Estimates of hypoxic volumes for 1985–2014 + their sensitivity to SLR (preliminary)

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Overview

We conducted two simulations with ChesROMS-ECB over the period 1985–2014 to estimate the hypoxic volume of the Chesapeake Bay:

1. using Phase-6 of the CBP WSM (CFBASE30Y20180615) for the riverine forcing;
2. using DLEM (dataset of 20180525) for the riverine forcing.
3. A third comparison point comes from an interpolation of the oxygen data from WQMP (1985–2014) by A.Bever.

We are also conducting sensitivity experiments to sea level rise (SLR). These experiments are identical to those above but include a fixed increase in sea level (ΔSL) representative of 2025, 2050, 2100. The experiments are ongoing and only preliminary results are available at this time.

(Bever et al. 2013, 2018)

Method: Model ChesROMS-ECB

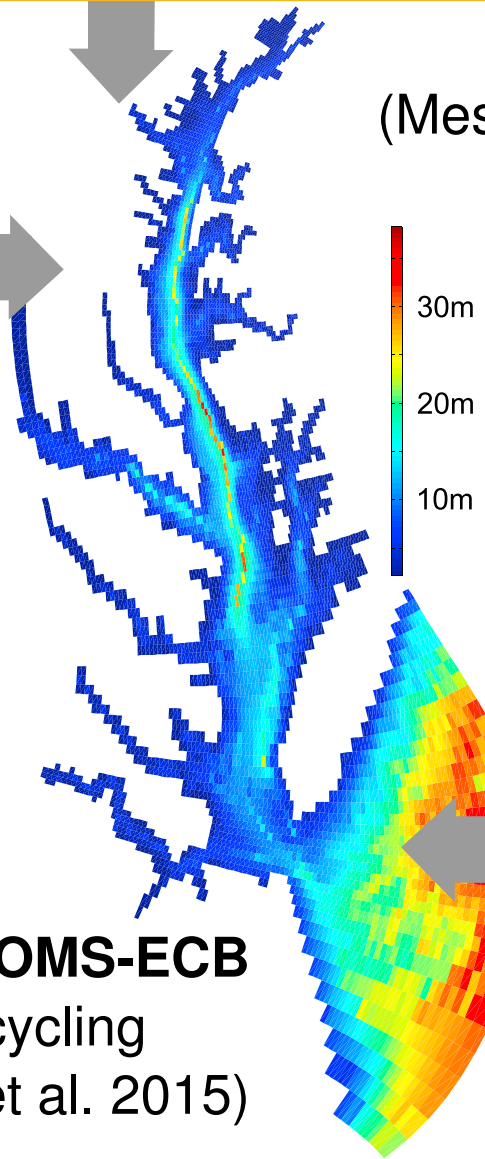
Atmospheric forcing

NARR
(Mesinger et al. 2006)

Riverine inputs

CBP WSM Phase-6
or
DLEM

(Tian et al. 2015
Yang et al. 2015)

