Water quality simulation under climate change conditions – plan for approval

Richard Tian and CBPO modeling team

Modeling Quarterly Review
07/16/2019
Annapolis

Outline

- Sea level rise
- Phytoplankton growth curve
- Wind effect
- Ocean open boundary

Sea Level Rise

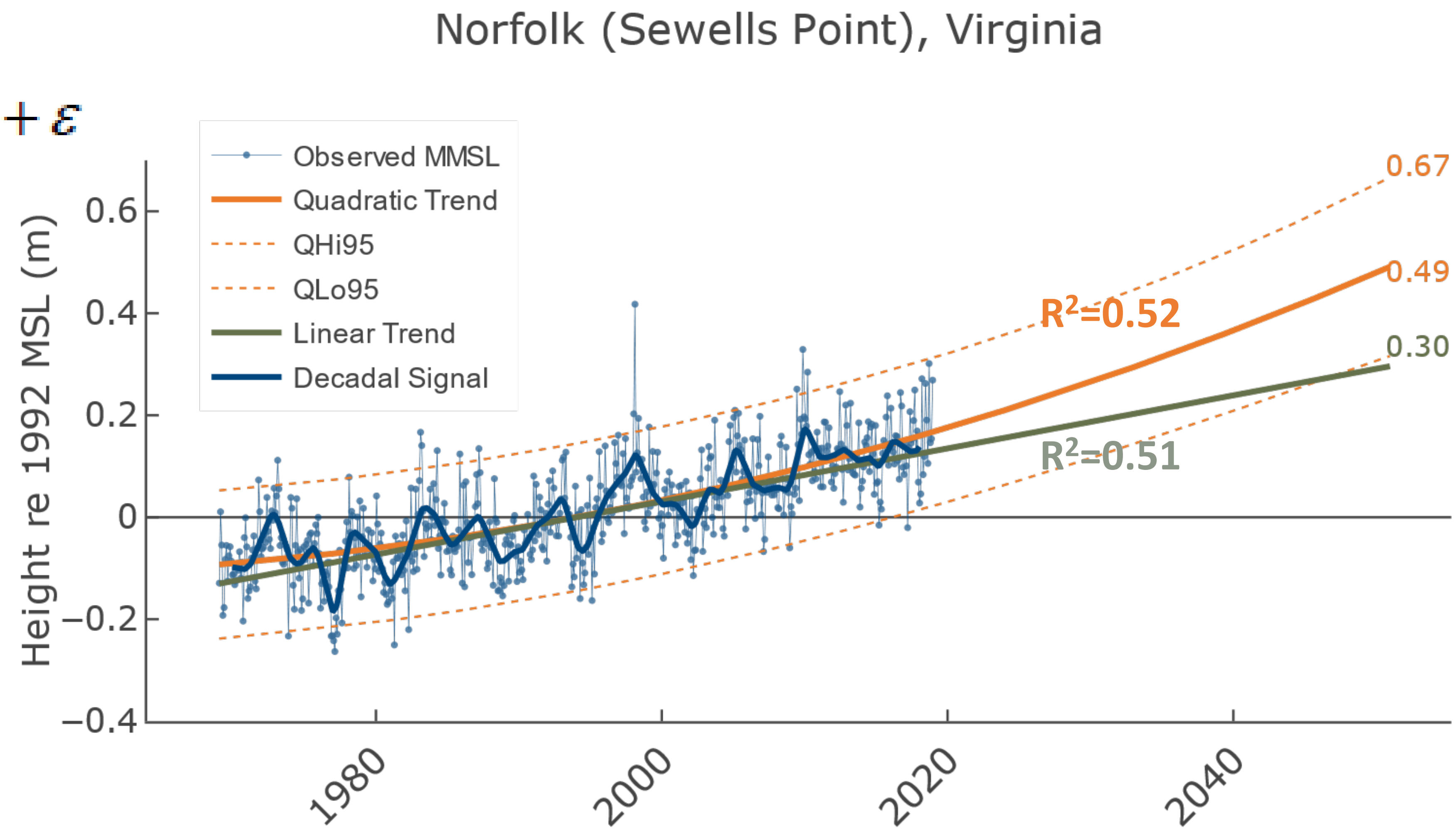
(Chapter 5.1.3)

Quadratic function projection, Norfolk

$$h = \beta_0 + \beta_1 t + \tfrac{1}{2}\beta_2 t^2 + \varepsilon$$

$\beta_1 = 5.203$ mm/yr
$\beta_2 = 0.12$ mm/yr^2

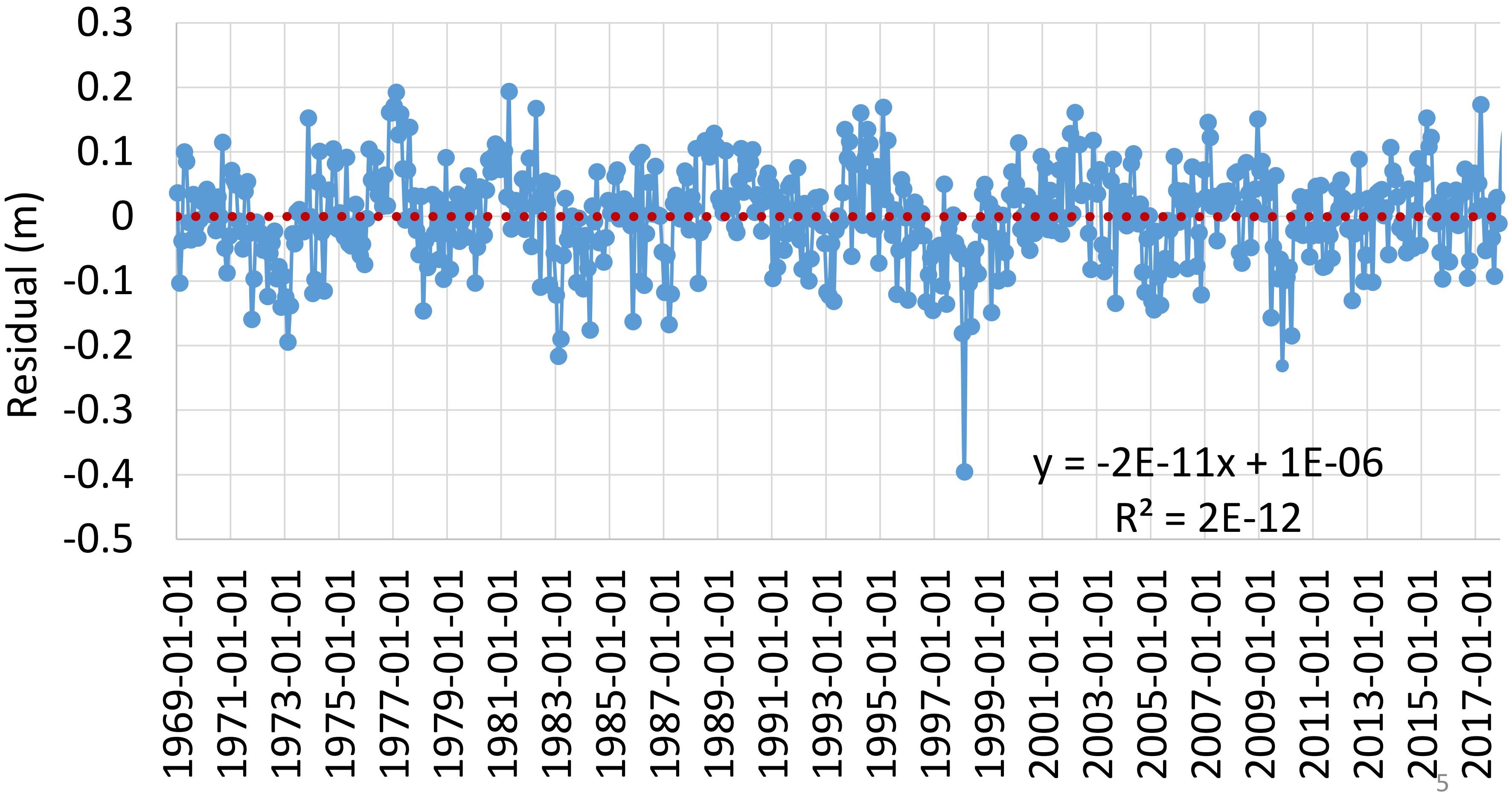
(with 2018 data.
Boon, Mitchel and others)



https://www.vims.edu/research/products/slrc/localities/norfolkva/index.php

Residual between Quadratic function projection and observation at Sewells Point, Norfolk, VA

No long-term trend or drift in time.



Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites (Kopp et al. 2014)

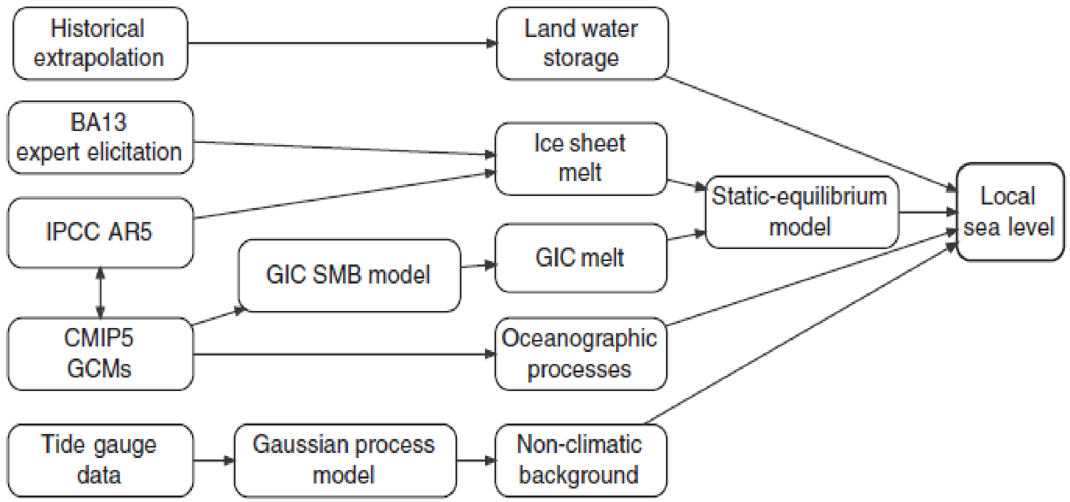
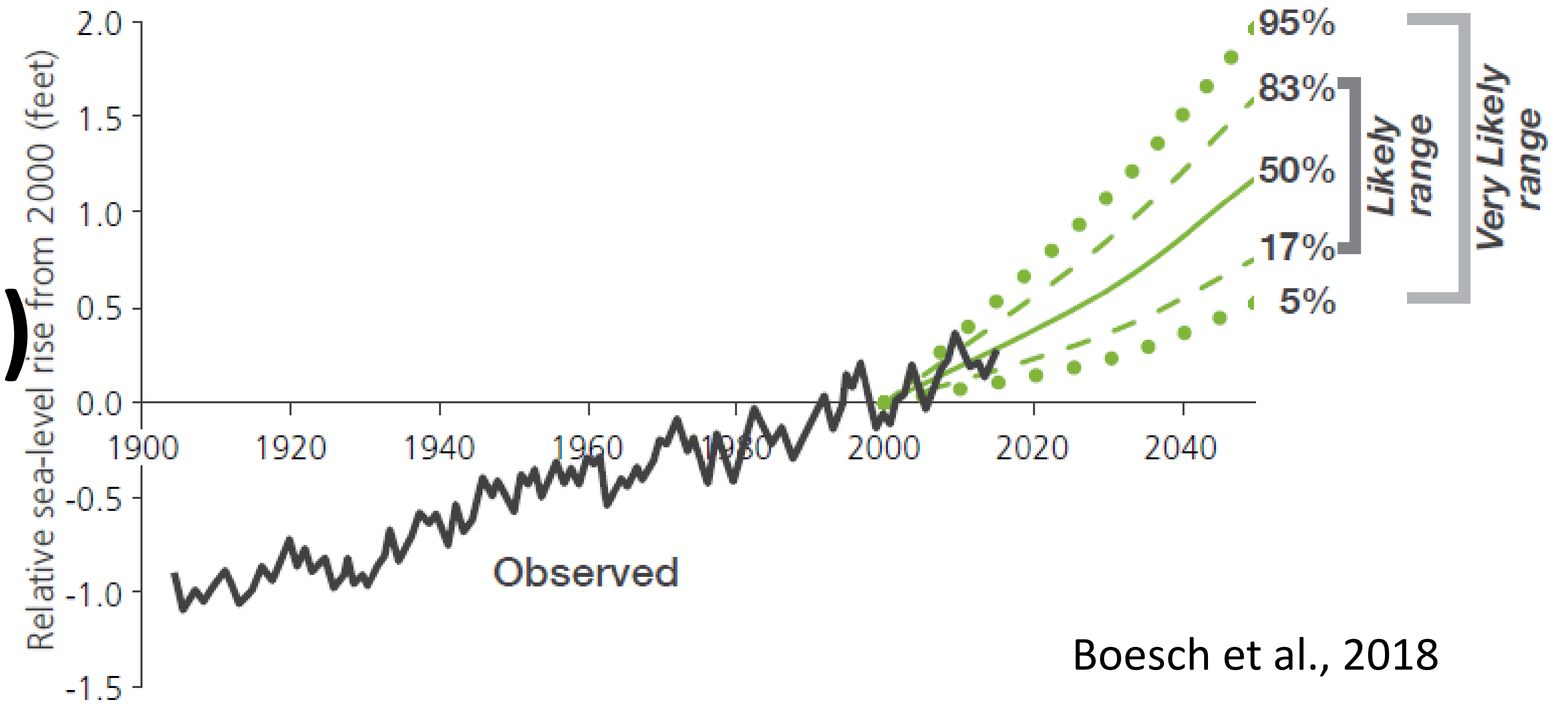


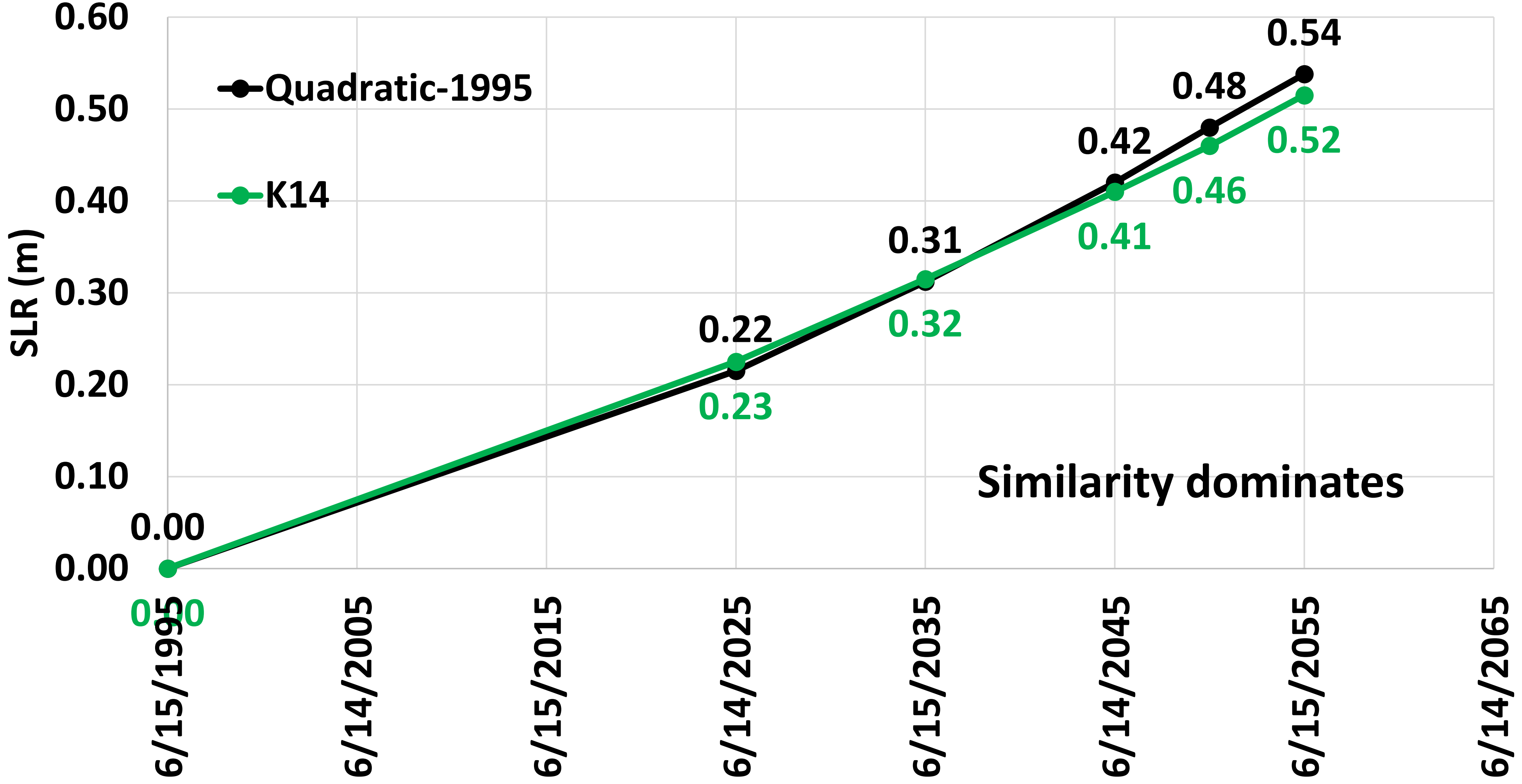
Figure 1. Logical flow of sources of information used in local sea-level projections. GCMs, global climate models; GIC, glaciers and ice caps; SMB: surface mass balance.



