Extent and Causes of Chesapeake Bay Warming

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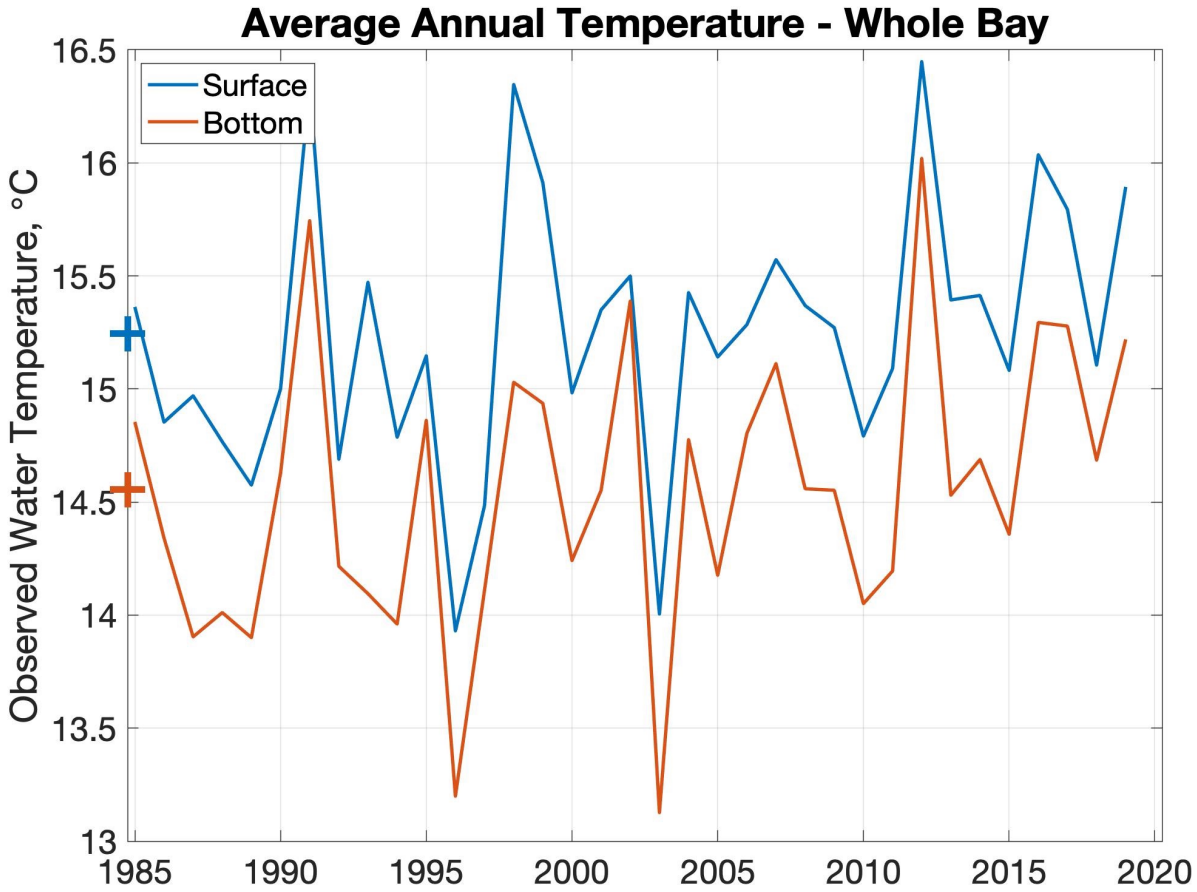
VIMS | William & Mary
Virginia Institute of Marine Science

Overview

- Preston (2004) – average water temperature increase of “~0.8-1.1°C” from 1949-2002
- Ding and Elmore (2015) found increase in surface water temperature of ~0.4-2°C from 1984-2010
- Tian et al. (2021) – change in water temperature of 0.85-0.9°C from 1995-2025

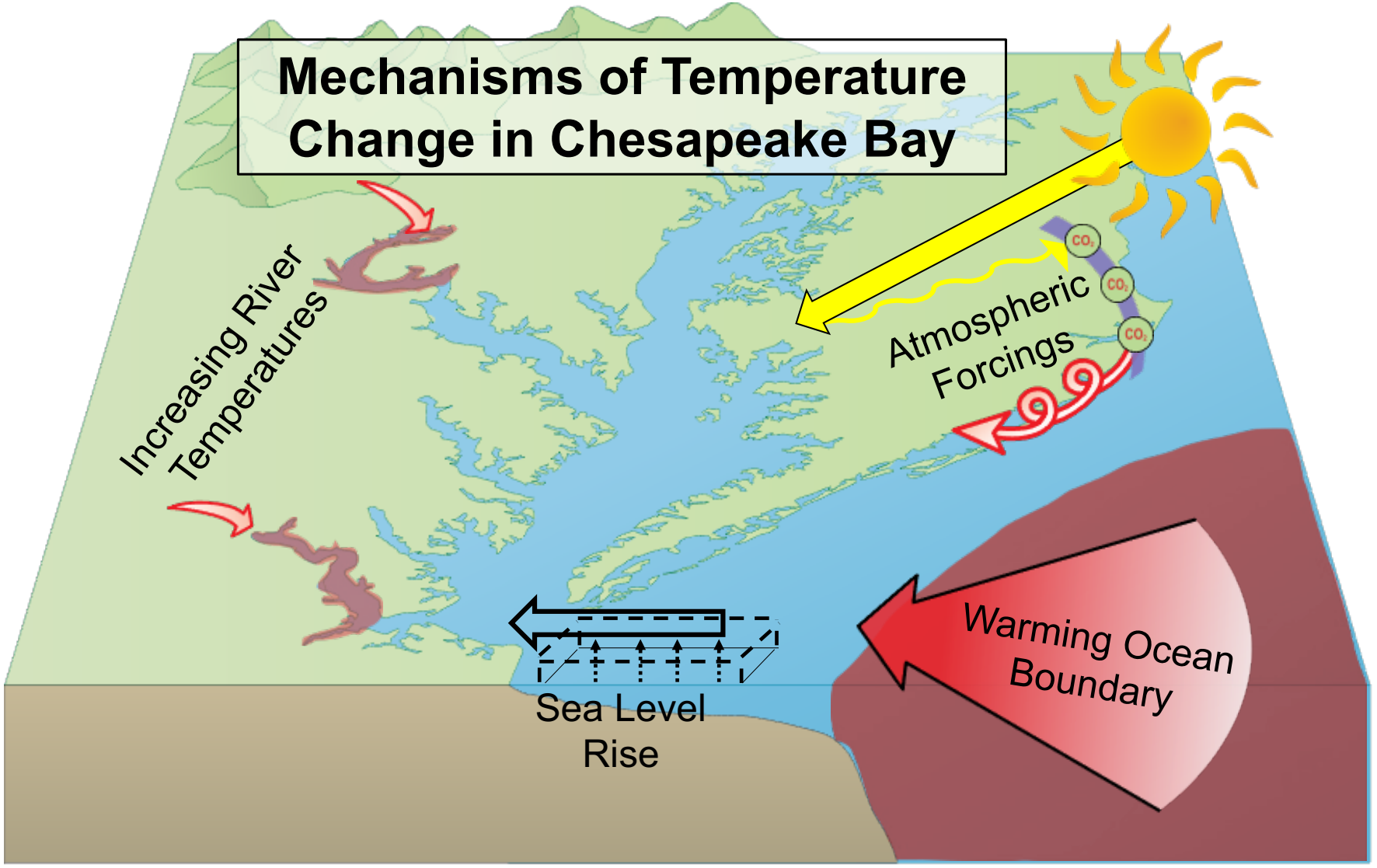


Research Objective

What are the relative magnitudes of mechanisms behind annual and seasonal Chesapeake Bay warming?

Photo Credit: VIMS

What is driving Chesapeake Bay warming?