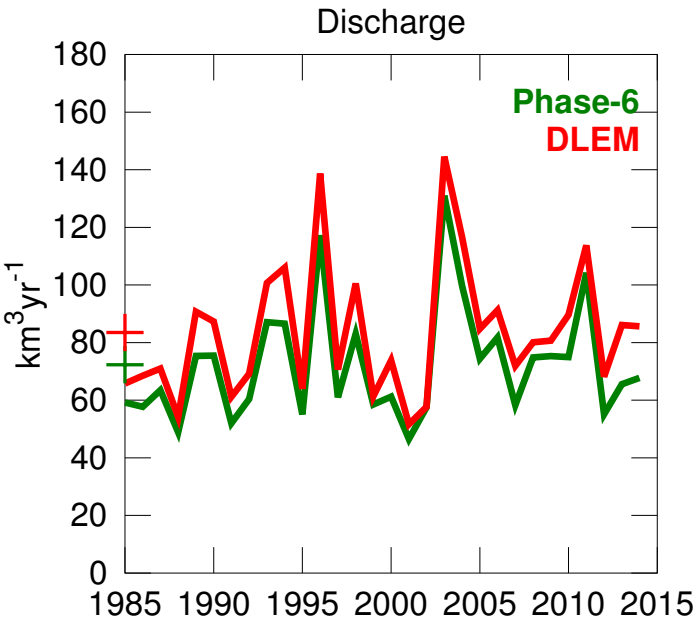


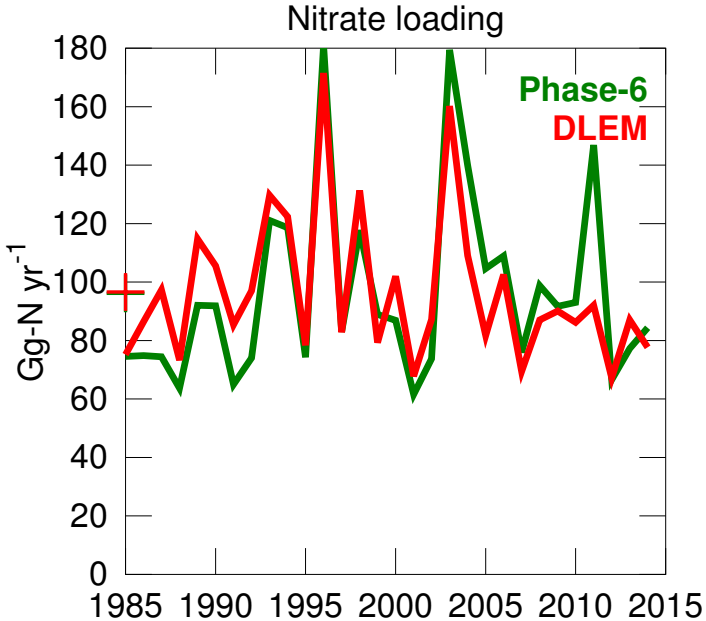
Coastal fluxes

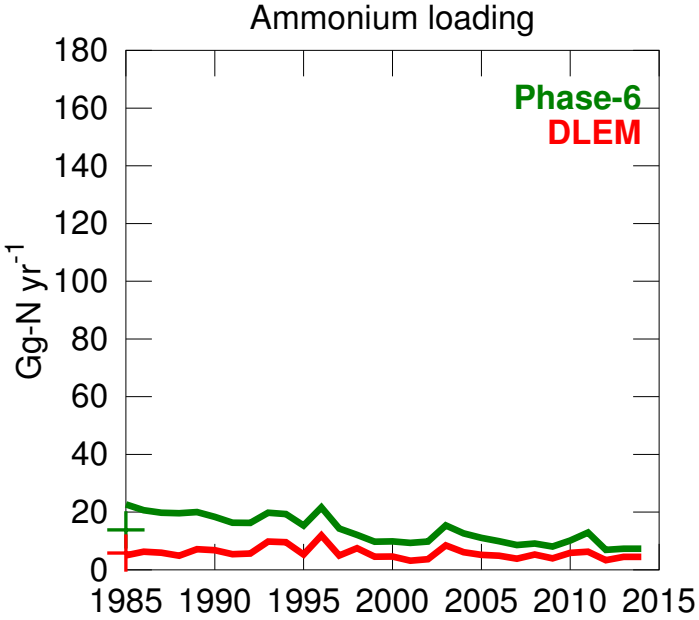
NOAA

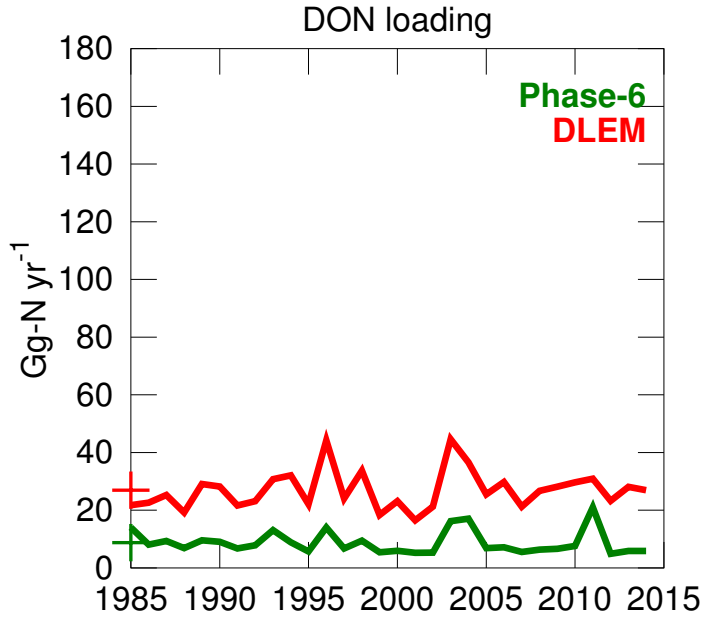
ChesROMS-ECB
C & N cycling
(Feng et al. 2015)