BA13: *Bamber and Aspinall* [2013].
GIC: glacier and ice cap.
SMB: surface mass balance.

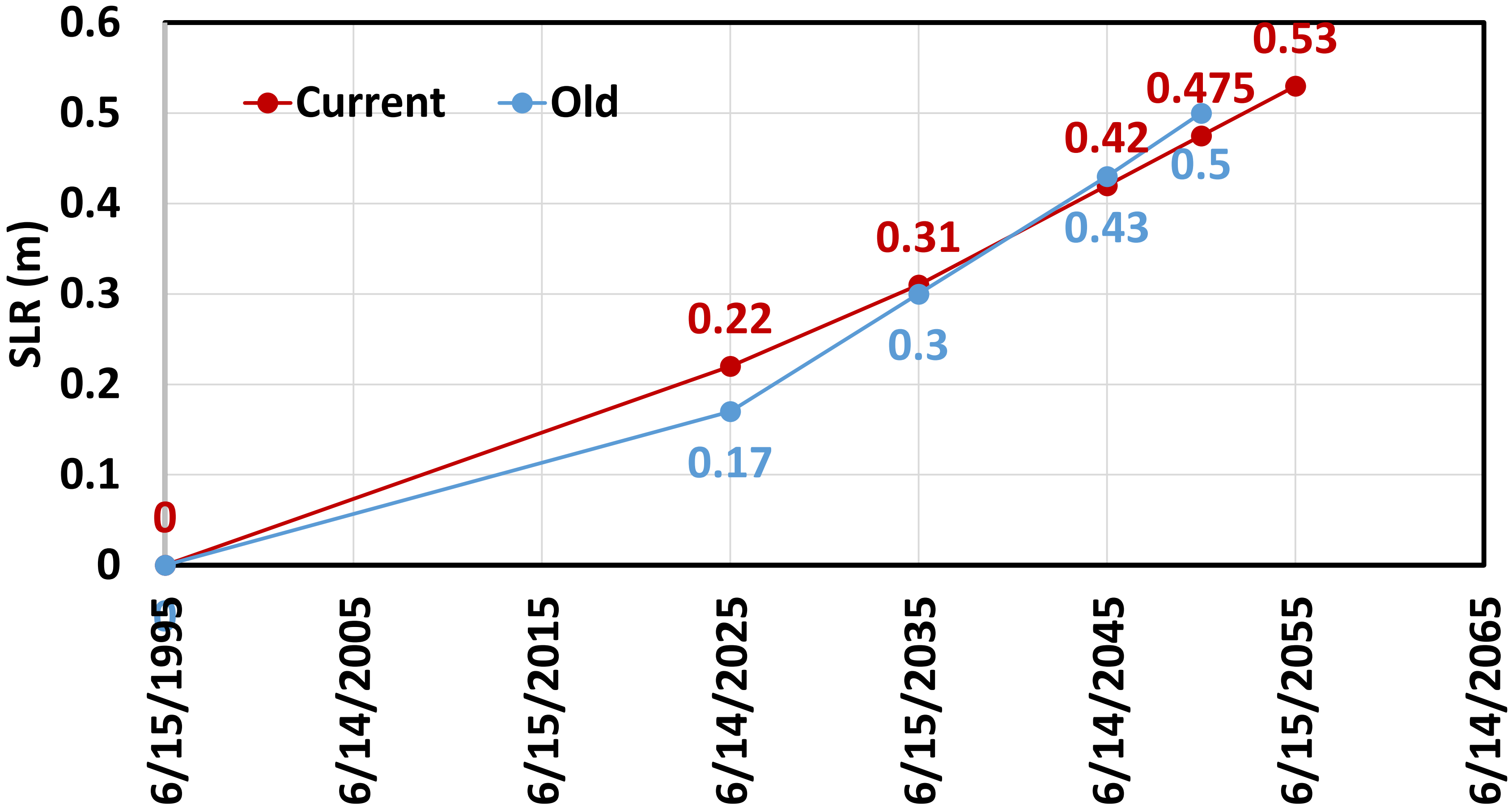
Boesch et al., 2018

SLR future projection-Sewells Point

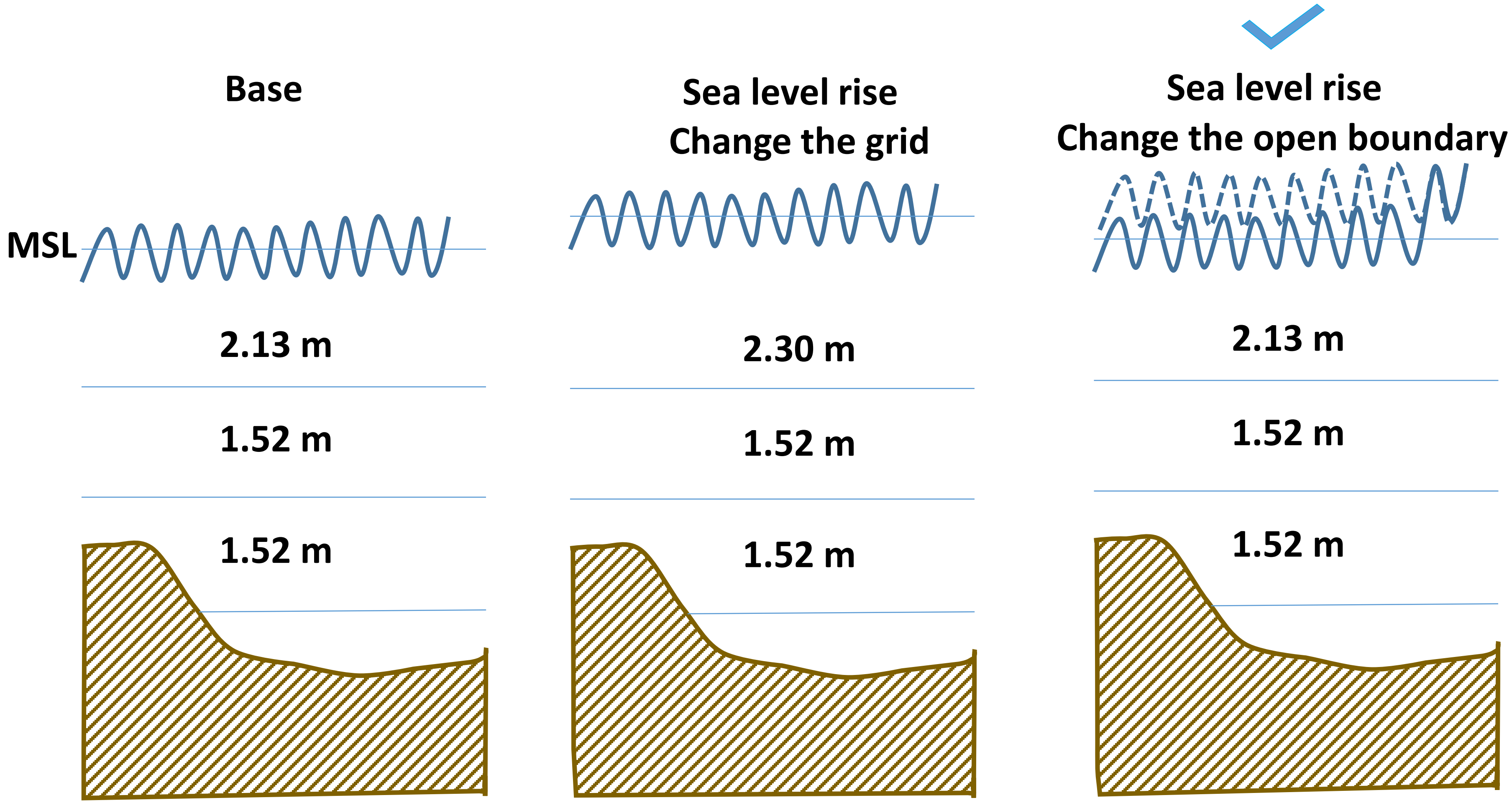


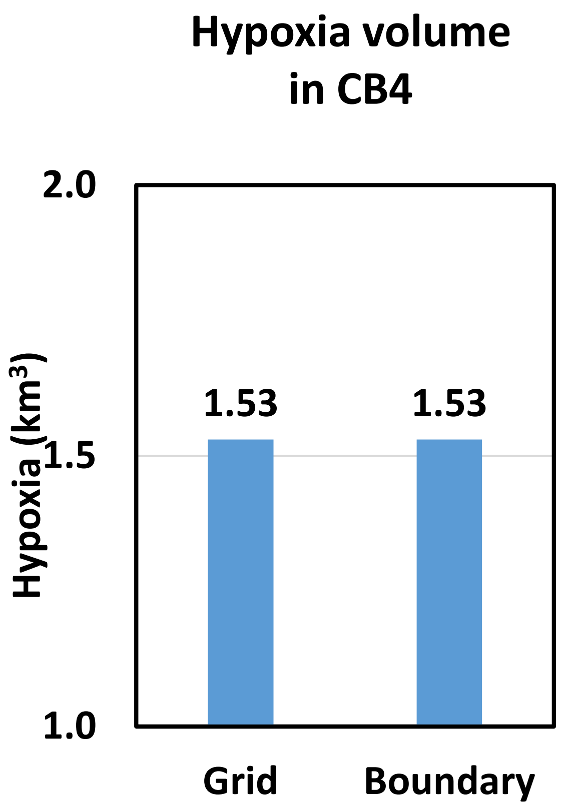
SLR future projection-Sewells Point

(Average between quadratic and K14 projections, based on recommendation of Climate Resiliency Group)



Sea level rise simulation





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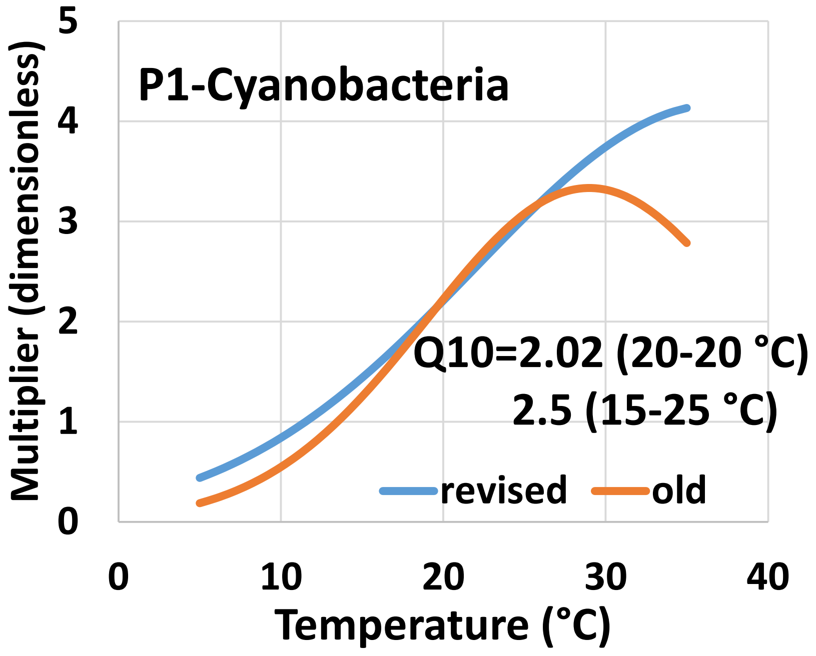
Discussion and decision

Phytoplankton growth and respiration curve

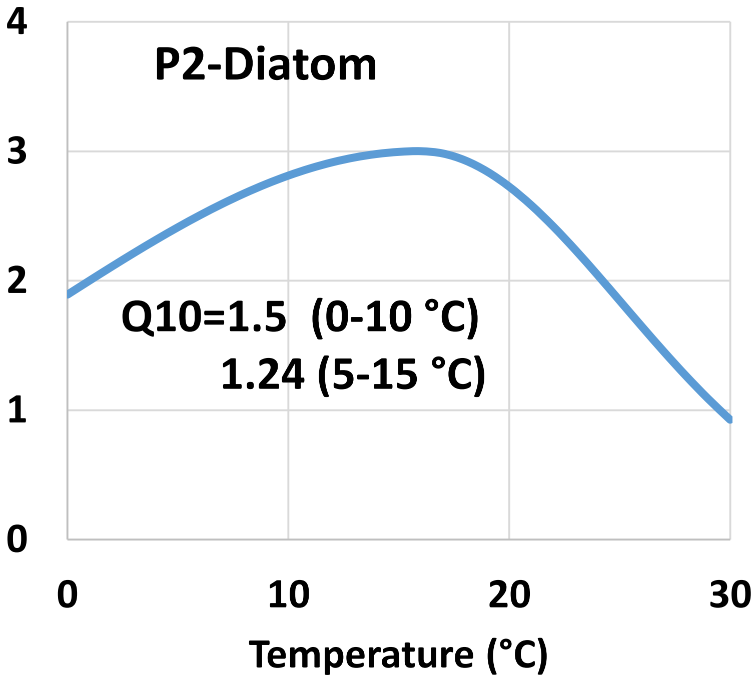
(chapter 5.2)

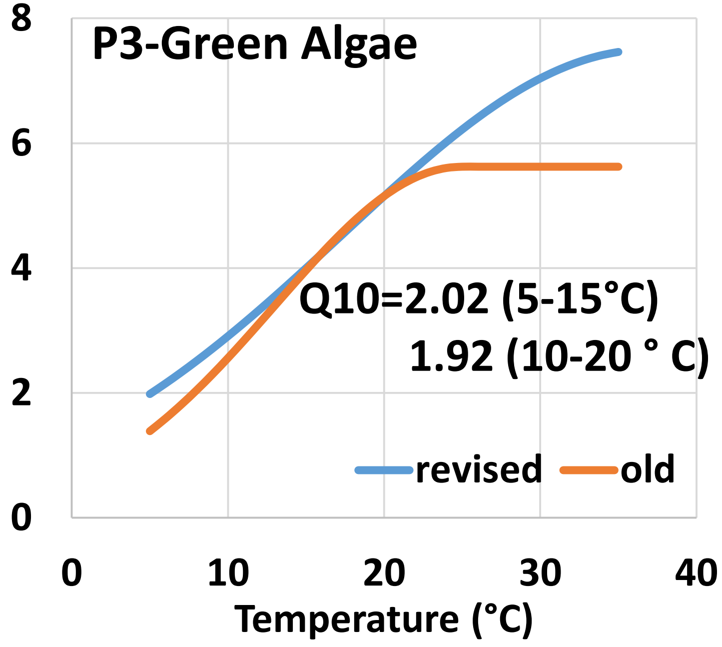
Revised temperature control on phytoplankton growth rate

$$f(T)=\begin{cases} e^{-k1(T-Topt)^2}, T \le T_{opt} \\ e^{-k2(T-Topt)^2}, T > T_{opt} \end{cases}$$