ChesROMS-ECB Overview

Atmospheric Forcings

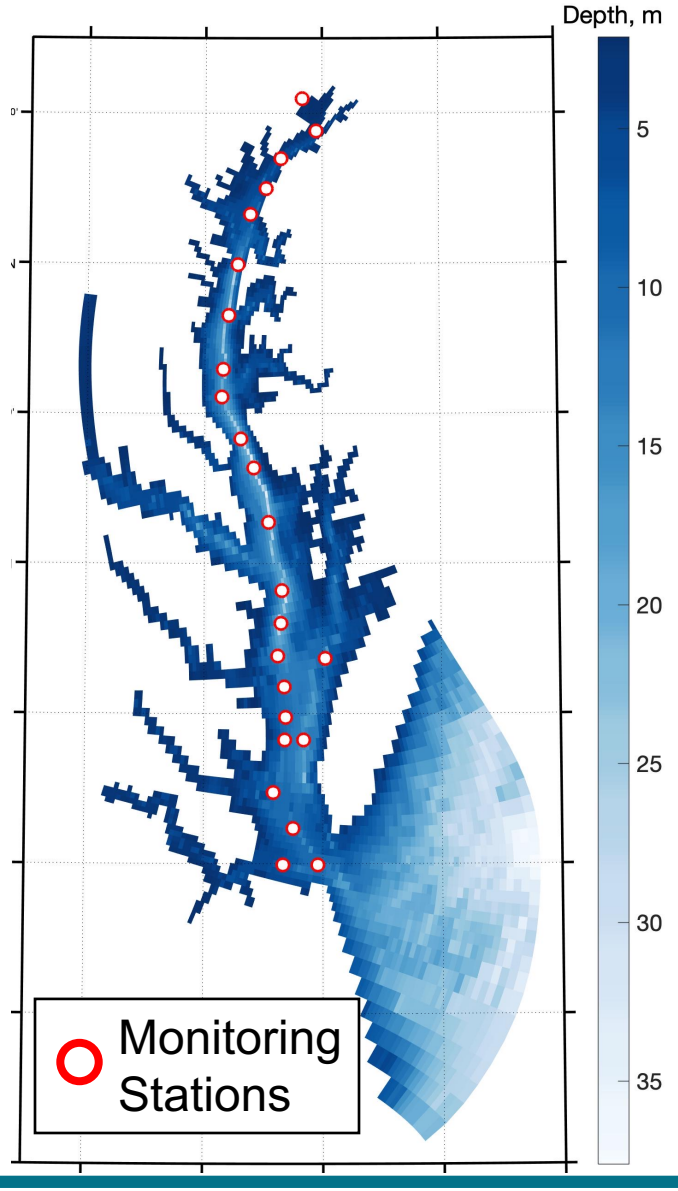
→ Hindcast weather data (ERA5 Reanalysis)

Coastal Fluxes

→ Climatological data

Riverine Inputs

→ Phase 6 Watershed Model



Model Information

3-D model, 20 depth levels
Daily outputs

Model Outputs

Bay Temperatures

Hydrodynamics and Biogeochemistry

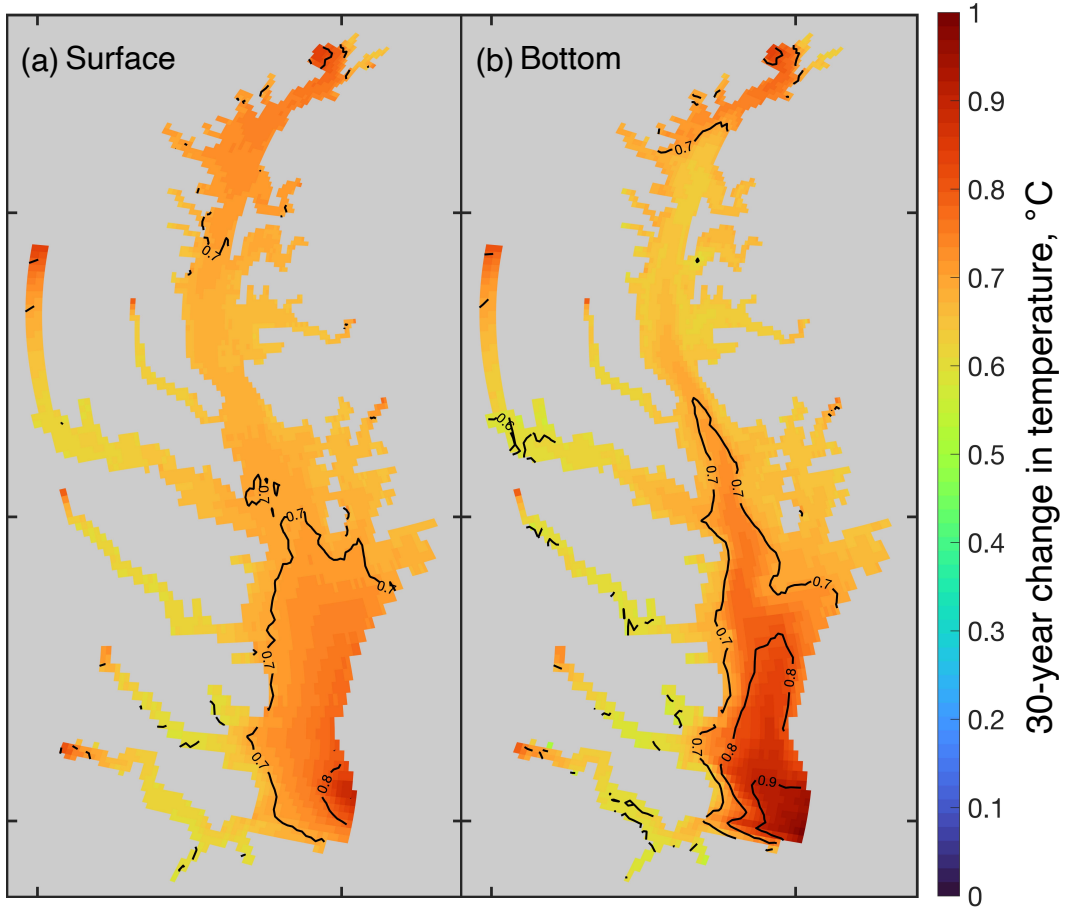
Methods: Assessing Warming Mechanisms

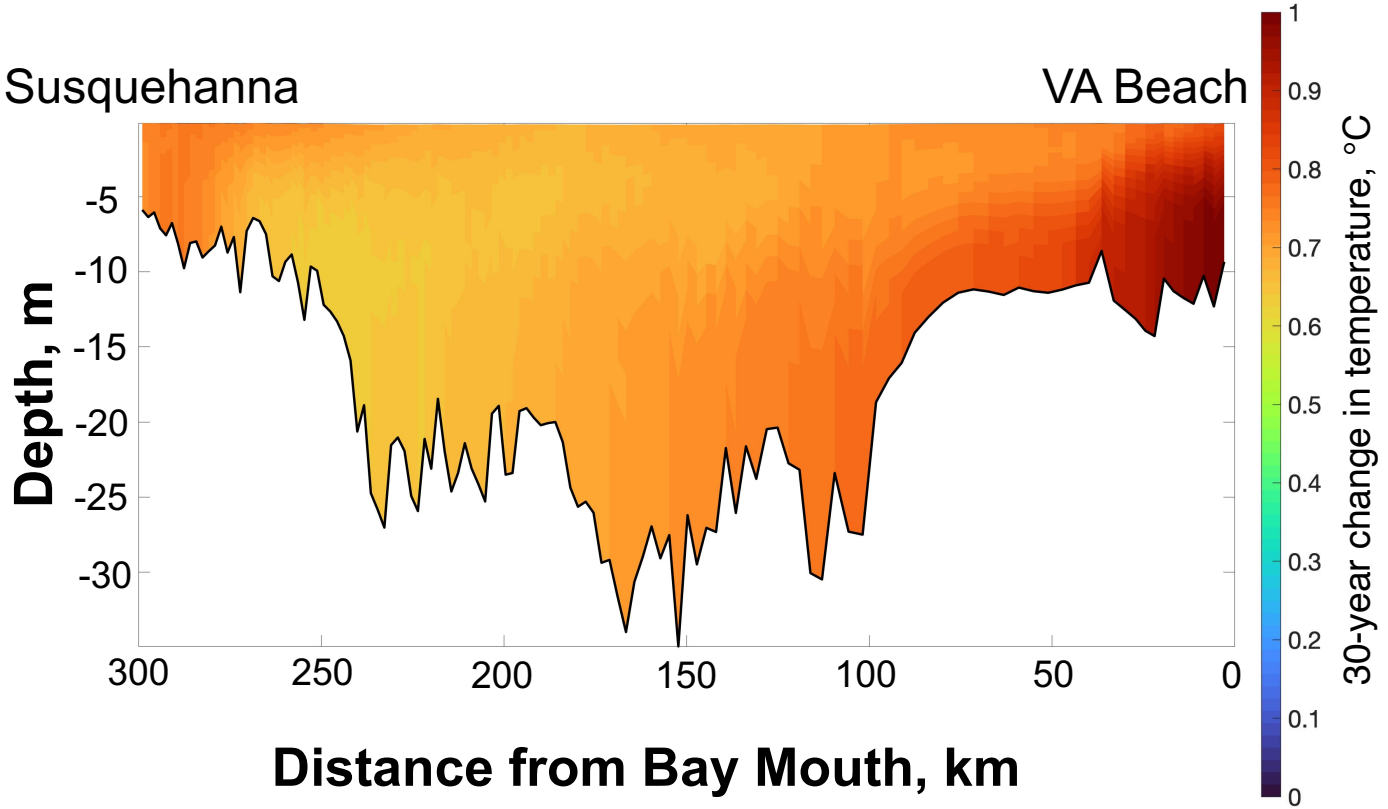
- Scenarios compared to a realistic 1985-1989 reference run, ***BASE***
- Delta approach (*2015-2019 minus 1985-1989 conditions*) applied
  → All other conditions held constant

