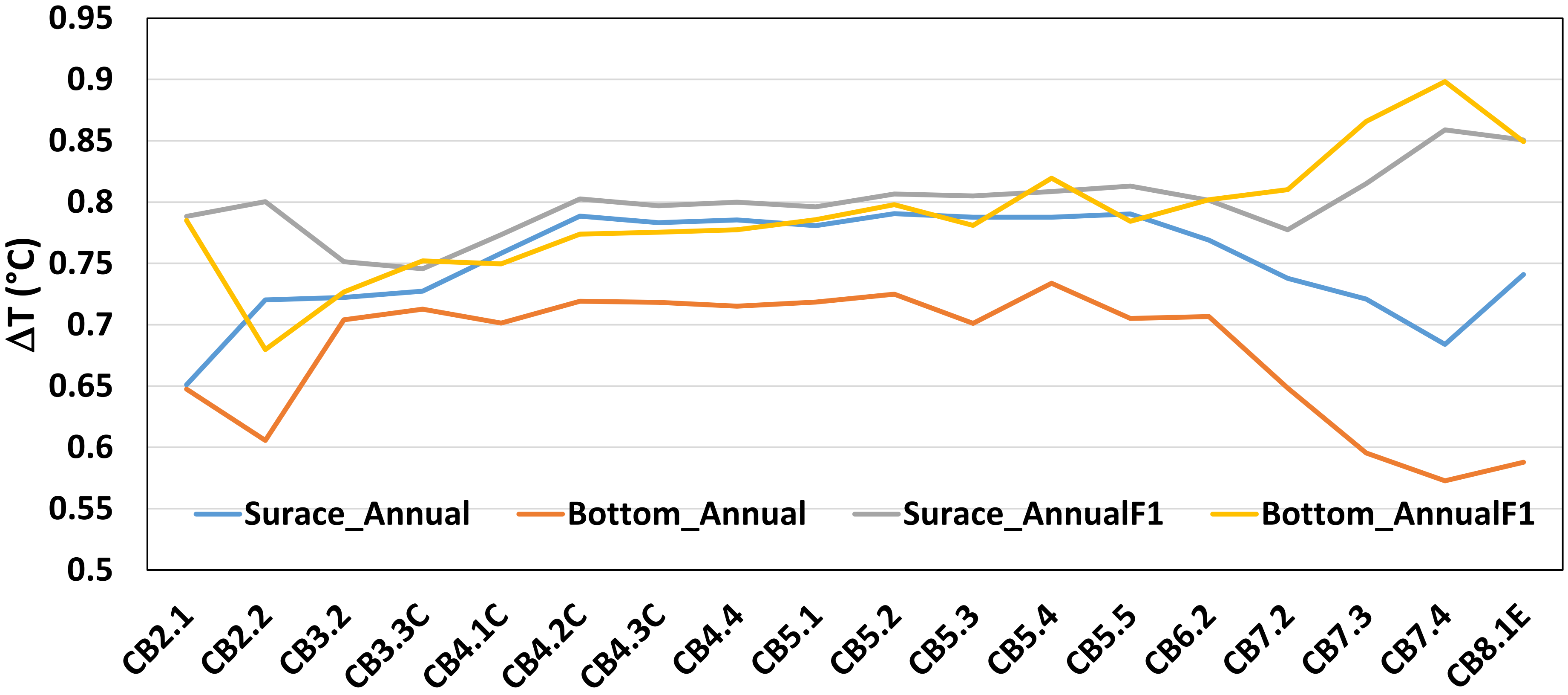




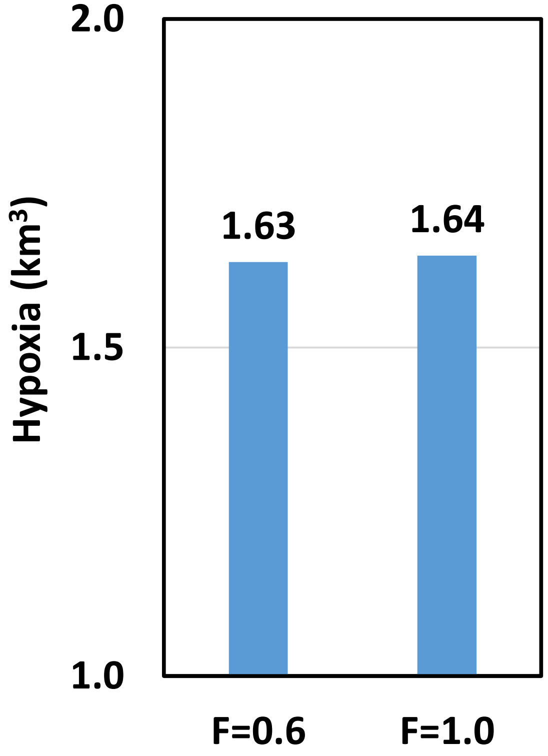
m: average over 10 years

Year

Changes in surface T simulation by alter open boundary from 0.6 to 1 times of ΔT_{air}