SATC recommendation





From Carl Cerco

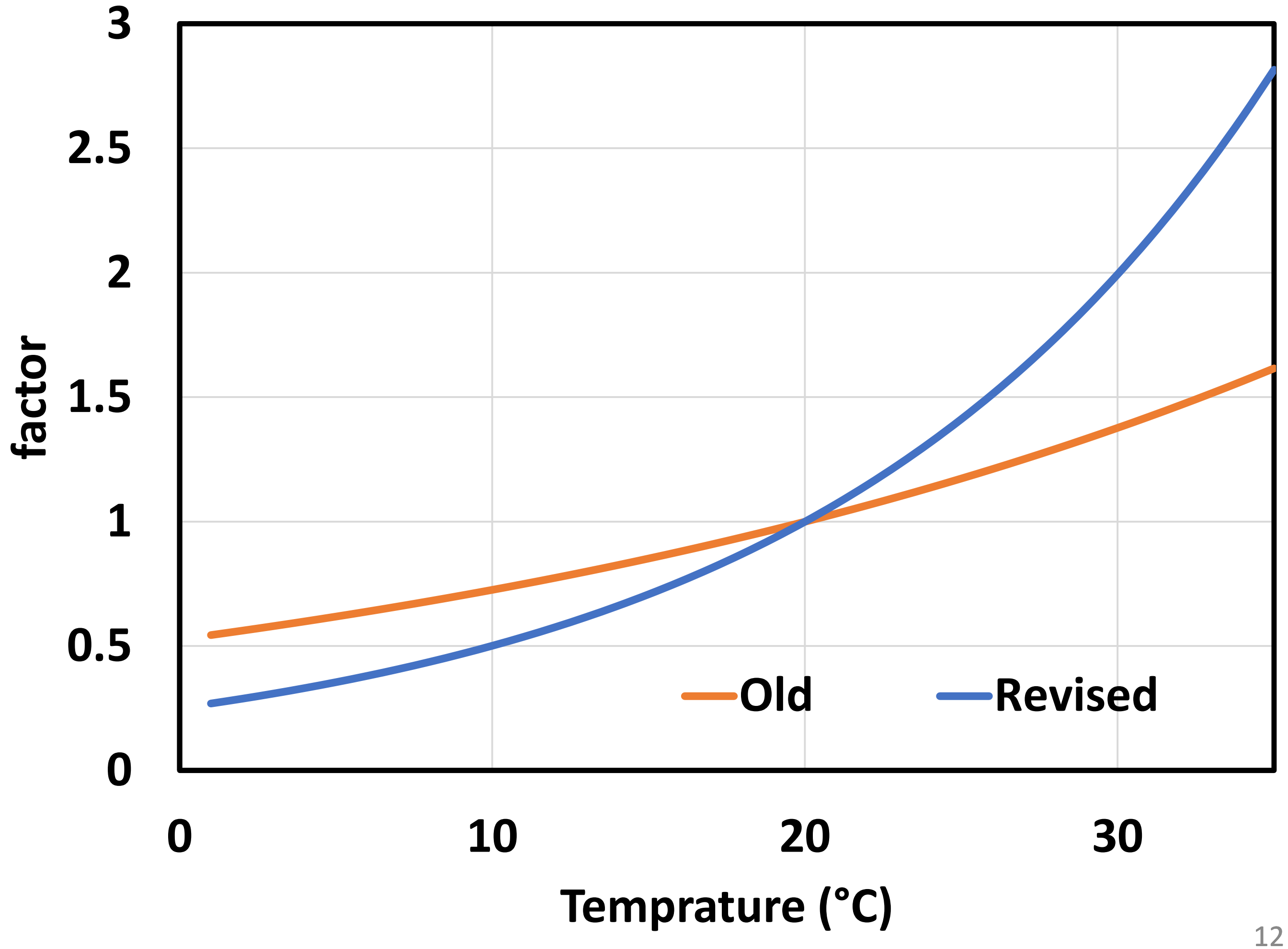
Chesapeake Bay Q10=1.7-3.4 (Q10: Rate increase over 10 °C) (Lomas et al., 2002).

Revised temperature control on phytoplankton respiration

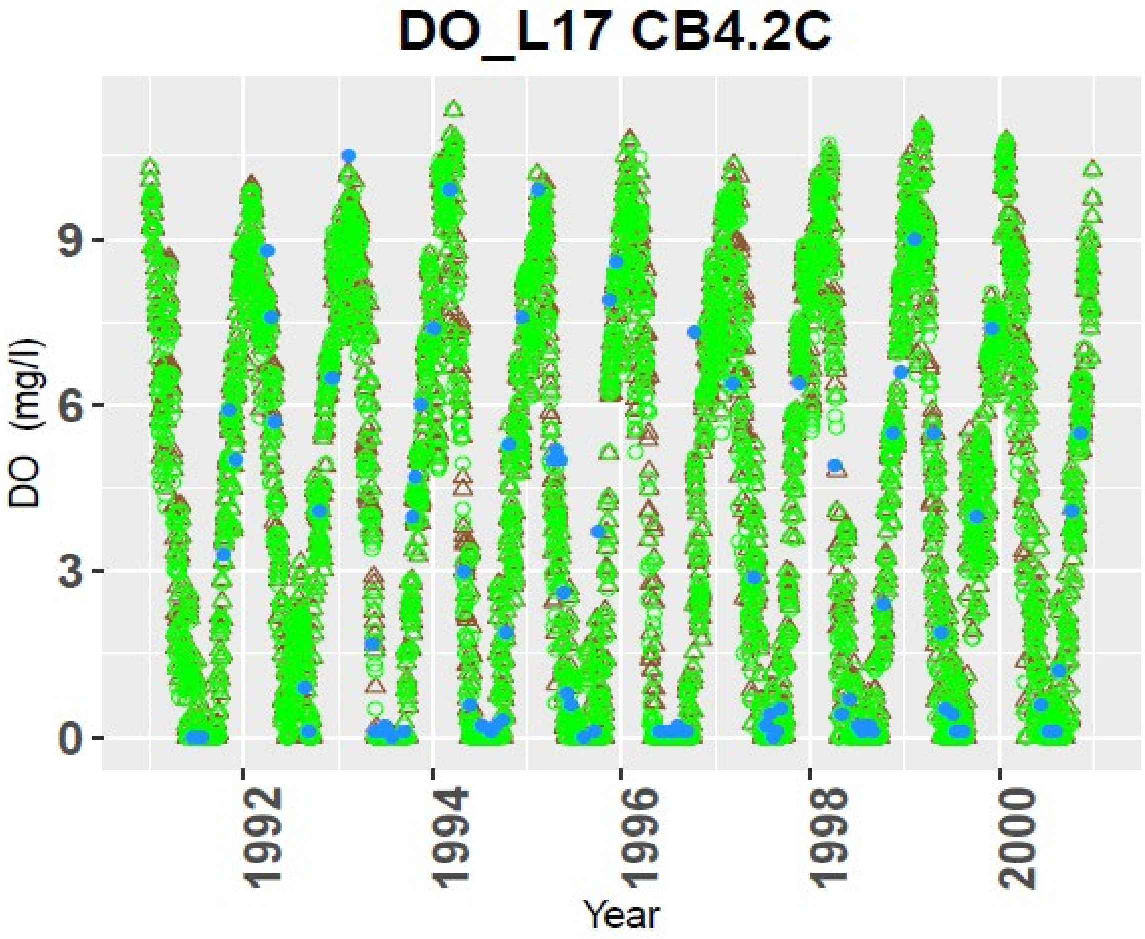
$$a_{res} = \alpha_r B e^{kr(T - T_0)}$$

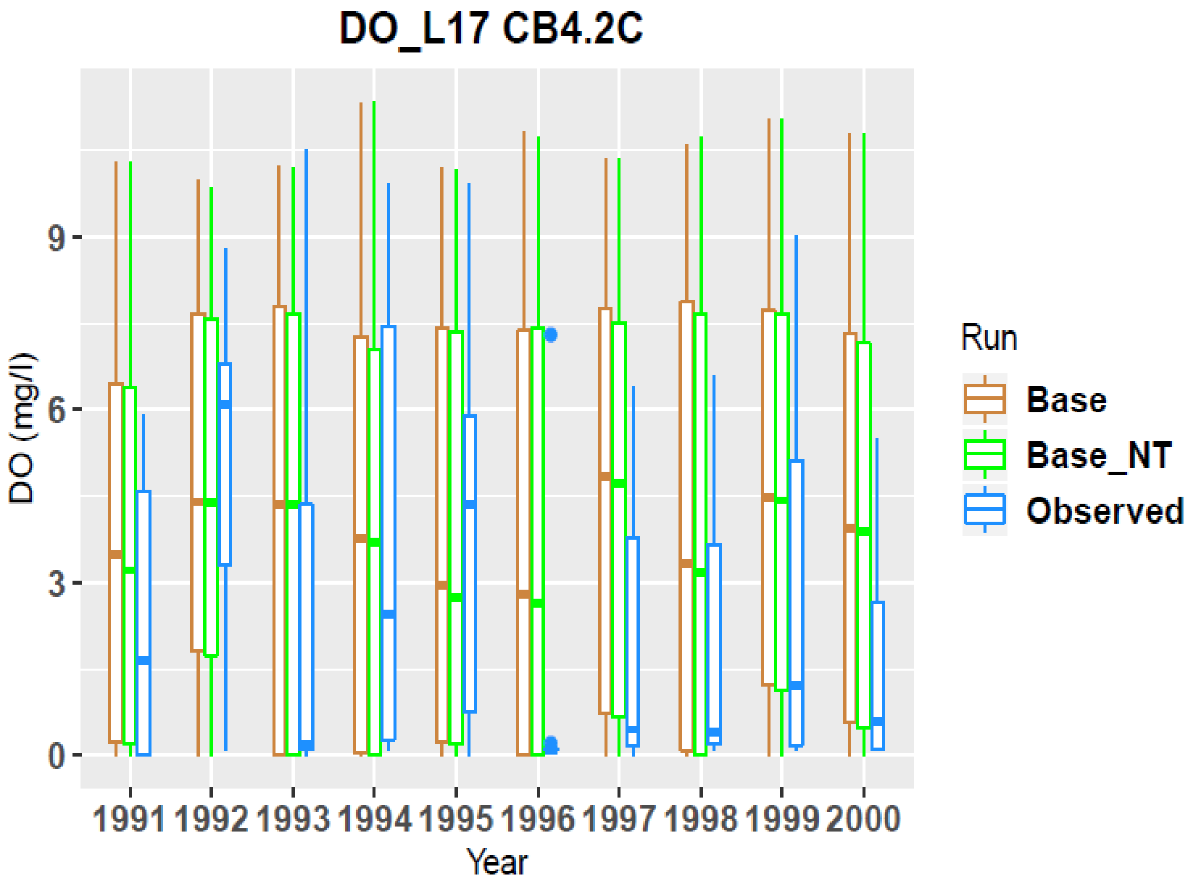
Old: kr=0.0322 (Q10=1.4)
Revised: kr = 0.069 (Q10=2.0)

STAC recommendation



Bottom DO at Station CB4.2C



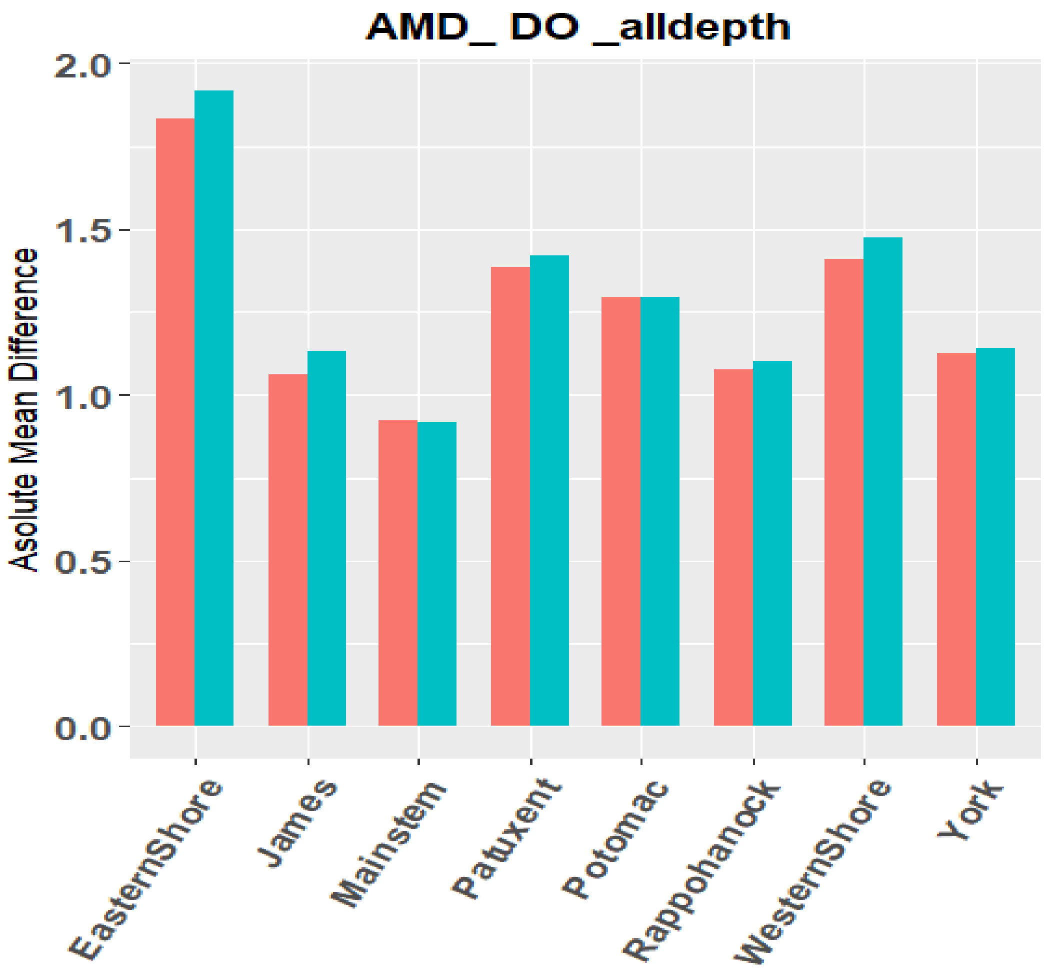


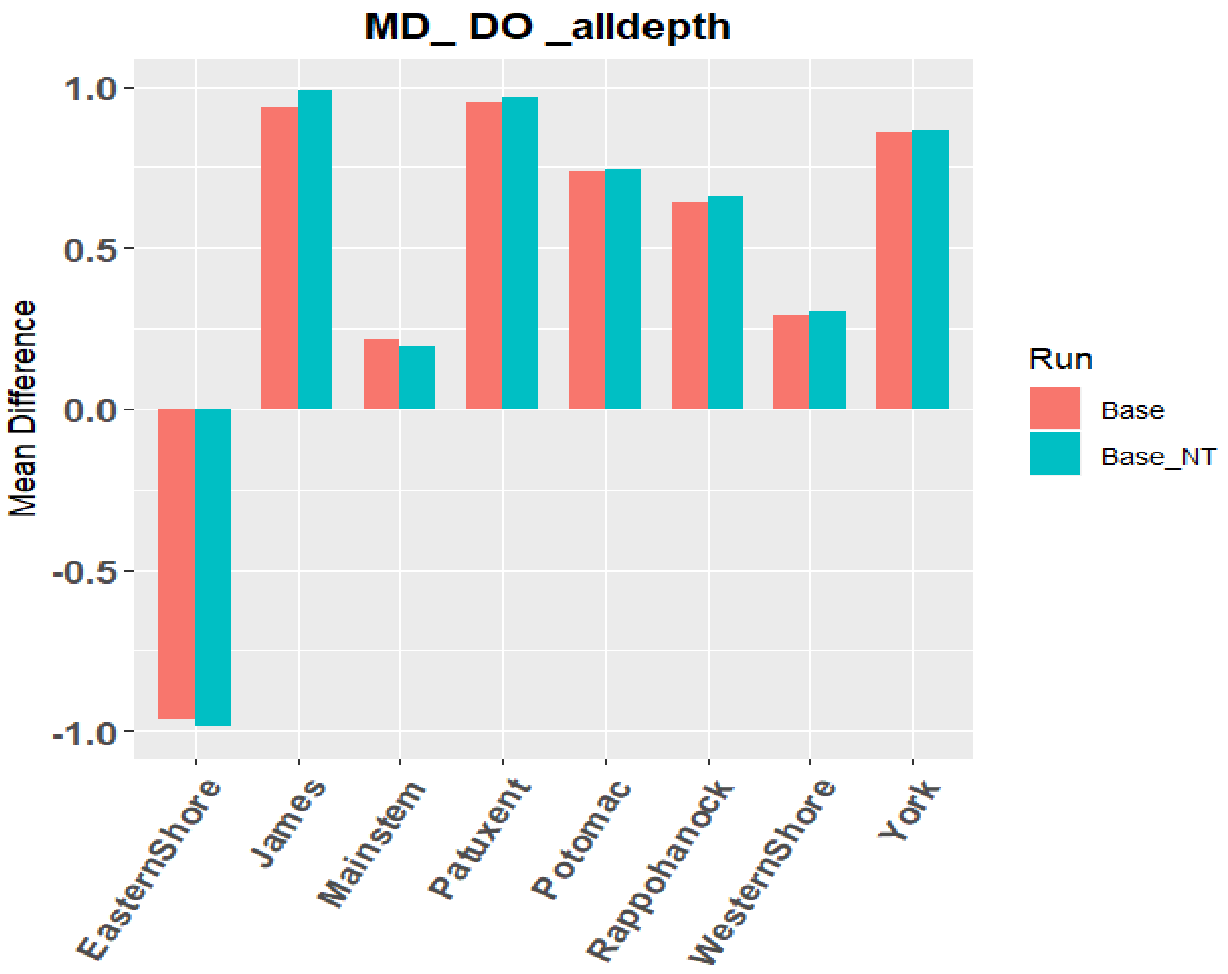
DO mean difference (AMD) and absolute mean difference (MD)