Experiment	Ocean Temp[a]	Air Temp[b]	Longwave Radiation[b]	River T[c]	SLR[d]
Combined	BASE +2.19°C	BASE + 0.75°C	BASE + 6.84 W m^{-2}	BASE + 0.84°C	BASE + 0.15m
OceanTemp	BASE + 2.19° C	BASE	BASE	BASE	BASE
AtmTemp	BASE	BASE + 0.75°C	BASE + 6.84 W m^{-2}	BASE	BASE
RiverTemp	BASE	BASE	BASE	BASE + 0.84°C	BASE
SeaLevel	BASE	BASE	BASE	BASE	BASE + 0.15m

[a]Derived from in situ coastal data; **varies seasonally*
[b]Derived from ERA5 trend (1985-2019); **varies spatially and monthly*
[c]Derived from Rice and Jastram (2015)
[d]Derived from Duck, NC and Lewes, DE tide gauge

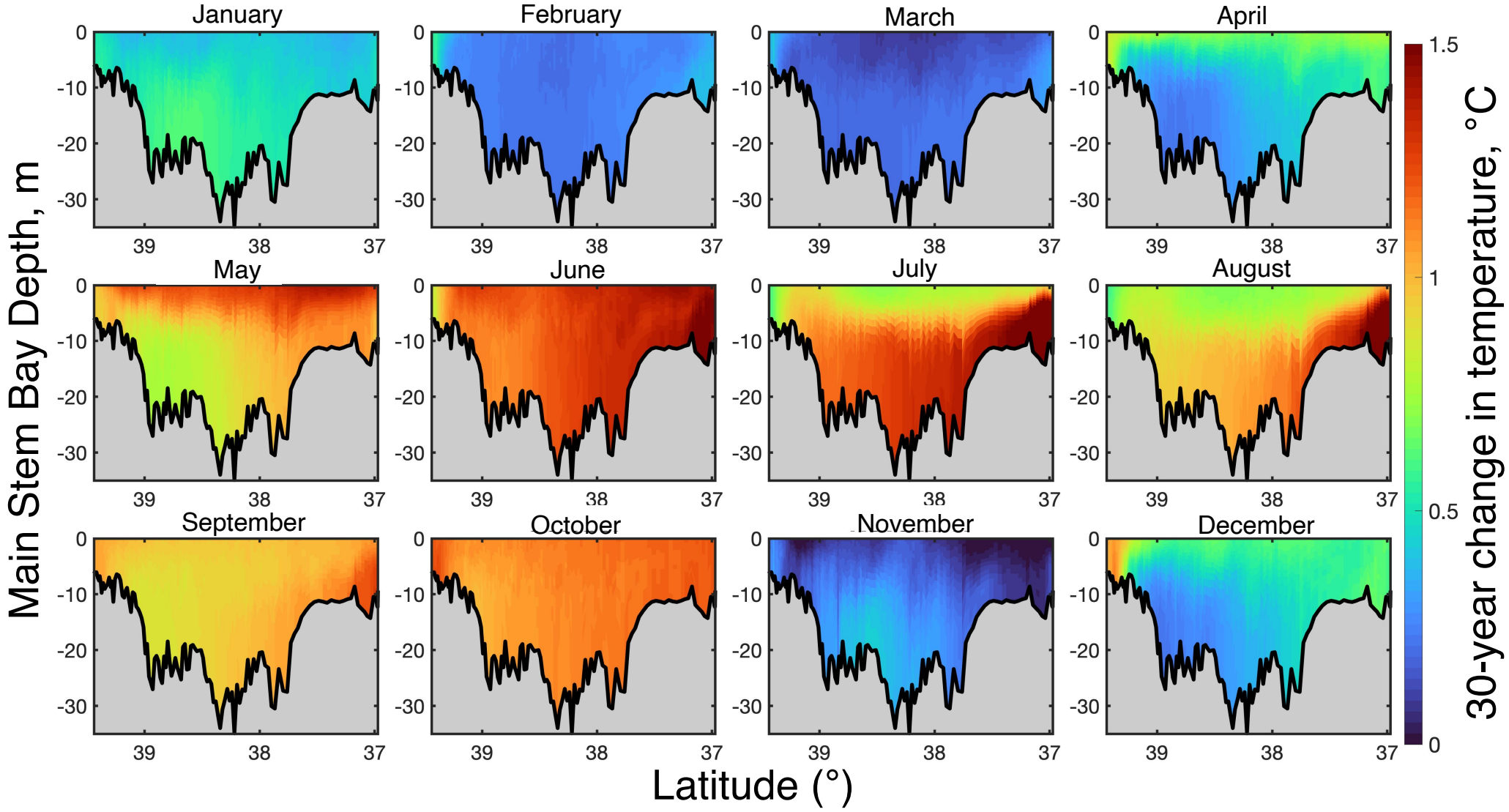
How have all factors warmed the Bay?





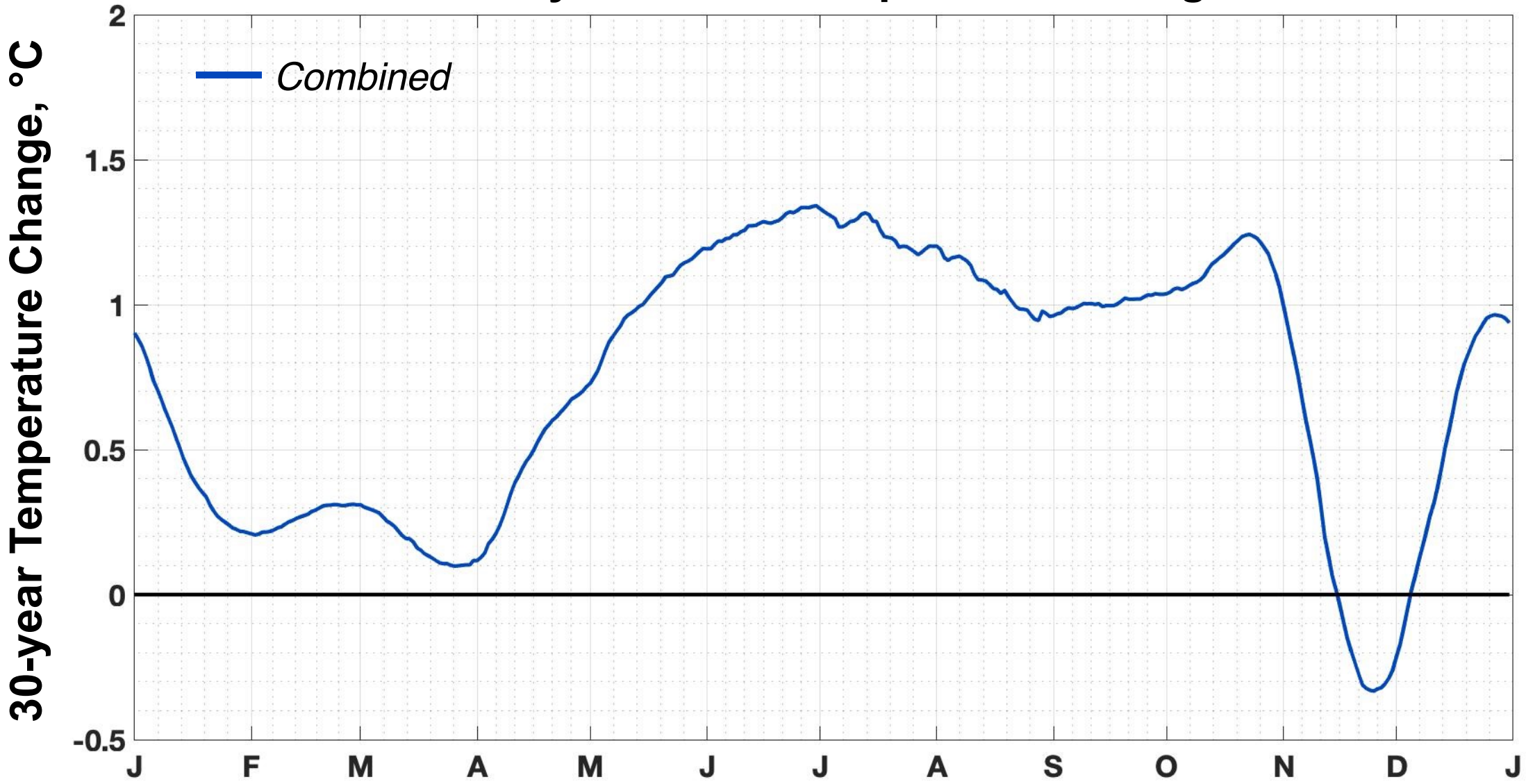
- Similar changes at surface and bottom, some regional differences
- Annual average Bay-wide warming of ~0.7°C throughout water column

How have Bay temperatures changed seasonally?



