# Progress in WQSTM Climate Change Analyses and Plans for Sensitivity Scenarios

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**and CBPO modeling team**

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# Outline

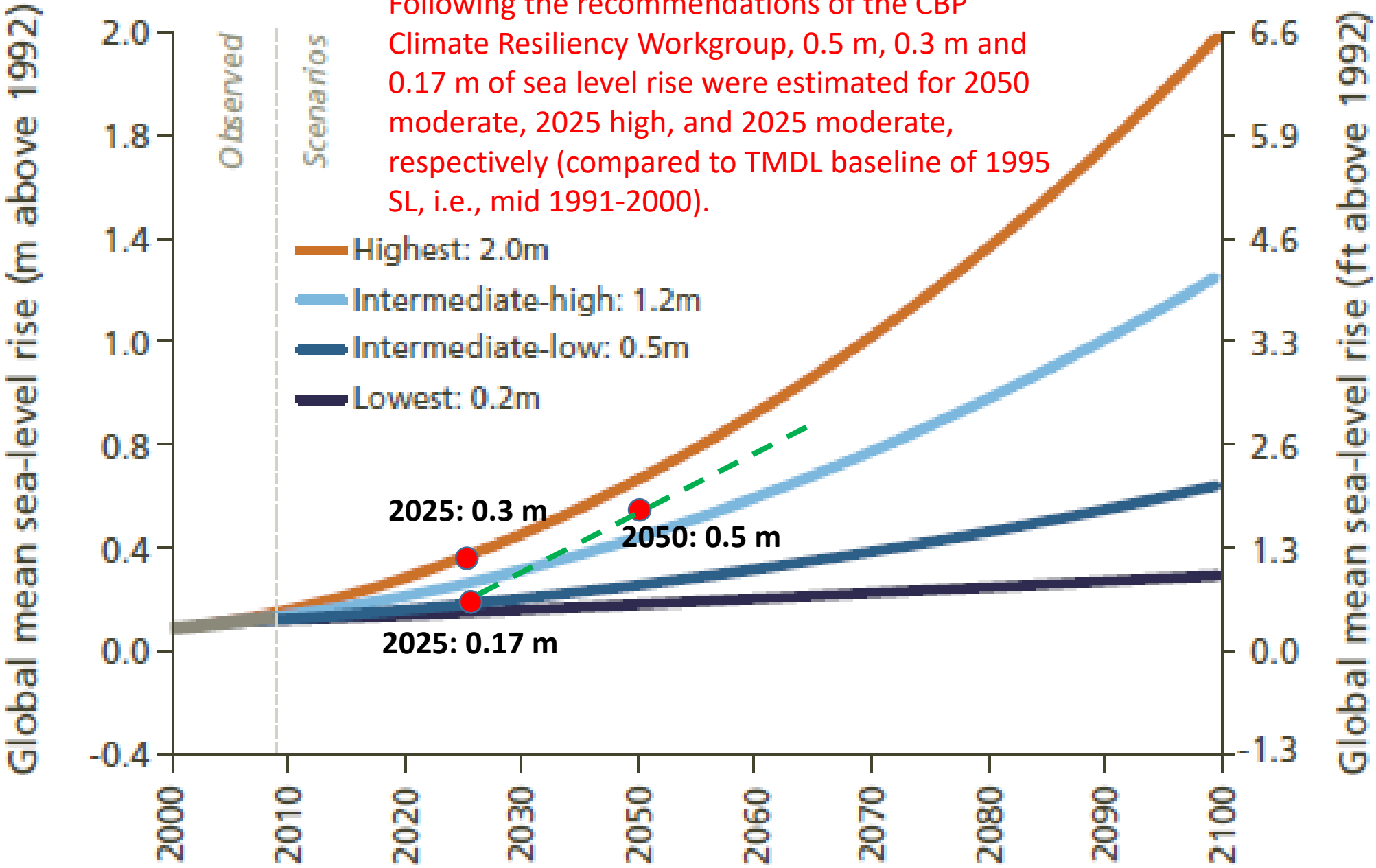
- **What we have done.**
- **Preliminary analysis.**
- **Plan for the near future in response to the STAC meeting.**

# Sea level rise numbers

Following the recommendations of the CBP Climate Resiliency Workgroup, 0.5 m, 0.3 m and 0.17 m of sea level rise were estimated for 2050 moderate, 2025 high, and 2025 moderate, respectively (compared to TMDL baseline of 1995 SL, i.e., mid 1991-2000).

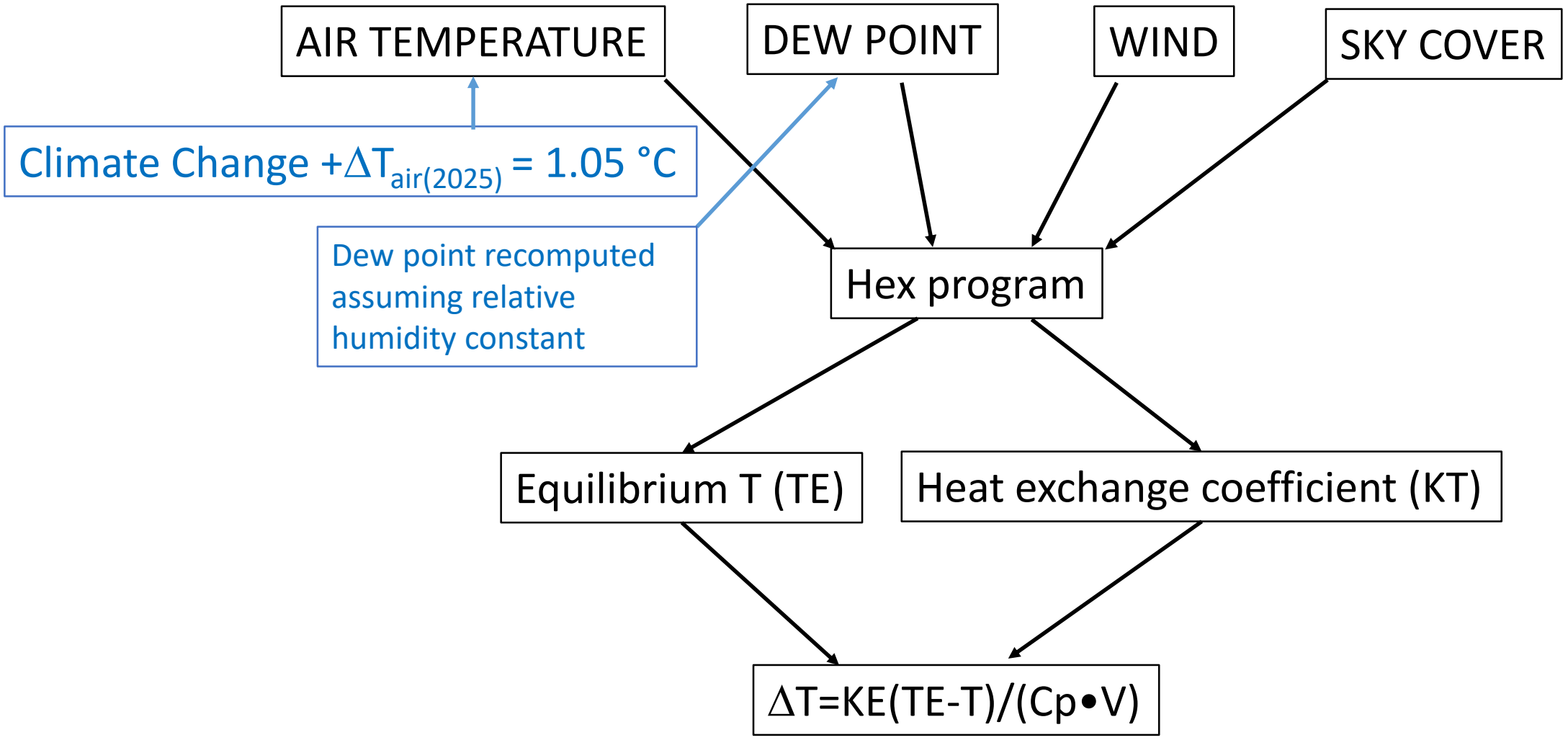
**Linear interpolation and extrapolation for 2035 (0.3 m), 2045 (0.43 m), 2055 (0.57 m) and 2065 (0.7 m).**