$$MD = \frac{\sum_{i=1}^{N}(P_i - O_i)}{N}$$

$$AMD = \frac{\sum_{i=1}^{N}|P_i - O_i|}{N}$$

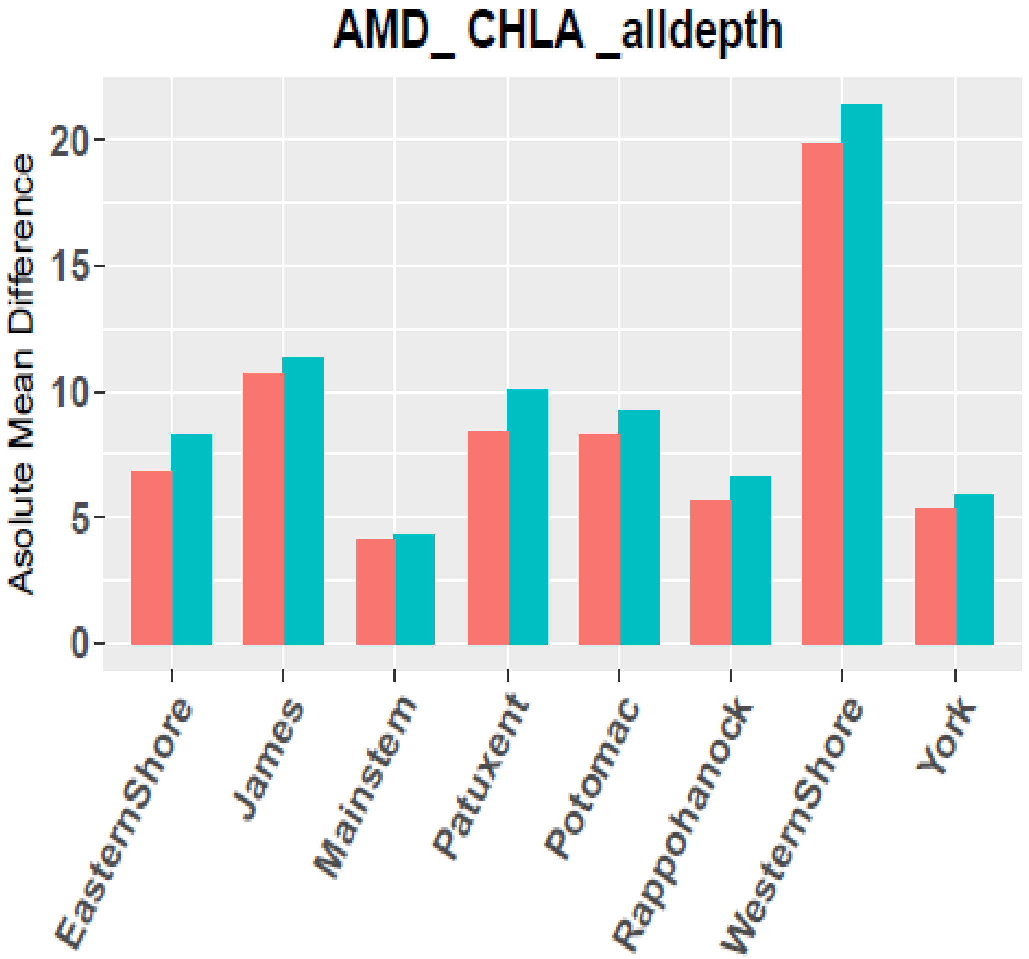
Unit: mg/l)

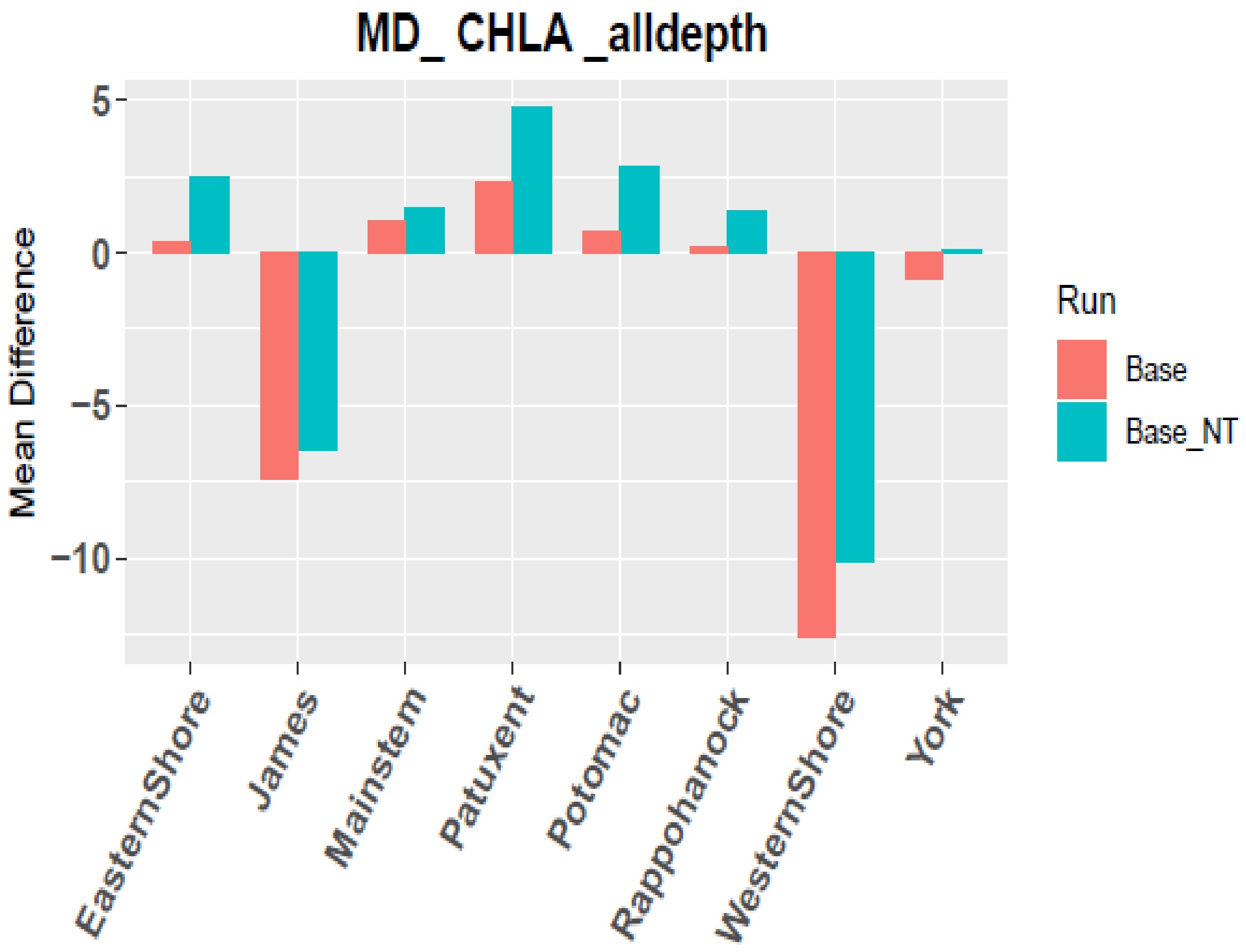




Chlorophyll absolute mean difference (AMD) and mean difference (MD)

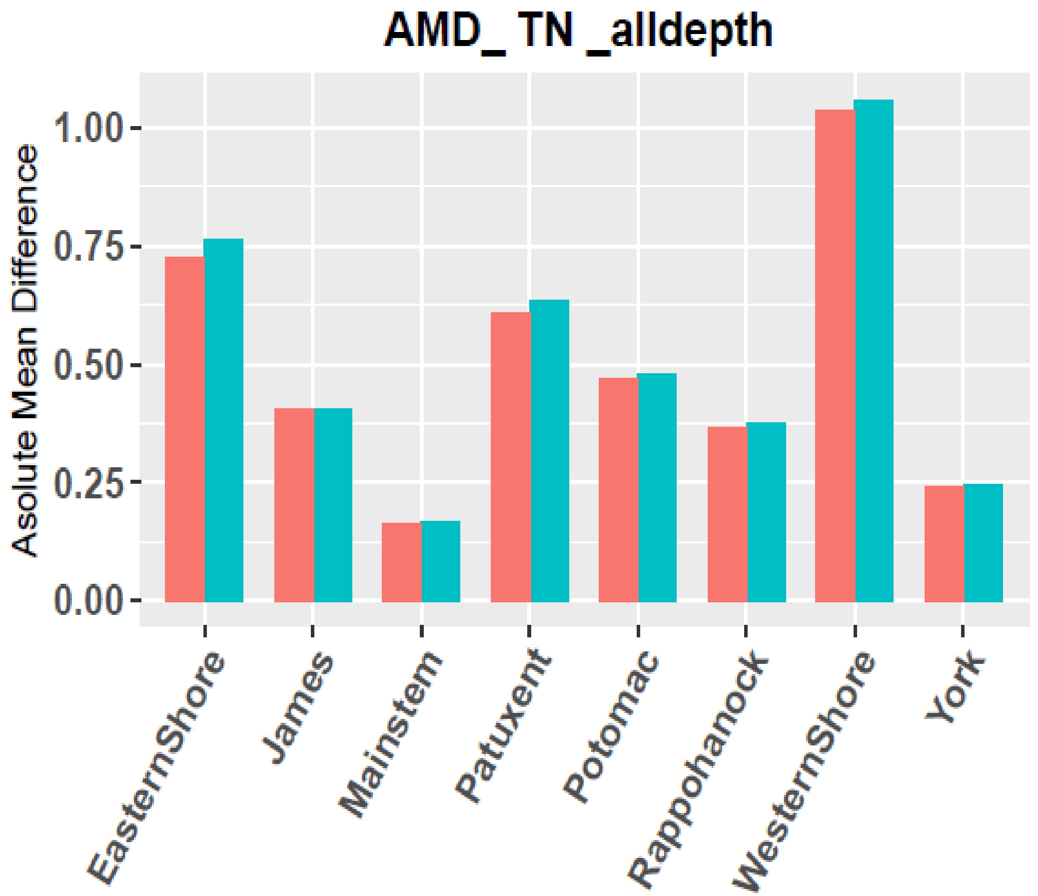
Unit: ug/l)

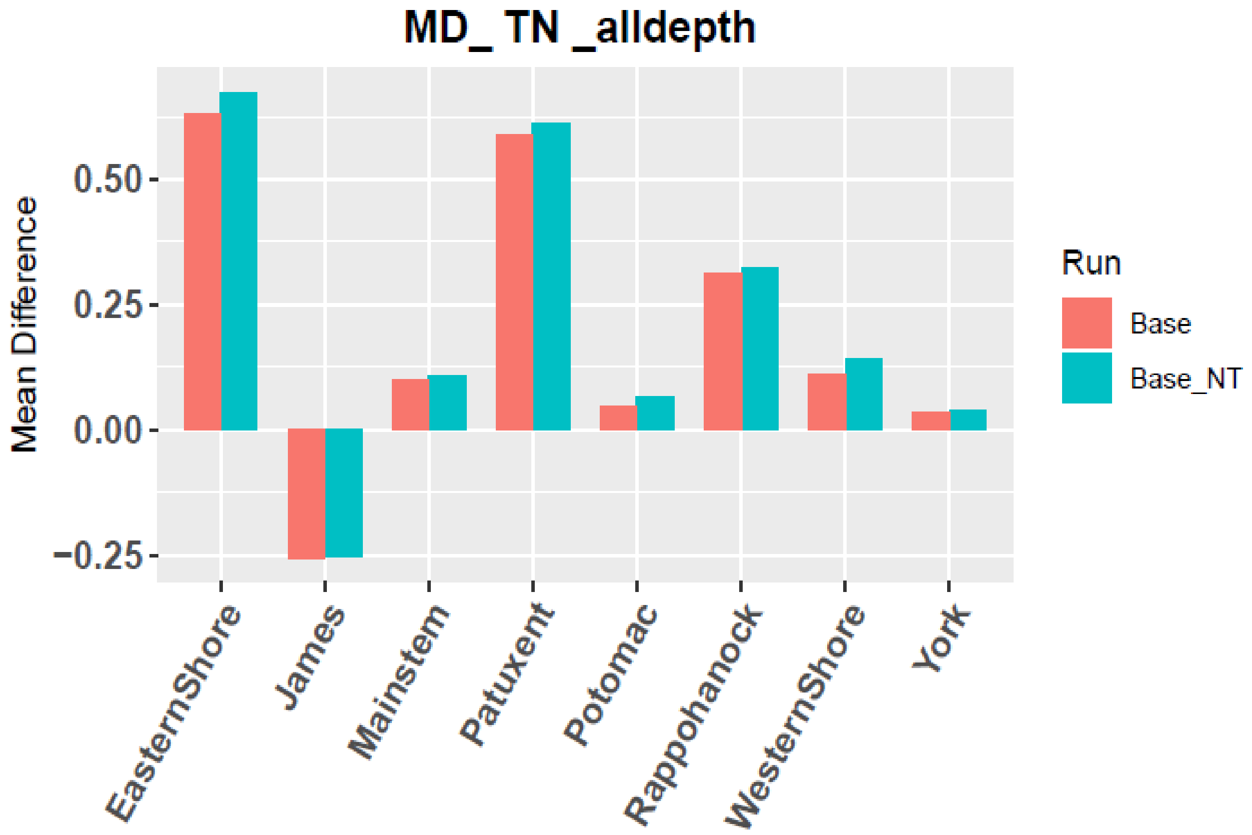




TN absolute mean difference (AMD) and mean difference (MD)

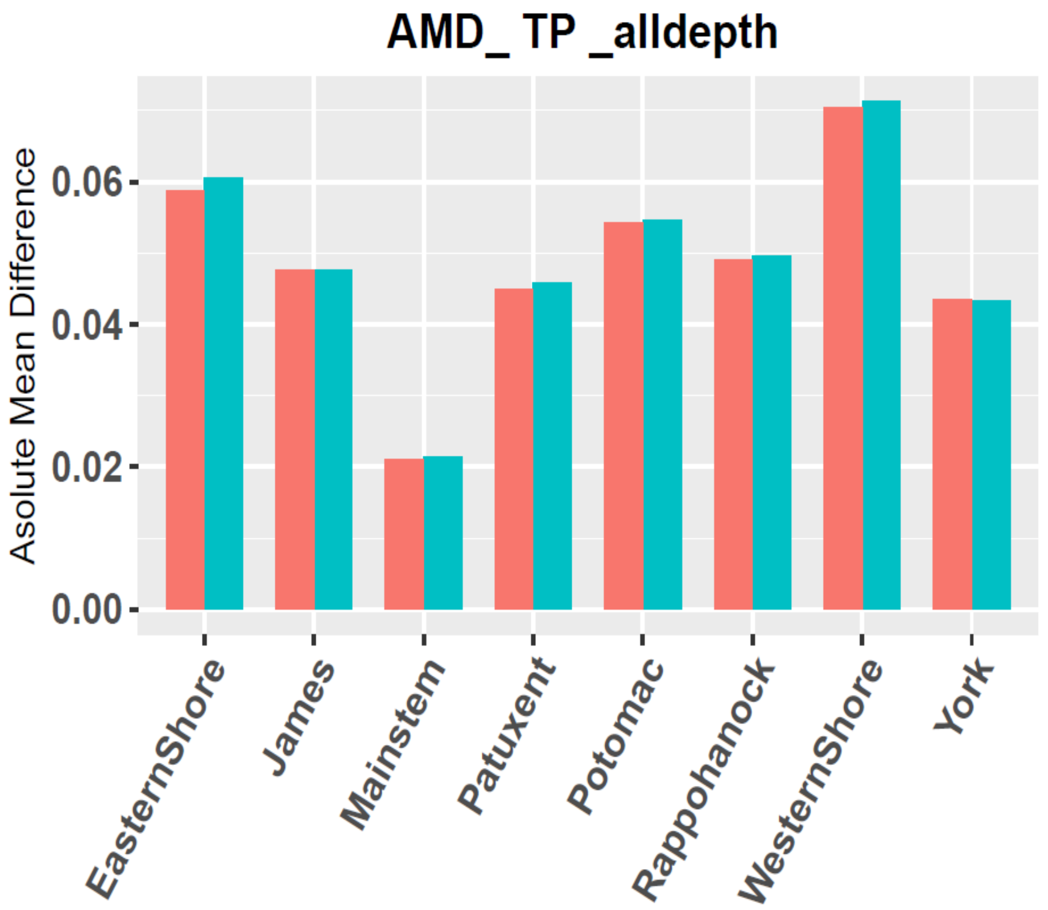
Unit: mg/l)

