Impacts of Sea Level Rise on Hypoxia—A Model Intercomparison

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Objectives:

Review Section 5.3.1 Deep Water Hypoxia Response to Sea Level Rise:

"Clear and unambiguous validation of the effect of sea level rise on dissolved oxygen is impossible because of the absence of observational data. There is, however, the opportunity to compare the WQSTM results to the results of other models with equivalent sea level rise (SLR) projections, as well as to evaluate them relative to what would be expected with theory. A model intercomparison was conducted by Pierre St-Laurent under the direction of Dr. Marjorie Friedrichs at the Virginia Institute of Marine Science for the impacts of SLR on hypoxia over the period 1991-1995. Four scenarios were considered: a base case with historical sea levels and cases where the sea level is raised by 0.17m, 0.50m, and 1.00m (roughly representative of years 2025, 2050, and 2100, respectively). All aspects other than the sea level (e.g., atmospheric conditions, oceanic temperatures, and salinity) were kept the same across the four scenarios. Four Chesapeake Bay models (covering a spectrum of model resolutions, boundary conditions, and numerical algorithms) were considered: WQSTM/CH3D-ICM, ChesROMS-ECB, UMCESROMS-RCA, and SCHISM-ICM."

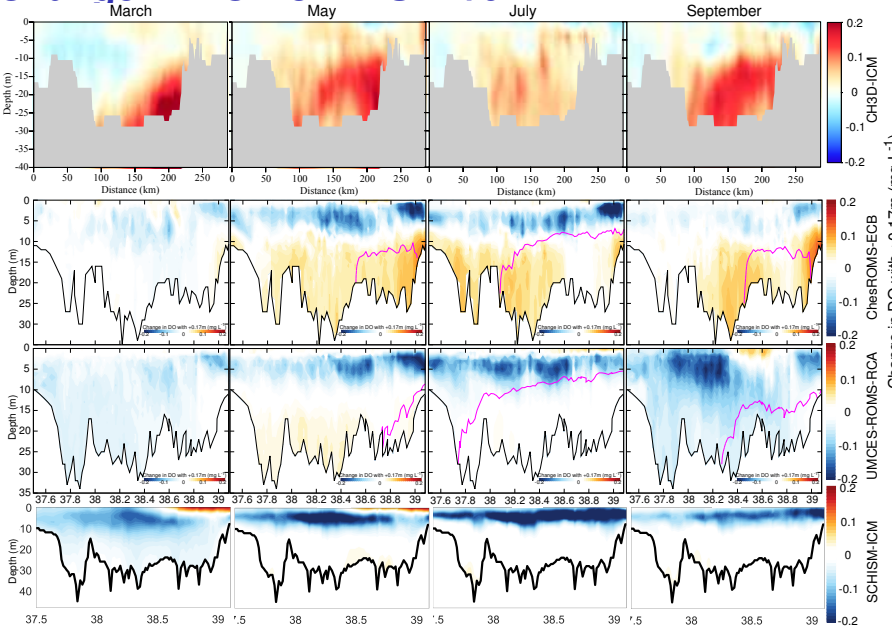
Objectives *(continued)*:

Review Section 5.3.1 Deep Water Hypoxia Response to Sea Level Rise:

"All four models exhibited some increases in DO concentrations in the bottom layer of the Bay's thalweg (a channel 25-30m deep aligned south-north that follows the main stem of the Bay) where hypoxia/anoxia is most prevalent (Figure 5-22). This improvement in bottom DO tended to be concentrated in the summer season and increased quasi-linearly with SLR. However, the absolute magnitude and duration of this improvement in summertime bottom DO varied substantially between the four models."

Changes in DO caused by ΔSL

Change in DO from ΔSL=+0.17m



For a sea level of +0.17m. . .

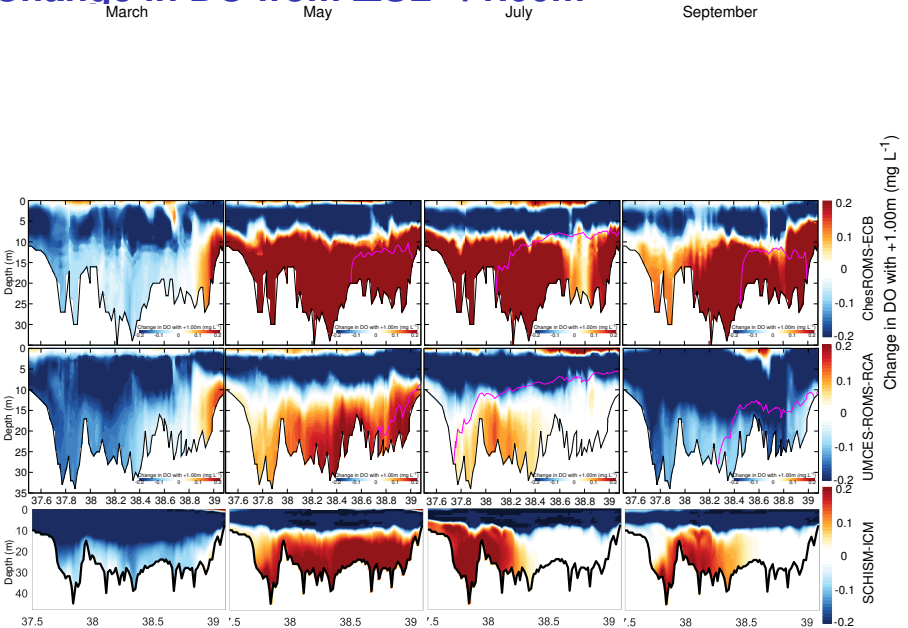
Less DO in upper 10m.

