Interdecadal trends and drivers of oxygen in the Northwest Atlantic Shelf

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Introduction and Background

Oxygen content can limit or harm ecosystems and fisheries when concentration becomes too low. Oxygen content in the ocean is declining globally since 1960 (Schmidtko et al., 2017) and at a rate of 0.8 µmol/kg/year in the subsurface water (below 50m) of the Northwest Atlantic Shelf (Figure 1; Nguyen et al, in prep). Deoxygenation here is defined as the loss of oxygen from the ocean. Warming temperatures reduce oxygen solubility, which contributes to deoxygenation. Respiration of organic material can also draw oxygen down. It is unclear whether this deoxygenation trend will continue in the future, and what mechanisms are responsible for this trend on the NWA Shelf.

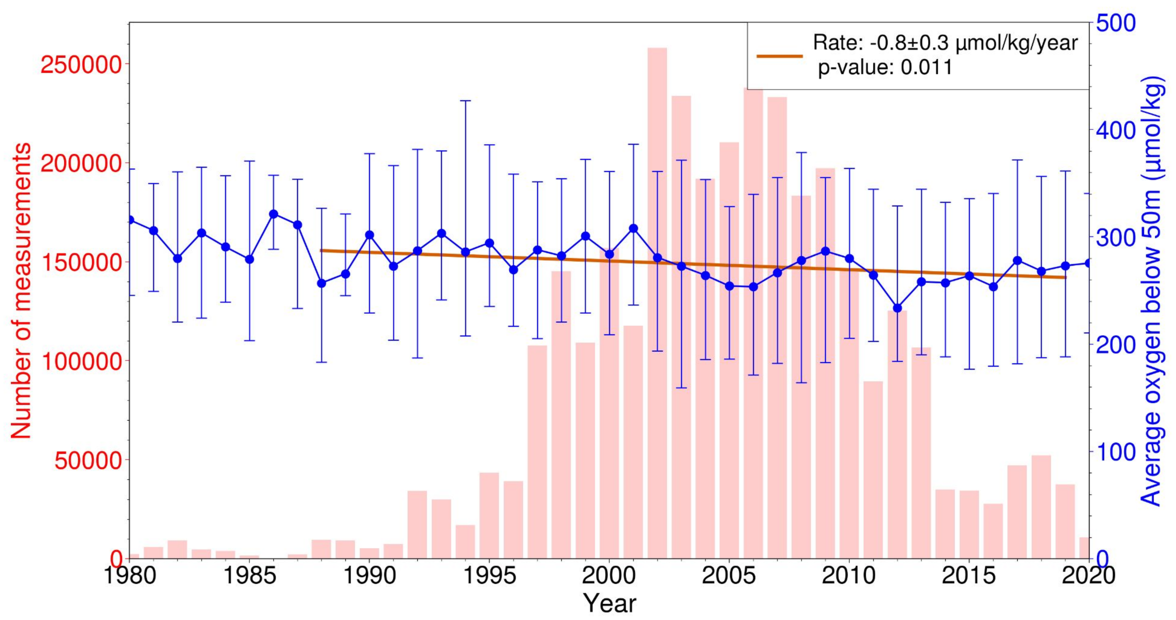

Figure 1: The number of oxygen measurements and annual average oxygen in the NWA Shelf below 50m, with the linear trend from 1988 to 2019 (Nguyen et al., in prep)

Methods: Model Description

Oxygen simulations from Northwest Atlantic Regional Modular Ocean Model (NWA-MOM6) coupled with COBALT (Figure 2, Stock et al. 2014) - a biogeochemical model that includes oxygen and had been previously evaluated in the region (Ross et al. 2023). NWA-MOM6 is forced with: GLORYS12 reanalysis at boundaries, WOA18 (nutrients, oxygen), ESPER (carbon), TPX09 v1 (tides), ERA5 (atmosphere), GloFAS and RC4US COAST (river).