Riverine forcing: Phase-6 vs. DLEM









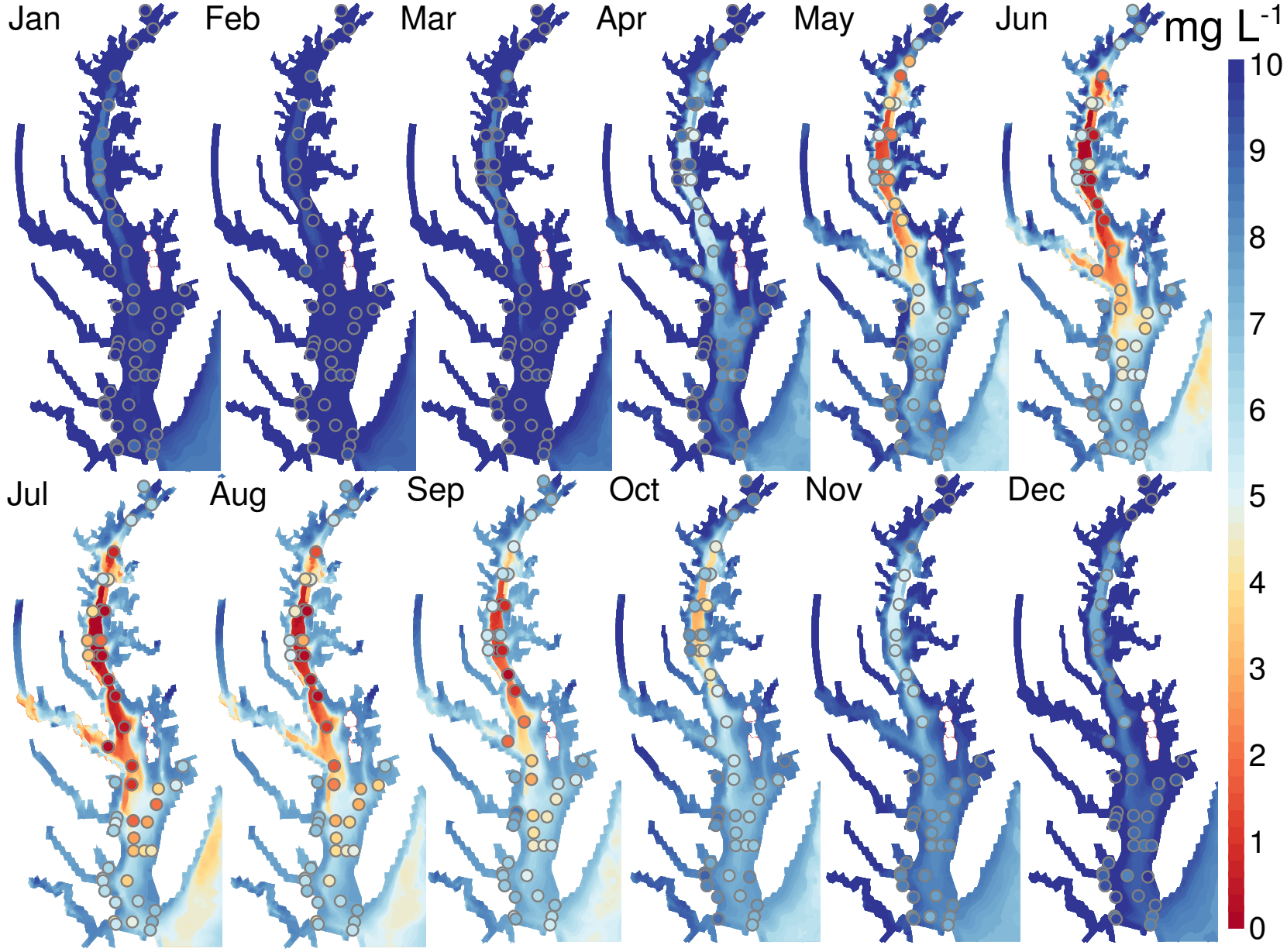
Discharge DLEM 15% > Phase-6

Nitrate: Same mean value; first DLEM > Phase-6 then < Phase-6

Ammonium Phase-6 is more than twice that of DLEM

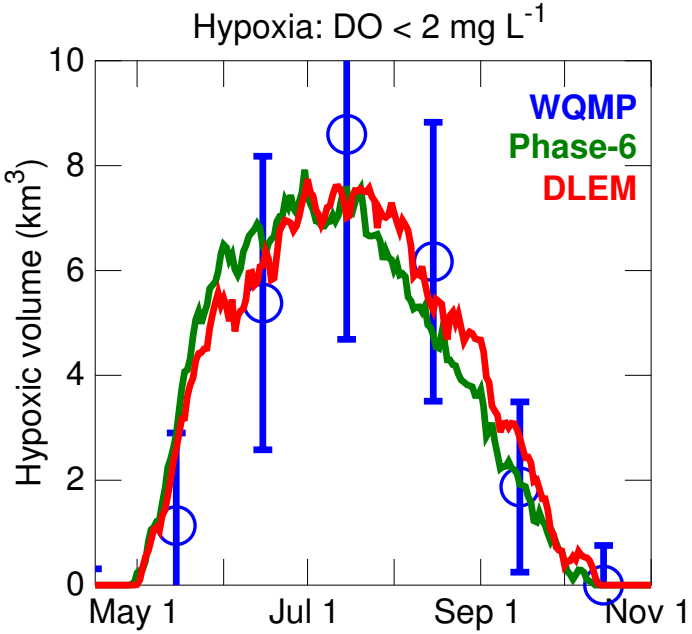