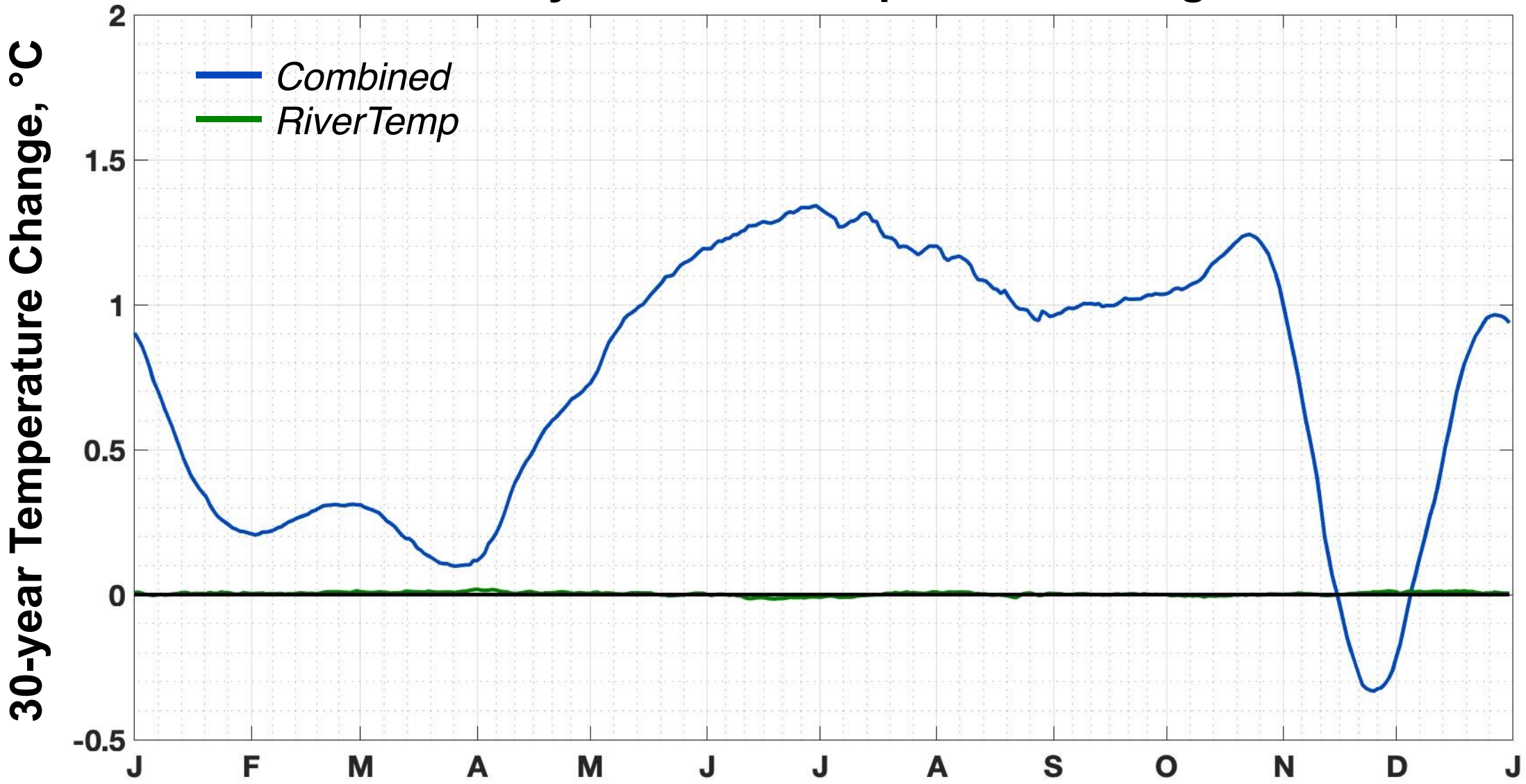
- Substantial variation between months, generally more warming from May-October than November-April

Whole Bay – Bottom Temperature Change



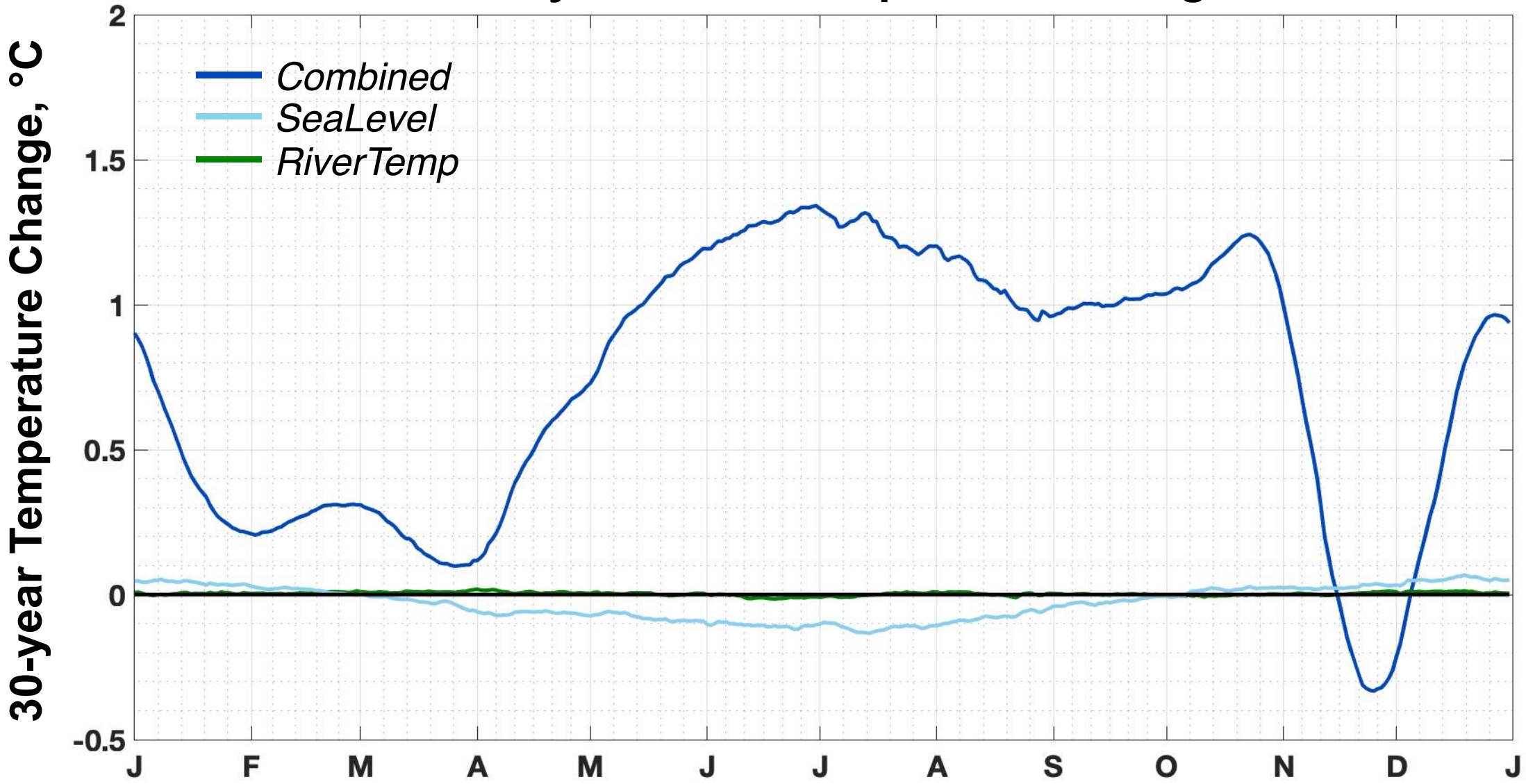
- Average change ± standard deviation in main stem bottom waters is 0.74 ± 0.46°C