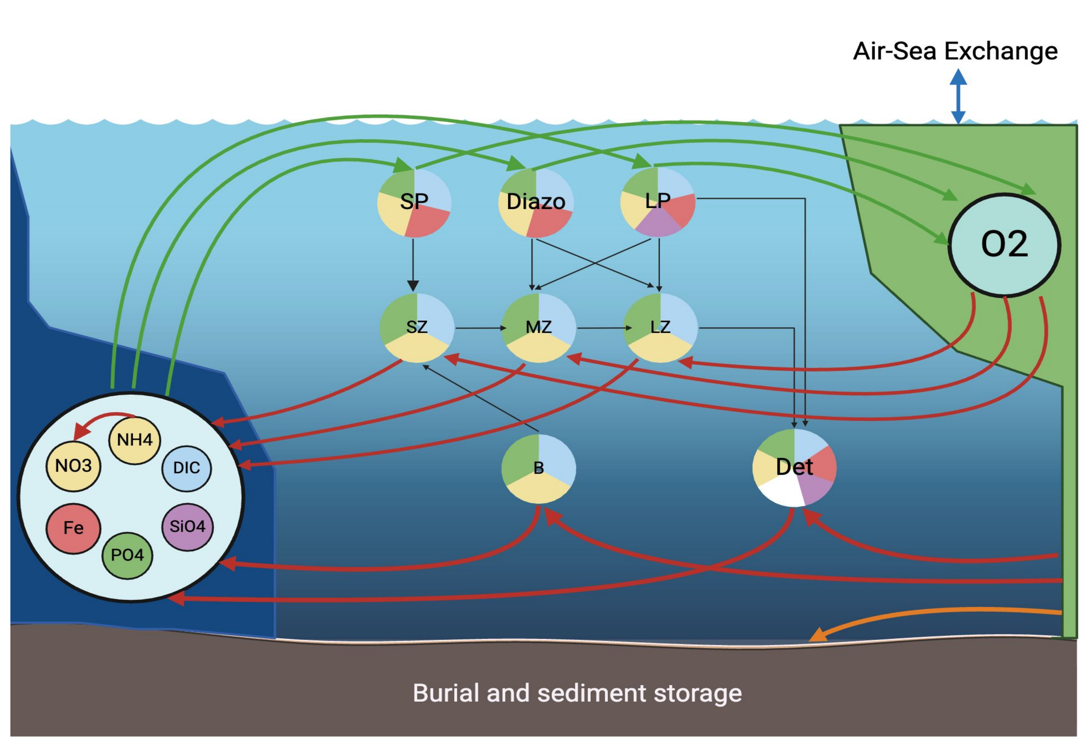

Figure 2: Schematic of tracers associated with oxygen in COBALT.

Objectives

Evaluate oxygen trends in a simulation from NWA-MOM6 model

Utilize NWA-MOM6 model to identify mechanism of deoxygenation trends on the NWA shelf

Results: Model Spatial Evaluation

NWA-MOM6 oxygen bias varies across the NWA Shelf (Figure 3), attributed to AOU bias (not shown).

