Interannual trends and drivers of oxygen on the Northwest Atlantic Shelf

Nguyen, Hung[1] (hung.nguyen@uconn.edu), Siedlecki, Samantha[1], Curchitser, Enrique[2], Andrew Ross[3], Stock, Charlie[3], Soares, Felipe[1], Chen, Zhuomin[1], Resplandy, Laure[4], Poupon, Mathieu[4], Ditkovsky, Sam[4], Yang, Fan[4]
[1]Department of Marine Sciences, University of Connecticut, Groton, CT 06340; [2]Department of Environmental Sciences, Rutgers University, New Brunswick, NJ; [3]NOAA GFDL, Princeton, NJ; [4]Department of Geosciences, Princeton University, Princeton, NJ 6649

Introduction: Observation

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 mixed-layer) of the Northwest Atlantic Shelf (Figure 1; Nguyen et al, 2026). 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 what mechanisms are responsible for this trend on the NWA Shelf.

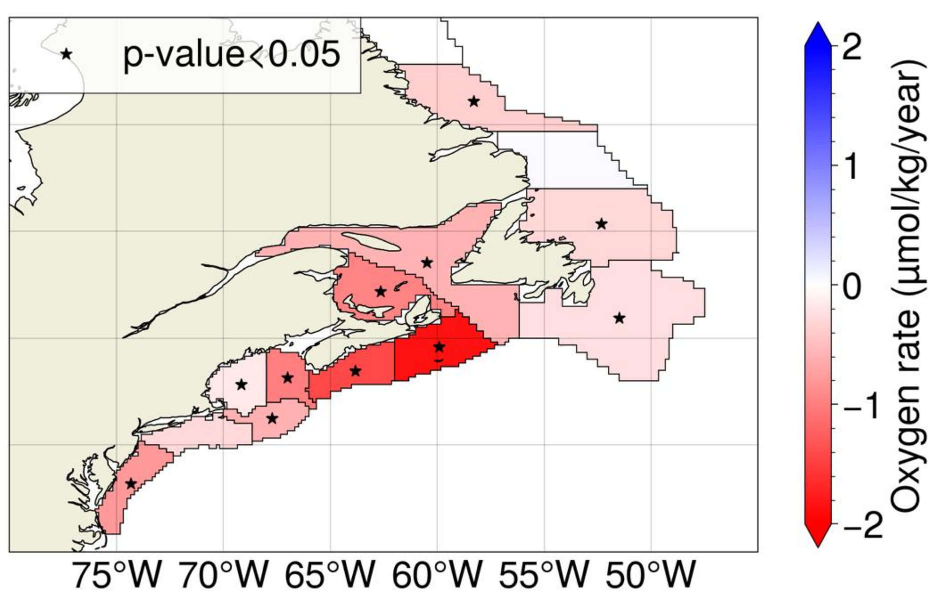


Figure 1: The observed rates of oxygen change in the subregions of NWA Shelf below mixed-layer depth, with the linear trend from 1988 to 2019 (Nguyen et al., 2026)

Oxygen Budget Terms Balance

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). Budget terms after Fan et al., 2025:

$$\frac{\partial(hO_2)}{\partial t} = -\vec{u}\cdot\vec{\nabla}_h(hO_2) - w\frac{\partial(hO_2)}{\partial z} + hK_H\nabla_H^2 O_2 + K_z\frac{\partial^2(hO_2)}{\partial z^2} + Biology$$

