Impacts of Sea Level Rise on Hypoxia—progress report

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Overview

We are investigating the impacts of sea level rise (SLR) on hypoxia using different models of the bay.

The experiments assume realistic conditions for the period **1991–1995** and use the same riverine forcing (Phase-6 CXXBASE).
We consider four scenarios:

1. No SLR: base run / control
2. SL raised by 0.17 m at the oceanic model boundary (2025)
3. SL +0.50 m (2050)
4. SL +1.xx m (2100)

Experiments completed / ongoing

Model ChesROMS-ECB:

- Control 1991–2000
- +0.17 m 1991–2000

Model UMCES-ROMS (physics) + RCA (biology):

- Control 1991–1995 (physics)
- Control 1991–1995 (biology)
- +0.17 m 1991–1995 (physics)
- +0.17 m 1991–1995 (biology)

Model SCHISM:

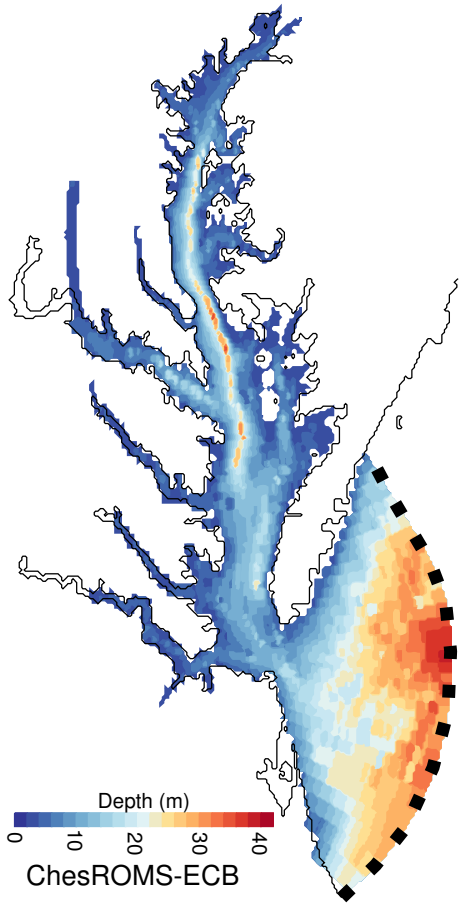
- Control 1991–1995 (physics)
- Control 1991–1995 (biology) (**ongoing**)
- +0.17 m 1991–1995 (physics) (**ongoing**)

We will analyze the +0.17m scenario fully before moving on to +0.50 m and +1.xx m.