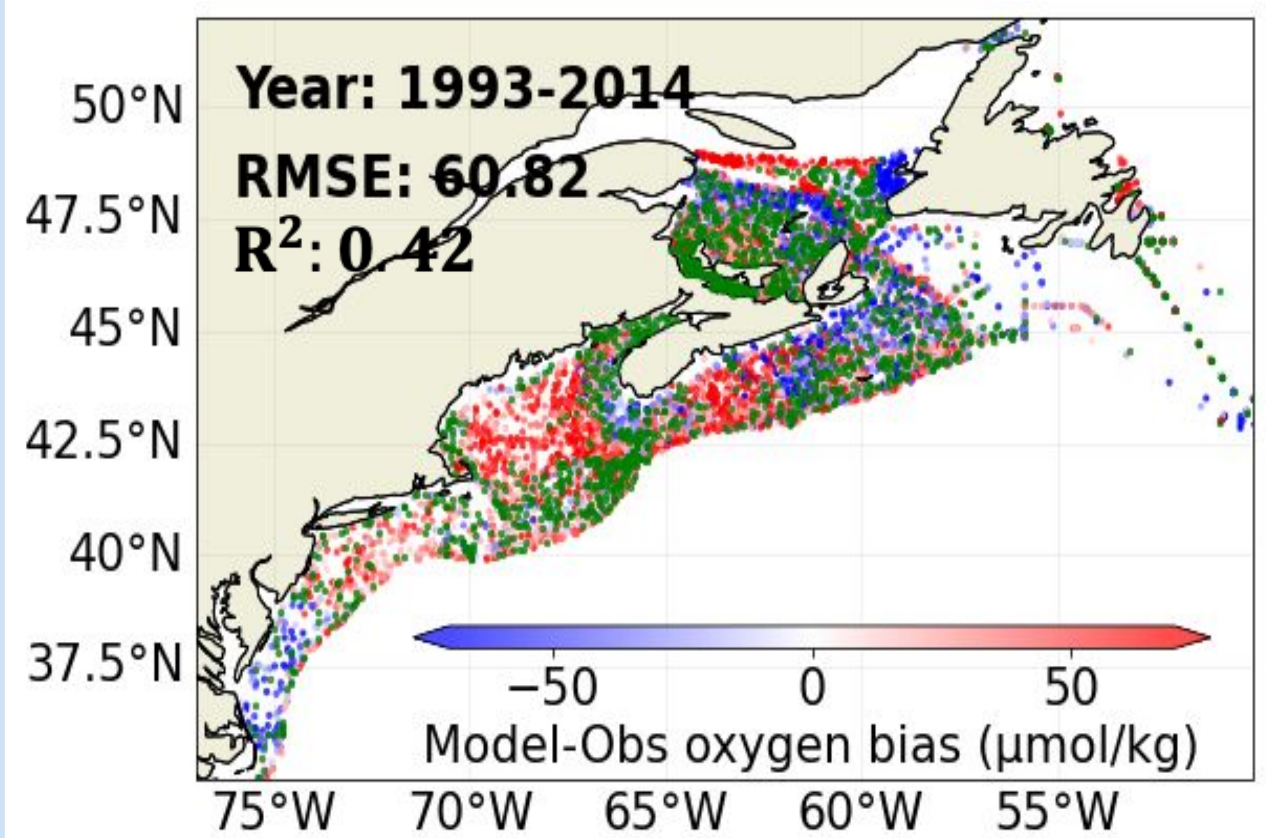

Figure 3: MOM6 bias for bottom oxygen. MOM6 is compared against World Ocean Database.

Results: Model Temporal Evaluation

NWA-MOM6 simulation reasonably captures the decadal oxygen trends (Figure 4).