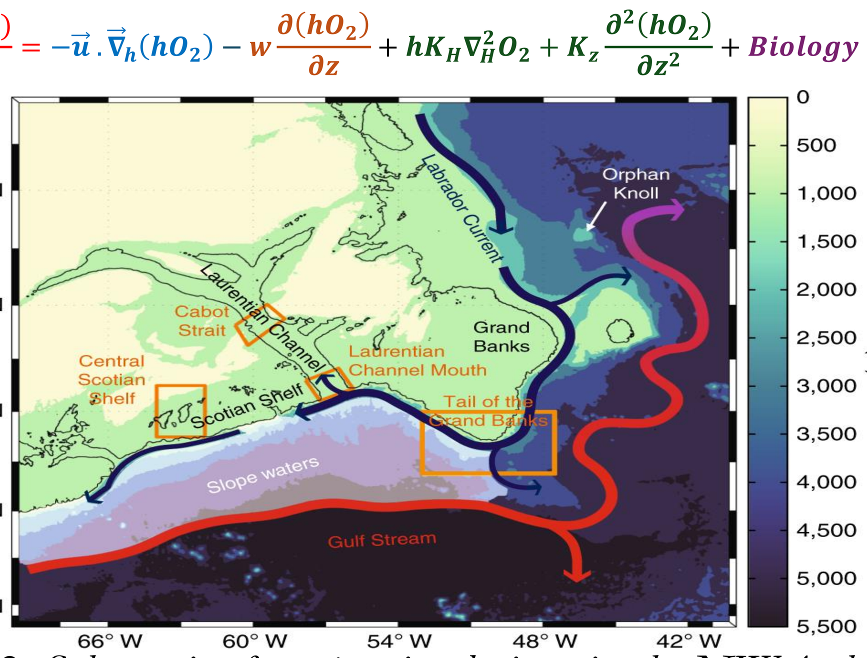


Figure 2: Schematic of major circulations in the NWA shelf (from Claret et al., 2018).

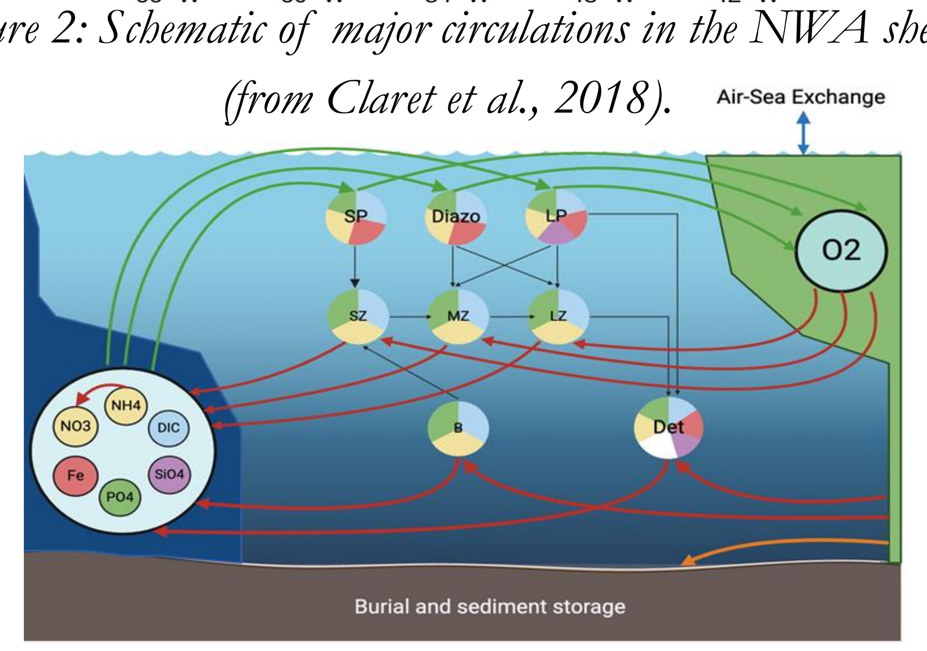


Figure 3: COBALT biogeochemical tracers associated with oxygen.