**Climate resiliency group will revise these numbers**



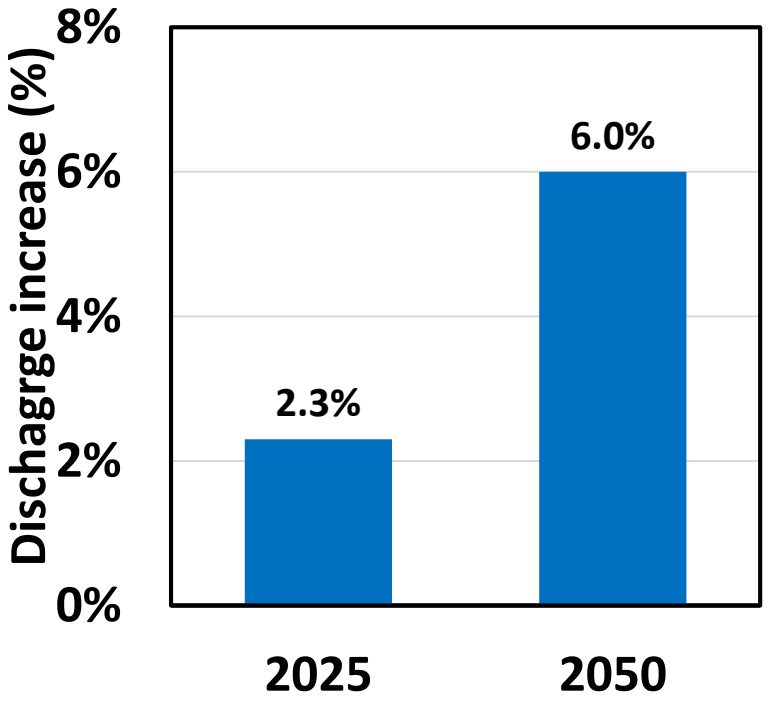

From Parris et al. (2012). *Global Sea Level Rise Scenarios for the United States National Climate Assessment. NOAA Technical Report OAR CPO-1. (1992 used as the starting year)*