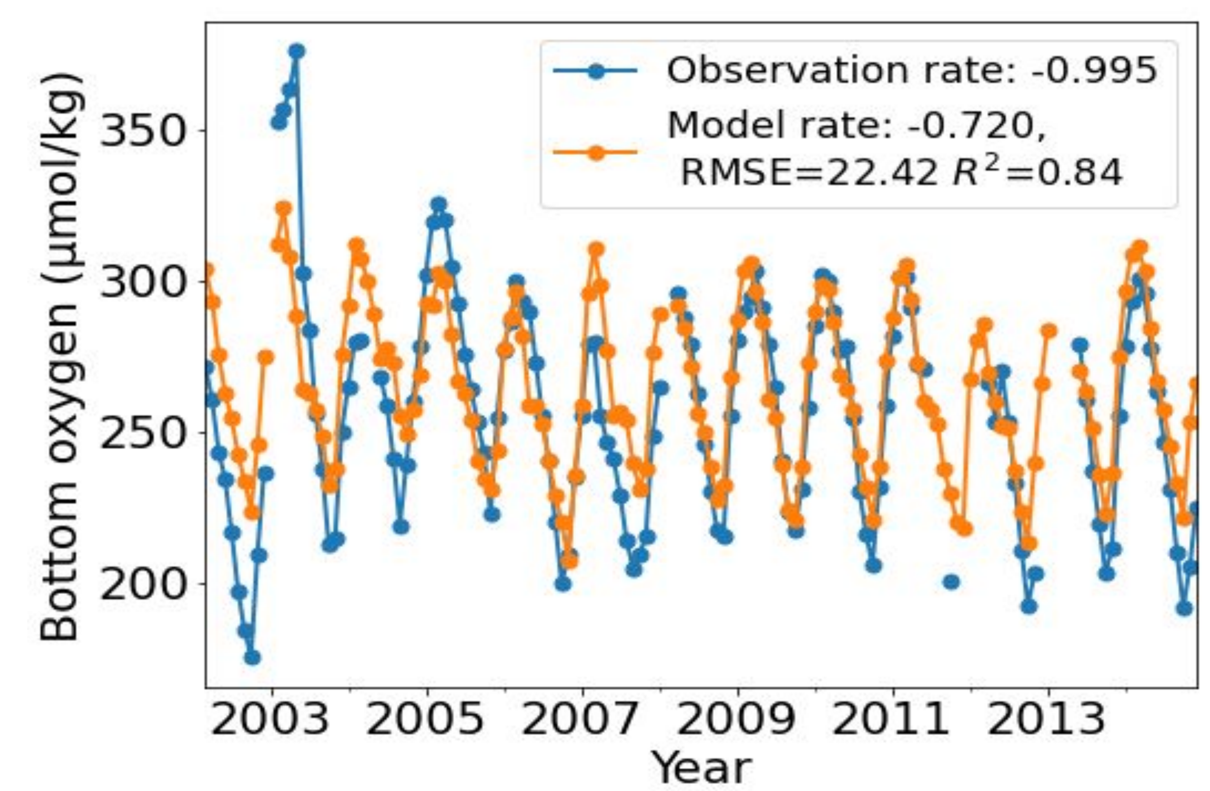

Figure 4: Monthly average bottom oxygen from A01 Buoy (Gulf of Maine) and MOM6. Rates are in µmol/kg/year.

Results: Oxygen Trends

The bottom oxygen in the NWA Shelf will decline by 0.28 µmol/kg/year from 1993-2022 under SSP5-8.5, with the most severe decline happens in Gulf of St.Lawrence (Figure 5).