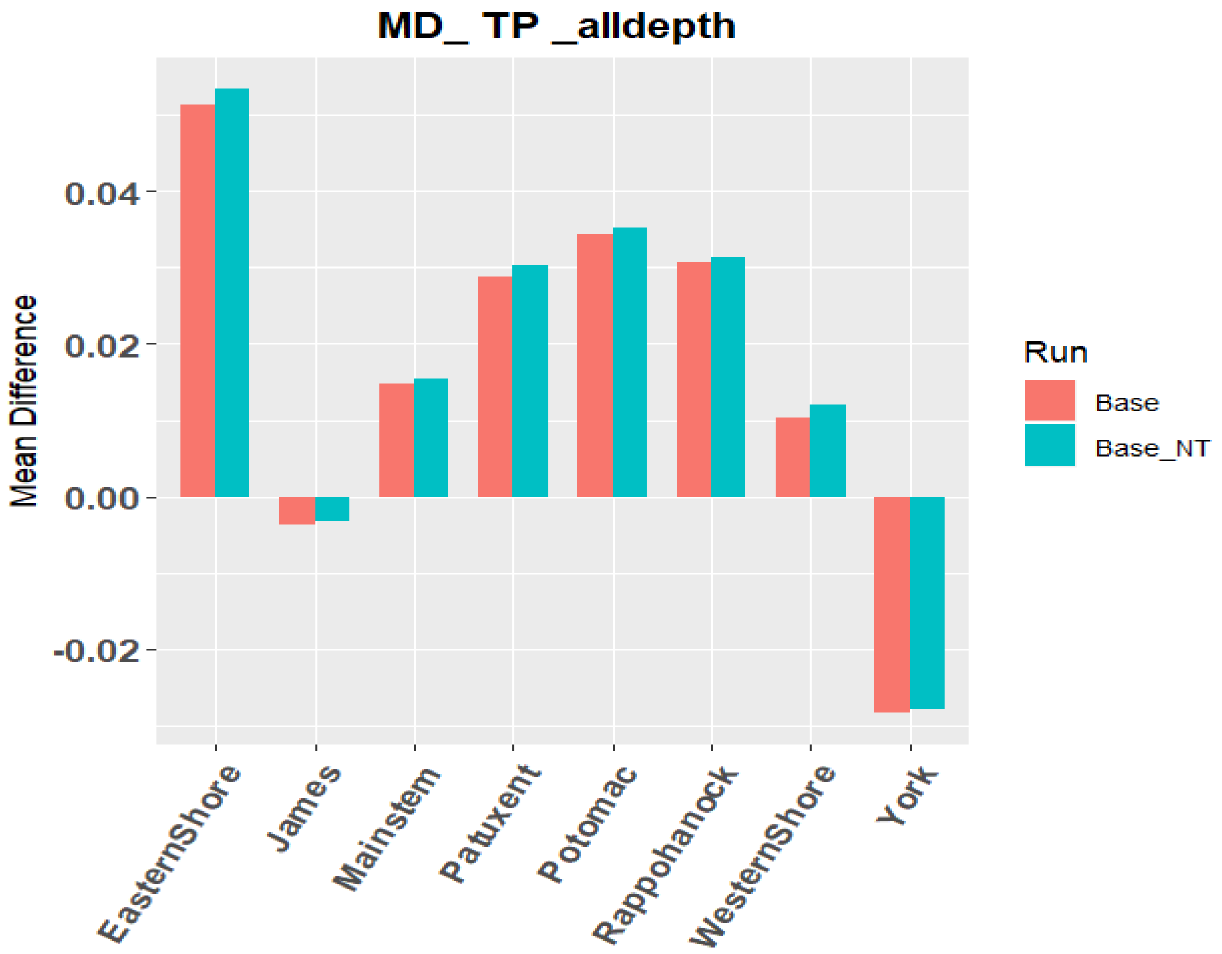




TN absolute mean difference (AMD) and mean difference (MD)

Unit: mg/l)





Conclusion

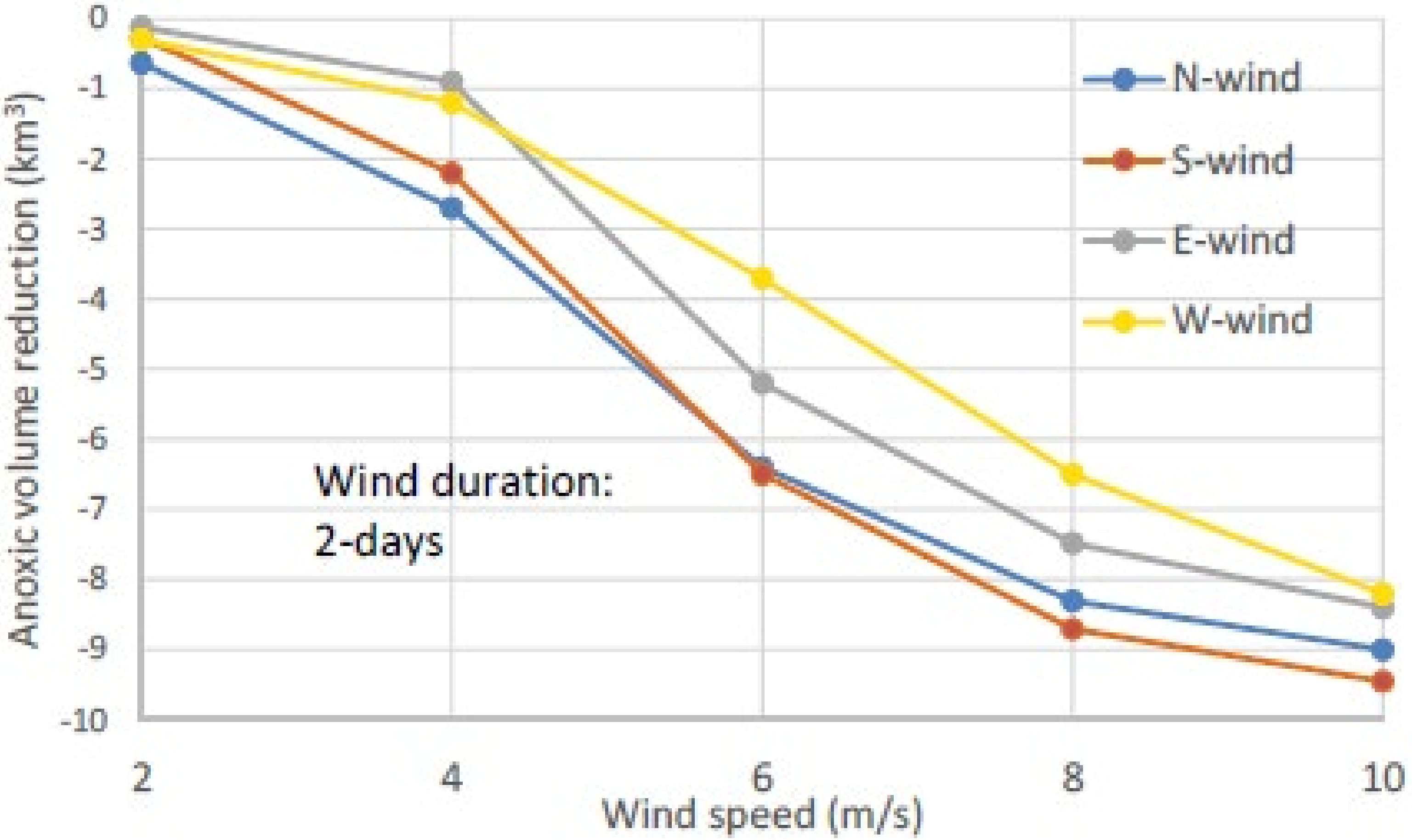
The optimal temperature is adjusted from 25 to 37 °C for the green algae group and from 29 to 37 ° C for the cyanobacteria group, covering the potential temperature increase range under climate change conditions, meanwhile the Q10 is kept at an appropriate level. The revised parameter values appear thus suitable for water quality assessment under climate change conditions.

Discussion and decision

Wind effect

(Chapter 5.1.2)

Effect of wind speed on hypoxia volume in Chesapeake Bay



- **Wind of 2 m/s does not have significant impact on hypoxia, >4 m/s have.**

Wang et al., 2016

List of CMIP5 GCMs used in MACA wind speed projection (20 GCMs)

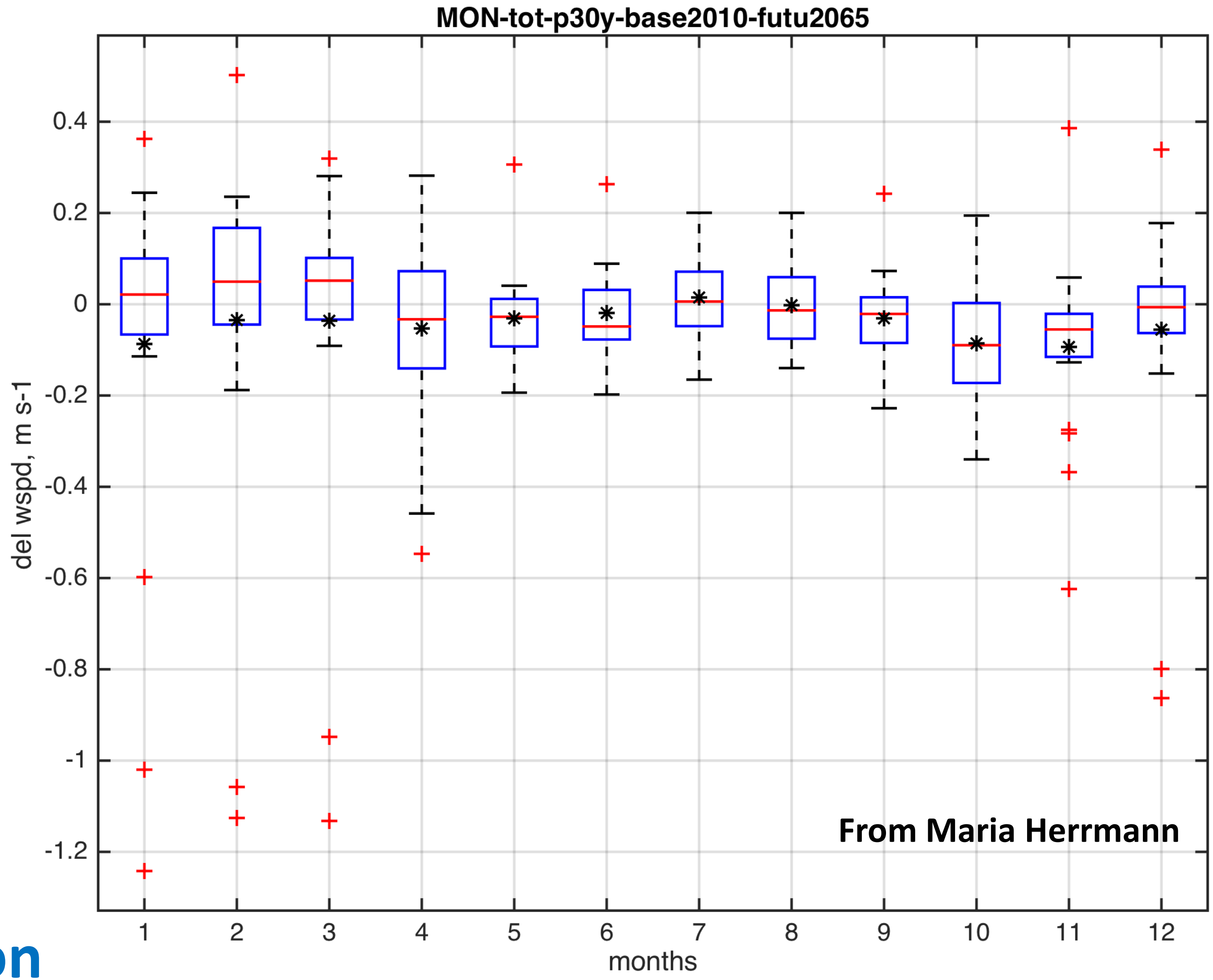
Model Name	Model Country	Model Agency	Atmosphere Resolution(Lon x Lat)	Ensemble Used
bcc-csm1-1	China	Beijing Climate Center, China Meteorological Administration	2.8 deg x 2.8 deg	r1i1p1
bcc-csm1-1-m	China	Beijing Climate Center, China Meteorological Administration	1.12 deg x 1.12 deg	r1i1p1
BNU-ESM	China	College of Global Change and Earth System Science, Beijing Normal University, China	2.8 deg x 2.8 deg	r1i1p1
CanESM2	Canada	Canadian Centre for Climate Modeling and Analysis	2.8 deg x 2.8 deg	r1i1p1
CCSM4	USA	National Center of Atmospheric Research, USA	1.25 deg x 0.94 deg	r6i1p1
CNRM-CM5	France	National Centre of Meteorological Research, France	1.4 deg x 1.4 deg	r1i1p1
CSIRO-Mk3-6-0	Australia	Commonwealth Scientific and Industrial Research Organization/Queensland Climate Change Centre of Excellence, Australia	1.8 deg x 1.8 deg	r1i1p1
GFDL-ESM2M	USA	NOAA Geophysical Fluid Dynamics Laboratory, USA	2.5 deg x 2.0 deg	r1i1p1
GFDL-ESM2G	USA	NOAA Geophysical Fluid Dynamics Laboratory, USA	2.5 deg x 2.0 deg	r1i1p1
HadGEM2-ES	United Kingdom	Met Office Hadley Center, UK	1.88 deg x 1.25 deg	r1i1p1
HadGEM2-CC	United Kingdom	Met Office Hadley Center, UK	1.88 deg x 1.25 deg	r1i1p1
inmcm4	Russia	Institute for Numerical Mathematics, Russia	2.0 deg x 1.5 deg	r1i1p1
IPSL-CM5A-LR	France	Institut Pierre Simon Laplace, France	3.75 deg x 1.8 deg	r1i1p1
IPSL-CM5A-MR	France	Institut Pierre Simon Laplace, France	2.5 deg x 1.25 deg	r1i1p1
IPSL-CM5B-LR	France	Institut Pierre Simon Laplace, France	2.75 deg x 1.8 deg	r1i1p1
MIROC5	Japan	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies,and Japan Agency for Marine-Earth Science and Technology	1.4 deg x 1.4 deg	r1i1p1
MIROC-ESM	Japan	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies	2.8 deg x 2.8 deg	r1i1p1
MIROC-ESM-CHEM	Japan	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies	2.8 deg x 2.8 deg	r1i1p1
MRI-CGCM3	Japan	Meteorological Research Institute, Japan	1.1 deg x 1.1 deg	r1i1p1
NorESM1-M	Norway	Norwegian Climate Center, Norway	2.5 deg x 1.9 deg	r1i1p1