1993-2025 Oxygen simulation: Oxygen declines, deoxygenation accelerates

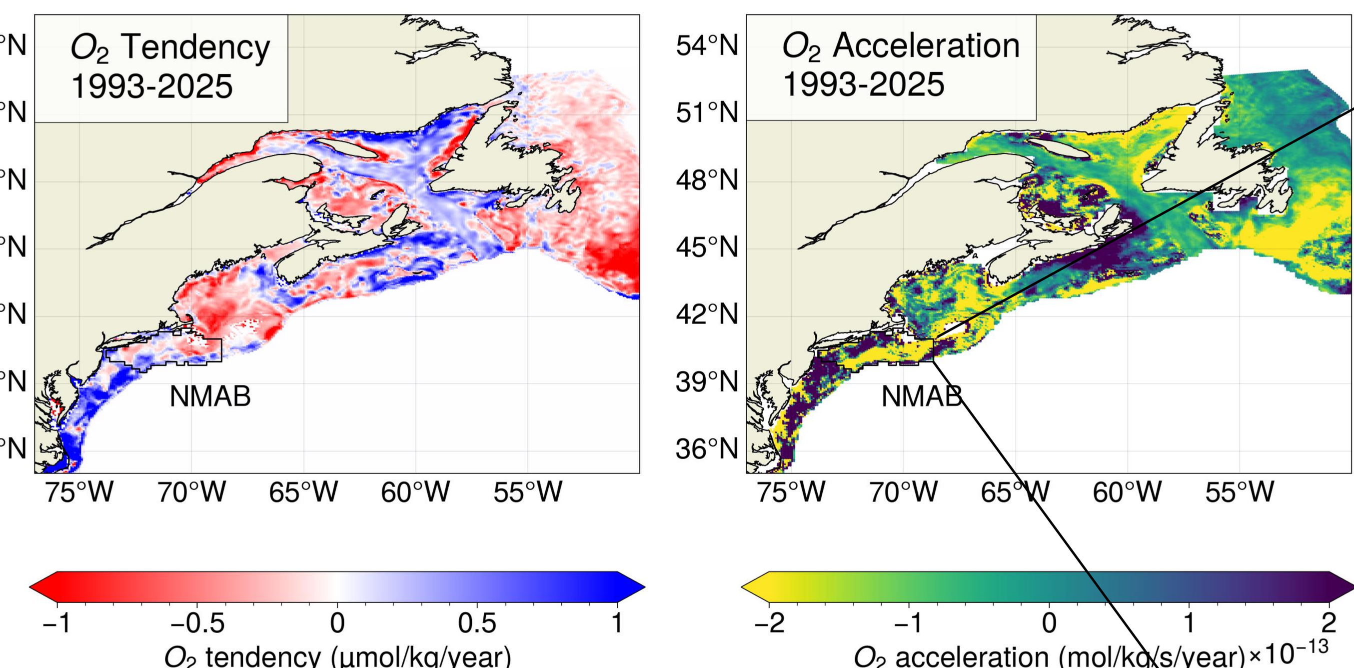


Figure 4: Simulated oxygen tendency (left) and oxygen acceleration (right) below the mixed-layer from 1993 to 2025.