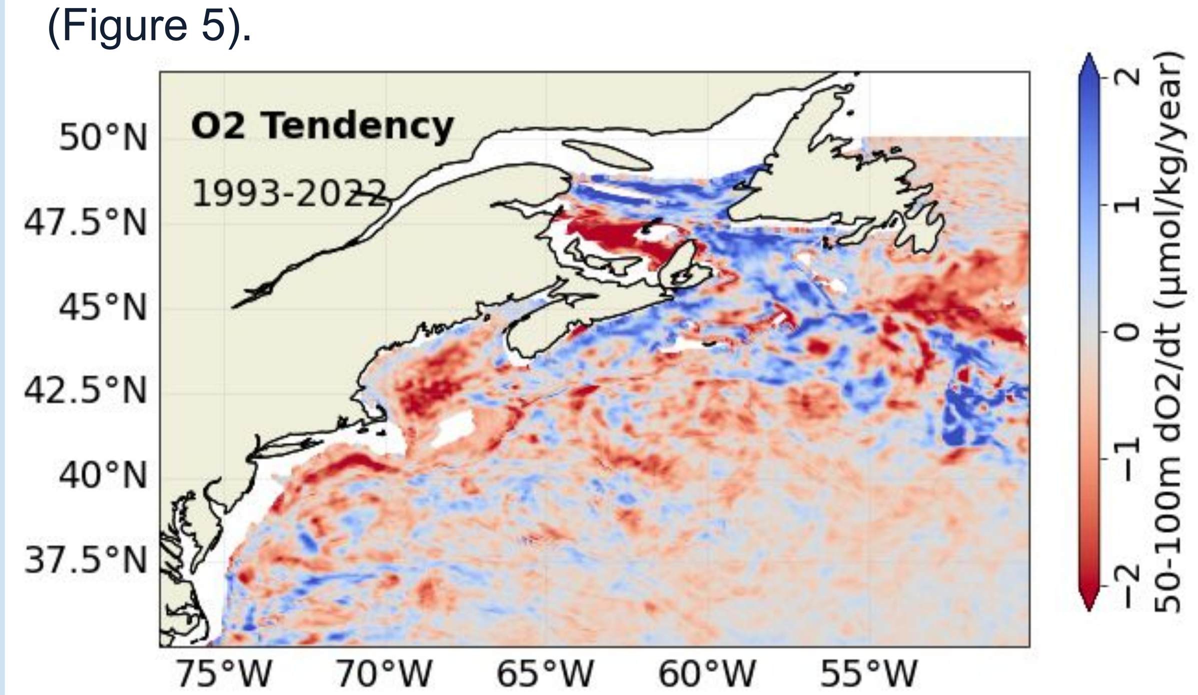

Figure 5: The subsurface oxygen trends in the NWA Shelf from 1993 to 2022

The oxygen change compose of the circulation change, ventilation and biological components:

$$\underbrace{\frac{\partial (hO_2)}{\partial t}}_{\text{Oxygen content change}} = \underbrace{-\vec{u}.\vec{\nabla}_h (hO_2) - w\frac{\partial (hO_2)}{\partial z} + hK_H \nabla_H^2 O_2 + K_z \frac{\partial^2 (hO_2)}{\partial z^2}}_{\text{Circulation and ventilation change}} + Biology$$

Results: Drivers of Oxygen Trends

The contribution of circulation and biology to the oxygen change varies across NWA Shelf (Figure 6).