Questions raised in previous conference calls

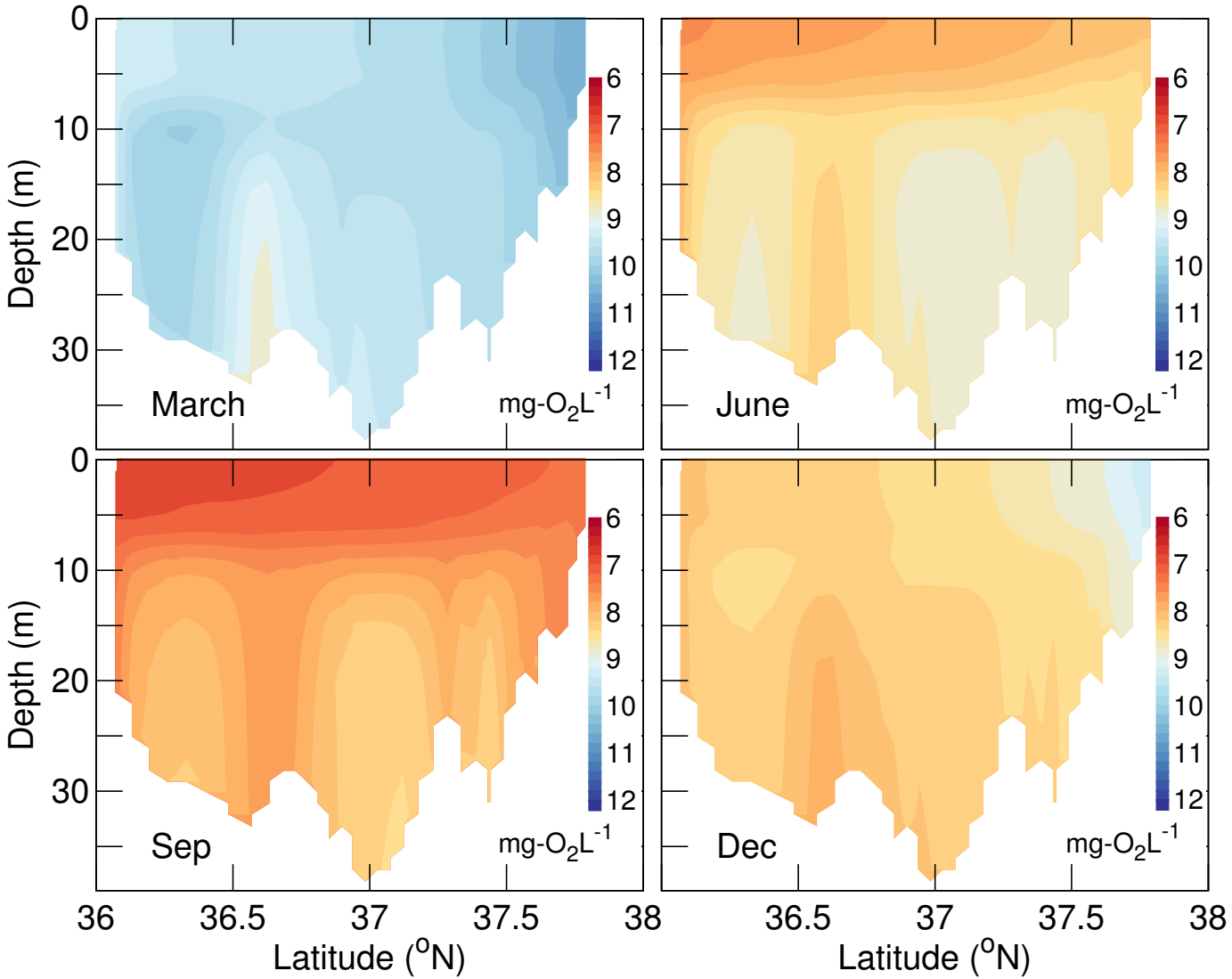
At the Modeling Workgroup Quarterly Review (Feb.19, 2019), Richard asked whether the models used similar conditions at their oceanic boundary (on the continental shelf). Wenfei Ni (UMCES, student of Ming Li) confirmed that the two ROMS models use either the same or very similar conditions for:

- sea level (tidal and non-tidal variability),
- salinity and temperature,
- DIN and DON.



For dissolved oxygen (DO), UMCES-ROMS-RCA assumes a constant concentration of 12 mg L^{-1} at the oceanic boundary. ChesROMS-ECB assumes that DO is at saturation, i.e. DO varies in space and time following the temperature and salinity prescribed at the boundary.

DO at the oceanic boundary of the models



ChesROMS-ECB assumes a seasonal climatology of T,S (and therefore DO_{sat} too) at the oceanic boundary.

The climatological DO_{sat} is $< 12\,\text{mg L}^{-1}$ all year long.