More DO below 10m: CH3D-ICM, ChesROMS-ECB.

UMCES-ROMS-RCA: Mixed response.

SCHISM-ICM: No visible improvement in bottom DO.

Change in DO from ΔSL=+1.00m



Patterns above/below 10m are amplified.

All the models show improvements in bottom DO in May–July.

The DO>0 **persists** in ChesROMS-ECB and SCHISM-ICM.

UMCES-ROMS-RCA: DO>0 disappears.

Mechanisms leading to $\triangle$DO in the deep channel

One way to look at the question: In the bottom layer of the deep channel,

$$\frac{\partial \text{DO}}{\partial t} \approx \text{DO } \textit{Transport} - \textit{Respiration}, \tag{1}$$

where "DO Transport" represents the net effect of DO advection/diffusion and is assumed > 0. No "production" in this bottom layer.

During the summer, Respiration $>$ DO Transport, and thus $\partial \text{DO}/\partial t < 0$.

An improvement in bottom DO implies that $\partial \text{DO}/\partial t$ is *less negative* with SLR.

This happens if there is: (Eq. 1)

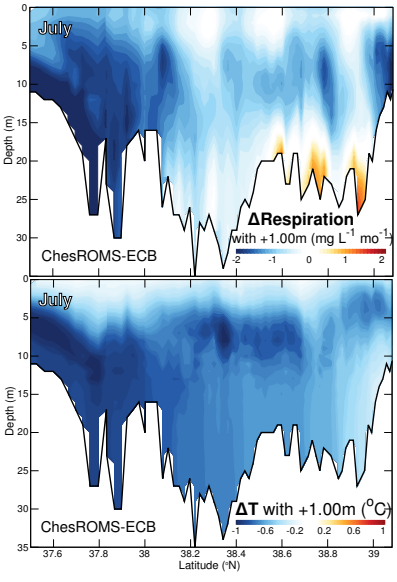
- **More** DO Transport,
- **Less** Respiration.

Mechanisms leading to ΔDO in the deep channel

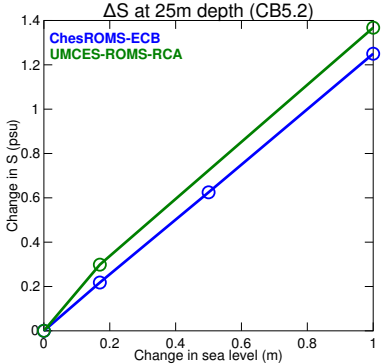
We find in ChesROMS-ECB that:

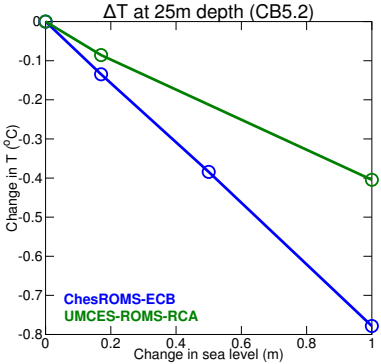
- **Less Respiration** is the cause of the improvement in bottom DO within the deep channel.
- The improvement is not caused by an increase in “DO Transport”.

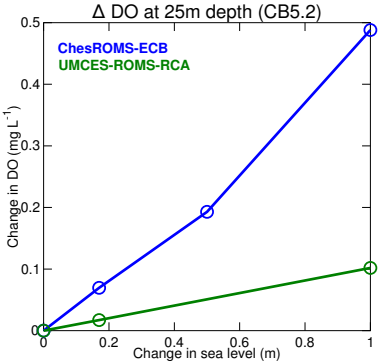
Not surprising: Respiration rates depend on T, and T is lower during summer with ΔSL.



Linearity of response to ΔSL







Changes in the bottom layer of station CB5.2 (deep channel, just north of Potomac River):

- $S \nearrow$, $T \searrow$, DO$\nearrow$
- Changes are very close to being linear with ΔSL.

Summary

1. All models reproduce the observed summer DO reasonably well.
2. There is considerable agreement in how SLR affects S, T (models are quantitatively close).
3. All models show *some* improvement in the bottom DO of deep channel.
   Models disagree in the magnitude/duration of this improvement:
   UMCES-ROMS-RCA $<$ SCHISM-ICM $<$ ChesROMS-ECB $<$ CH3D-ICM
4. Solubility cannot explain the improvements in bottom DO: ΔS offsets ΔT.
5. DO worsens in the upper $\sim$ 10 m of the water column but the changes are relatively smaller.
6. Summer cooling and decreased respiration cause the improvement in ChesROMS-ECB.
7. We are testing quantitatively whether differences in ΔT among models are the cause of the disagreement in the magnitude/duration of DO improvements.
8. Changes in S, T,DO are $\approx$ linear with ΔSL.