DON DLEM is 3x that of Phase-6

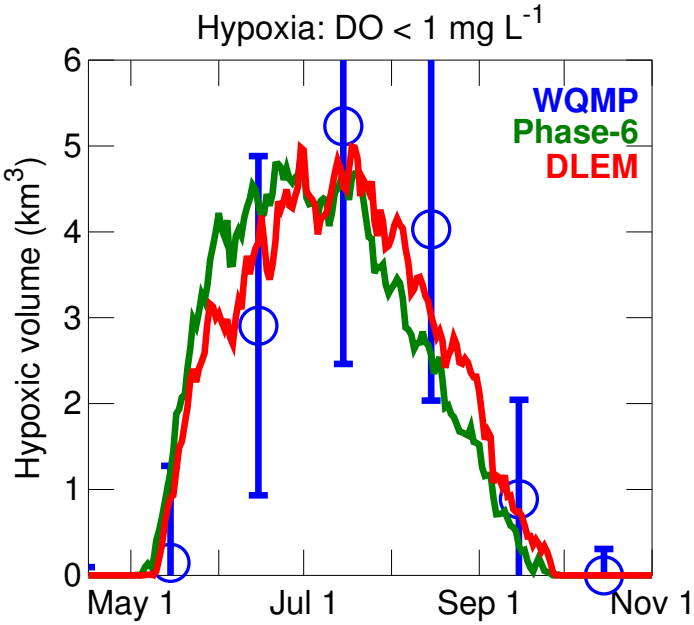
Spatial + Seasonal bott. DO (Phase-6, 1991–1995)

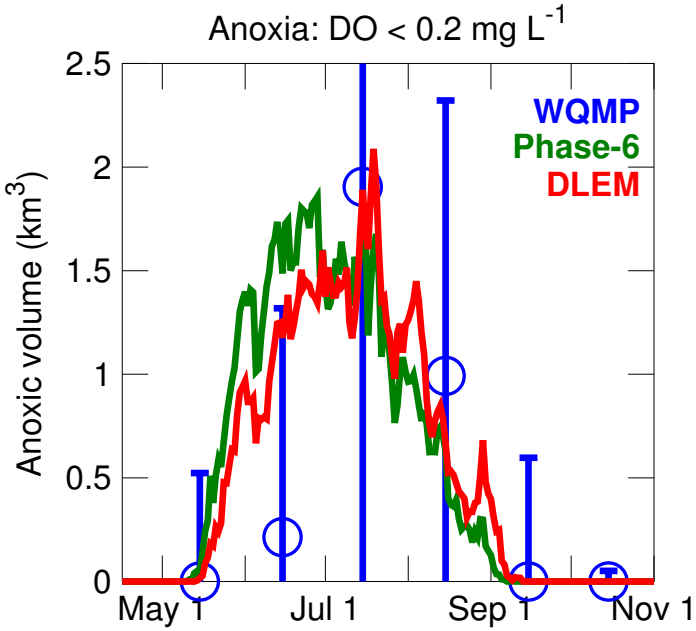


Correct pattern; hypoxia underest. lower Bay Similar pattern with DLEM

Daily hypoxic volume (climatology 1985–2014)