# ICM Meteorological Forcing for Heat Transfer From Air to the Tidal Waters

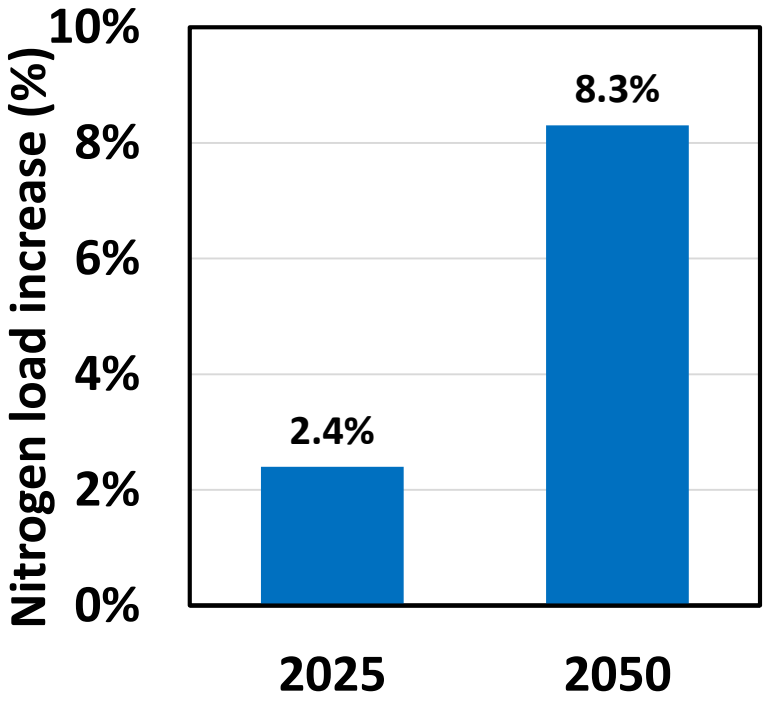


# Changes in river discharge and nutrient loading in the 2025 and 2050 climate change scenarios

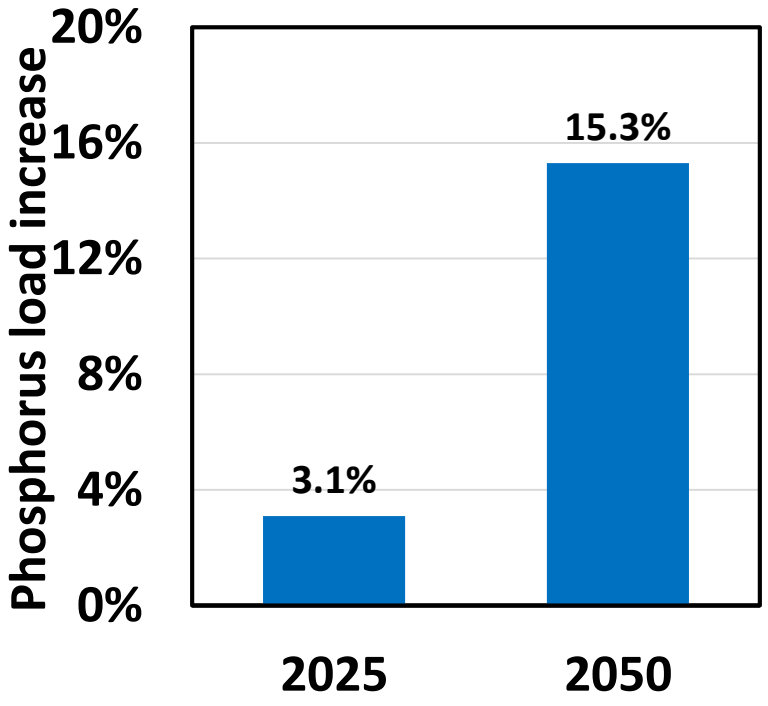
River discharge




Nitrogen loading




Phosphorus loading



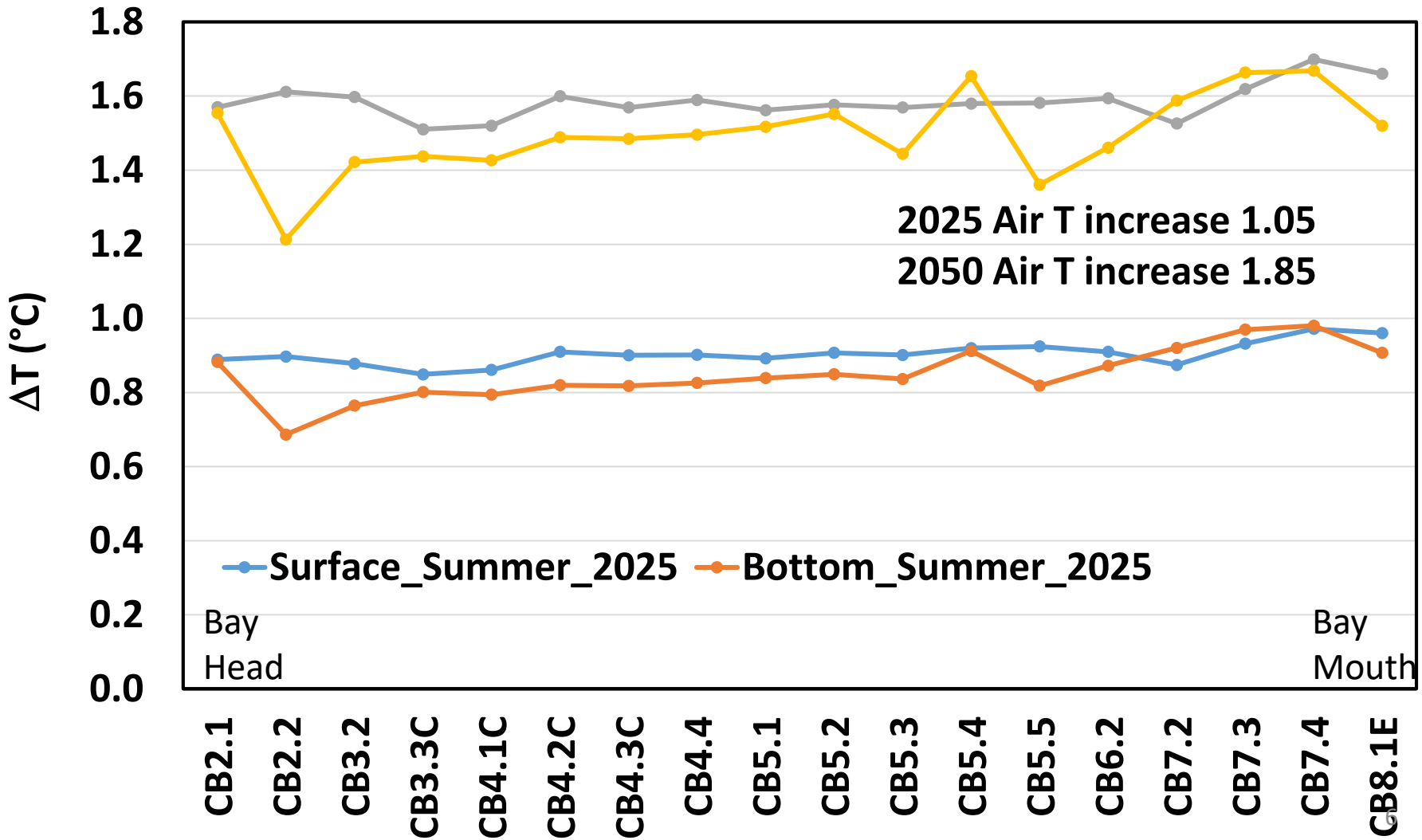

From Gopal Bhatt

# Surface water T change under 2025 and 2050 CC

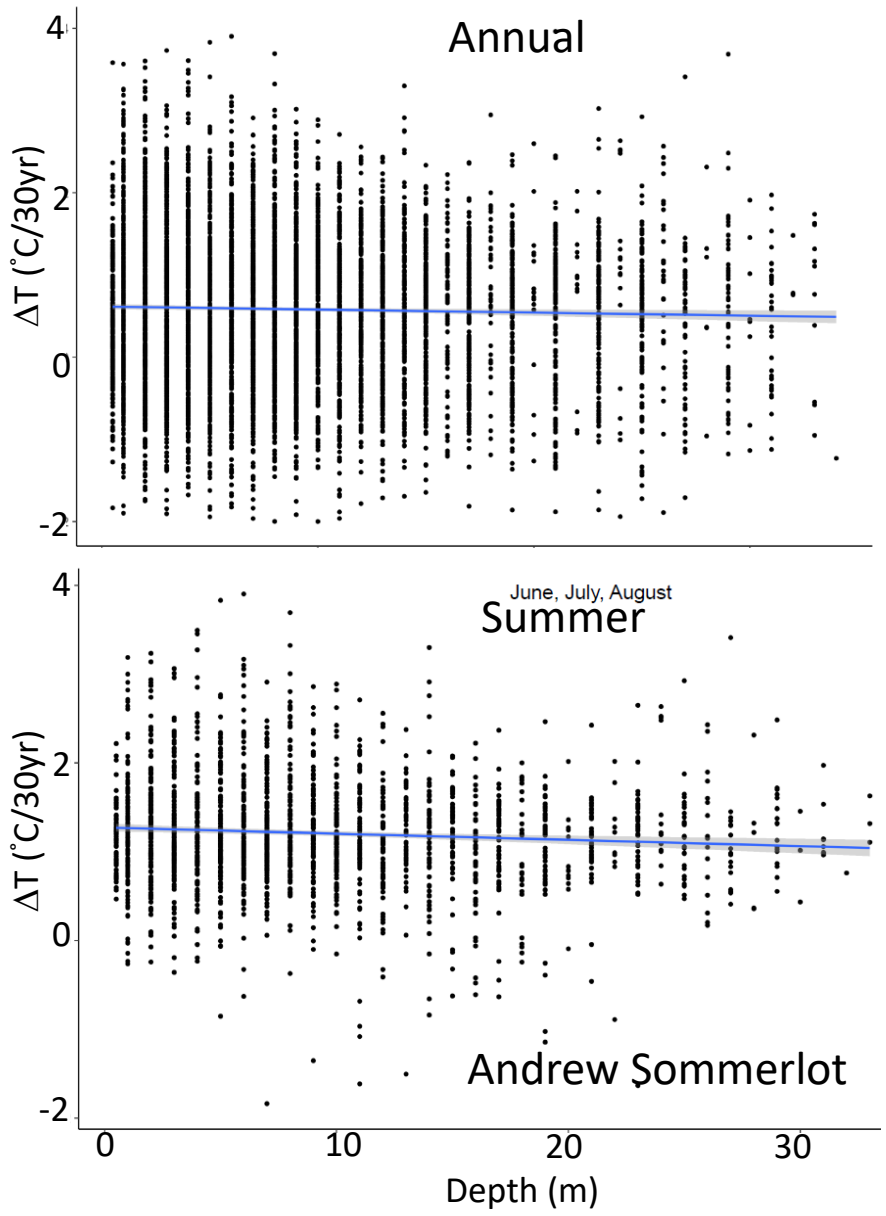
**Thomas et al 2017: data 1982-2014, 0.3 °C per decade;**

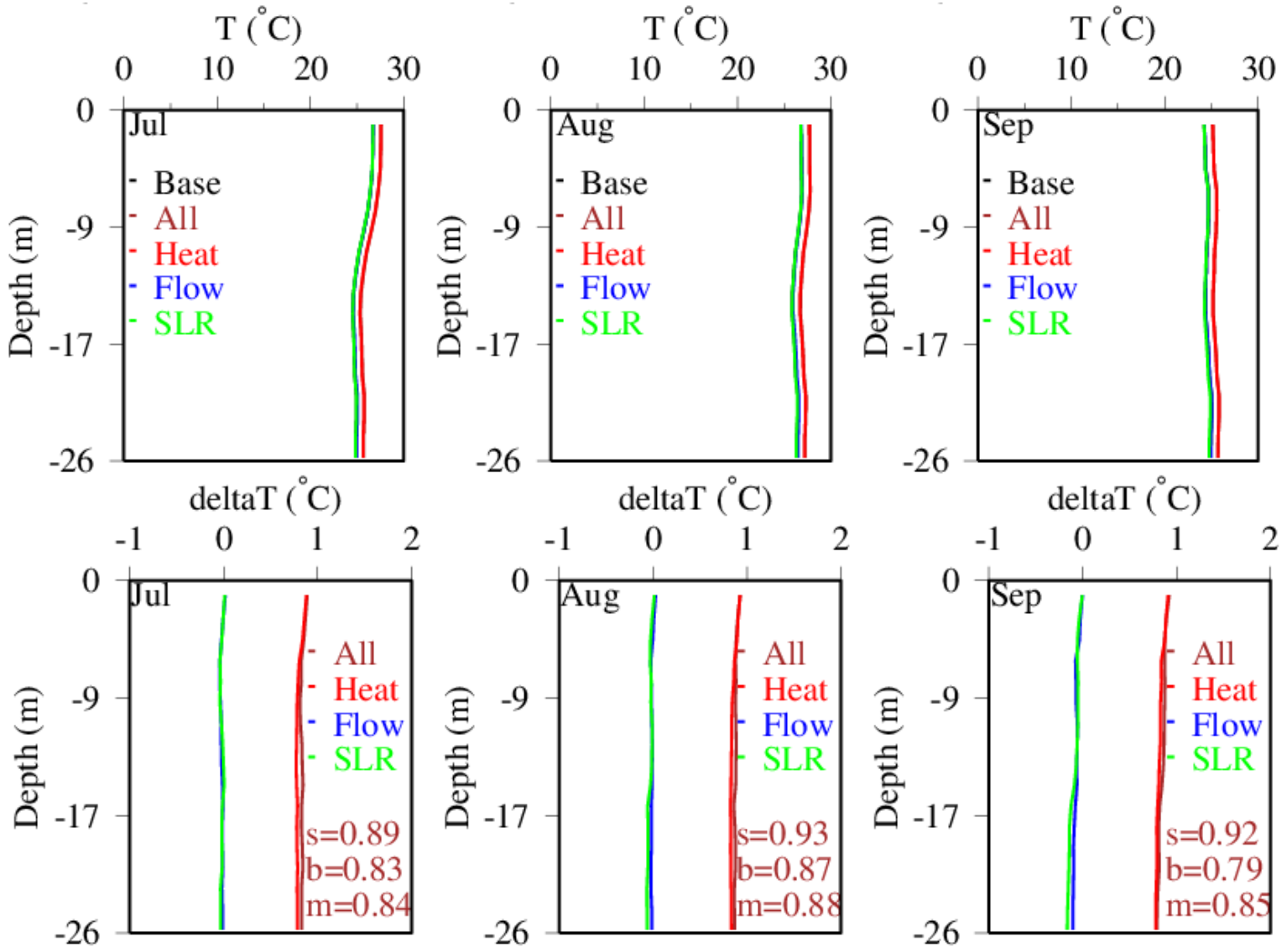
**Preston 2004: Data 1949-2002: 0.185 °C per decade;**

