Effects of SLR on the seasonal cycle of Chesapeake tidal water temperatures

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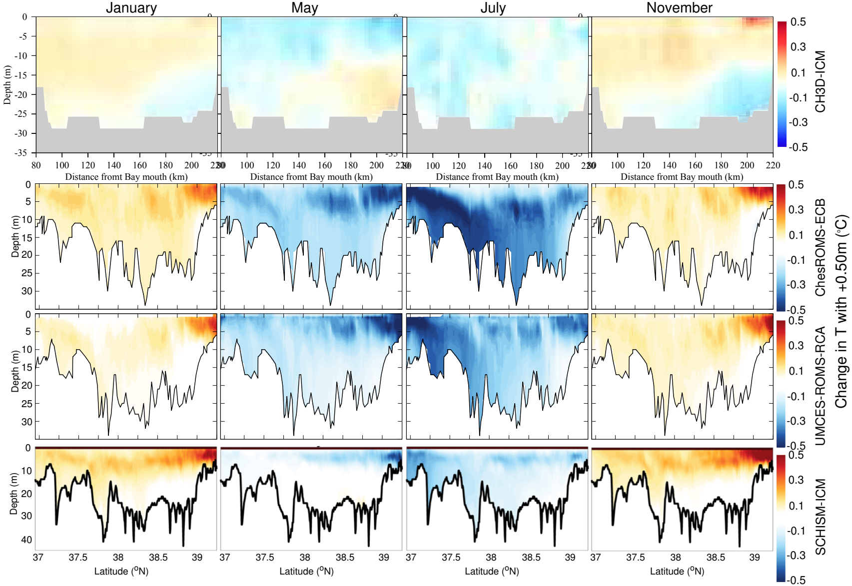
Effect of SLR on the seasonal cycle of T

In October 2019 we presented a model intercomparison on the effects of SLR in the Bay.
The simulations covered the period 1991–1995 with different increases in SL.
SL was the only thing that varied between the experiments (no climate change).

All four models showed slightly warmer T in winter, and slightly cooler T in summer.
We did not investigate the causes of this pattern at the time.

I will be focusing specifically on the case where SL is increased by +1.00 m.
(The outcomes of the analyses are qualitatively the same in the cases +0.17 m and +0.50 m.)

Warmer *T* in winter, Cooler *T* in summer



Change in *T* with +1 m of SL:

$\sim +0.2°C$ in Nov–Jan.

$\sim -0.2°C$ in May–Jul.

Figure from Oct. 2019 report, available at:

`nordet.net/etc/report_slr_october2019.pdf`

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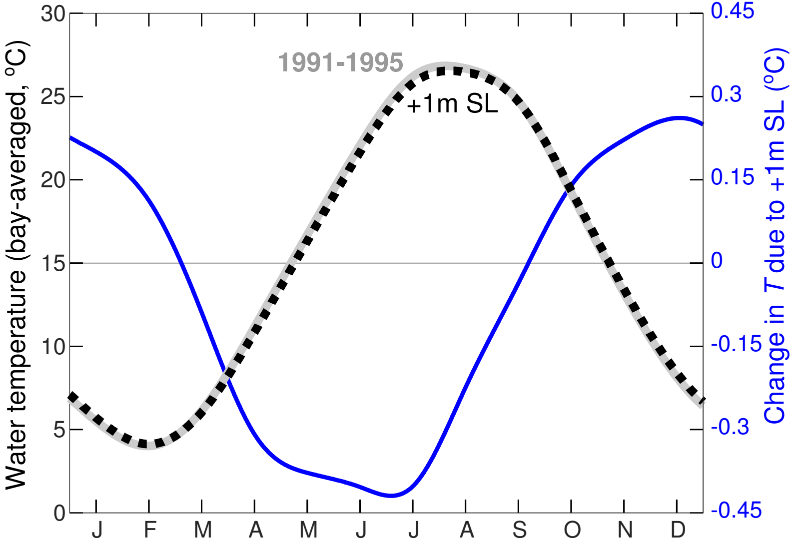

←A different visualization using timeseries:

The seasonal extremes, highest T and lowest T, are not very different.

$\Delta T \approx \sin(t - lag) - \sin(t)$,
i.e.,
the Bay appears slower to warm up after March, and slower to cool down after September.

Can we determine why?