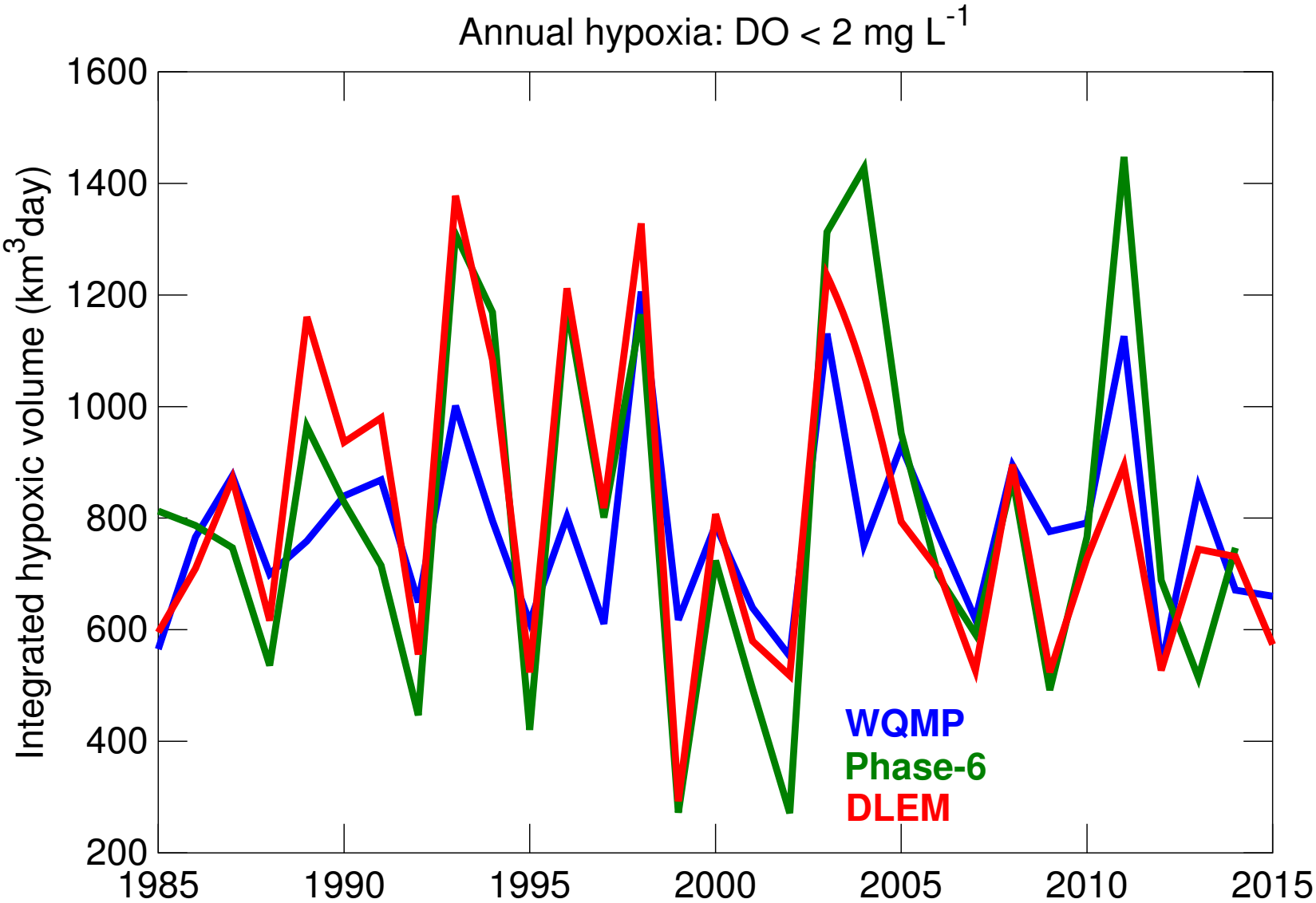




ChesROMS-ECB hypoxia begins slightly early

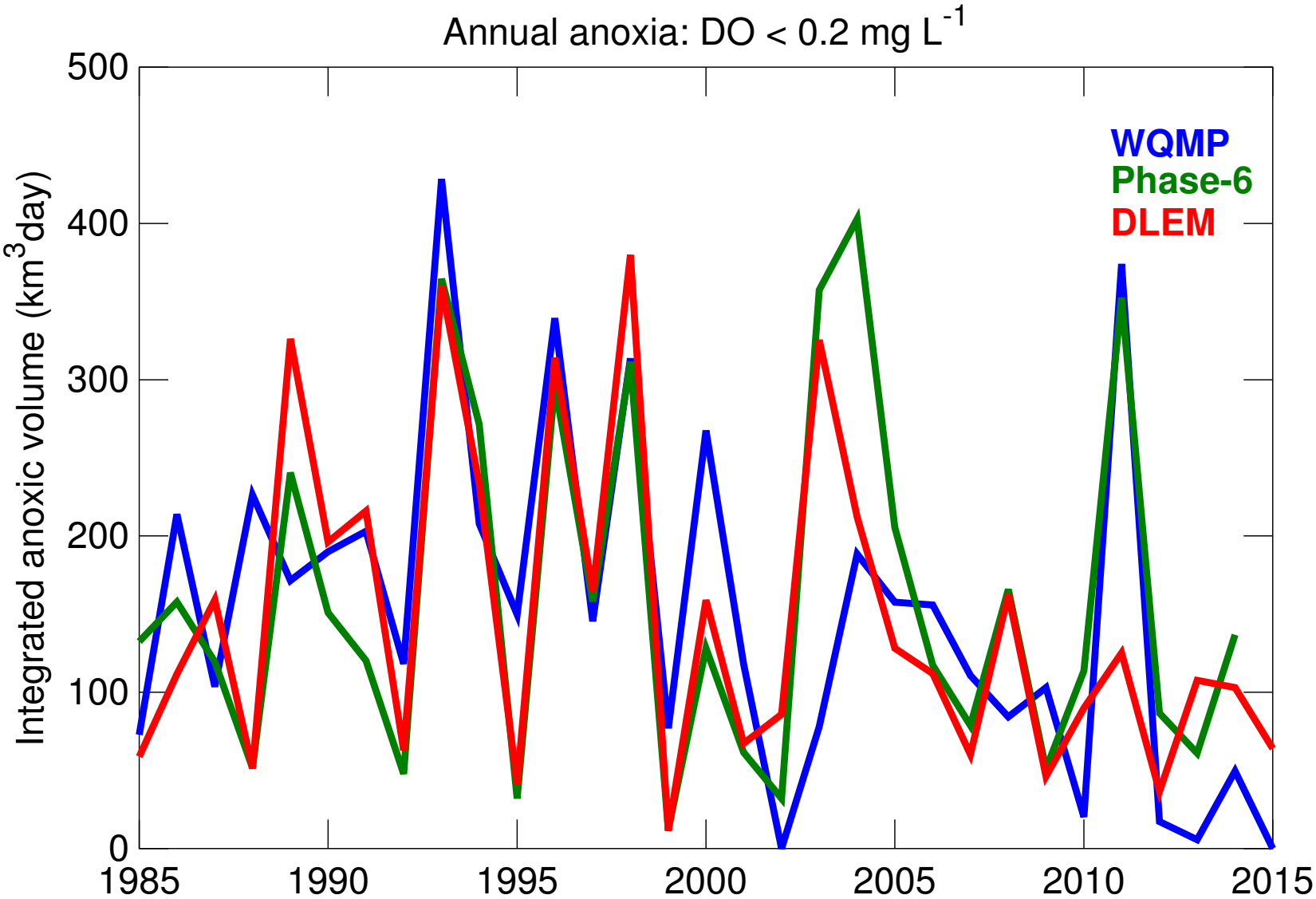
Hypoxia slightly earlier with Phase-6 than DLEM, but similar overall volume