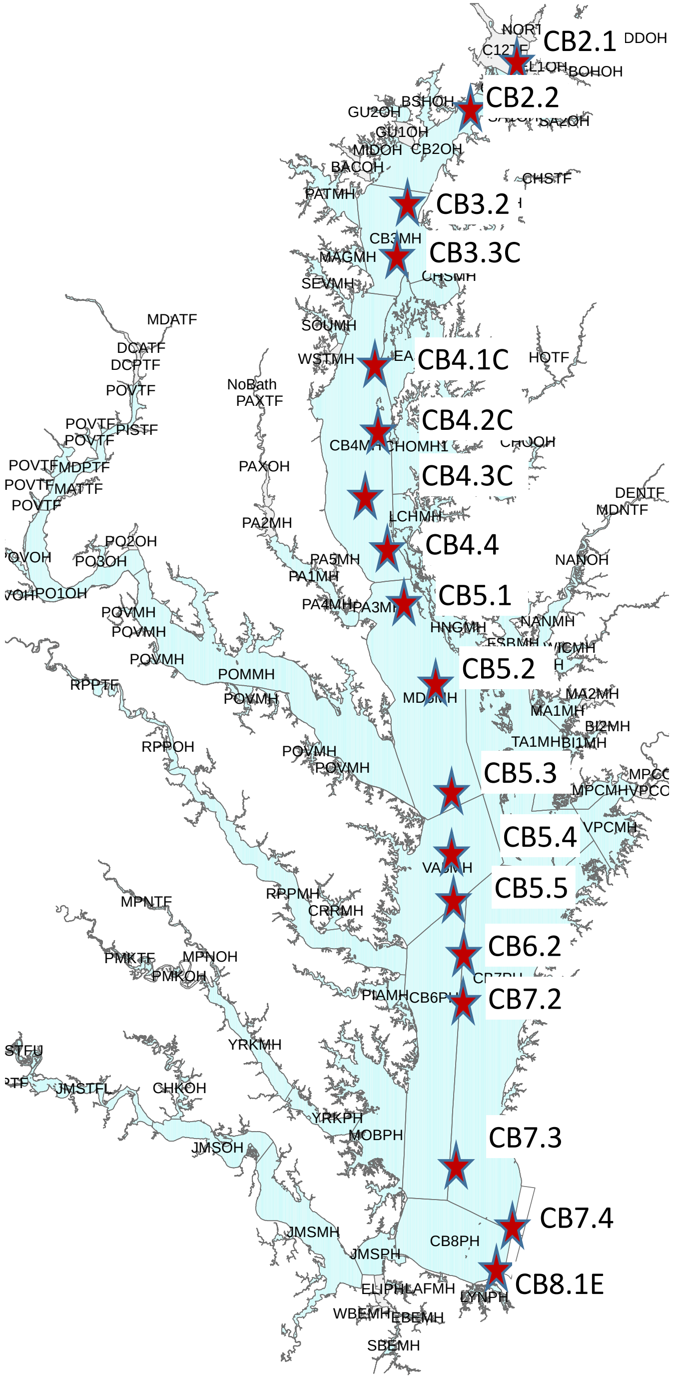


Hypoxia volume in CB4 under 2025 CC condition

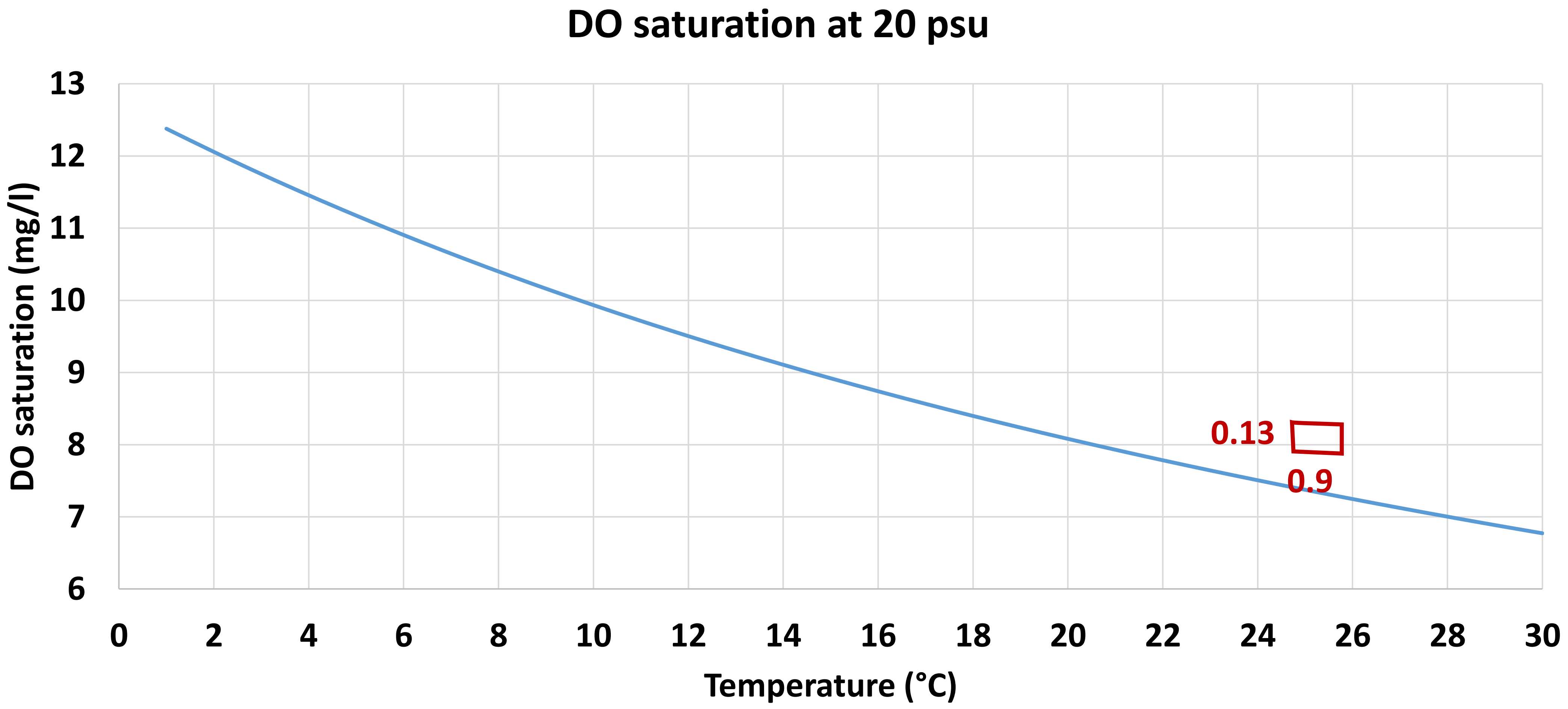


Open boundary has more influence in deeper layer than in the surface

18 stations along the main stem were analyzed



DO saturation as a function of temperature (Garcia and Gordon, 1992)