**Irby et al., 2018: 1.75 °C for 2050.**



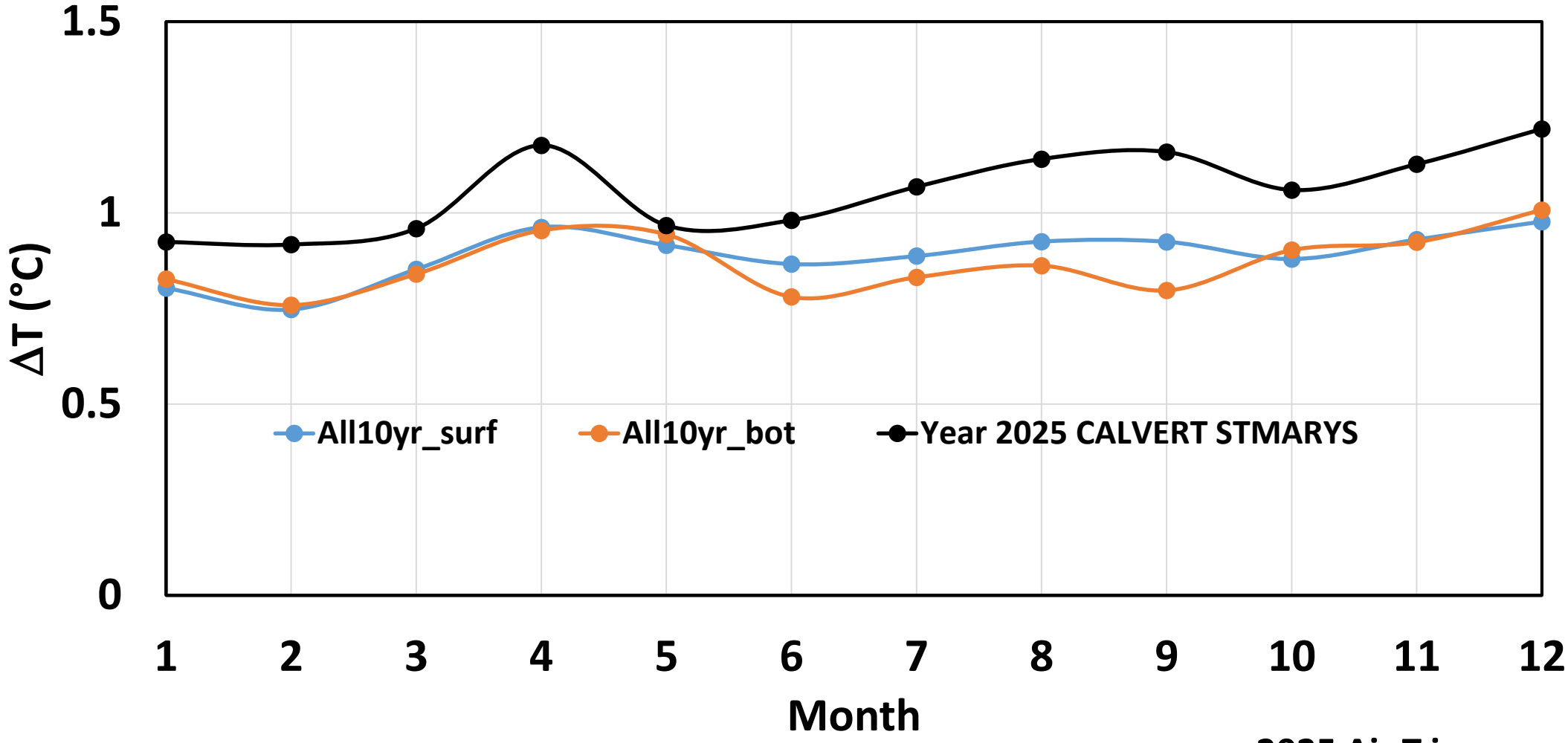
# T and ΔT profile at CB4.3C under 2025 CCC




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

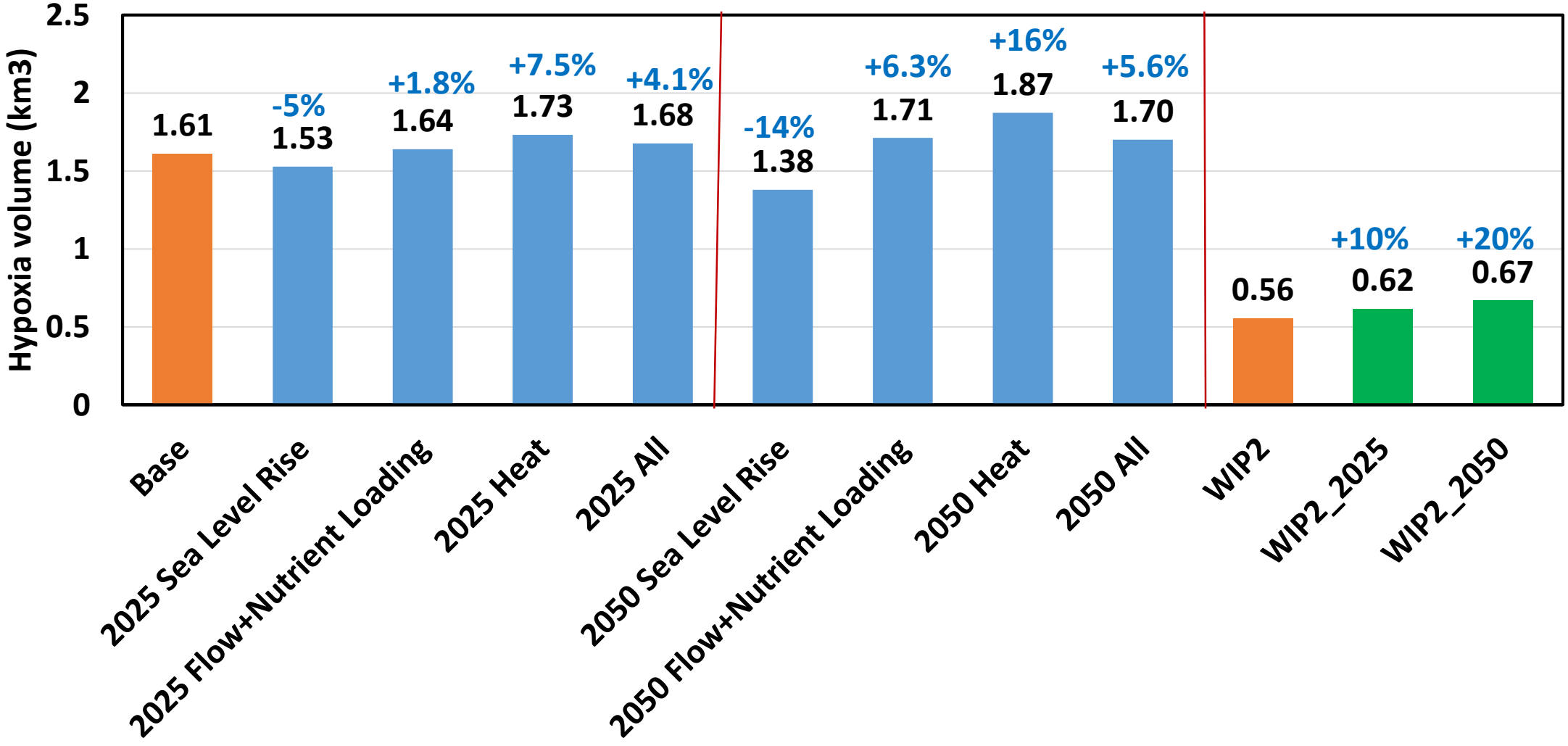
# Monthly air T change and surface T simulation at CB4.3C




2025 Air T increase 1.05

2050 Air T increase 1.85

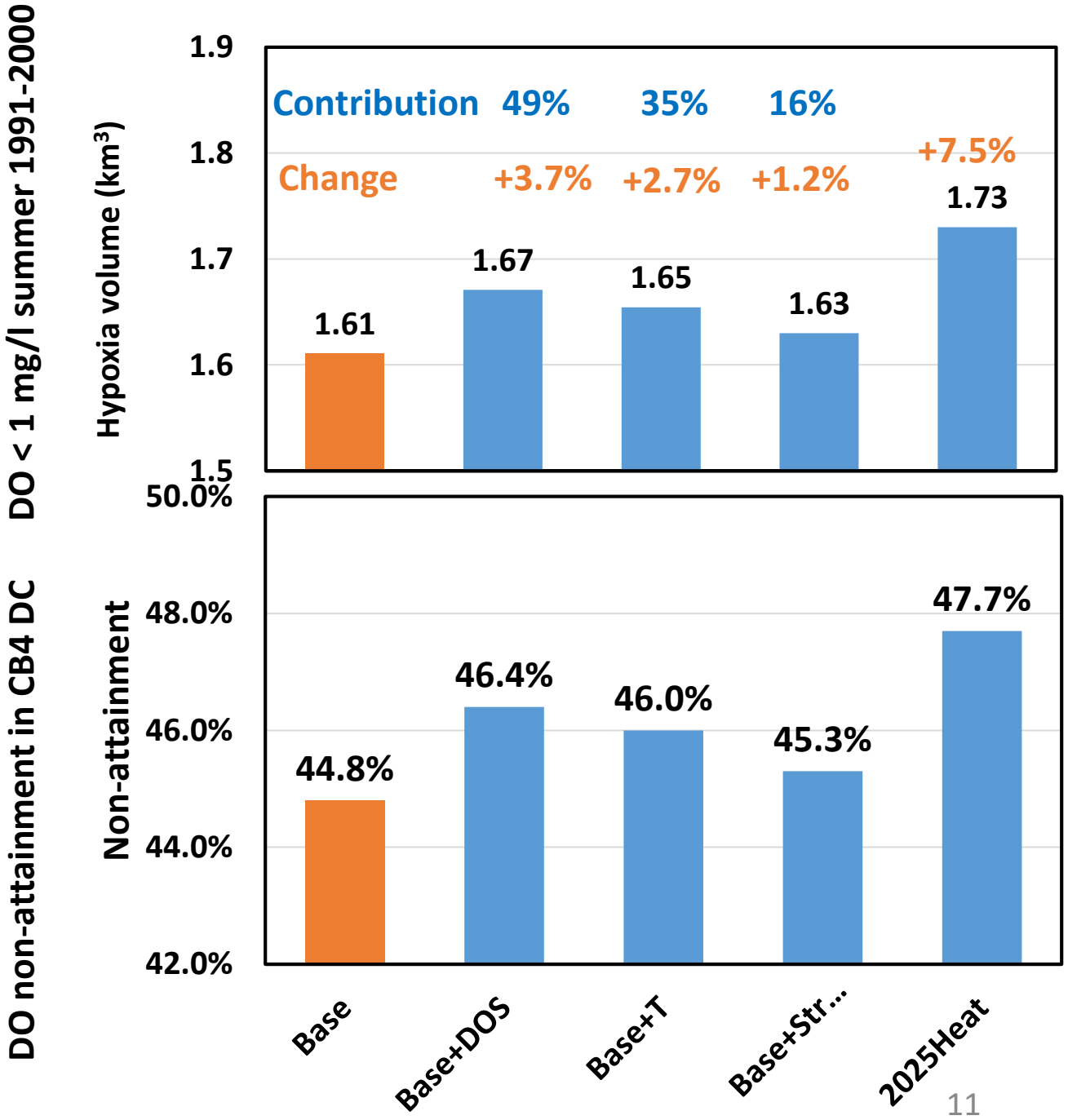
# Hypoxia volume (<1 mg/l) in summer (Jun-Sep) 1991-2000 in CB4MH