From Maria Herrmann

Wind change by 2050

Only a few centimeters per second

Minor issue, not pursued at this point

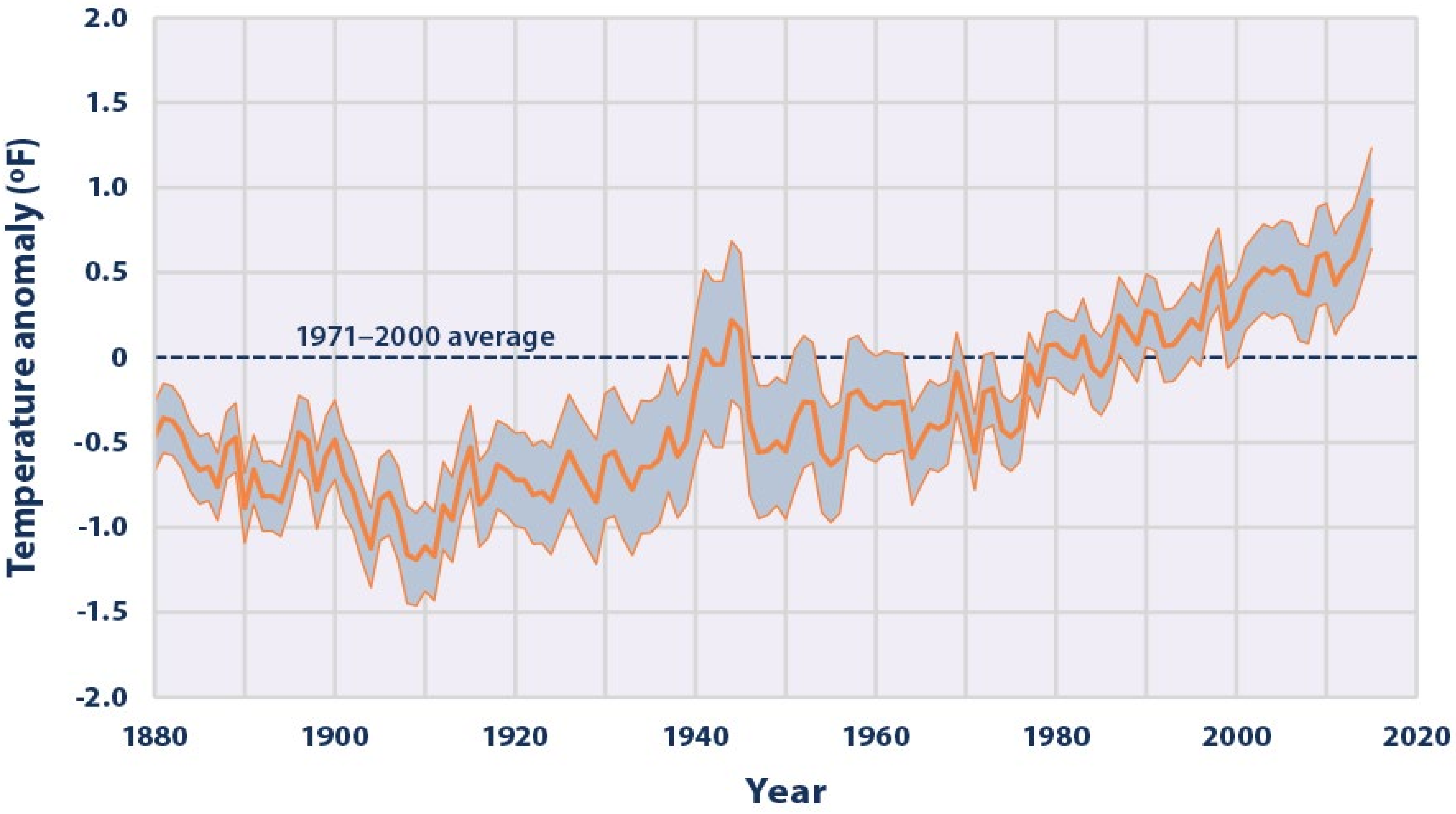


Discussion and decision

Ocean open boundary conditions for temperature and salinity

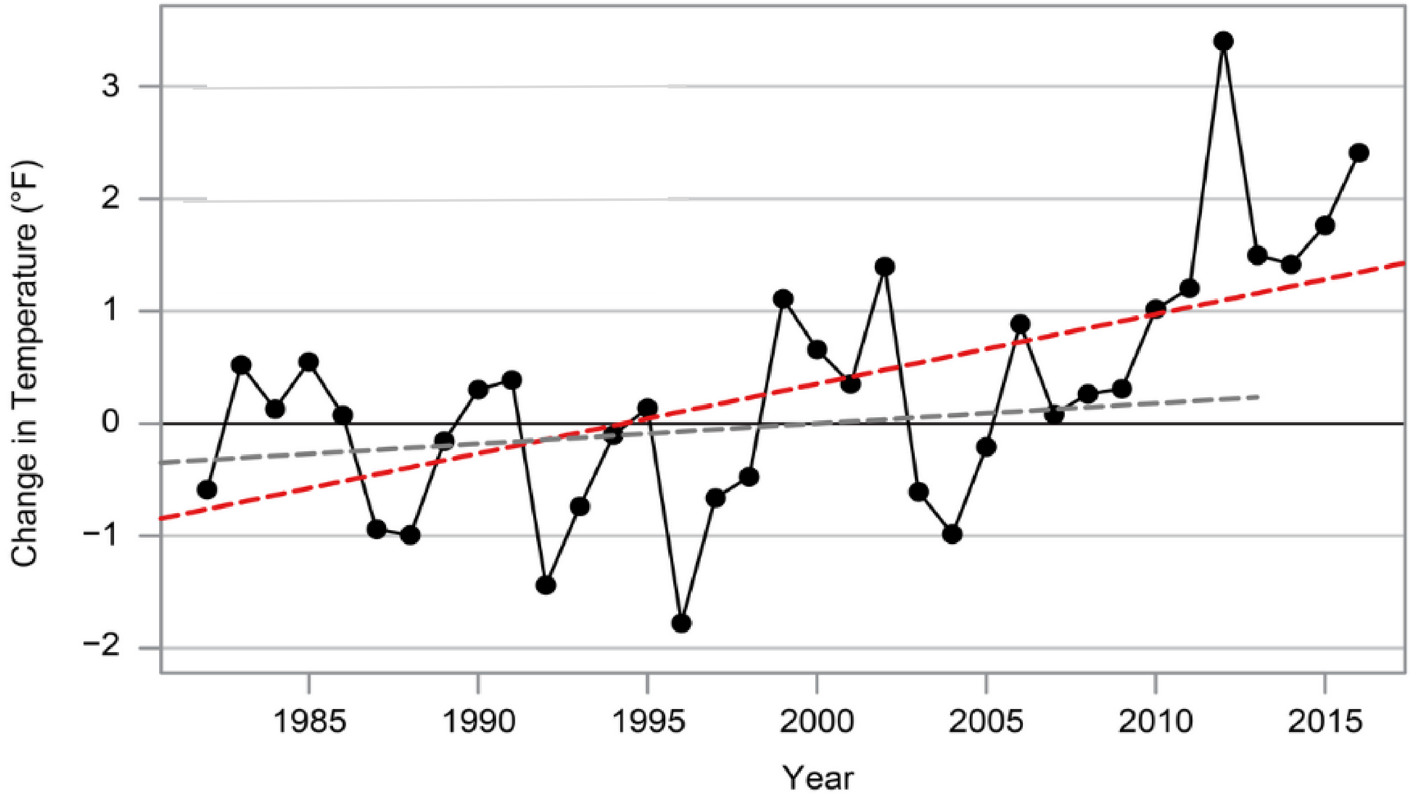
(Chapter 5.1.4)

Global sea surface temperature warming



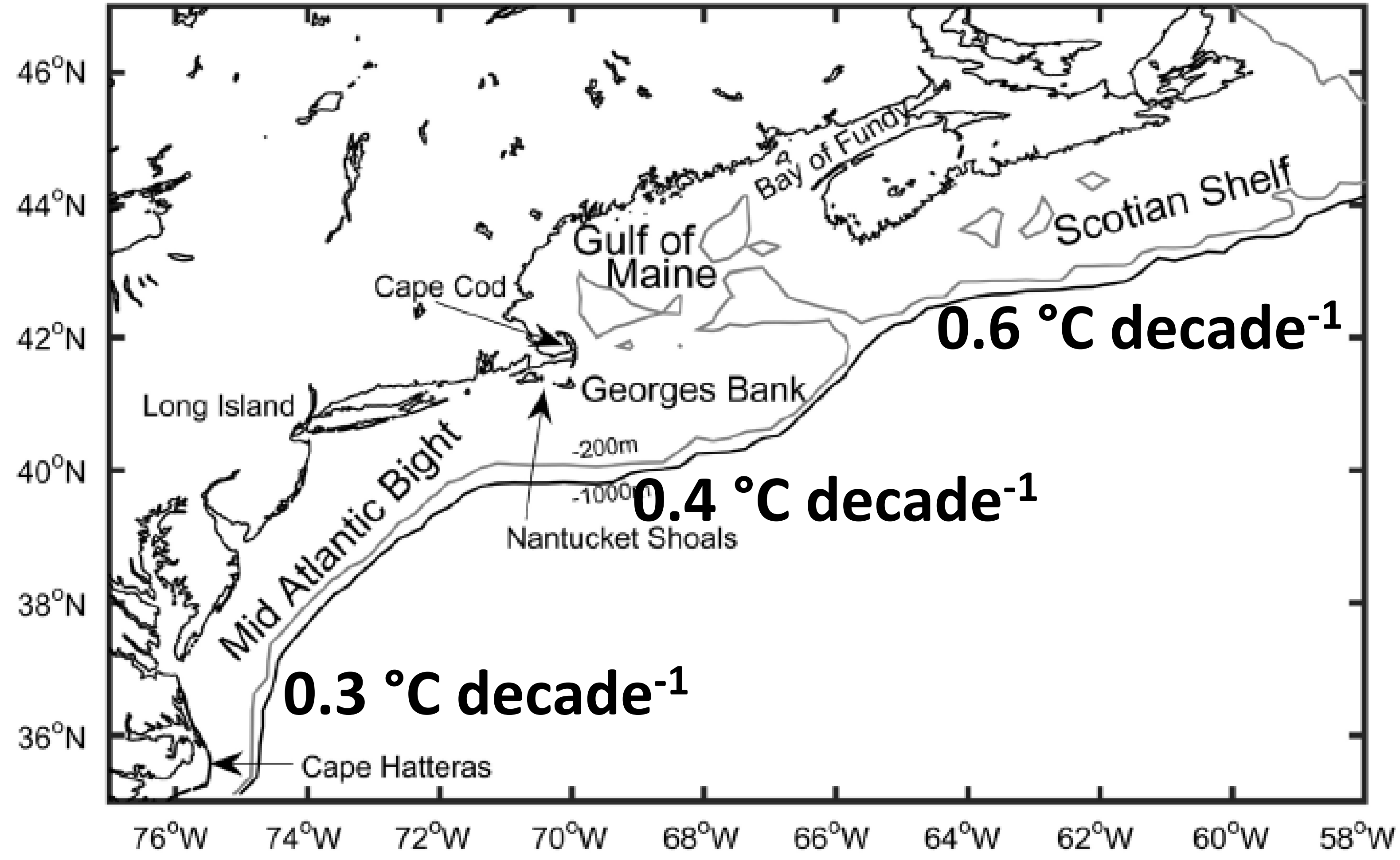
SST increased 0.072 °C per decade from 1990 to 2015 (EPA, 2016).

SST trend on the northeast continental shelf of USA (Maine – Maryland)



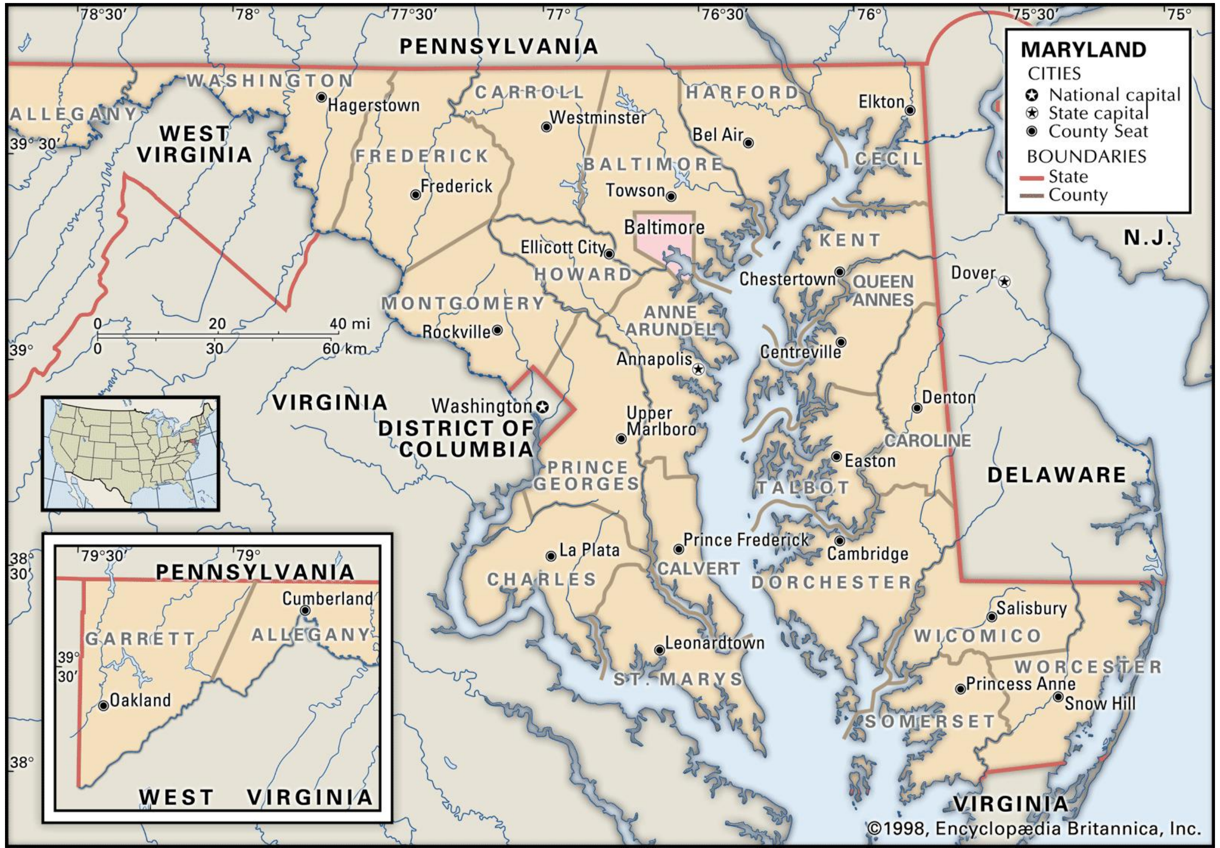
SST increased 0.33 °C per decade from 1982 to 2016 (NOAA, Dupigny-Giroux et al., 2018).

SST increase region by region



Data from 1982-2014; Thomas et al., 2017

Atmospheric forcing data from the Naval Air Station located at the Patuxent River mouth between Calvert and St. Mary’s counties



Atmospheric forcing data for climate change are from downscaling analysis of 31 GCMs to counties level