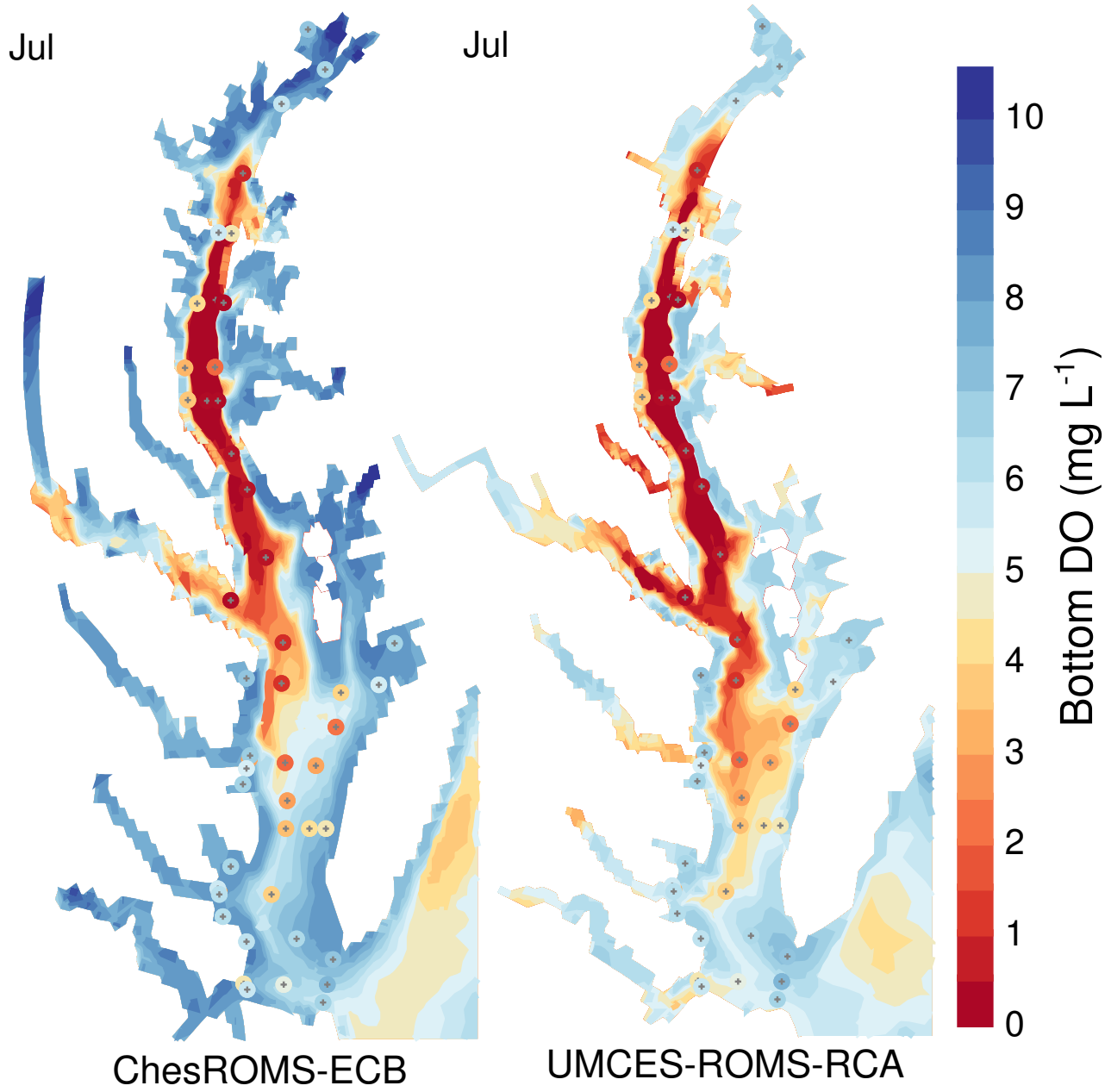
DO at the oceanic boundary of the models

However, this difference has little impact on the models behavior inside the bay.

At the mouth of the bay, the two models have similar DO.

In the lower bay, ChesROMS has higher DO than RCA (i.e., the opposite of the previous slide).

(The figure is bottom DO averaged over July 1991–1995.)