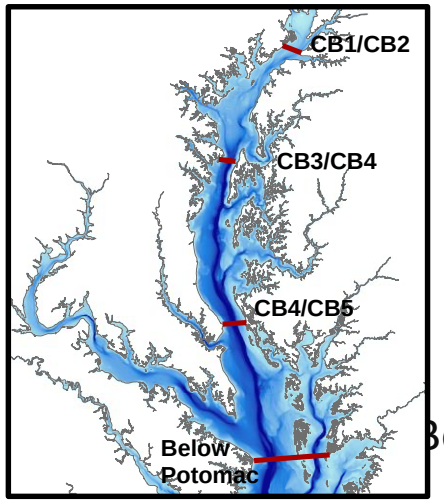
# Temperature effects

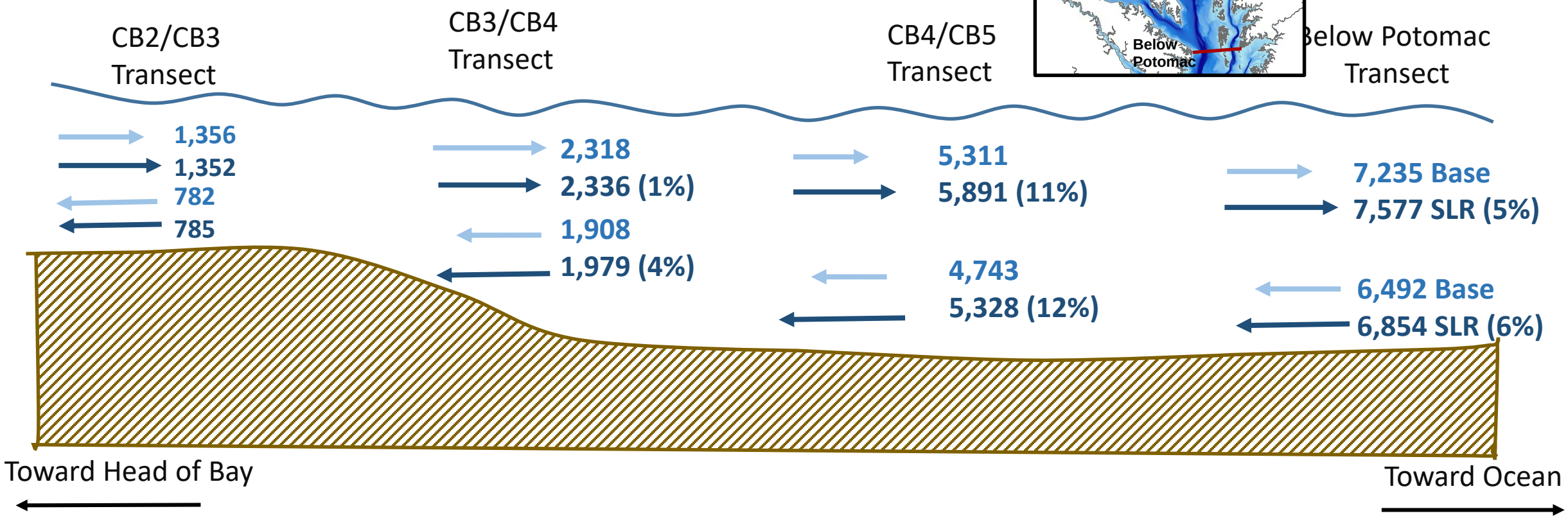
- **Solubility: 0.9 °C increase decreases solubility by 0.13 mg/l, or 1.7%.**
- **Biological rates: increase 6% over 0.9 °C ($Q_{10}$=2)**
- **Stratification (physics)**

# Sensitivity analysis of T modified DO-solubility (DOS), biological rate and stratification (physics) 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.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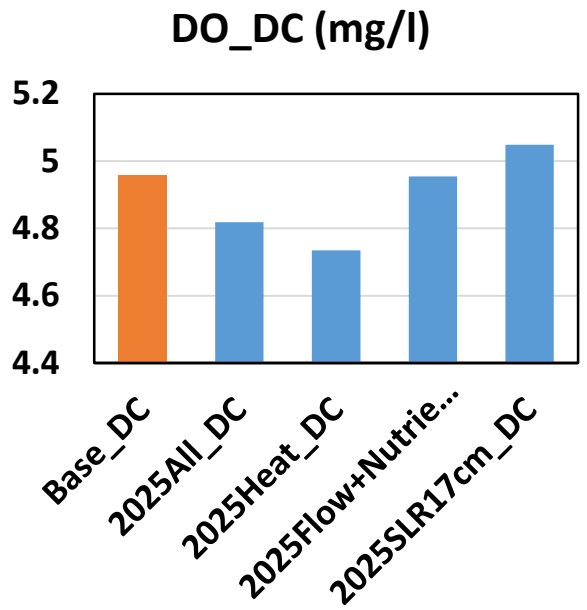
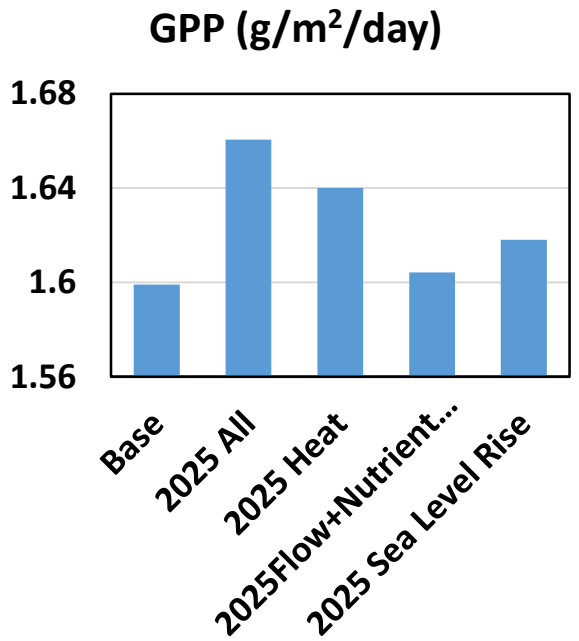
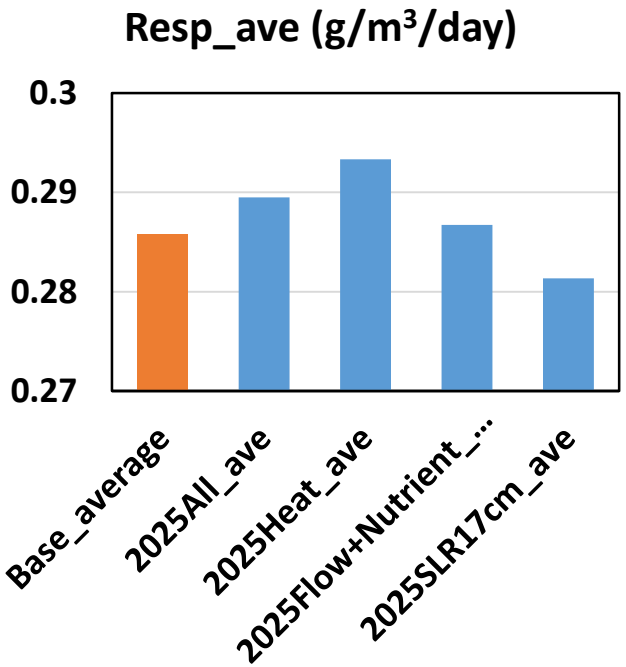
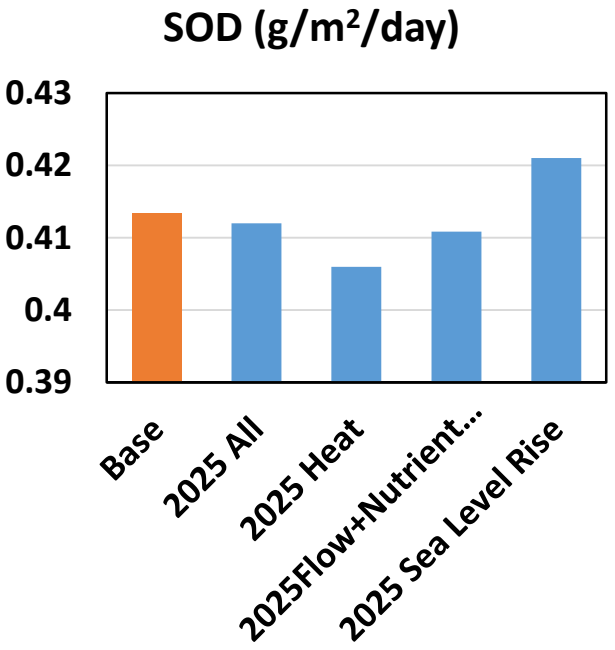
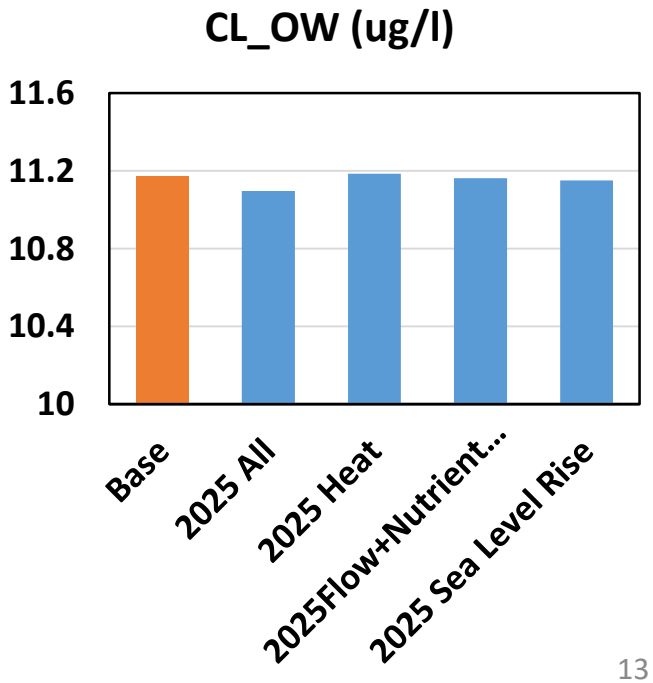
# Diagnosis on Climate Change Scenarios, CB4, average 1991-2000