Deoxygenation acceleration contributed by circulation transport and biology

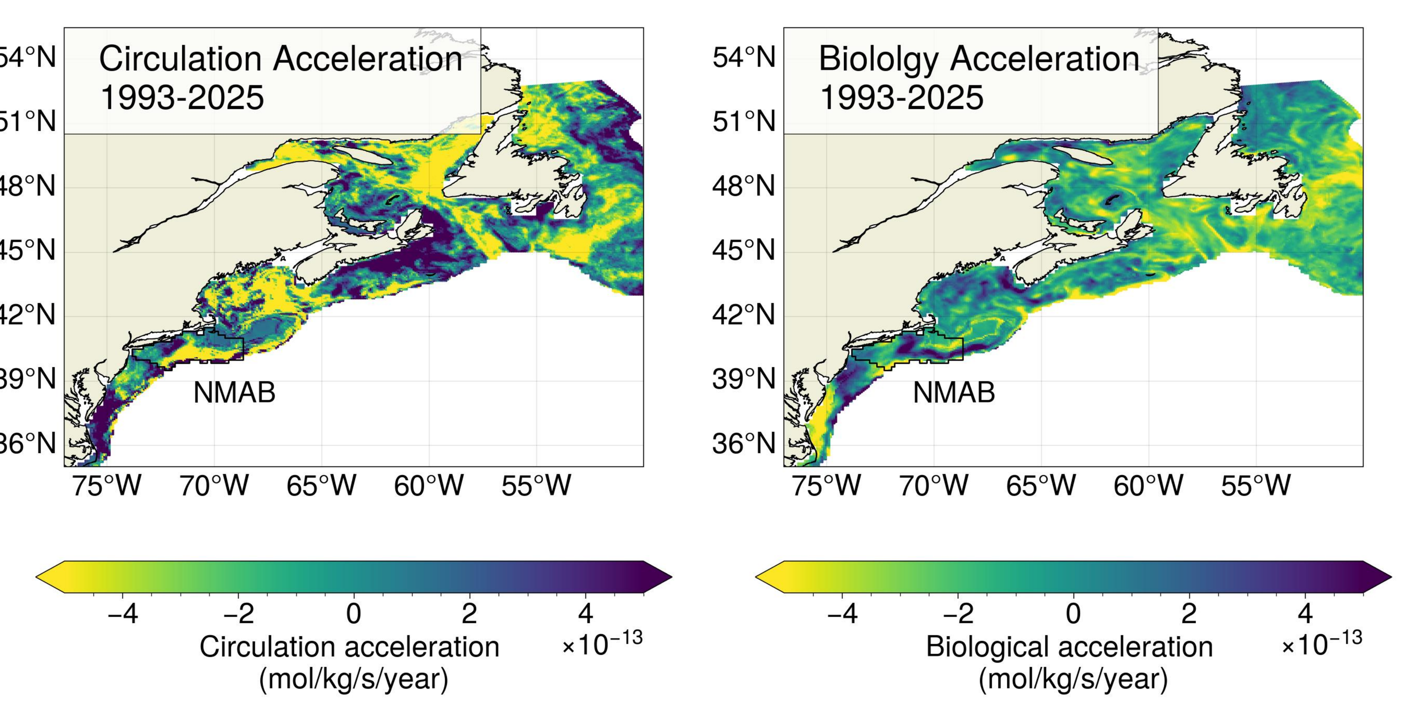
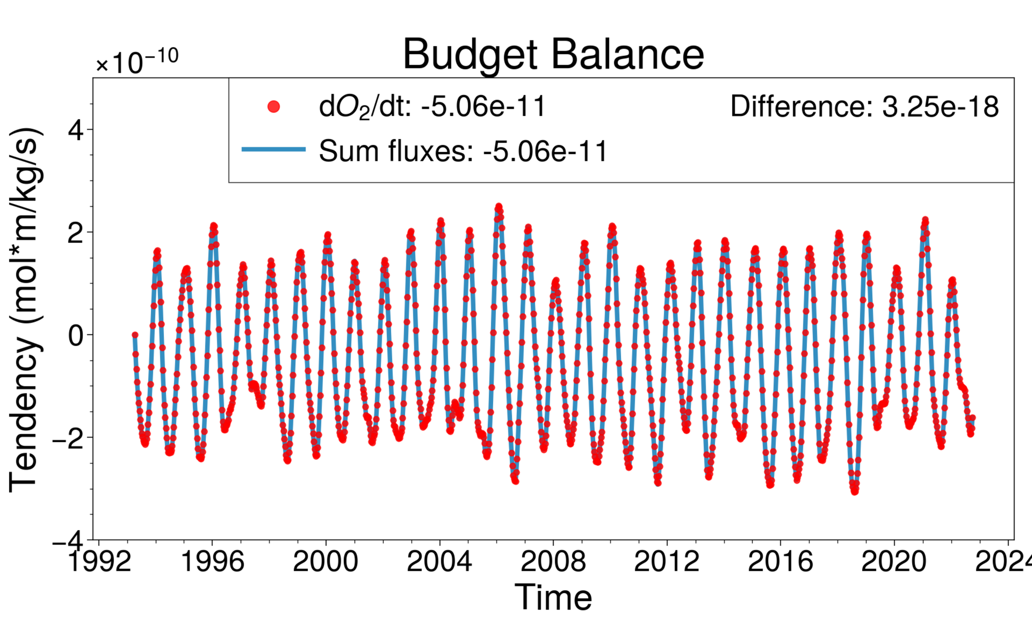
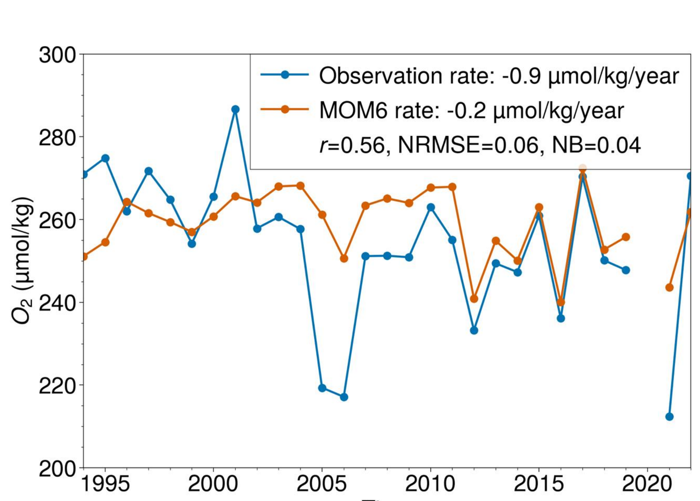