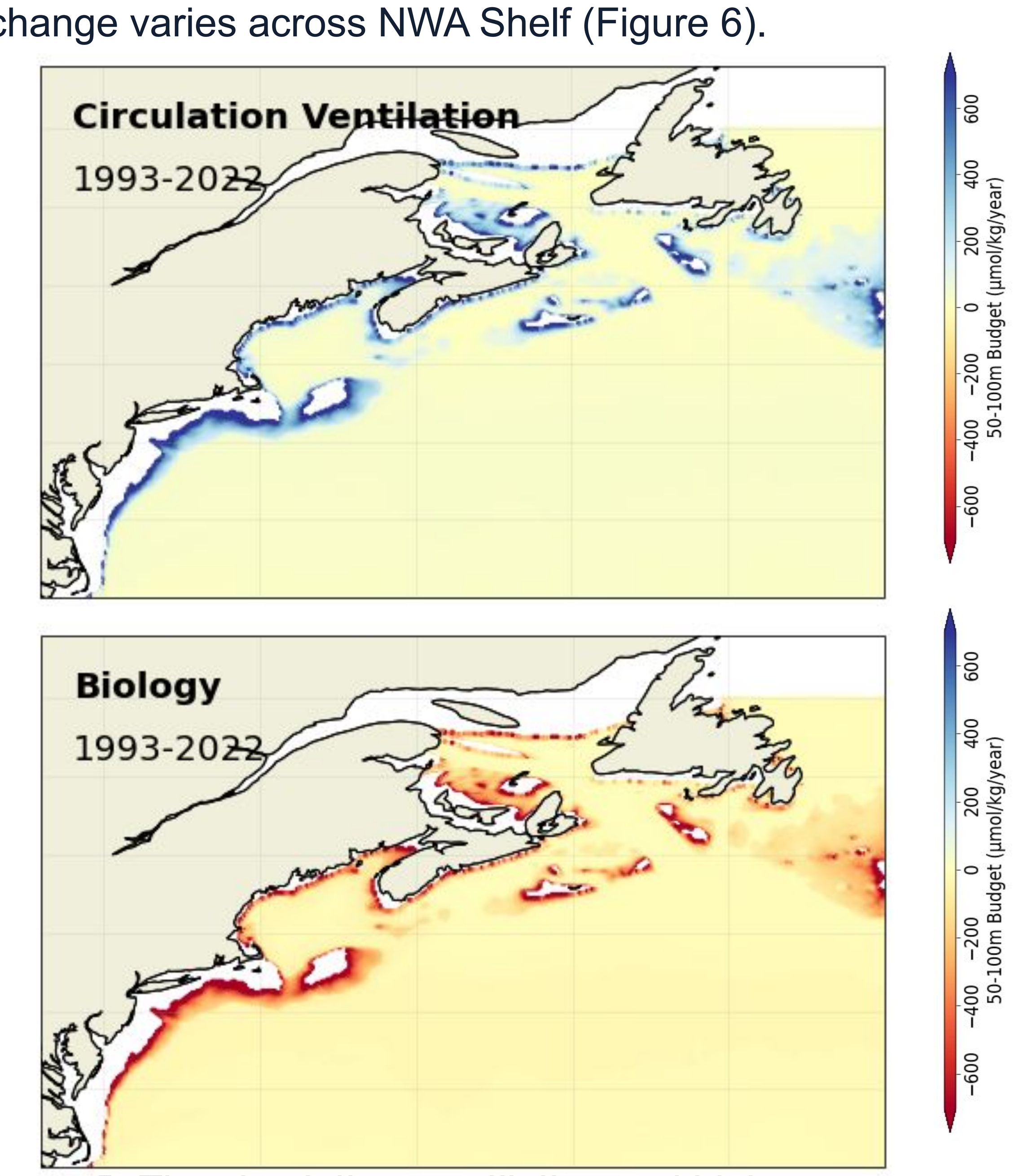

Figure 6: The circulation, ventilation and biology components associated with the oxygen change from 1993 to 2022.

Results: Minimal Oxygen

The simulation projects that some well-oxygenated regions (over 250 µmol/kg) of the shelf will disappear by 2098 under SSP5-8.5 (Figure 7). Minimum oxygen concentrations occur at the bottom (100%) but also at midwater column depths in the Mid-Atlantic Bight and on Georges Bank in particular (Figure

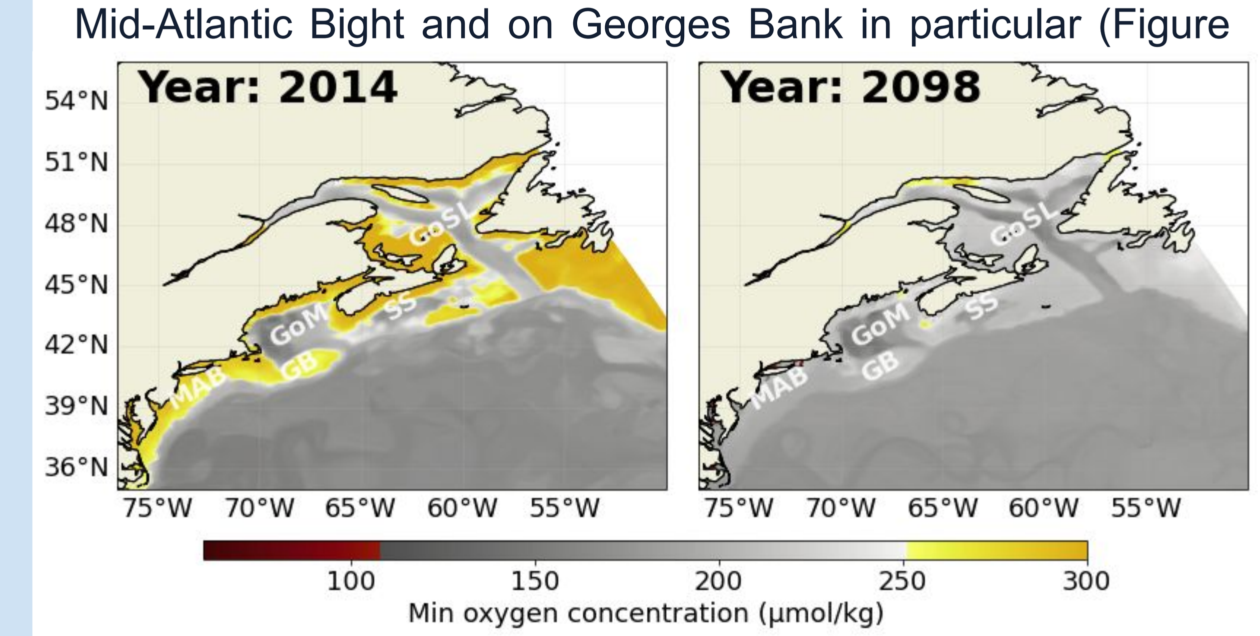

Figure 7: The min oxygen concentration in 2014 (left) and 2098 (right) from ROMS simulation