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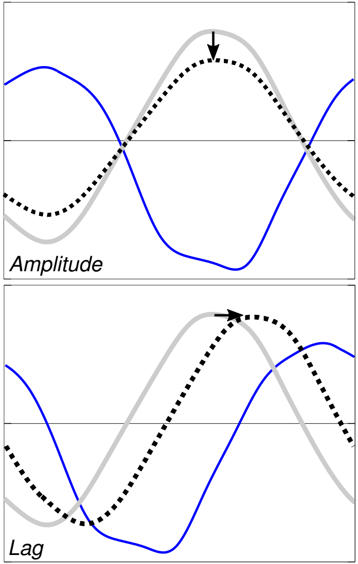

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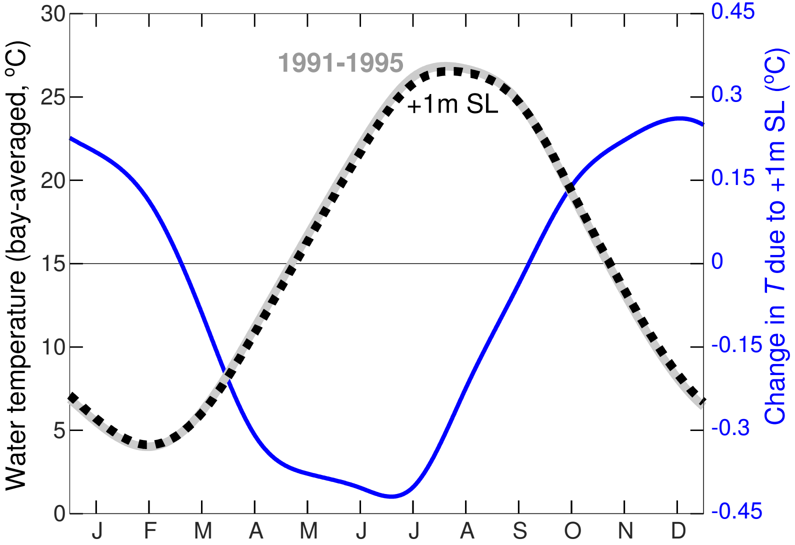

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Why is the seasonal cycle different?

The model diagnostics allow us to build a heat budget of the form:

$$\overline{\frac{\partial T}{\partial t}}(t) = \left[O + R + A\right] V^{-1}, \quad (1)$$

where:

- $\overline{\partial T / \partial t}$ is the bay-averaged water temperature tendency ($^\circ$C s^{-1}),
- O is the heat exchange with the Ocean at the mouth of the Bay ($^\circ$C m^3 s^{-1}),
- R is the heat coming in from the Rivers ($^\circ$C m^3 s^{-1}),
- A is the heat exchange with the Atmosphere ($^\circ$C m^3 s^{-1}),
- V is the volume of the Bay (m^3).

How to interpret the budget: $\overline{\partial T / \partial t}$ can be explained by the combination of O, R, A.
We examine the magnitude of O, R and A for the *Control experiment* in the next slide.

(Analysis focuses on 1 of 4 models (ChesROMS-ECB) because I had all the diagnostics in hand.)

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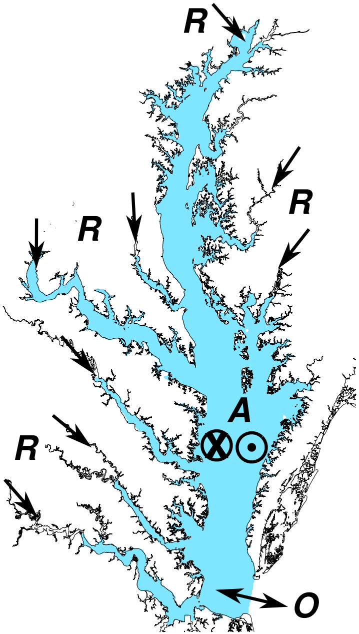

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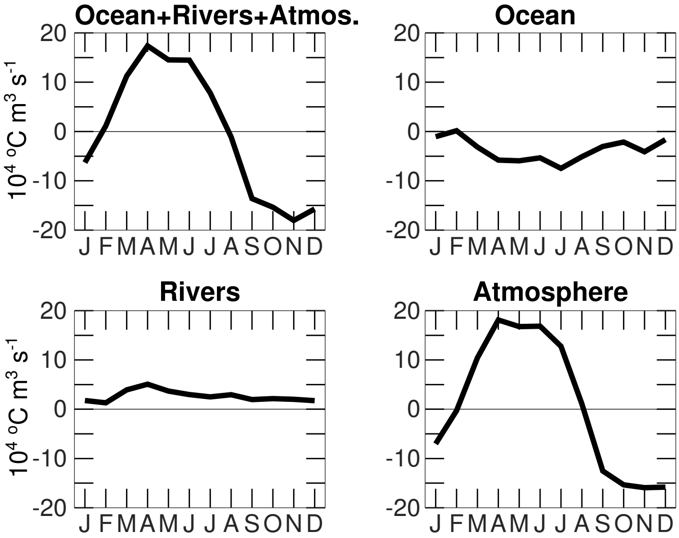
Heat exchanges with the Ocean, Rivers and Atmos. (Control)



This is for the Control experiment, years 1991–1995:

Bay gains heat during Feb–July, loses heat during Aug–Jan.

Exchanges at the mouth of the Bay are a loss of heat for the Bay.

Rivers represent a small input of heat.

Atmosphere dominates the heat fluxes.
It is primarily responsible for the seasonality of T.