Whole Bay – Bottom Temperature Change



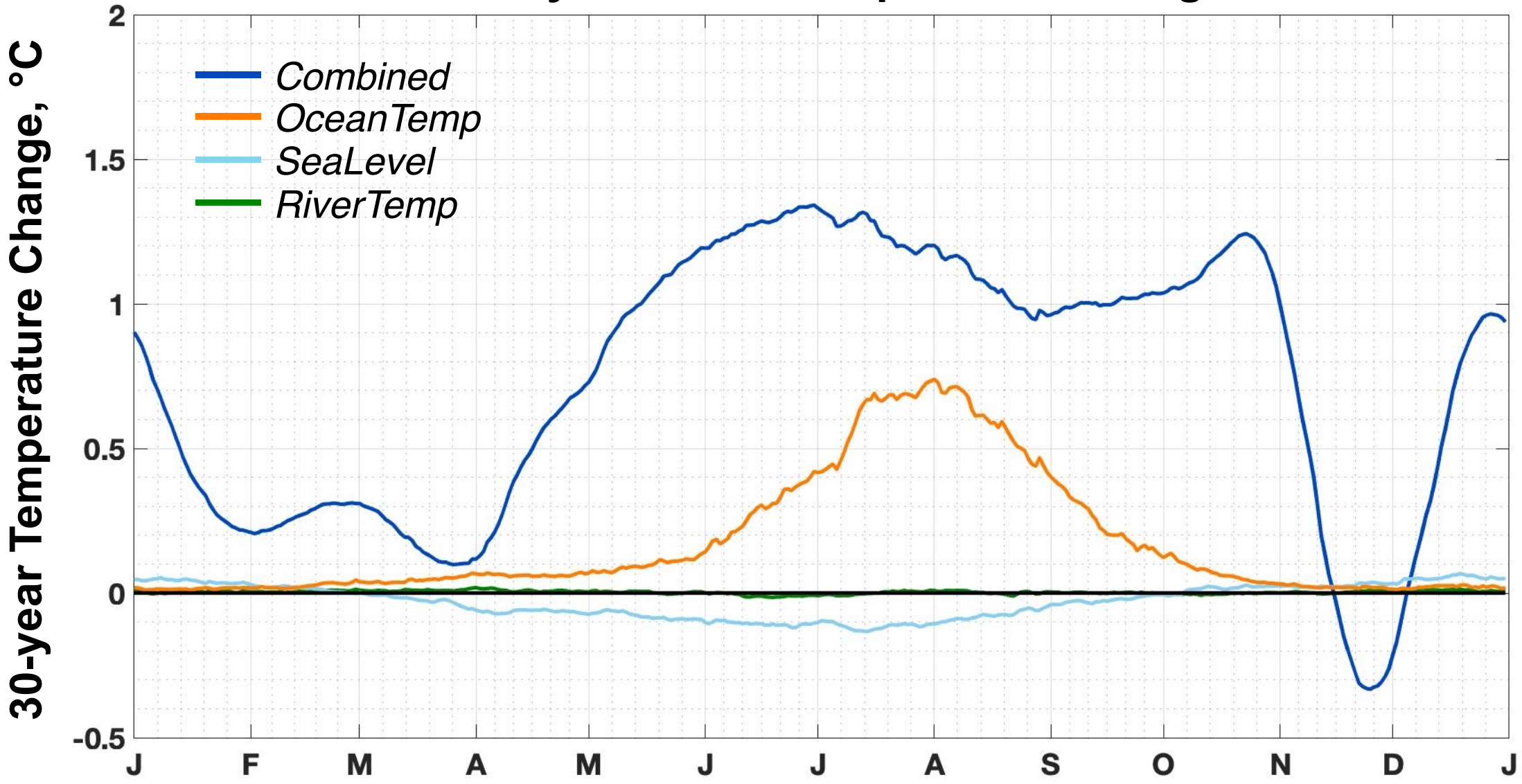
- Increasing river temperatures produce little to no warming in the Bay's main stem

Whole Bay – Bottom Temperature Change



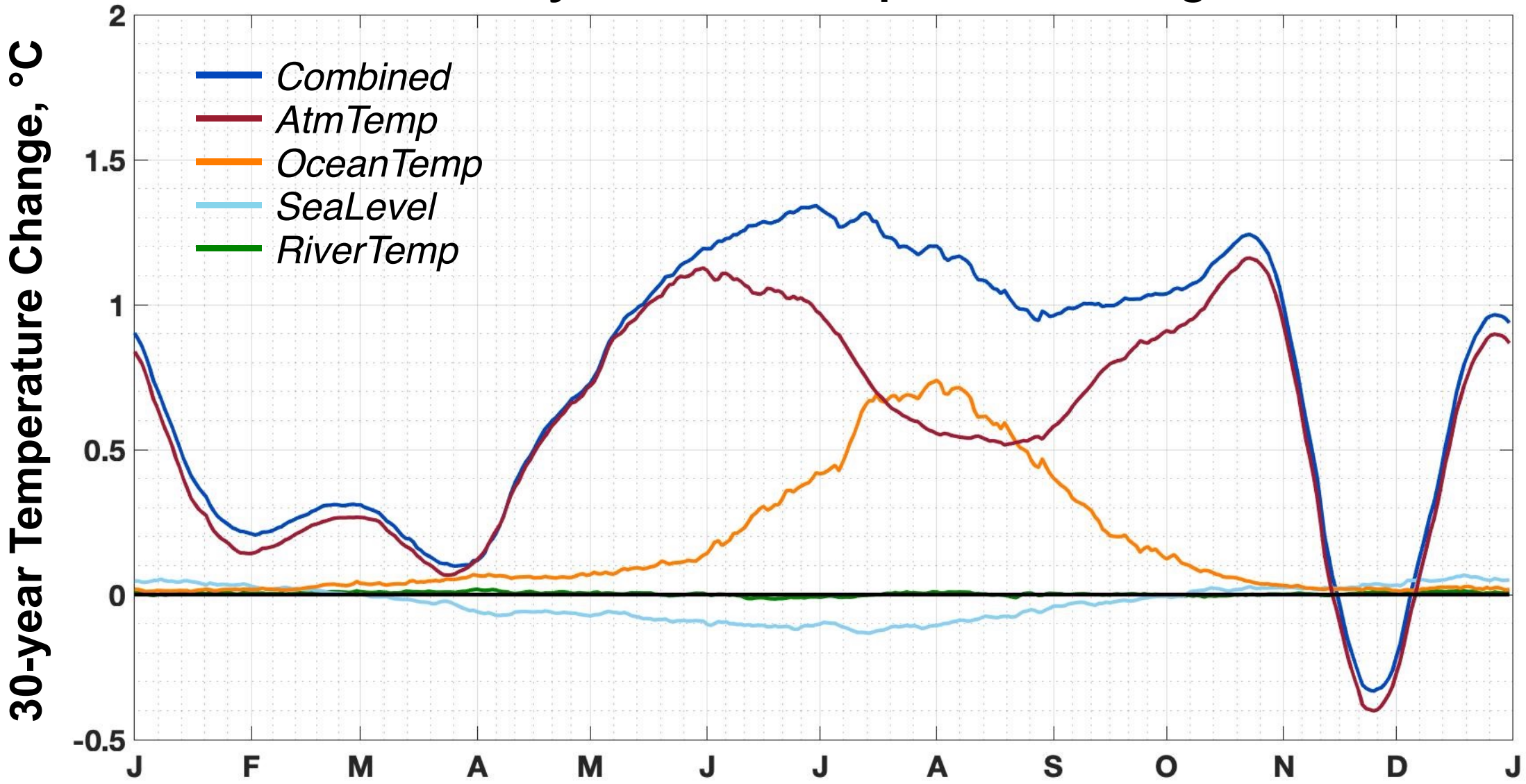
- Sea level rise slightly cools main stem from Apr-Sep and warms bottom waters in winter

Whole Bay – Bottom Temperature Change

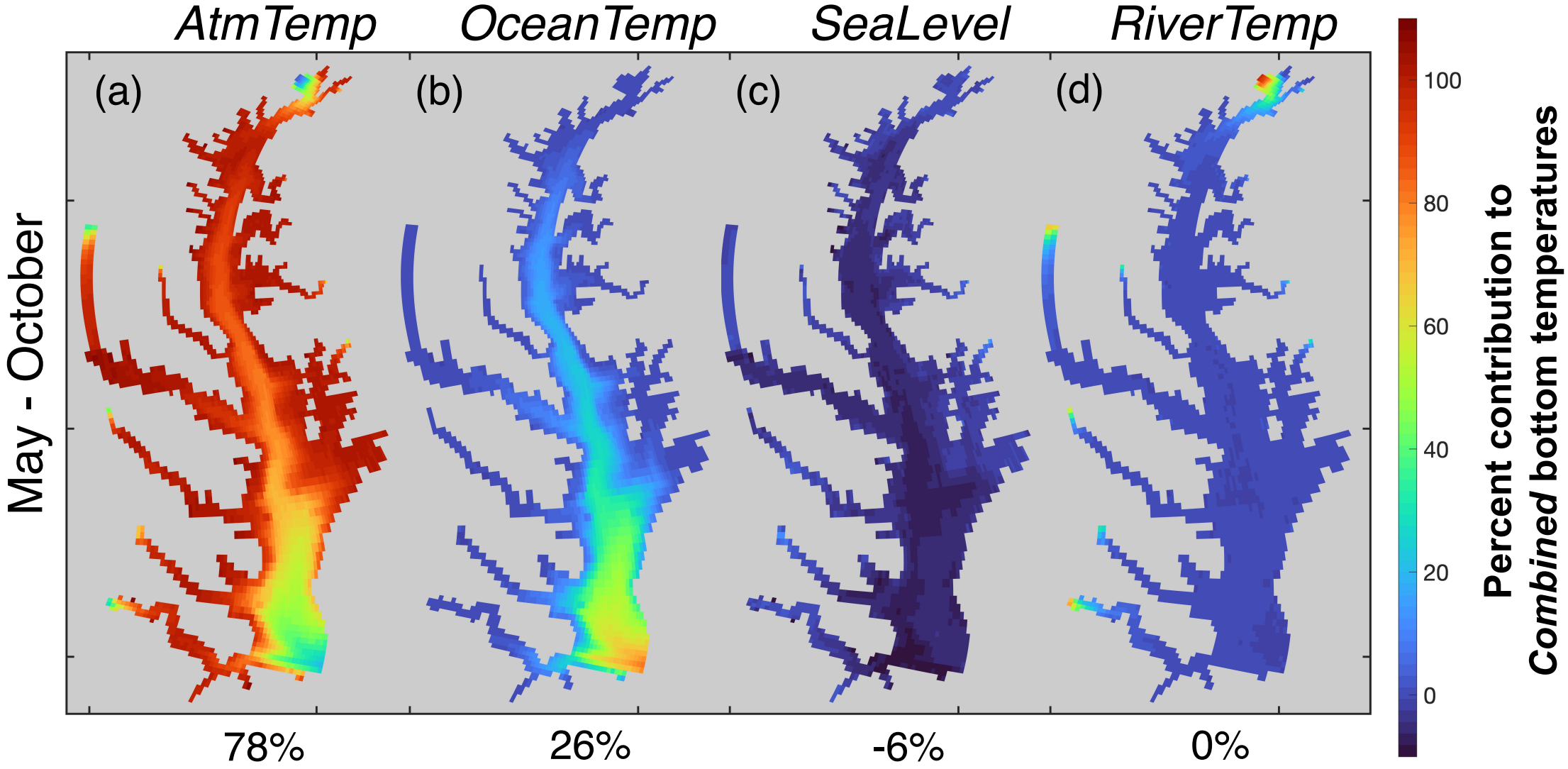


- Increasing ocean temperatures important in summer warming, small effect otherwise