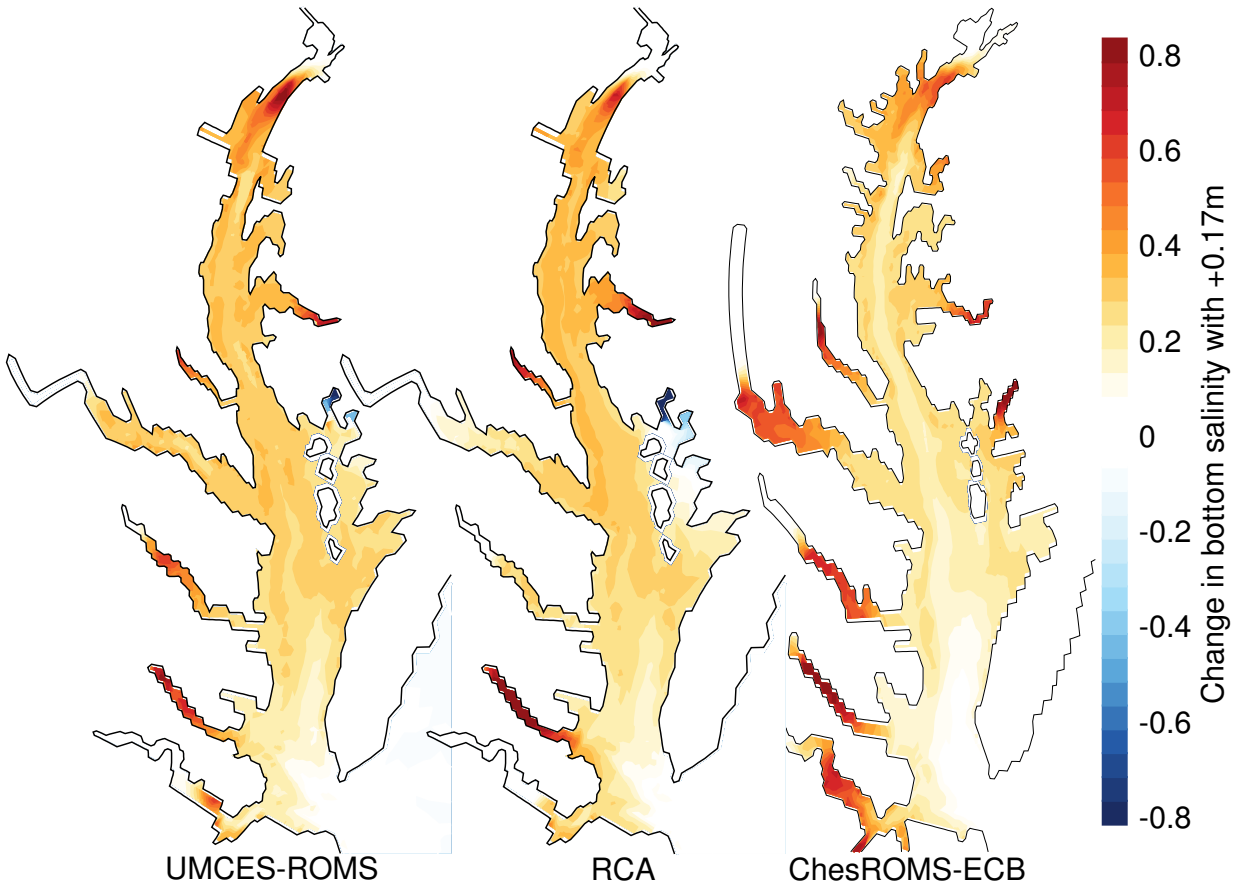


Model response to ΔSL = +0.17m

Another question concerned the use of separate models for the physics and biology (with, e.g., different algorithms for advection+diffusion). It appears that RCA (biology) produces a salinity field that is substantially fresher than UMCES-ROMS (physics).

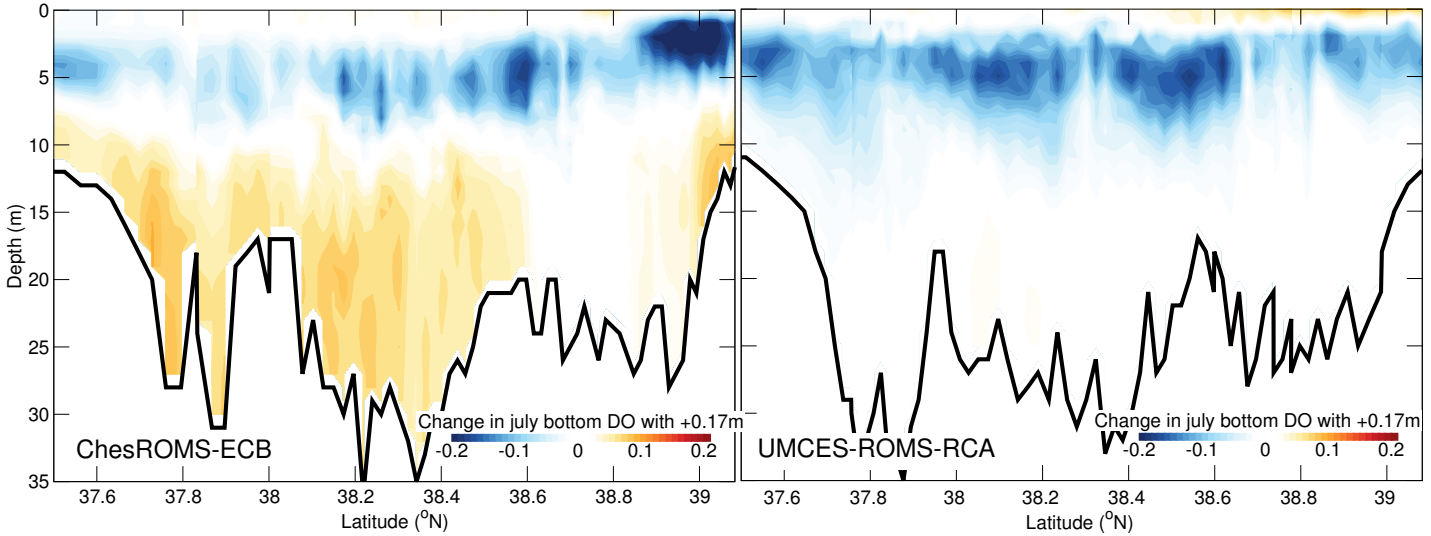
On the other hand, we find that these differences are not overly important when we focus on the effects of SLR (i.e., anomalies).