Annual volume



2002, 2004, 2011: Peaks of Phase-6 more pronounced than DLEM

Annual volume



2003: both overestimate; 2011: Phase-6 does well but DLEM is too low

Annual volume

A few observations:

- There seems to be a decreasing trend in anoxia after 2005.
- Correlation between model and data of WQMP is relatively high $\rightarrow$
- Highest correlation can be with Phase-6 or DLEM; depends on threshold.
- In many cases the model overestimates the amplitude of the interannual variations.
- The differences in absolute values between Phase-6/DLEM are smaller than the differences from the observations.

Table: Pearson's correlation (r) when comparing with data of WQMP. All values significant at $p < 0.01$ level.

$DO_{hypoxia}$ mg L^{-1}	Phase-6	DLEM
< 2	0.69	0.76
< 1	0.73	0.81
< 0.2	0.65	0.54

Sensitivity to Sea Level Rise (SLR)

Preliminary analysis of ongoing experiments

Motivation

Similar models of Chesapeake Bay show conflicting results in regard to SLR and hypoxia:

1. CH3D-WQSTM (Ping Wang et al.): SLR improves hypoxia
2. ChesROMS-ECB (Irby, Friedrichs et al.): SLR improves hypoxia
3. UMCES-ROMS-RCA (Wenfei Ni, Ming Li): SLR exacerbates hypoxia

We are currently conducting new simulations with ChesROMS-ECB and UMCES-ROMS-RCA:

- same SLR perturbation,
- same riverine dataset (Phase-6),

to figure out why the models produce different outcomes.

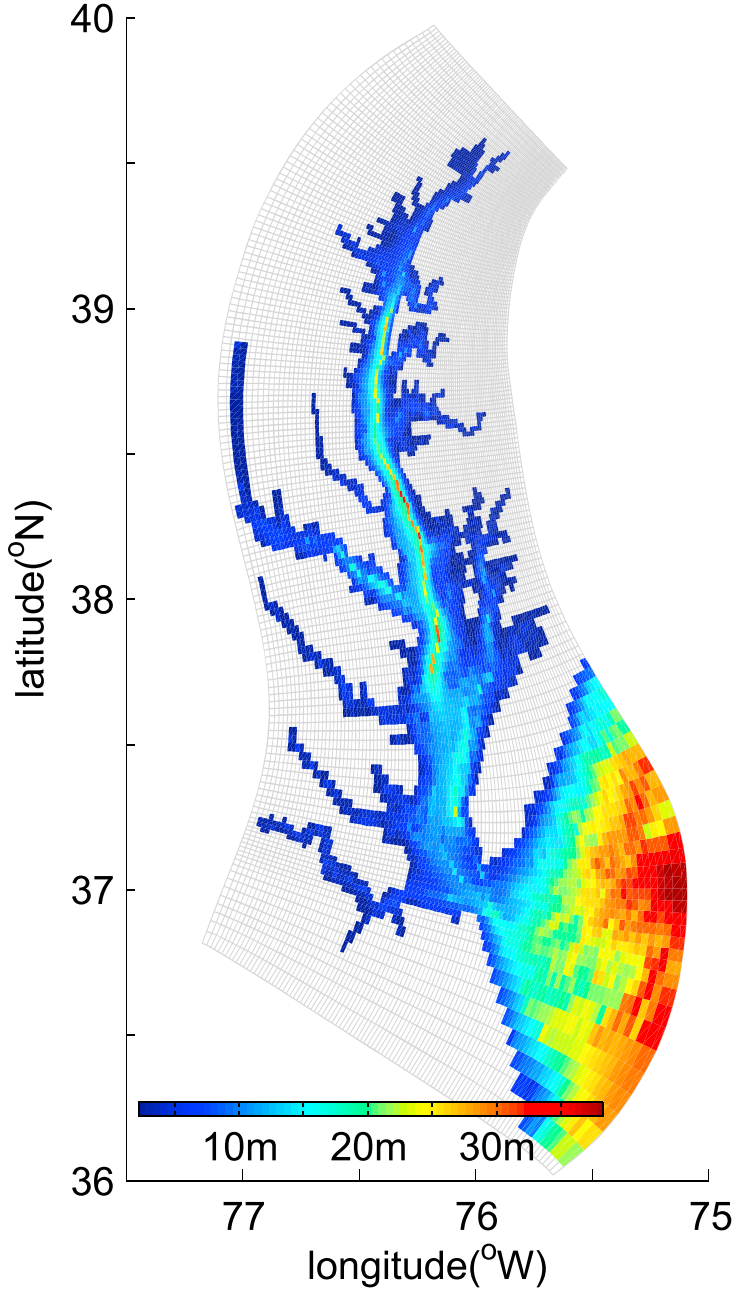
Sensitivity experiment: $\Delta SL = +0.17$ m, 1991–1995