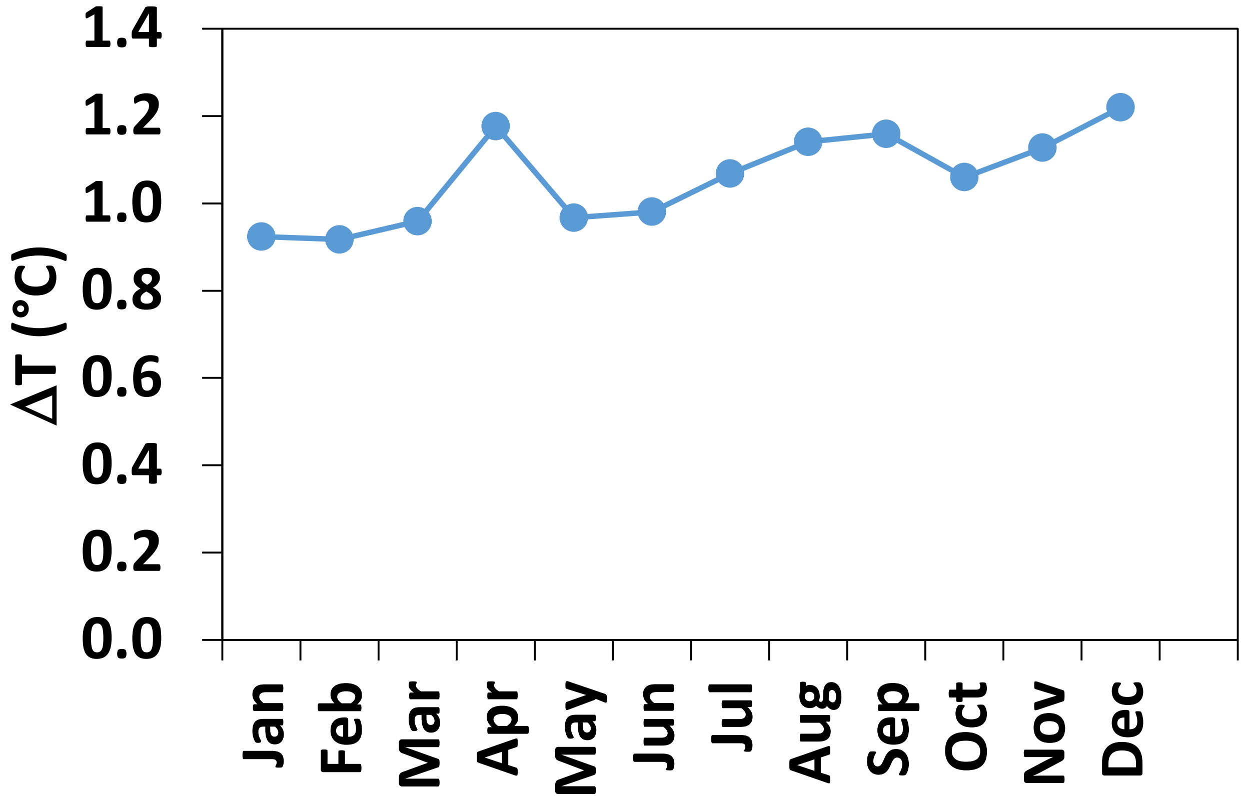
Model Name	Model Country	Model Agency	Atmosphere Resolution(Lon x Lat)	Ensemble Used
bcc-csm1-1	China	Beijing Climate Center, China Meteorological Administration	2.8 deg x 2.8 deg	r1i1p1
bcc-csm1-1-m	China	Beijing Climate Center, China Meteorological Administration	1.12 deg x 1.12 deg	r1i1p1
BNU-ESM	China	College of Global Change and Earth System Science, Beijing Normal University, China	2.8 deg x 2.8 deg	r1i1p1
CanESM2	Canada	Canadian Centre for Climate Modeling and Analysis	2.8 deg x 2.8 deg	r1i1p1
CCSM4	USA	National Center of Atmospheric Research, USA	1.25 deg x 0.94 deg	r6i1p1
CNRM-CM5	France	National Centre of Meteorological Research, France	1.4 deg x 1.4 deg	r1i1p1
CSIRO-Mk3-6-0	Australia	Commonwealth Scientific and Industrial Research Organization/Queensland Climate Change Centre of Excellence, Australia	1.8 deg x 1.8 deg	r1i1p1
GFDL-ESM2M	USA	NOAA Geophysical Fluid Dynamics Laboratory, USA	2.5 deg x 2.0 deg	r1i1p1
GFDL-ESM2G	USA	NOAA Geophysical Fluid Dynamics Laboratory, USA	2.5 deg x 2.0 deg	r1i1p1
HadGEM2-ES	United Kingdom	Met Office Hadley Center, UK	1.88 deg x 1.25 deg	r1i1p1
HadGEM2-CC	United Kingdom	Met Office Hadley Center, UK	1.88 deg x 1.25 deg	r1i1p1
inmcm4	Russia	Institute for Numerical Mathematics, Russia	2.0 deg x 1.5 deg	r1i1p1
IPSL-CM5A-LR	France	Institut Pierre Simon Laplace, France	3.75 deg x 1.8 deg	r1i1p1
IPSL-CM5A-MR	France	Institut Pierre Simon Laplace, France	2.5 deg x 1.25 deg	r1i1p1
IPSL-CM5B-LR	France	Institut Pierre Simon Laplace, France	2.75 deg x 1.8 deg	r1i1p1
MIROC5	Japan	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies,and Japan Agency for Marine-Earth Science and Technology	1.4 deg x 1.4 deg	r1i1p1
MIROC-ESM	Japan	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies	2.8 deg x 2.8 deg	r1i1p1
MIROC-ESM-CHEM	Japan	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies	2.8 deg x 2.8 deg	r1i1p1
MRI-CGCM3	Japan	Meteorological Research Institute, Japan	1.1 deg x 1.1 deg	r1i1p1
NorESM1-M	Norway	Norwegian Climate Center, Norway	2.5 deg x 1.9 deg	r1i1p1

Monthly air temperature change by 2025, averaged between Clavert and St. Mary's counties

Annual average: 1.058 °C

For 2025 boundary:
0.9x1.058=0.95 °C
Which is the average between the NOAA and Thomas et al.'s findings.

The factor 0.9 will be applied to other periods 2035, 2045 and 2055, with acceleration included in the GCMs.



From Gopal Bhatt

Water temperature change in the water column at the open boundary

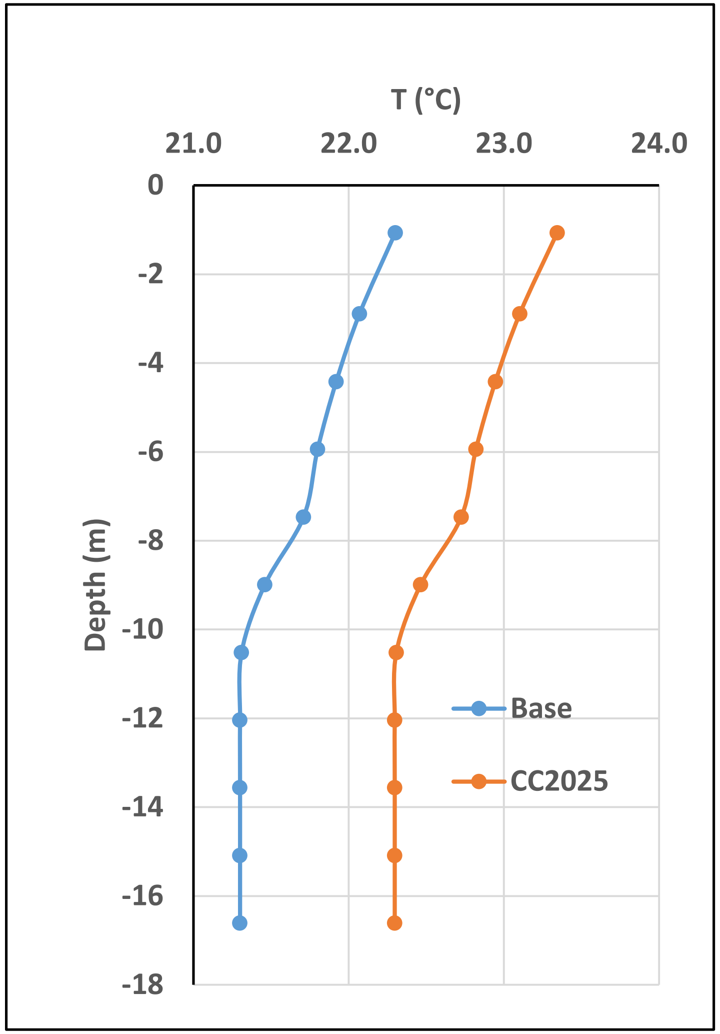
$$\Delta T_{water}=0.9\bullet\Delta T_{air} \bullet T_{water}/T_{surface}$$

where

T_{water} = water temperature.

$T_{surface}$ = surface water temperature.

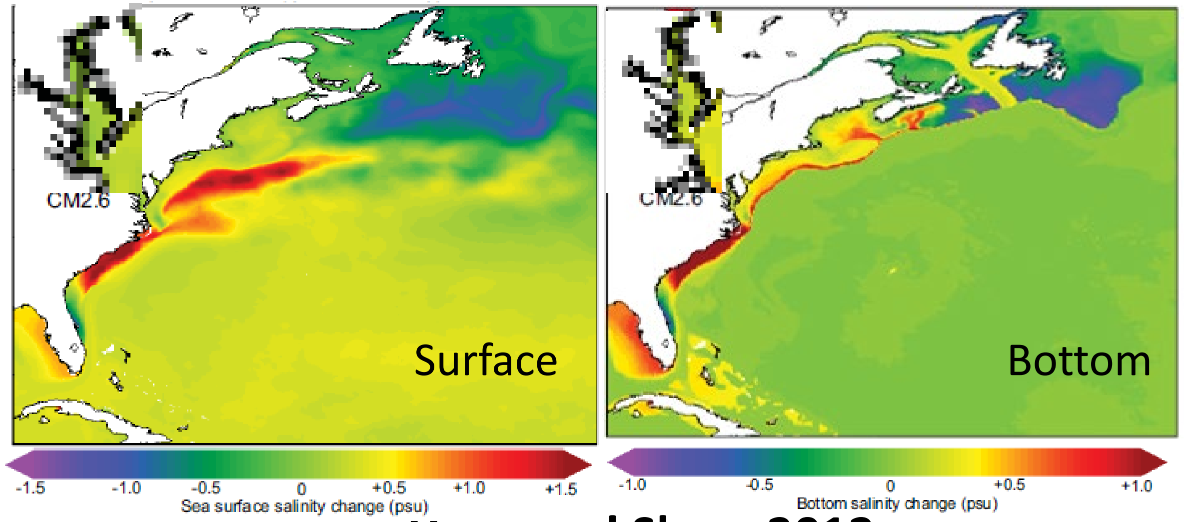
ΔT_{air} = air temperature change under climate change condition from downscaling GCMs ensemble projection.



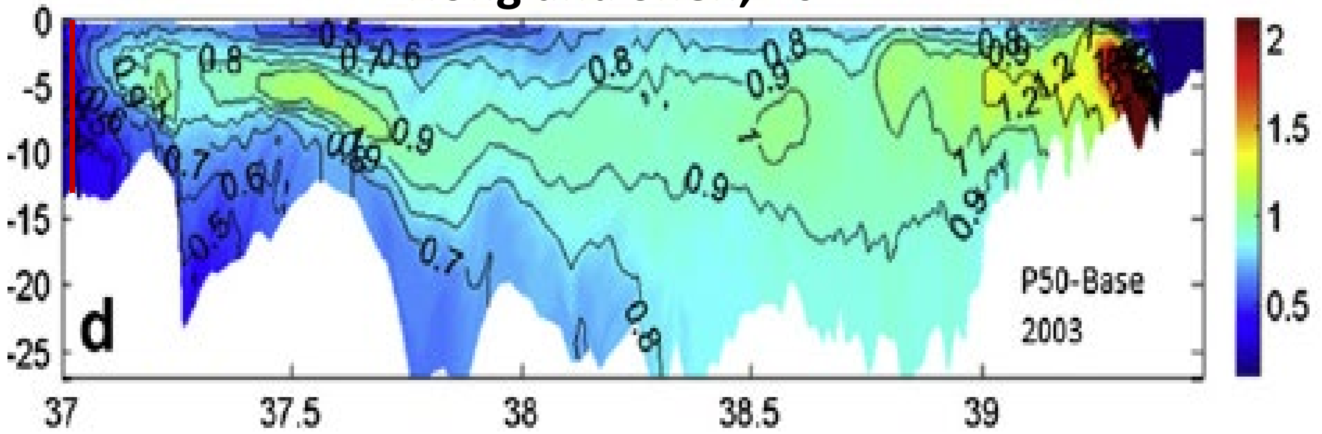
Discussion and decision

Salinity change at the open boundary

Saba et al. (2016): Salinity increase under future climate change condition due to the retreat of the Labrador Current, northerly shifting of the Gulf Stream, the weakening Atlantic Meridional Overturning Circulation (AMOC) and an increase of Warm Slope Water entering the Northwest Atlantic Shelf.



Hong and Shen, 2012



$$\Delta S = 0.4\Delta\zeta/0.5$$

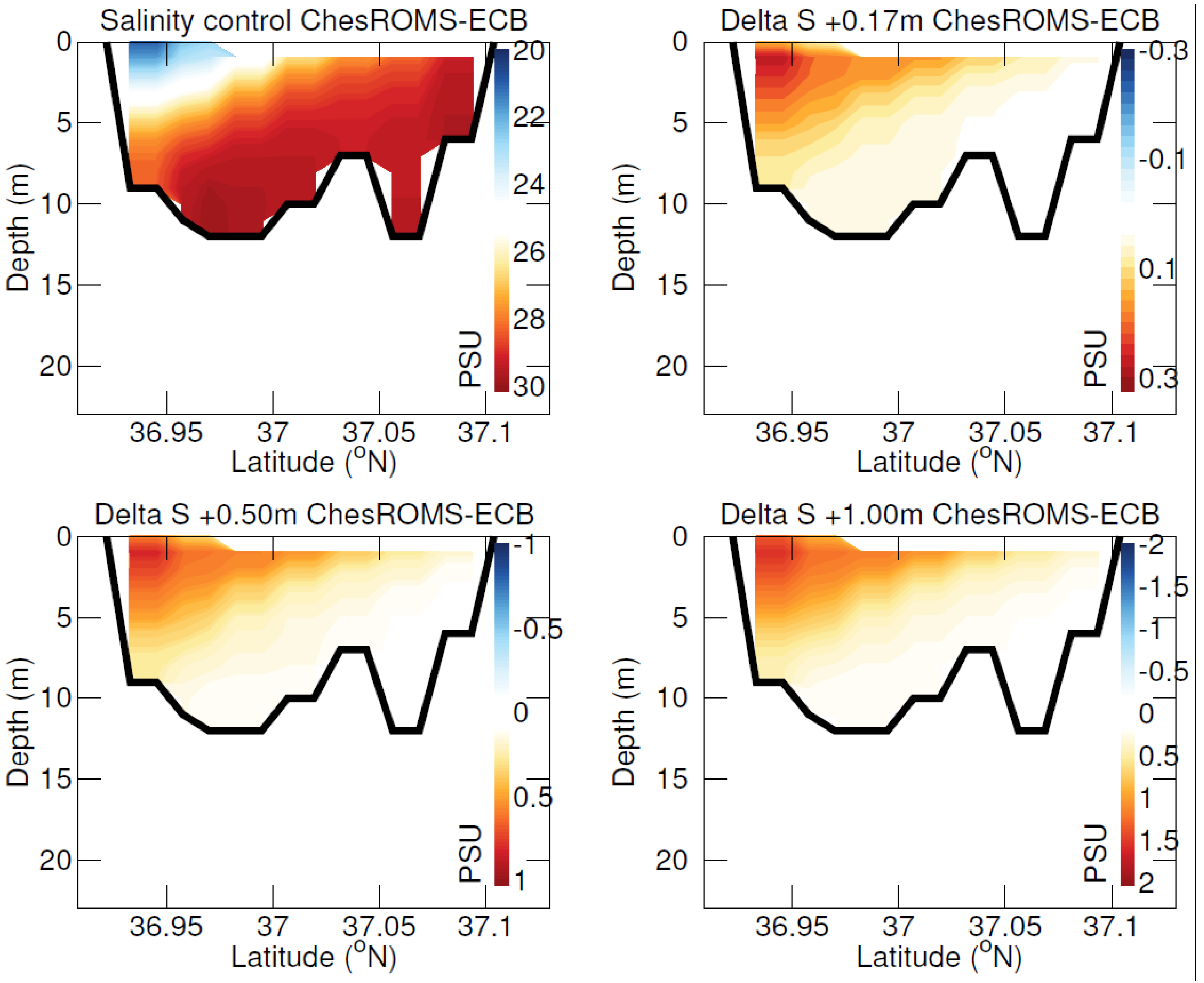
where

ΔS = salinity change at the open boundary,

$\Delta\zeta$ = sea surface level rise (m).