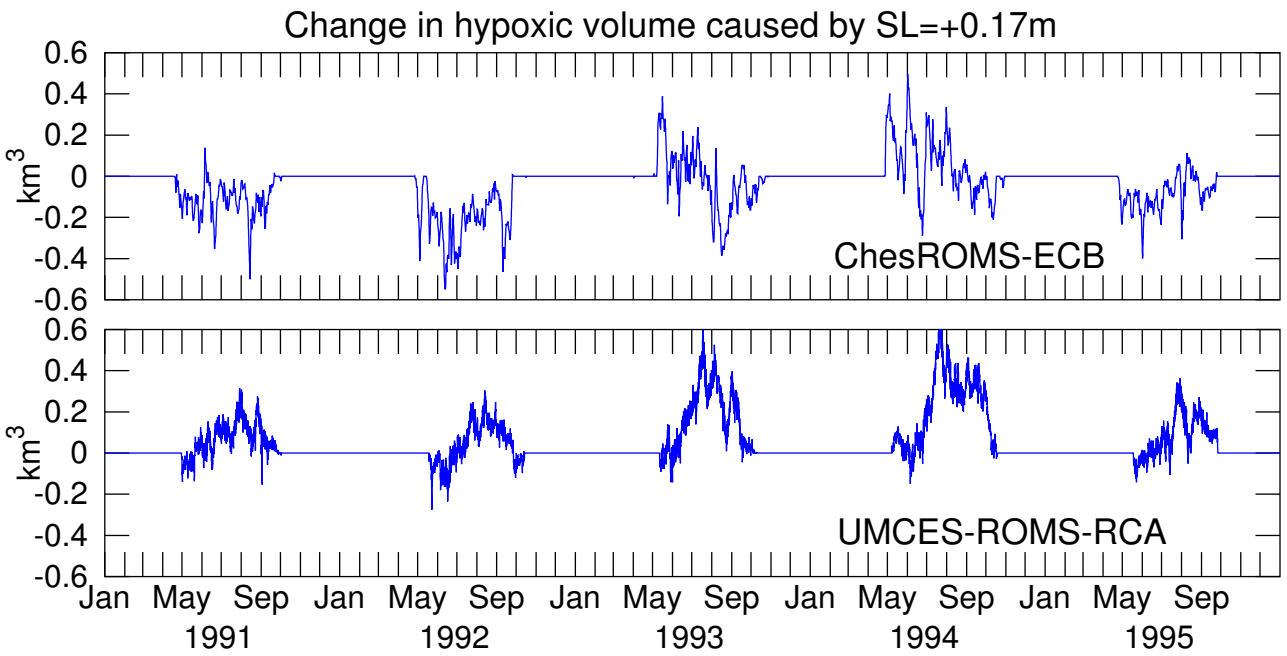
All three models (UMCES-ROMS, RCA, ChesROMS-ECB) show the same increase in bottom salinity, $\Delta S \approx +0.3$ psu, in response to a sea level rise of 0.17 m:



Model response to ΔSL = +0.17m

In the last conf.call, we saw that both ROMS models predict lower DO at 5m depth. In the bottom layer, their response differs:





The figure above is an average over 1991–1995. It is interesting to also look at the interannual variability from the two models:

Model response to ΔSL = +0.17m

Table: Change in annual hypoxic volume (AV) caused by $\Delta SL = +0.17\,\mathrm{m}$ (**ChesROMS-ECB**)

Year	AV km^3 day	ΔAV km^3 day	ΔAV %
1991	715	-18	-3
1992	447	-32	-7
1993	1309	-4	0
1994	1169	$+11$	$+1$
1995	420	-13	-3

Table: Change in annual hypoxic volume (AV) caused by $\Delta SL = +0.17\,\mathrm{m}$ (**UMCES-ROMS-RCA**)

Year	AV km^3 day	ΔAV km^3 day	ΔAV %
1991	982	$+10$	$+1$
1992	780	$+6$	$+1$
1993	1290	$+25$	$+2$
1994	818	$+36$	$+4$
1995	640	$+11$	$+2$

- The changes in hypoxic volume are relatively small, typically a few %.
- Nevertheless, the two models predict the opposite change for 3/5 years.
- This is thus a robust result whose cause should become clear as we continue to analyze the model outputs.

Next steps

- A budget for DO over the main stem would probably be very useful. Such a budget would highlight the differences in horizontal transport (estuarine circulation) and how they affect the bottom DO of the two models. This work is underway.
- We may also conduct additional experiments to test specific hypotheses. E.g., we can evaluate the role of the vertical mixing parameters and how they may contribute to the differences.
- Simulate the cases +0.50 m and +1.xx m (2050 and 2100, resp.)
- Investigate the linearity of the response to SLR
  (and potential complications)
- SCHISM: Follow-up with Joseph's team once their runs are completed.

Appendix

Mean salinity 1991–1995 (no sea level rise)