Heat budget in presence of SLR

Control experiment (no SLR):

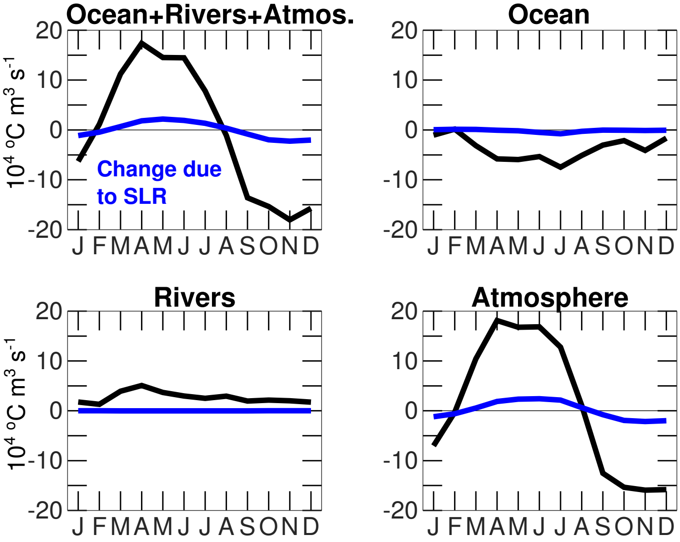
$$\overline{\frac{\partial T}{\partial t}}(t) = \left[O + R + A\right] V^{-1},$$

and we define a similar equation for the model scenario with +1 m of SL:

$$\left.\overline{\frac{\partial T}{\partial t}}\right|_{\text{slr}}(t) = \left[O_{\text{slr}} + R_{\text{slr}} + A_{\text{slr}}\right] V_{\text{slr}}^{-1}. \quad (2)$$

Is the “summer cooling” caused by changes in the heat fluxes? (O, R, A)
Or is it due to changes in the Bay’s volume? (V)

Changes in heat fluxes due to SLR



Changes in O,R,A are small, i.e.,
$O + R + A \approx O_{slr} + R_{slr} + A_{slr}$.

Moreover, in March–July,
$O_{slr} + R_{slr} + A_{slr} > O + R + A$

This, by itself, would produce a *warmer summer*.

Let's turn our attention to the role of V.

Changes in the Bay's volume due to SLR

Control experiment (no SLR):

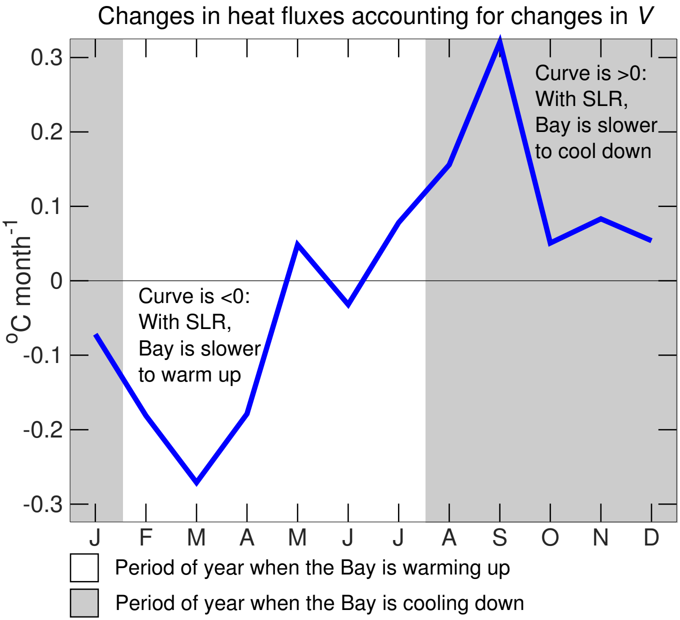
$$\overline{\frac{\partial T}{\partial t}}(t) = \left[O + R + A\right] V^{-1}$$

Case with +1 m of SLR:

$$\left.\overline{\frac{\partial T}{\partial t}}\right|_{\text{slr}}(t) = \left[O_{\text{slr}} + R_{\text{slr}} + A_{\text{slr}}\right] V_{\text{slr}}^{-1}$$

$V \sim 77\,\text{km}^3$ in 1991–1995, versus $V_{\text{slr}} \sim 87\,\text{km}^3$ when SL +1 m.

Next slide: $\left[O_{\text{slr}} + R_{\text{slr}} + A_{\text{slr}}\right] / V_{\text{slr}} - \left[O + R + A\right] / V$,
(i.e., the change in the overall heat flux, but this time, taking into account the change in V.)



$$\left[O_{slr}+R_{slr}+A_{slr}\right]/V_{slr}-\left[O+R+A\right]/V$$

Summary

- SLR introduces a small lag in the seasonal cycle of T.
- The heat fluxes (O, R, A) do not change much with SLR,
and the way they change cannot explain the summer cooling.
- It is only when we take into account the change in volume
that we obtain a "summer cooling".
- Ming Li: Change in V means a change in the *thermal inertia* of the Bay.
With SLR,
Bay is slower to cool off during Fall ($\rightarrow$ warmer winter),
Bay is slower to warm up during Spring ($\rightarrow$ cooler summer).