SLR (cm)	22	31	42	53
ΔS (psu)	0.18	0.25	0.34	0.42

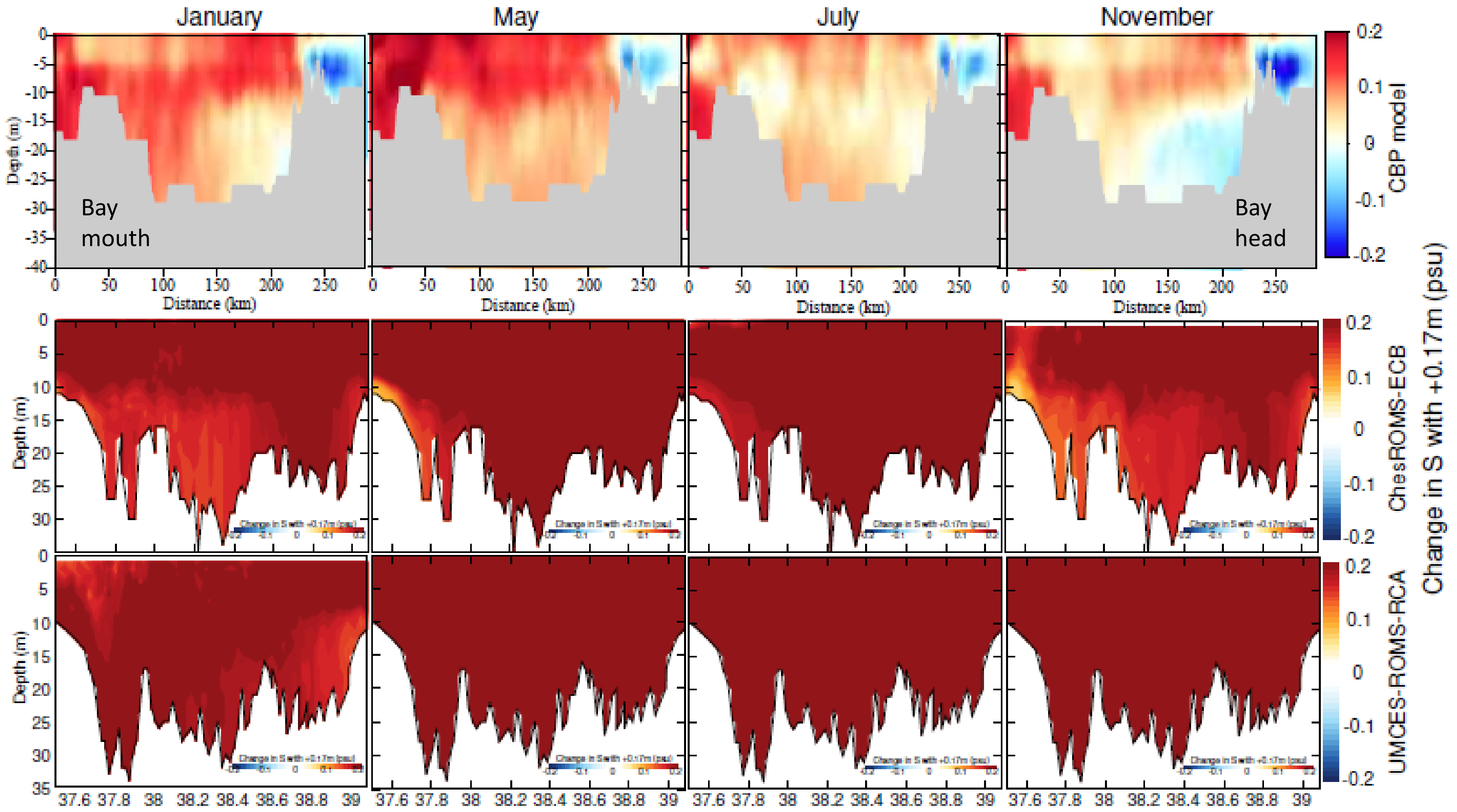
Salinity change at the entrance of the Bay predicted by the ROMS



Indicating no change at the deeper layers

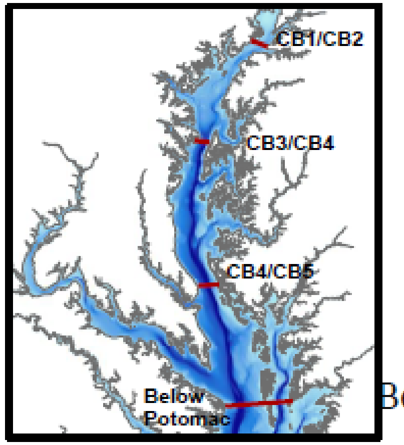
From Pierre St-Laurent

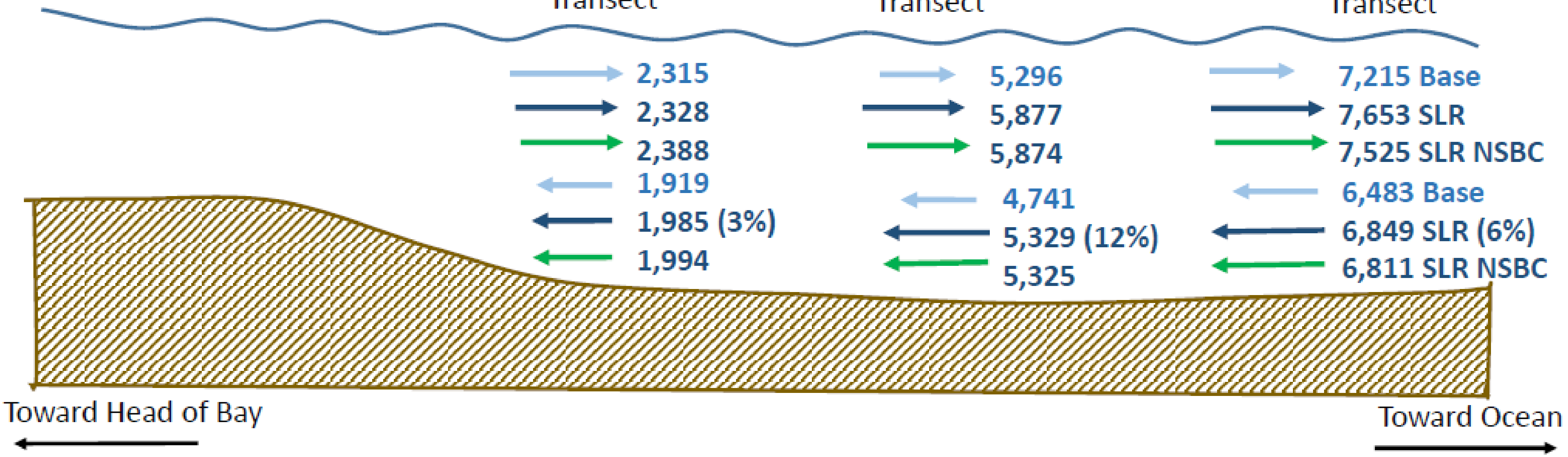
Compare with the ROMS



From Pierre St-Laurent

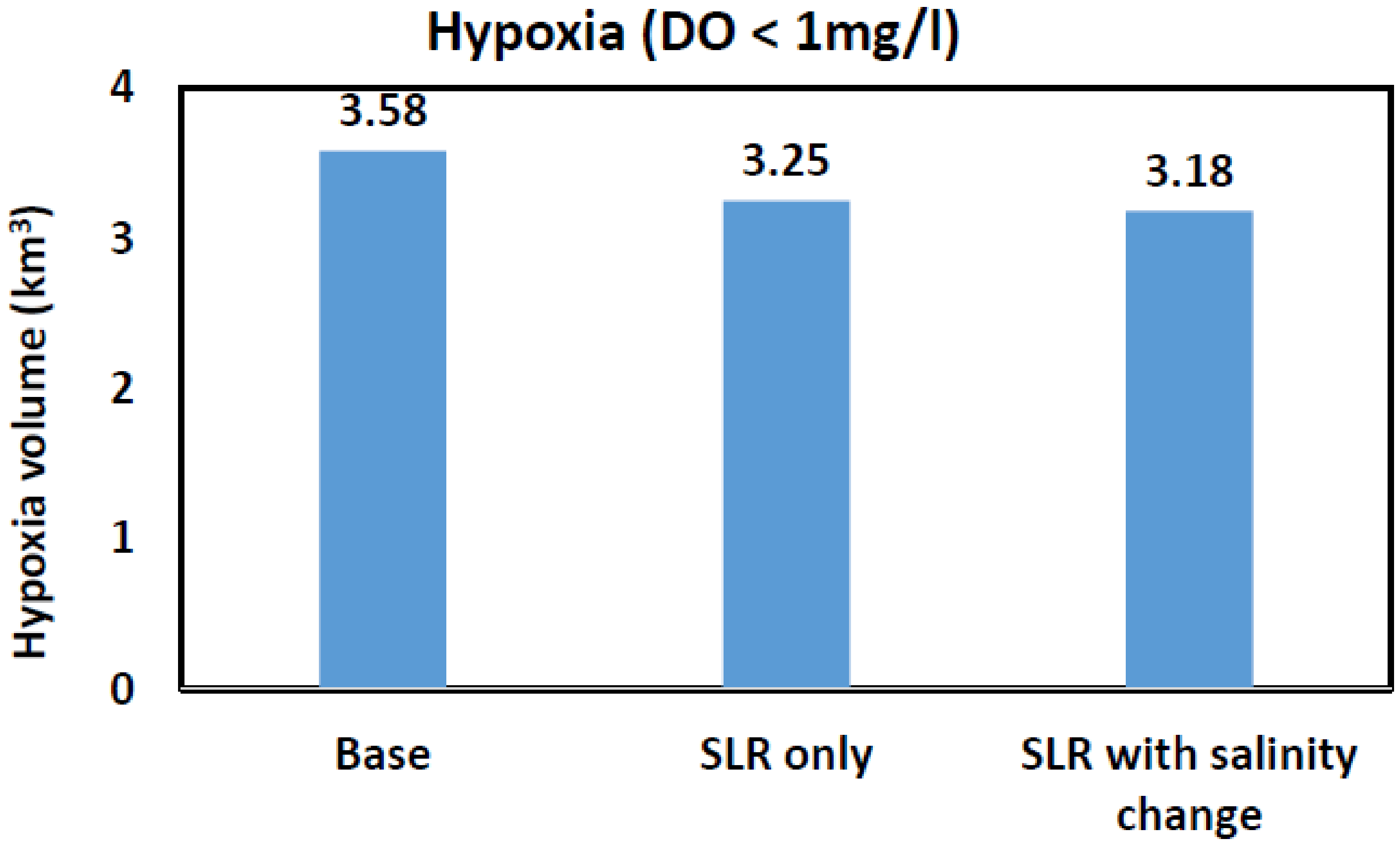
Cross-transect water fluxes (m^3/s) Base case versus sea level rise (SLR) of 0.5m. Summer 1993-1995





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.

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

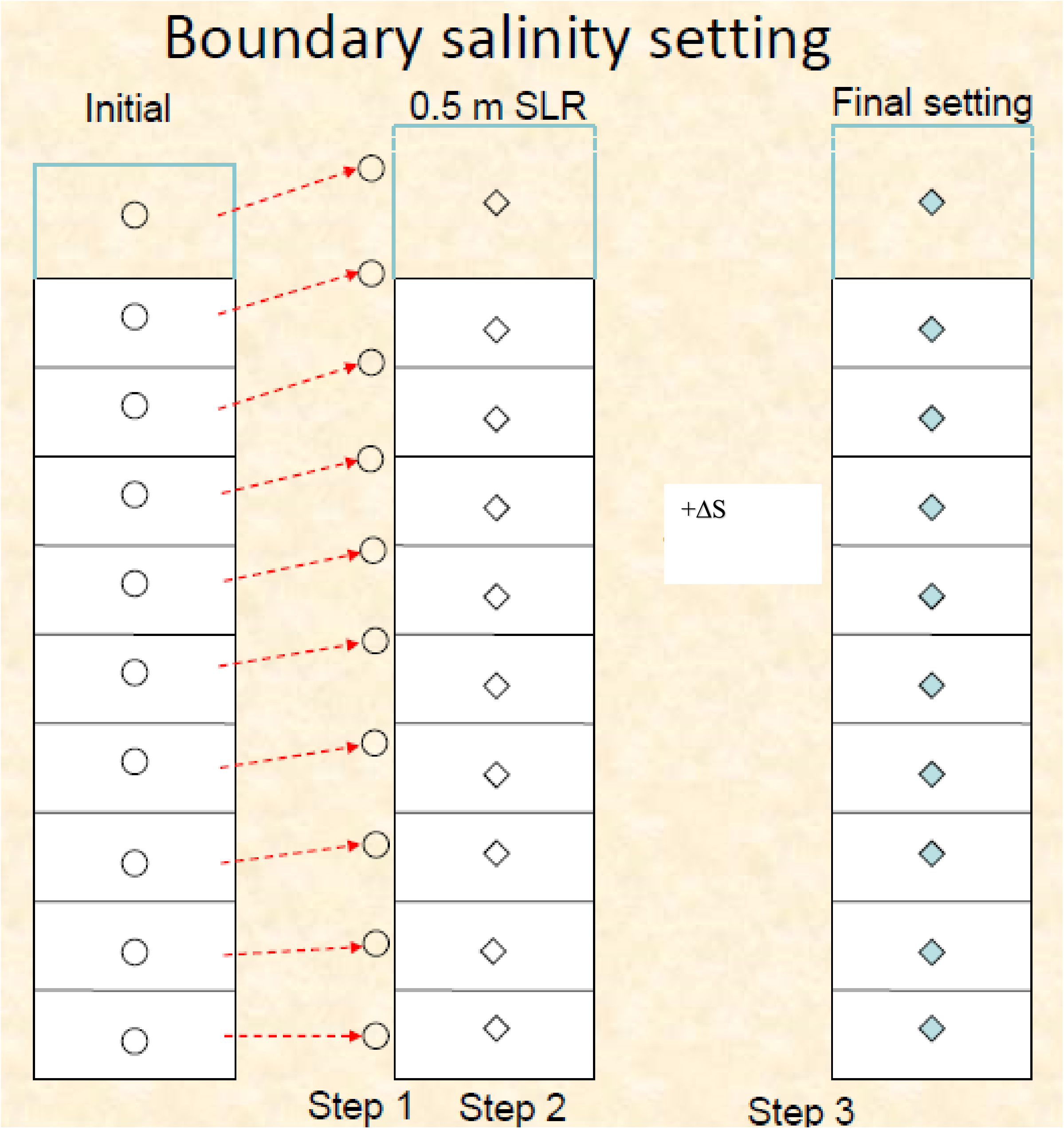


Decision on salinity adjustment at the ocean boundary:

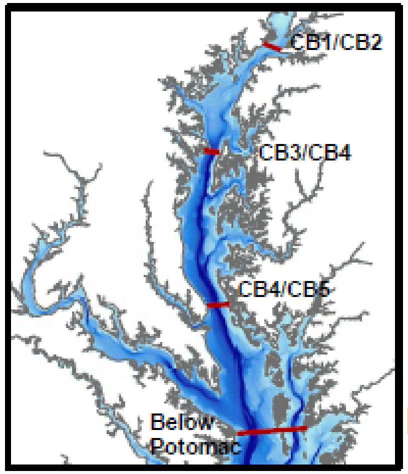
(1) Adjustment.
(2) Non adjustment.
(3) Non adjustment for SLR but adjustment for climate change.

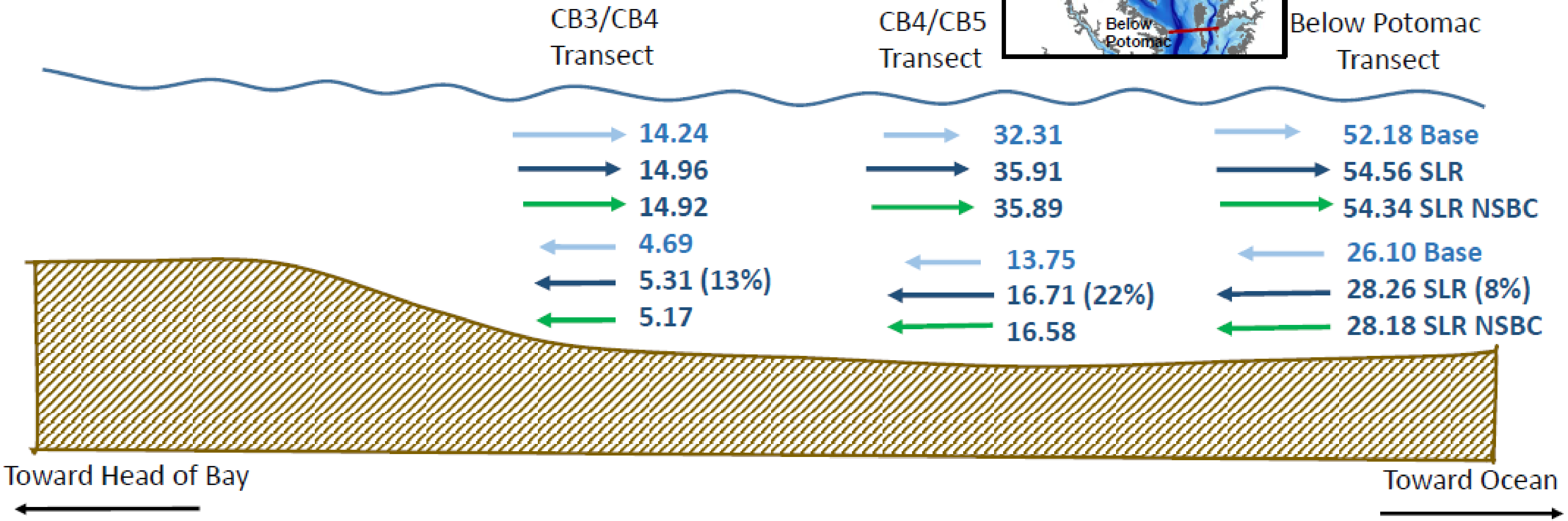
THE END

Interpolation of salinity to the new grid before adding the salinity change (ΔS) at the ocean open boundary.



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 Change.