Whole Bay – Bottom Temperature Change

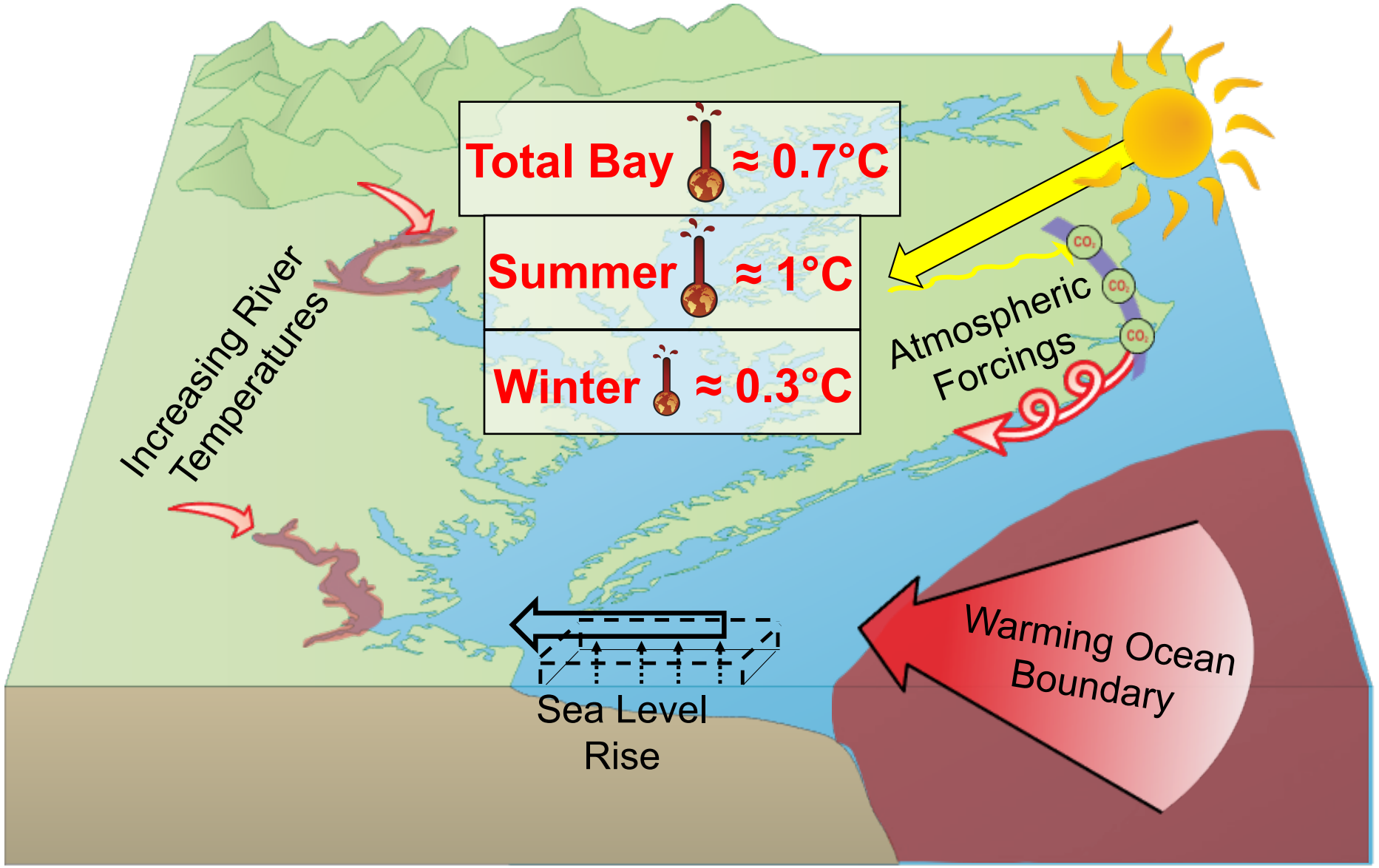


- Atmospheric forcings play biggest role, but effects are lessened during summer



- Atmospheric warming dominates almost everywhere
- Ocean warming plays large role in southern Bay
- Rivers important to heads of tributaries, SLR slightly cools everywhere

Conclusions



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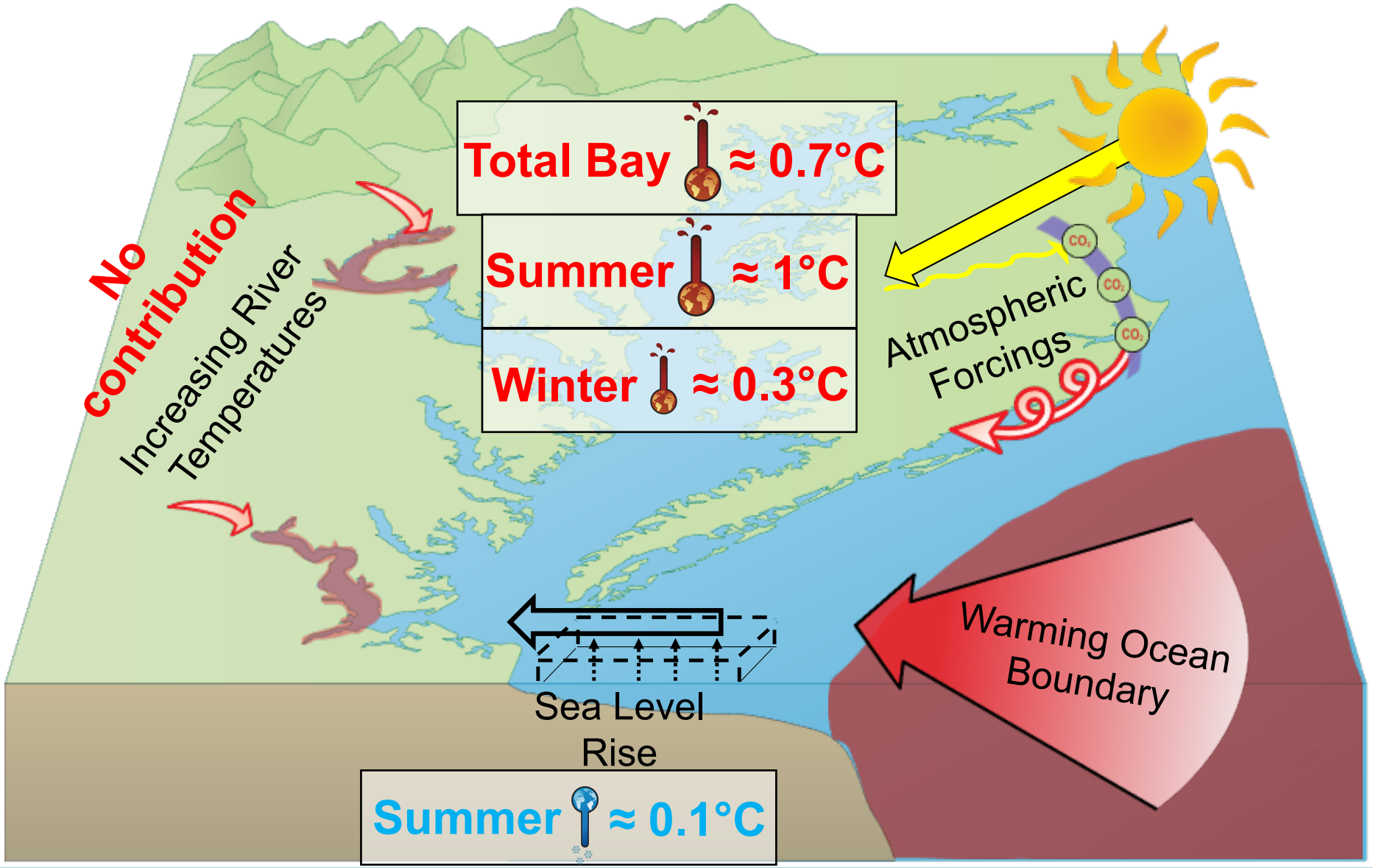