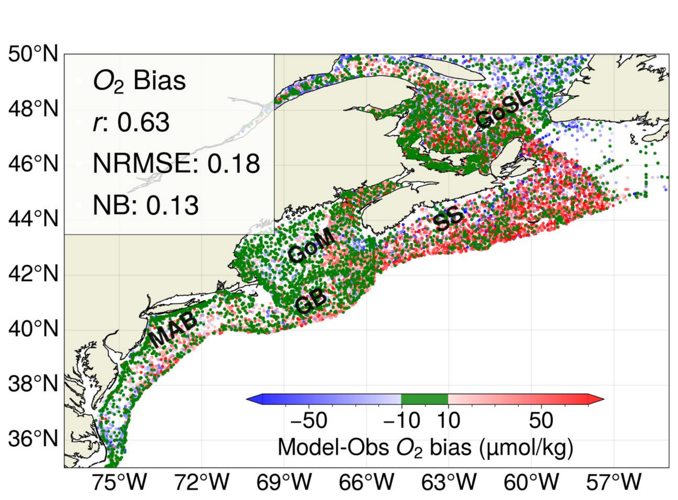
Figure 5: Circulation acceleration (left) and biological acceleration (right) for oxygen below the mixed-layer from 1993 to 2025.

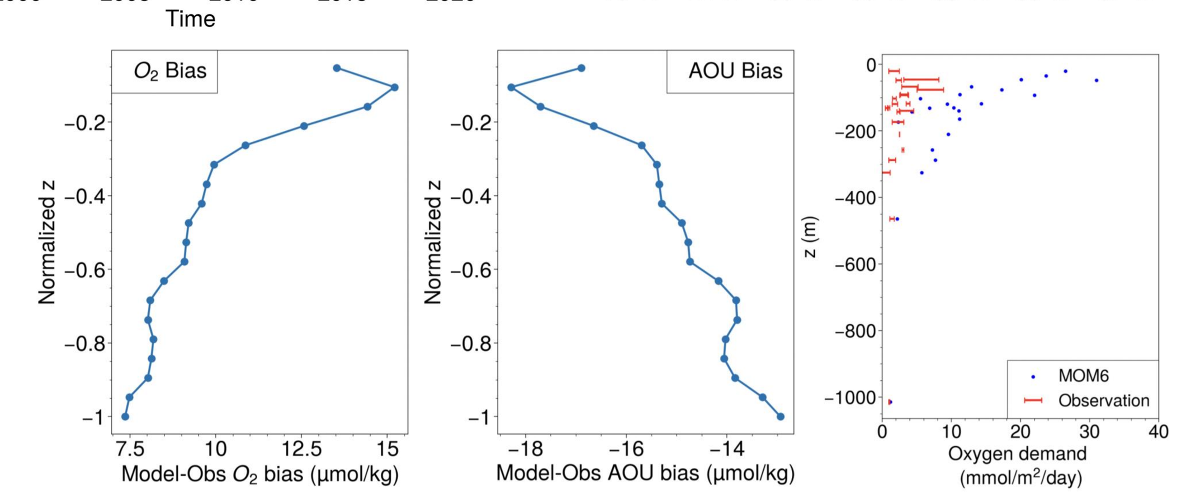
Model Evaluation: Balanced budget. Reasonably captures oxygen. Underestimating water-column respiration.

Temperature, salinity, O_2 from World Ocean Database. Sediment oxygen demand from Frenzel et al., in prep.