Effect of temperature increase on biological rates

$$a_{res} = \alpha B e^{k(T - Tr)}$$

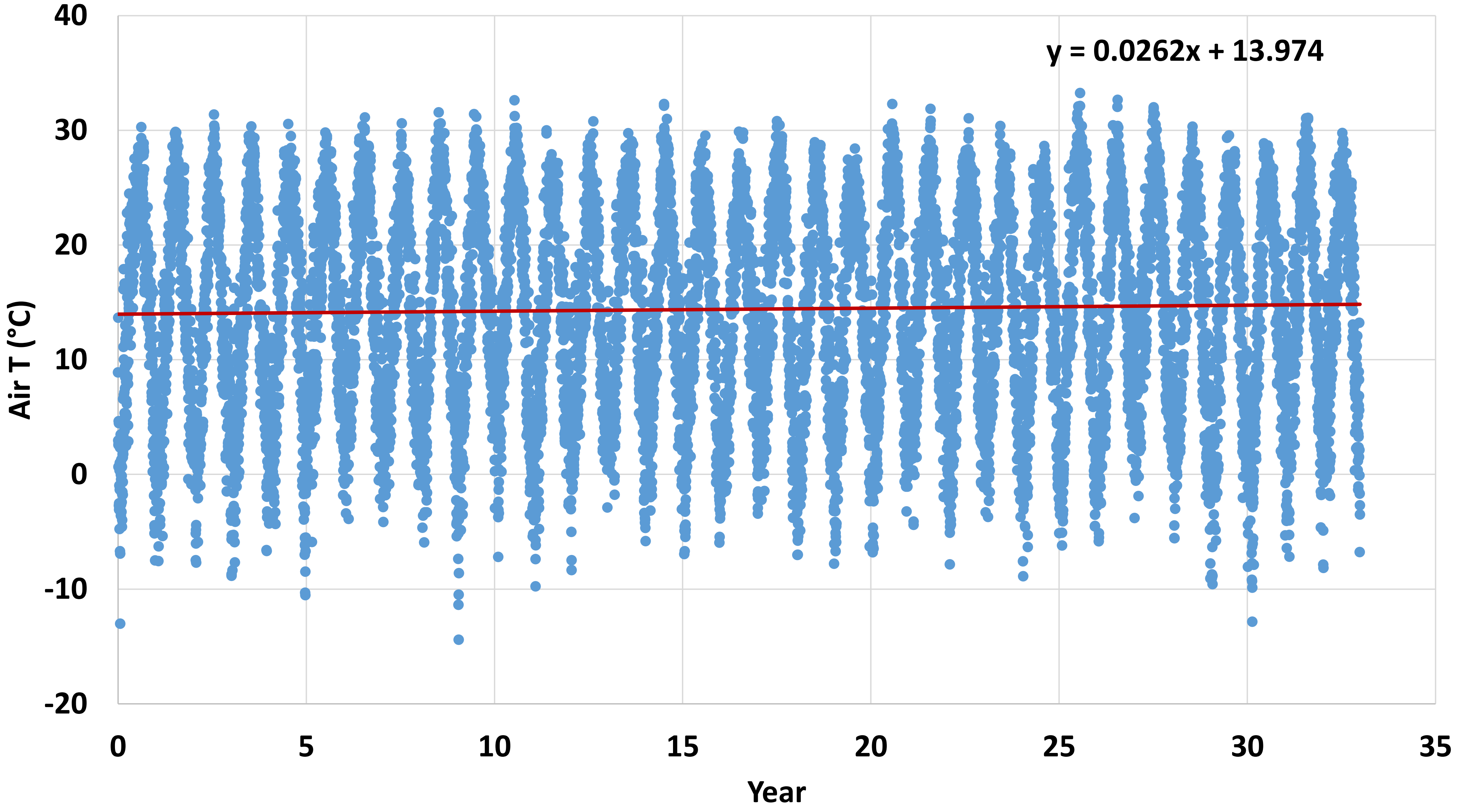
a_{res}: Respiration or remineralization rate; B: Biomass;
Tr: Reference temperature; α: rate at reference temperature;
k: Exponential coefficient of temperature effect (0.069; Q_{10}=2)