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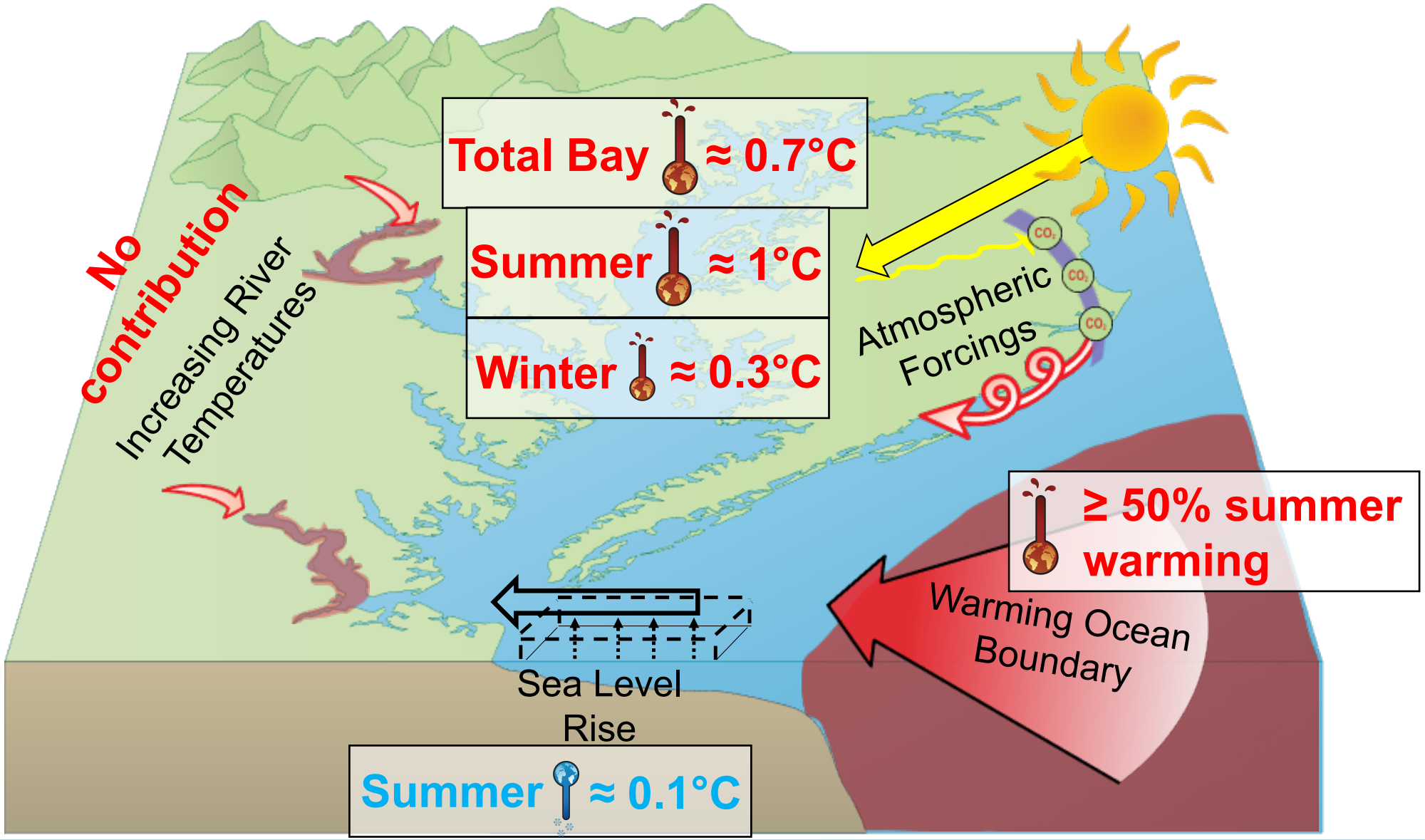

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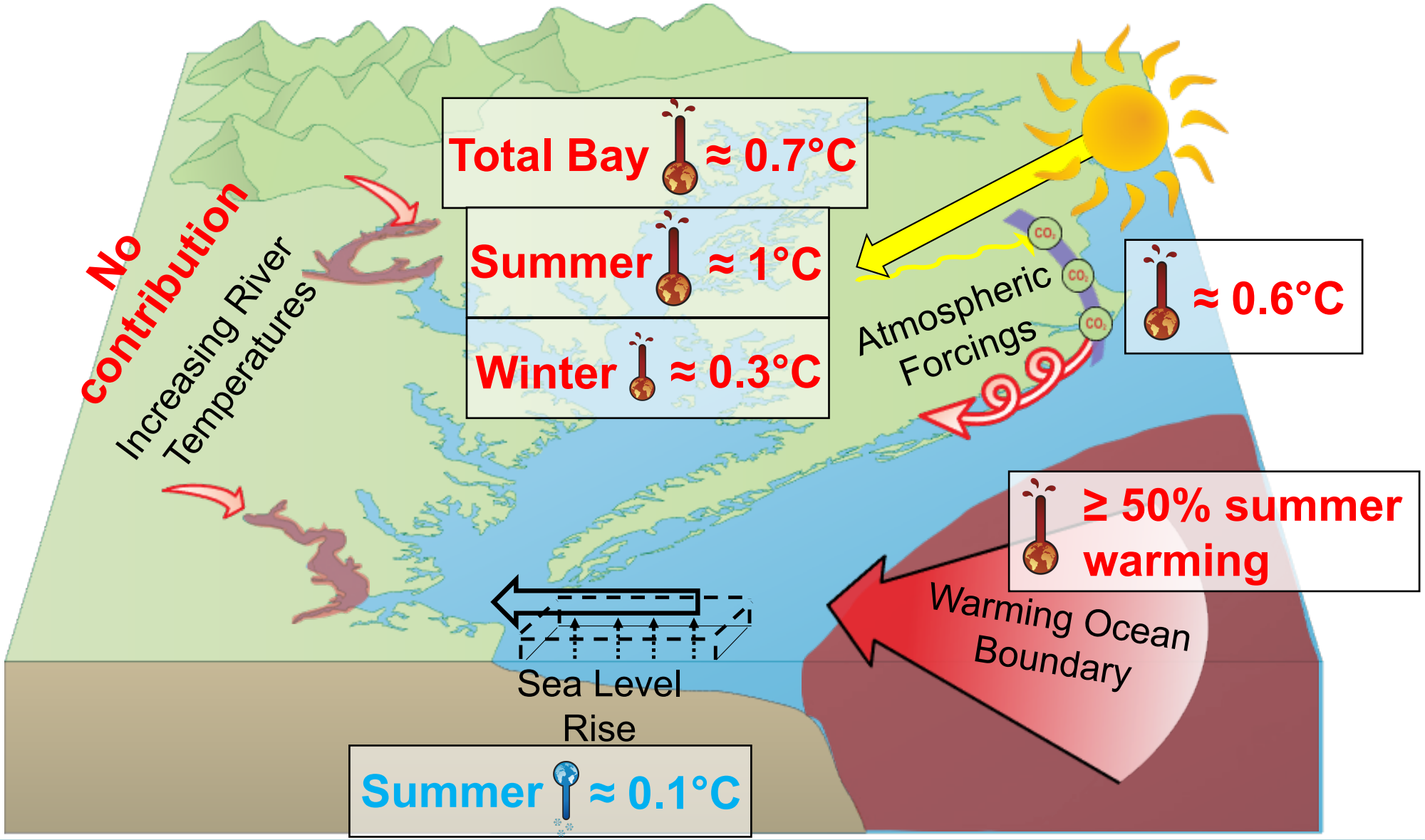
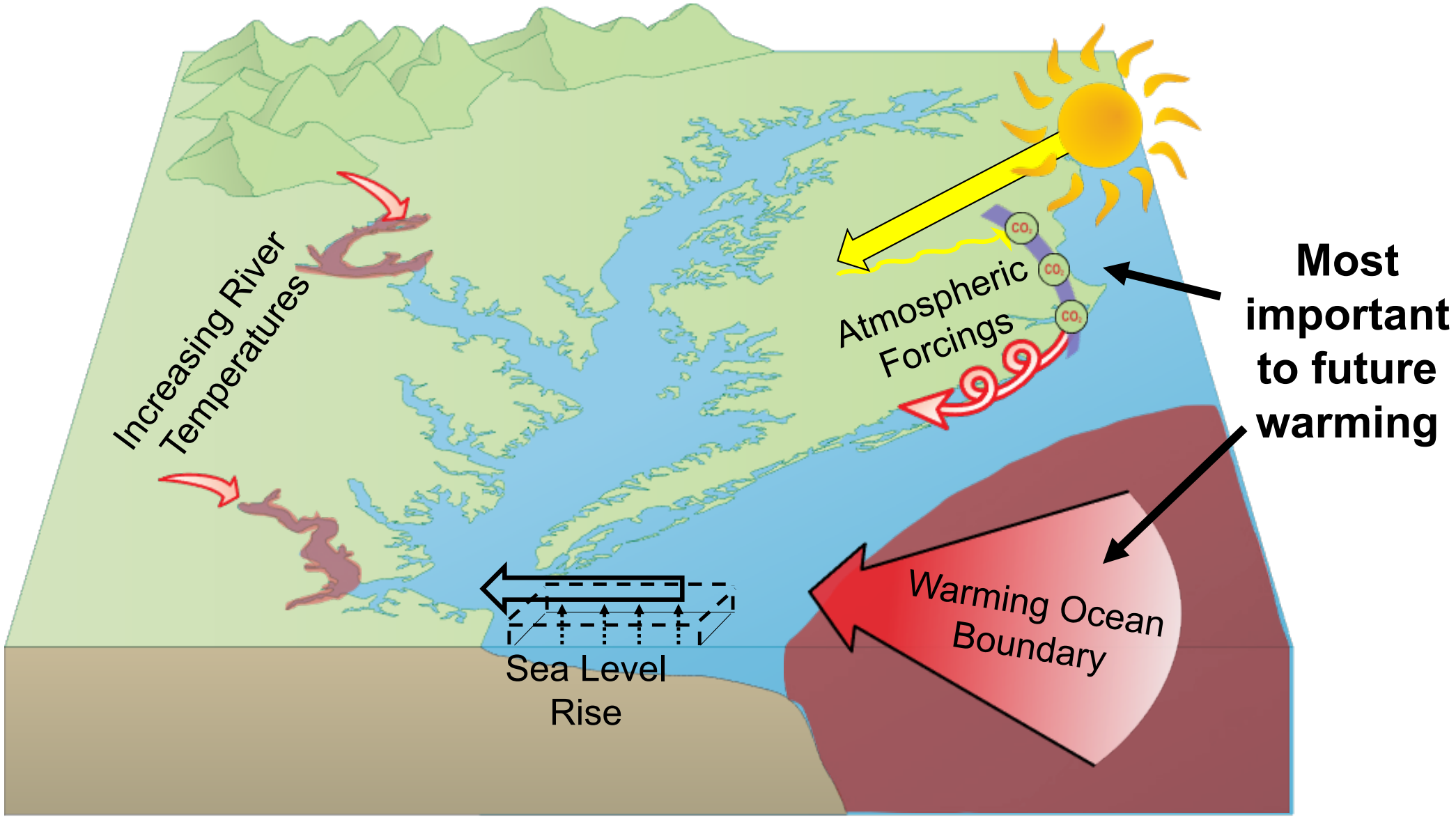