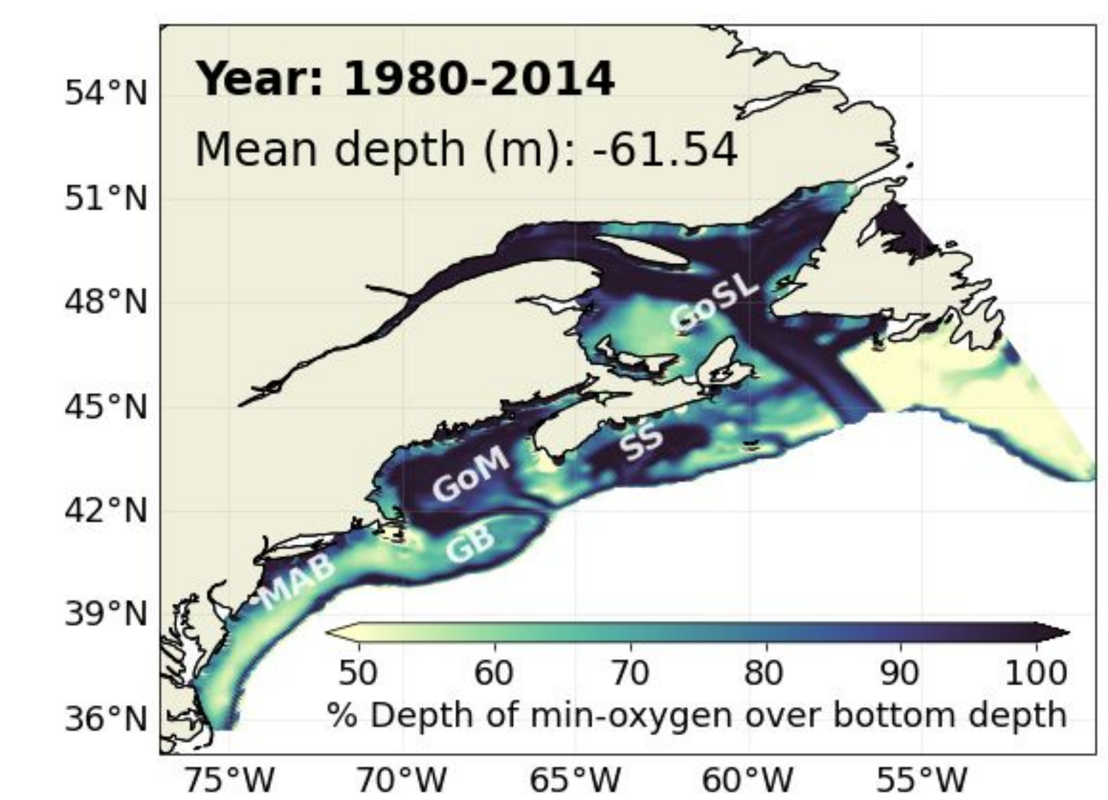

Figure 8: The depth level where minimal oxygen is located. The depth is normalized by the bottom depth

Discussions and Conclusions

- NWA-MOM6 simulation captures the historical deoxygenation trend in the region. The model's bias is attributed to bias in AOU.
- The contribution of advection, diffusion and biology to the oxygen change varies across NWA Shelf.
- Minimal oxygen occurs at the bottom but also at midwater column depths in MAB and GB.

Acknowledgements

Funding for this work has been obtained from the NOAA MAPP and NSF Convergence Accelerator programs.

References

https://docs.google.com/document/d/1hPaly_t1IqmldisDg4CSZbte1RIP8IonG4AVp118SJs/edit