Irby et al. 2018: Q_{10}=2.1

Londas et al., 2002. Microbial processes and temperature in Chesapeake Bay:

tial scatter in the data. Pelagic microbial rate processes (e.g. phytoplankton production, respiration, bacterial productivity) showed a remarkably constrained range of Q_{10} values from 1.7 to 3.4. The one notable exception to this was nitrogen uptake in the North and Mid Bay, which exhibited Q_{10} values <1.0. Proxies for phytoplankton biomass (e.g. chlorophyll) were largely independent of temperature while bacterial abundance was significantly related to temperature and was found to have a Q_{10} of 1.88.

Air T at the Patuxent River Station 1985-2017



Estimate on water quality attainment in the Deep Channel Designated Use

Scenario	name	Base	2025SLR_17cm	2025Flow	2025Heat	2025All	2050SLR_50cm	2050Flow	2050Heat	2050All	WIP2	WIP2_2025	WIP2_2050
Nitrogen	loading	325TN	325TN	333TN	325TN	333TN	325TN	352TN	325TN	352TN	195TN	200TN	211TN
Phosph	loading	21.9TP	21.9TP	22.6TP	21.9TP	22.6TP	21.9TP	25.3TP	21.9TP	25.3TP	13.7TP	14.1TP	15.8TP
CB3MH	MD	7.02%	6.50%	7.56%	9.00%	8.41%	4.41%	8.58%	10.91%	9.20%	0.00%	0.00%	0.00%
CB4MH	MD	44.76%	42.07%	45.51%	47.66%	46.44%	36.45%	48.27%	51.11%	47.71%	5.02%	6.80%	9.61%
CB5MH_	MD	20.68%	18.39%	20.58%	22.04%	21.74%	15.67%	23.05%	24.54%	23.00%	0.00%	0.00%	0.00%
CB5MH_	VA	4.03%	2.65%	4.63%	6.16%	5.39%	0.48%	7.66%	8.74%	6.97%	0.00%	0.00%	0.00%
POTMH_	MD	15.47%	13.56%	15.68%	17.21%	17.06%	10.32%	17.16%	19.39%	18.77%	0.00%	0.00%	0.00%
RPPMH	VA	13.33%	16.00%	16.34%	20.42%	18.15%	14.40%	20.82%	24.57%	27.14%	0.00%	0.00%	0.00%
ELIPH	VA	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CHSMH	MD	11.24%	17.08%	11.83%	12.84%	11.81%	14.53%	13.67%	16.18%	14.26%	0.00%	0.01%	1.19%
EASMH	MD	17.95%	17.20%	18.93%	20.54%	18.91%	14.72%	20.56%	22.64%	18.55%	5.62%	6.38%	6.45%

Diagnosis on Climate Change Scenarios, CB4, average 1991-2000