Conclusions

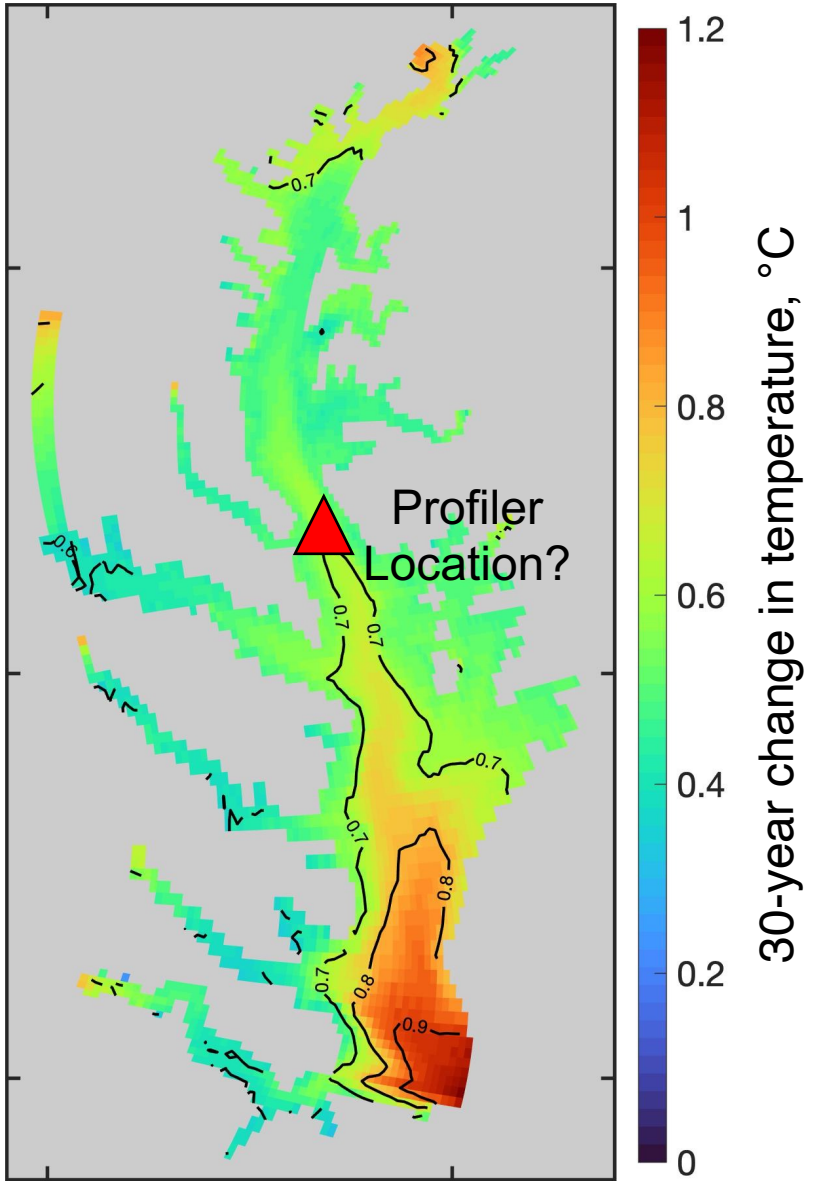


Management Implications

- Reducing river temperatures unlikely to affect main stem Bay warming

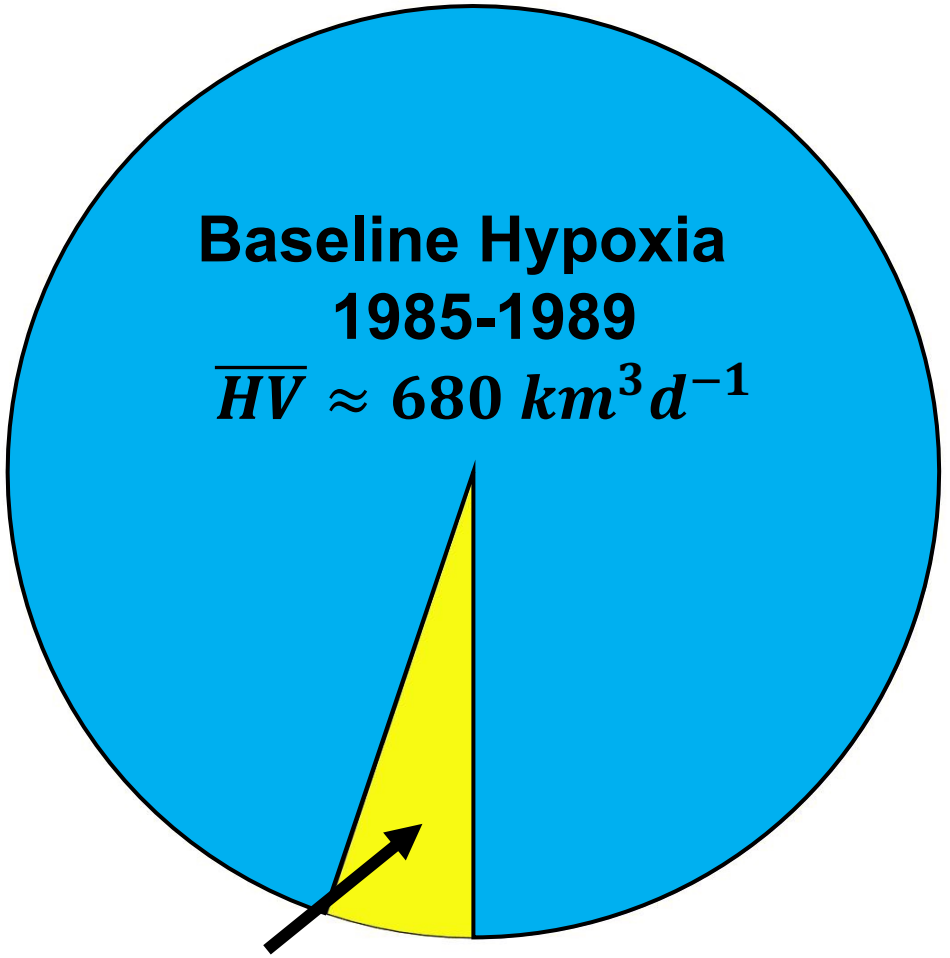
  → Still great for stream health outcomes in Chesapeake Bay Watershed Agreement!

- Detection of future warming – could help inform site selection of profiling sensors



Management Implications

- Ni et al. (2020)
  - ↑ Temperatures limit attainment of TMDL goals
- Tian et al. (2021)
  - Warming →↓ O_2 solubility, ↑ biological rates, and ↑ stratification
- Percent of hypoxia attributable to anthropogenic warming?



Questions?

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