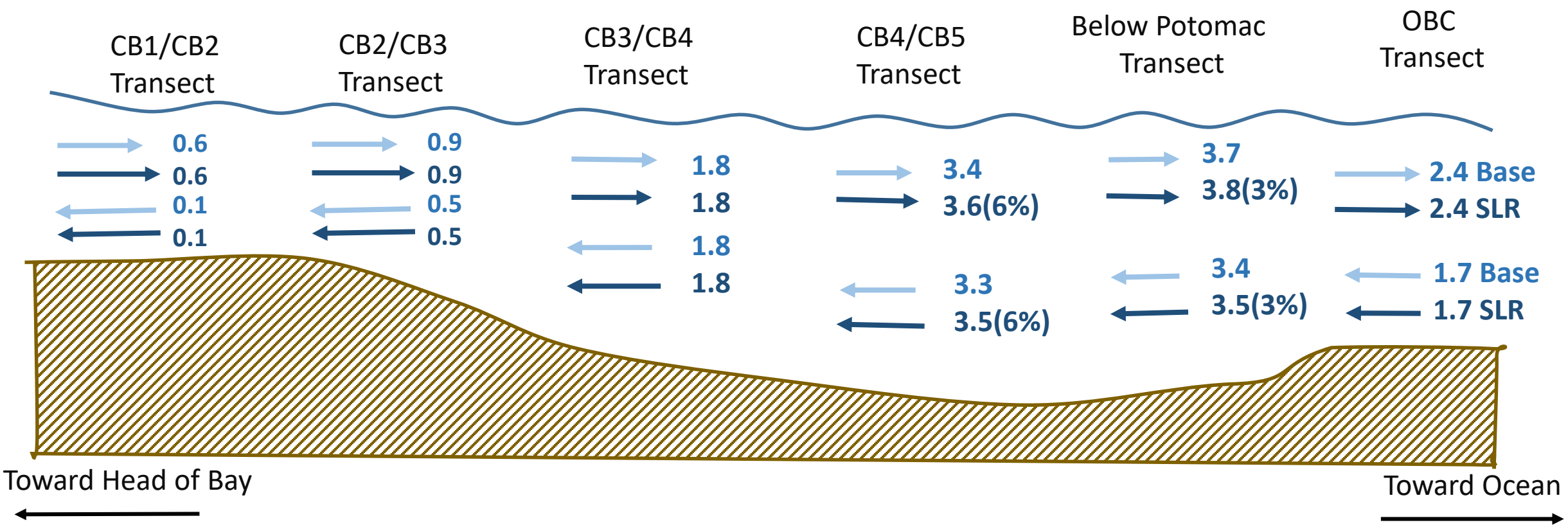



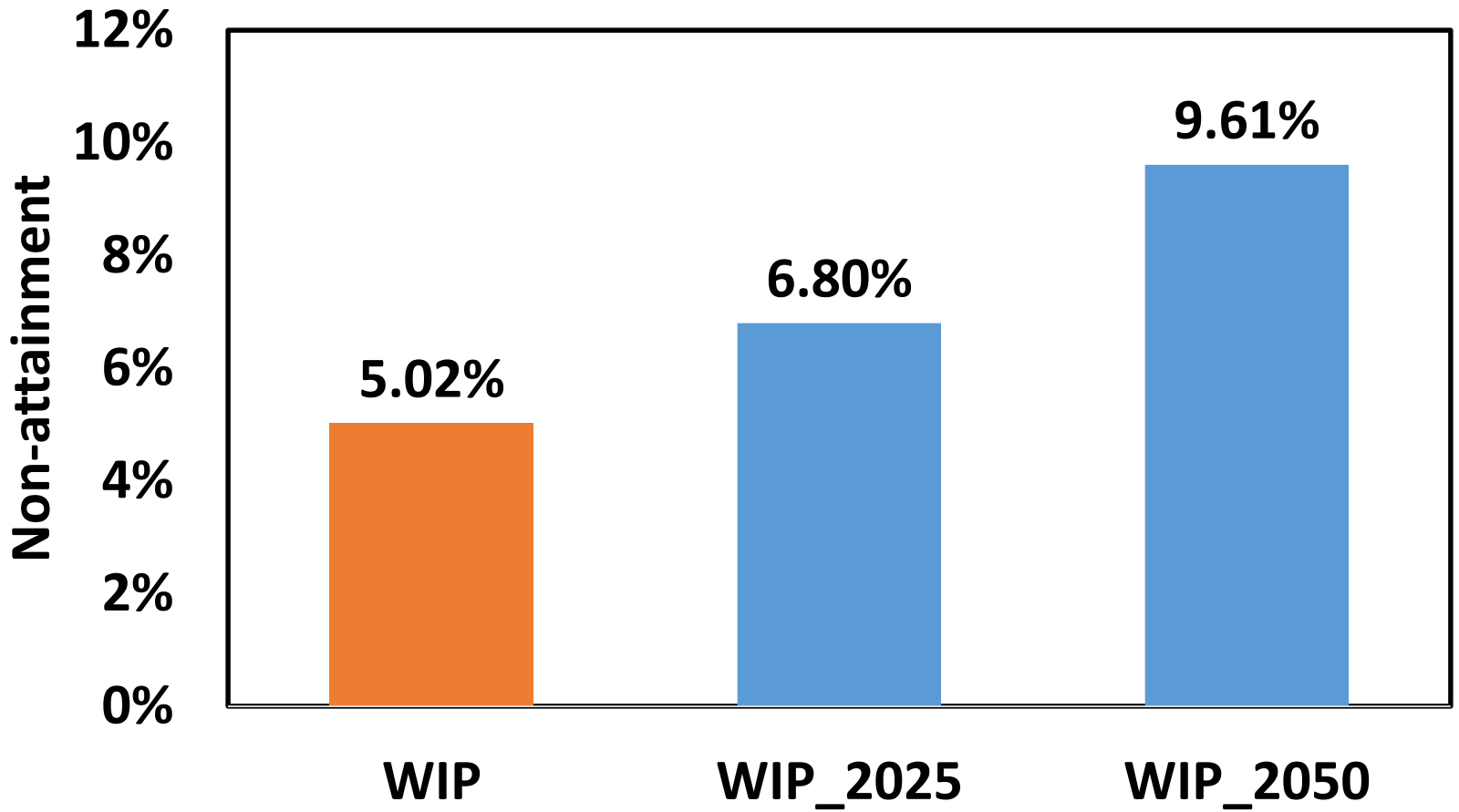



# Cross-transect TN fluxes: Base case versus sea level rise (SLR), summer 1993-1995




**Base = Beta 2 Calibration. SLR = 0.17m Sea Level Rise Scenario representing relative Chesapeake sea level rise from 1995 to 2025. Units in mean gram per second (g/s) averaged over June-Sep 1993-1995.**