In the next slides I will present results from a sensitivity experiment where the sea level was increased by 0.17 m at the oceanic boundary of the model →

$\Delta SL = +0.17$ m is the estimated change between 1995 and 2025. We use Phase-6 (CXXBASE) as the riverine dataset.

We provide a 5-year period to the model (1986–1990) for it to acclimate to the higher SL, and then analyze the next 5 years (1991–1995).

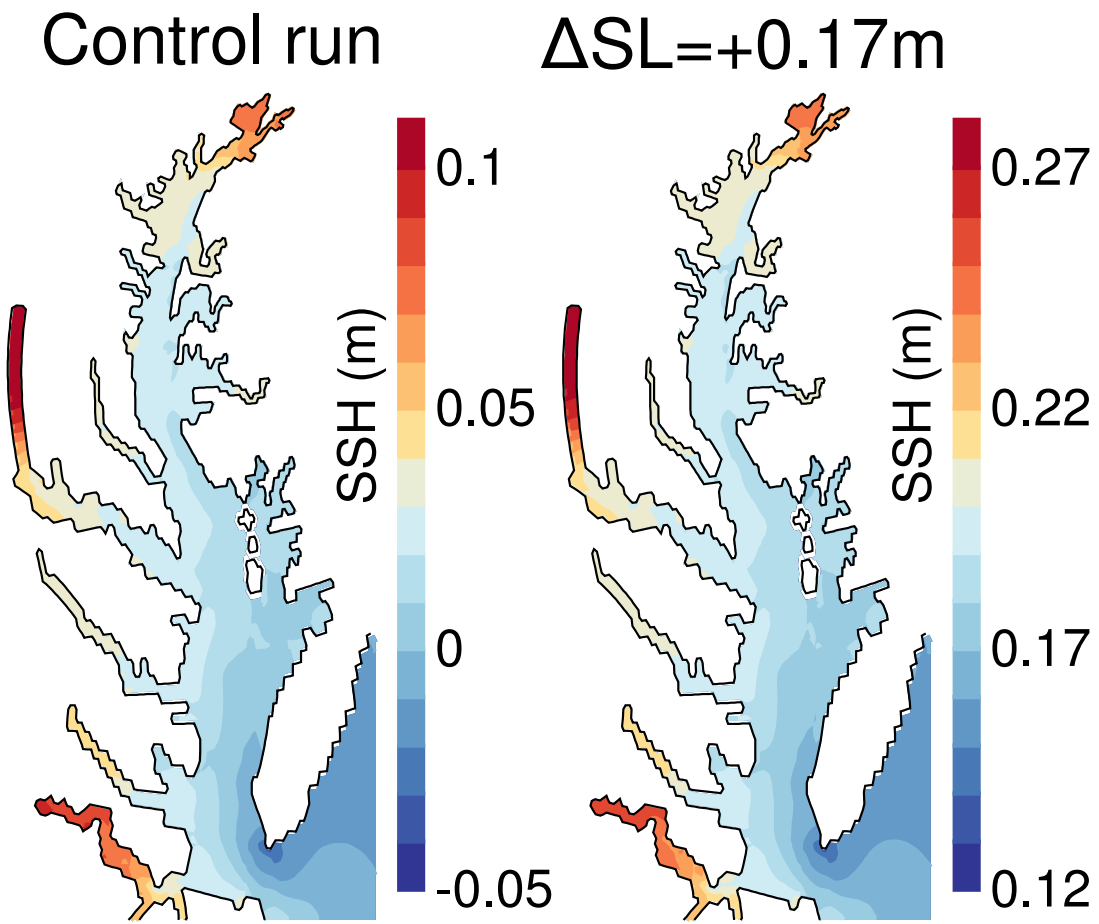
Note that the model setup prescribes monthly climatological S, T, $DO_{sat}(S, T)$ at the oceanic boundary. The same climatology is used in all model runs.