Accelerated deoxygenation dominated by oxygen transport decline in the MAB

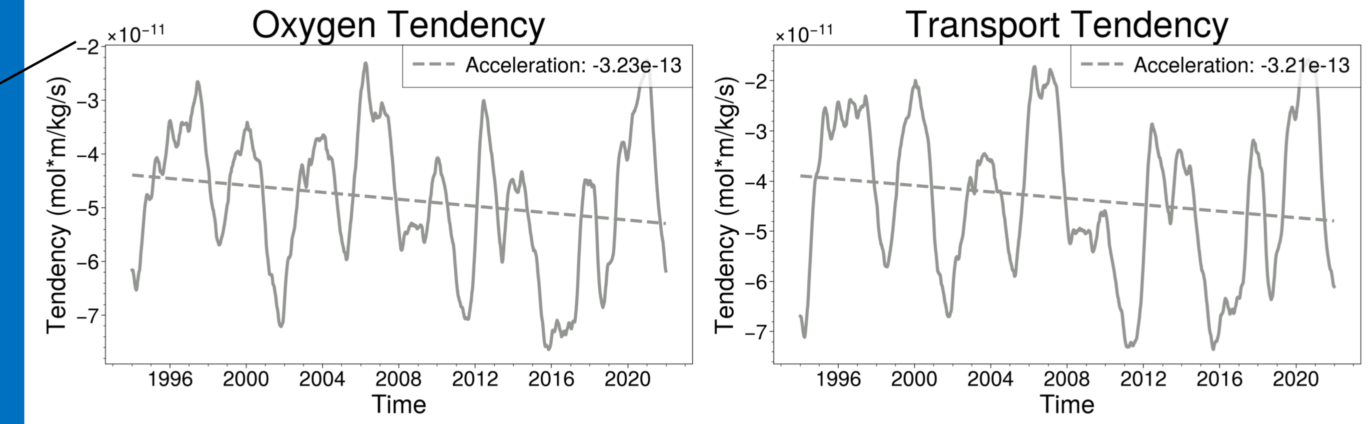


Figure 6: Oxygen tendency (left) and circulation tendency (right) in Northern MAB below the mixed-layer.

Oxygen transport decline due to decline in northward y-advection

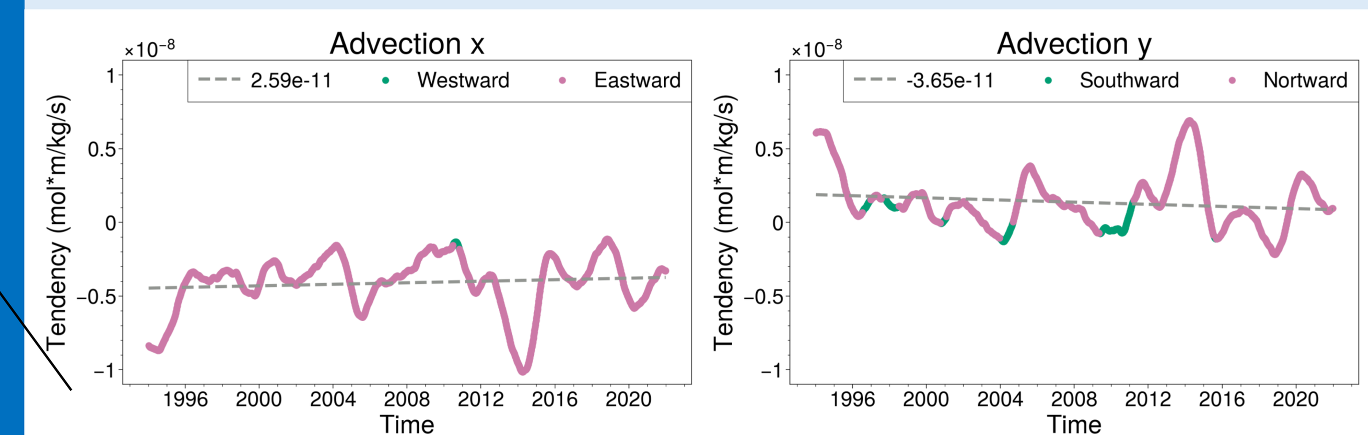


Figure 7: Advection x (left) and advection y (right) in Northern MAB below the mixed-layer.

Oxygen transport changes: Relative contribution of end-members or the oxygen content changes within end-members?

Relative contribution of water masses change: Statistically unchanged over 30 years