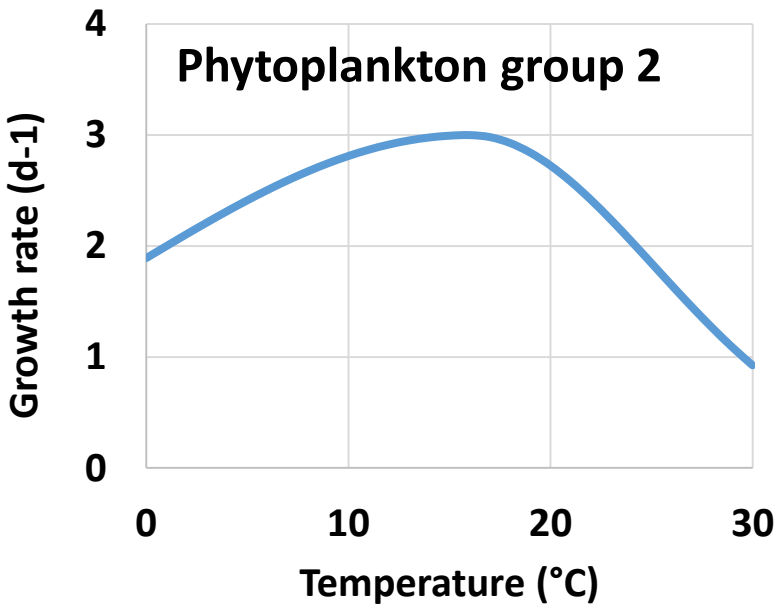
# Estimate on water quality attainment in the Deep Channel CB4MH Under the WIP condition

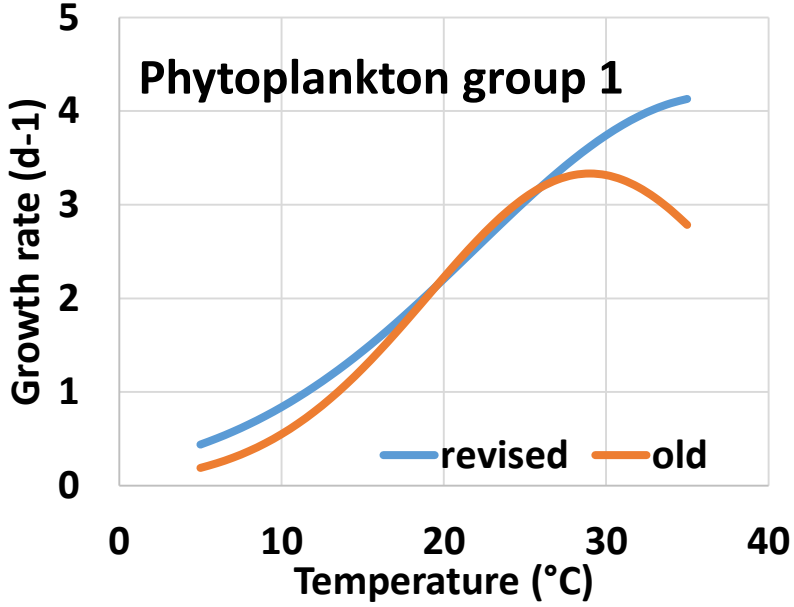


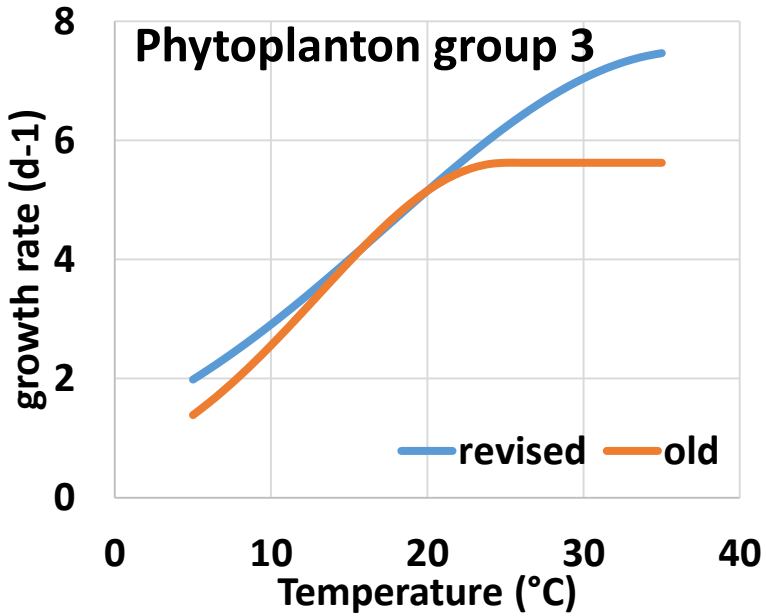
# Temperature effect of phytoplankton growth rate

| Phytoplankton group | Cyanobacteria | | Diatom | | Green algae | |
|---|---|---|---|---|---|---|
| Version | Old | New | Old | New | Old | New |
| $g_{max}$ | 200 | 250 | 300 | 300 | 450 | 600 |
| Optimal temperature | 29°C | 37°C | 16°C | 16°C | 25°C | 37°C |
| Exponential $K_1$ | 0.005 | 0.0022 | 0.0018 | 0.0018 | 0.0035 | 0.0013 |
| Exponential $K_2$ | 0.004 | 0 | 0.0022 | 0.002 | 0 | 0 |

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




From Carl Cerco

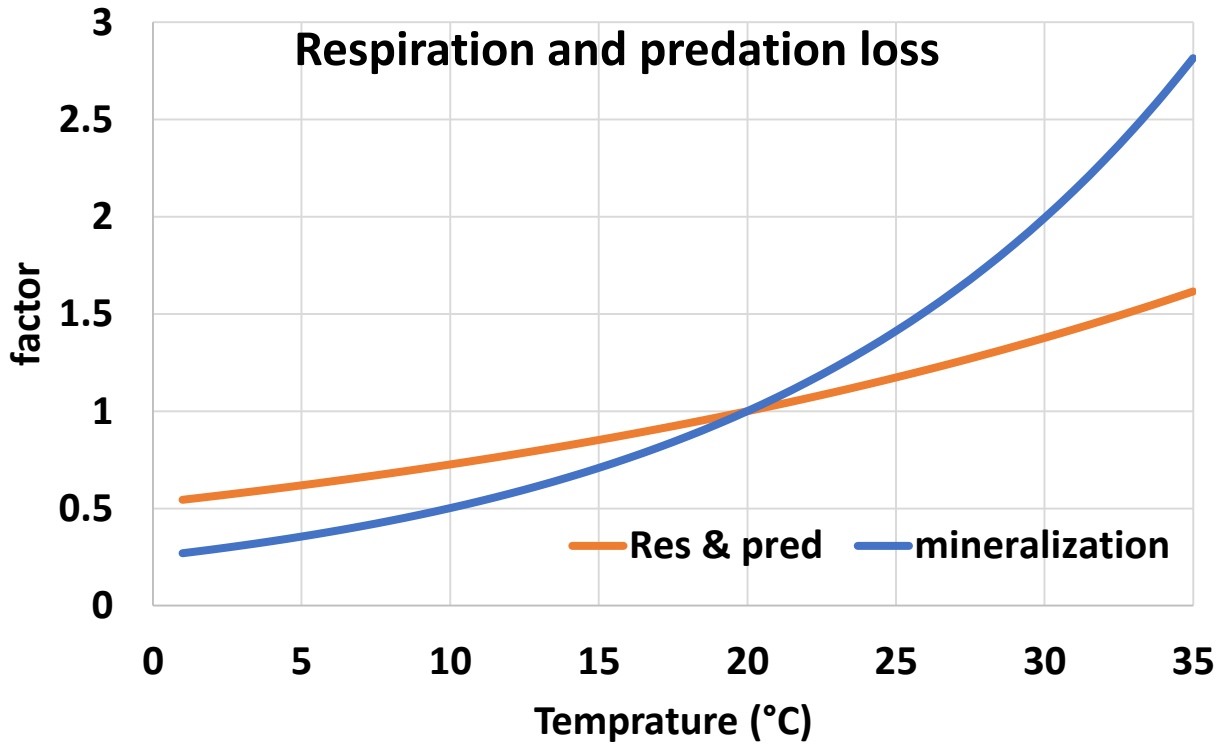
# Temperature effect on remineralization and phytoplankton respiration and predation loss