Sensitivity experiment: $\Delta SL = +0.17\,\mathrm{m}$, 1991–1995

These experiments do not attempt to predict the loss of land associated with ΔSL. They assume that the coastlines are armored and unchanged.

The model's response to ΔSL at the oceanic boundary is simply an offset in SL throughout the bay. The gradients in SL and the barotropic circulation are largely unaffected →



Sensitivity experiment: $\Delta SL = +0.17\,\mathrm{m}$, 1991–1995

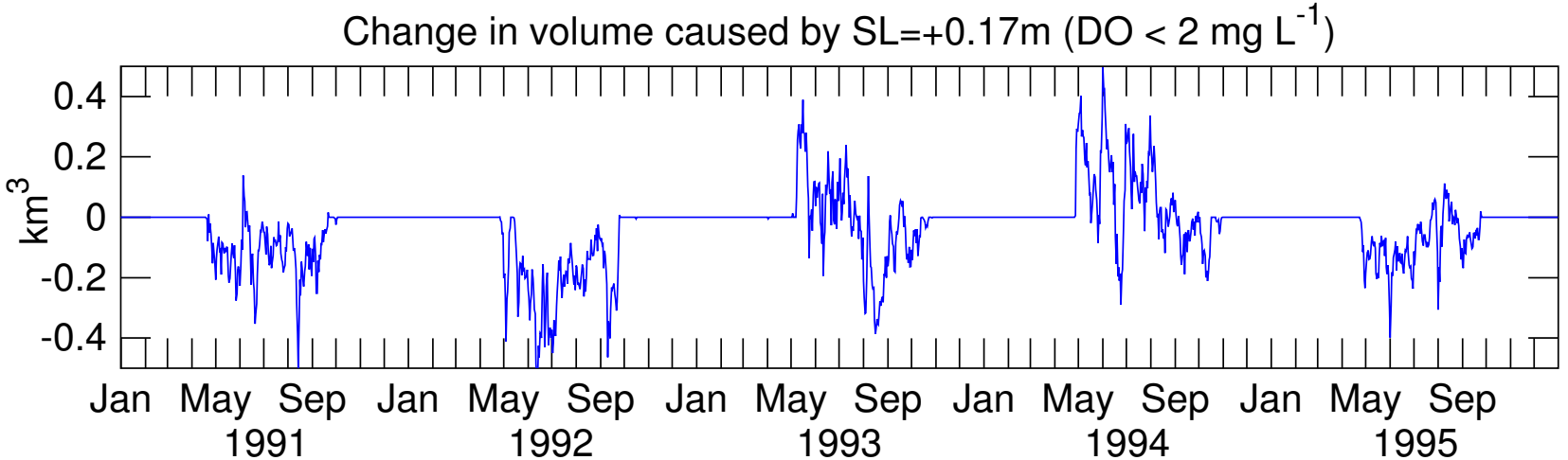
Changes in annual volume are small, $\pm 18\%$ at most, and largest for case $DO < 0.2\,\mathrm{mg\ L^{-1}}$

Less hypoxia in most years, but not all years (see 1994)

Daily timeseries (below): volume is ∼always smaller during 1991,1992,1995.
Years 1993,1994: both + and −

Table: Change in annual vol. (AV) caused by $\Delta SL = +0.17\,\mathrm{m}$ ($DO < 2\,\mathrm{mg\ L^{-1}}$)

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



Conclusions

1. Differences between riverine datasets (Phase-6/DLEM) are $\sim$minor
2. Differences between results obtained with two datasets are smaller than differences from WQMP
3. Model reproduces seasonal variability (timing, extent) and interannual variations ($0.54 < r < 0.81$) quite well with both Phase-6 and DLEM, though interannual $\nearrow$ $\searrow$ are exaggerated
4. Bias (both datasets): hypoxia underestimated in lower bay
5. It is possible that these biases originate from the biogeochemical model rather than the riverine datasets.

Ongoing work

Two ROMS models:

- UMCES-ROMS-RCA
- ChesROMS-ECB

Four model experiments with P6 WSM:

- Base Run for 1991–2000
- Base Run + SL of 2025
- Base Run + SL of 2050
- Base Run + SL of 2100

Analyses:

- Compare hydrodynamics of two simulations (physical terms)
- Compare biological results of two simulations (oxygen budget)
- Compare to model outputs from additional models as time allows (SCHISM, EFDC, WQSTM)