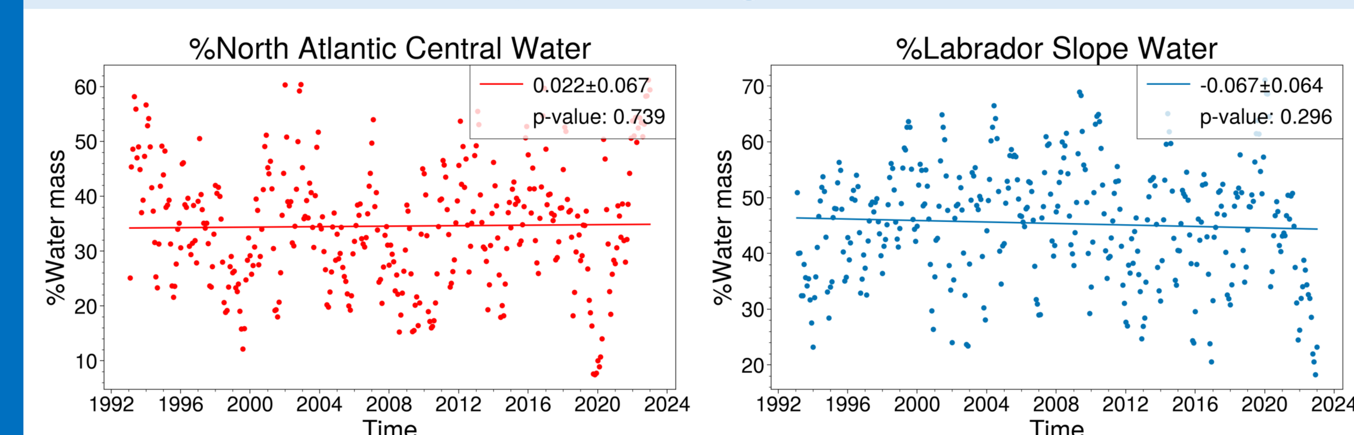


Figure 8: Contribution of water masses below the subsurface Northern MAB.

Oxygen concentrations change within water masses: Lower oxygen, more DIC

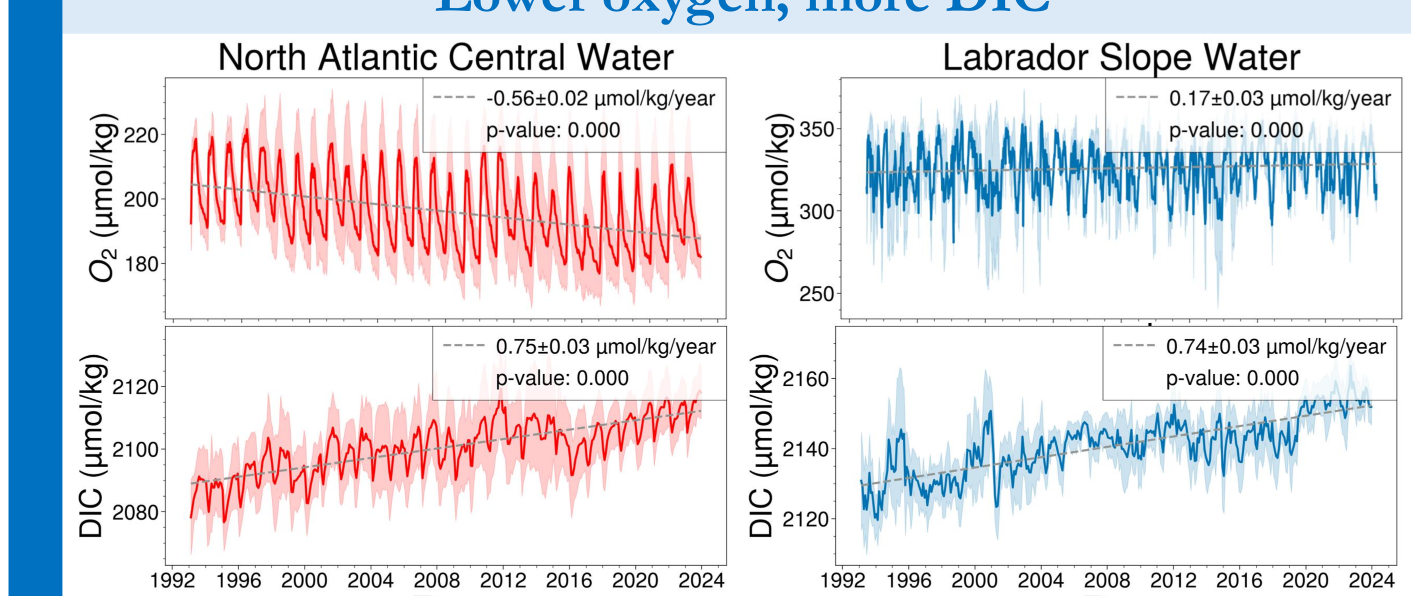


Figure 9: The oxygen and DIC of source water in the NWA Shelf. Location of source water from Gilbert et al., 2005.

Conclusions:

- MOM6 reasonably captures the spatial and temporal variability of oxygen changes on the NWA Shelf over the past 3 decades.
- Oxygen decline in the Mid-Atlantic Bight is driven by transport changes.
- The transport changes in the northern Mid-Atlantic Bight is driven by the oxygen and DIC content changes of the water masses.