$$a_{mnl} = \alpha_m DOC e^{km(T - Tm)}$$

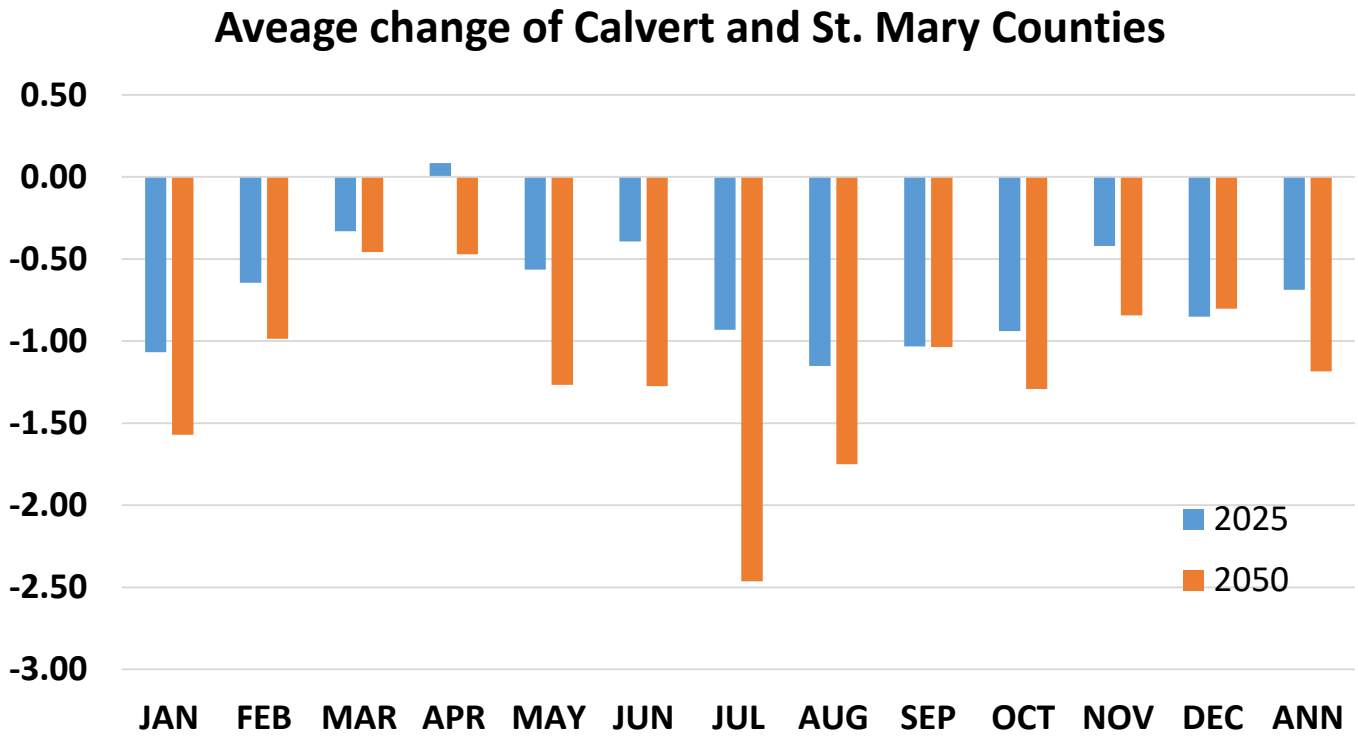
$$a_{res} = \alpha_r B e^{kr(T - Tr)}$$

$$a_{pr} = \alpha_p B^2 e^{kp\,(T - Tp)}$$

Km = 0.069
kr, kp = 0.032
Tr, Tp, Tm = 20



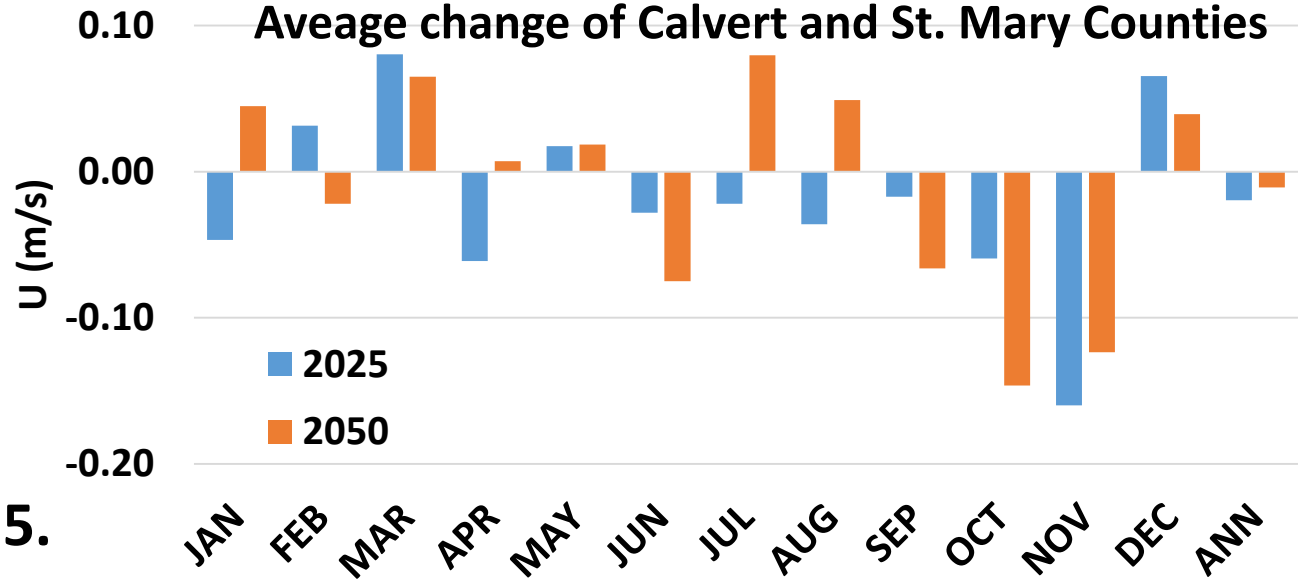
# Changes in relative humidity projected for 2025 and 2050




**From Gopal Bhatt, MACA downscale analysis, 20 CMIP5 GCMs ensemble, RCP8.5.**

# Changes in wind projected for 2025 and 2050

**From Gopal Bhatt, MACA downscale analysis, 20 CMIP5 GCMs ensemble, RCP8.5.**

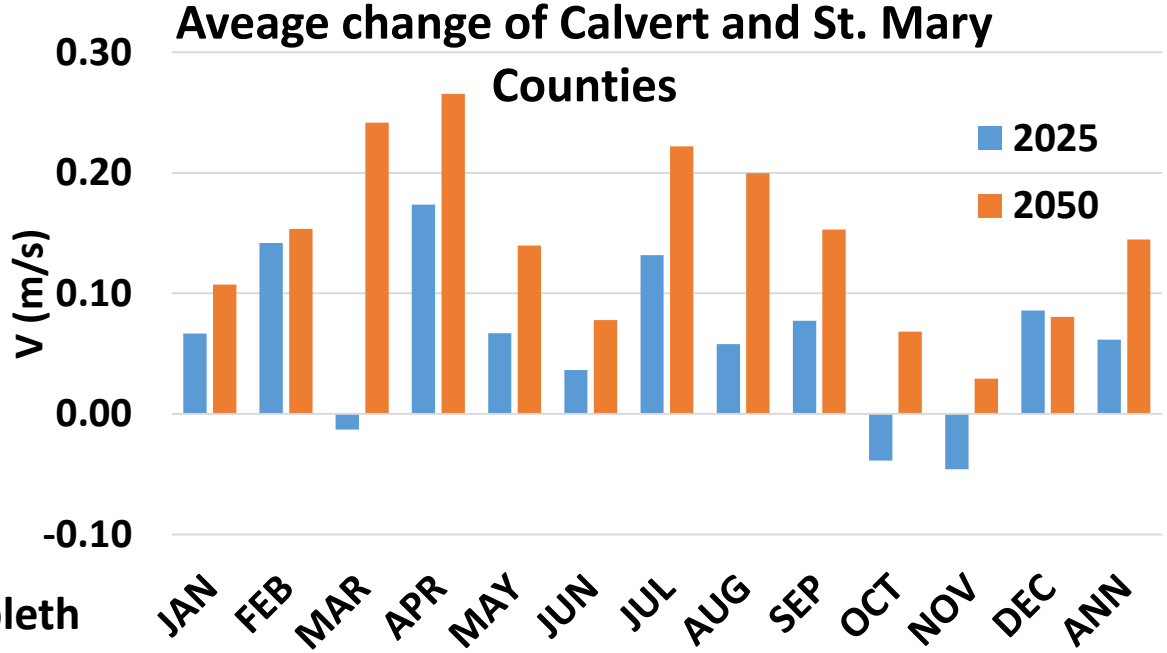



**Scully, 2010**

Table 1. Correlations with Hypoxic Volume

| Hypoxic Volume | Duration of Summer Wind | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | N | NE | E | SE | S | SW | W | NW |
| < 2 mg/L | 0.00 | 0.08 | 0.18 | -0.49* | -0.37* | 0.04 | 0.69* | 0.32* |
| < 1mg/L | -0.02 | 0.04 | 0.15 | -0.48* | -0.34* | 0.03 | 0.71* | 0.36* |
| < 0.2 mg/L | -0.11 | -0.08 | 0.05 | -0.42* | -0.17 | -0.10 | 0.55* | 0.30 |

* indicates significance at 95% confidence interval.




**Ping Wang: 2m/s during 1 hour did not change the 0 isopleth**

# Messages

- **Temperature is the most sensitive variable in controlling DO under climate change conditions, followed by sea level rise and nutrient loading.**
- **Solubility contribute 50% to temperature effect.**
- **Temperature deteriorates water quality whereas sea level rise improves DO in the deep channel, with combined effect of 1.8% degradation of attainment under the WIP condition.**
- **Future runs in progress: Temperature effect the phytoplankton growth, changes in wind and relative humidity.**
- **Projection for 2035 and 2045.**