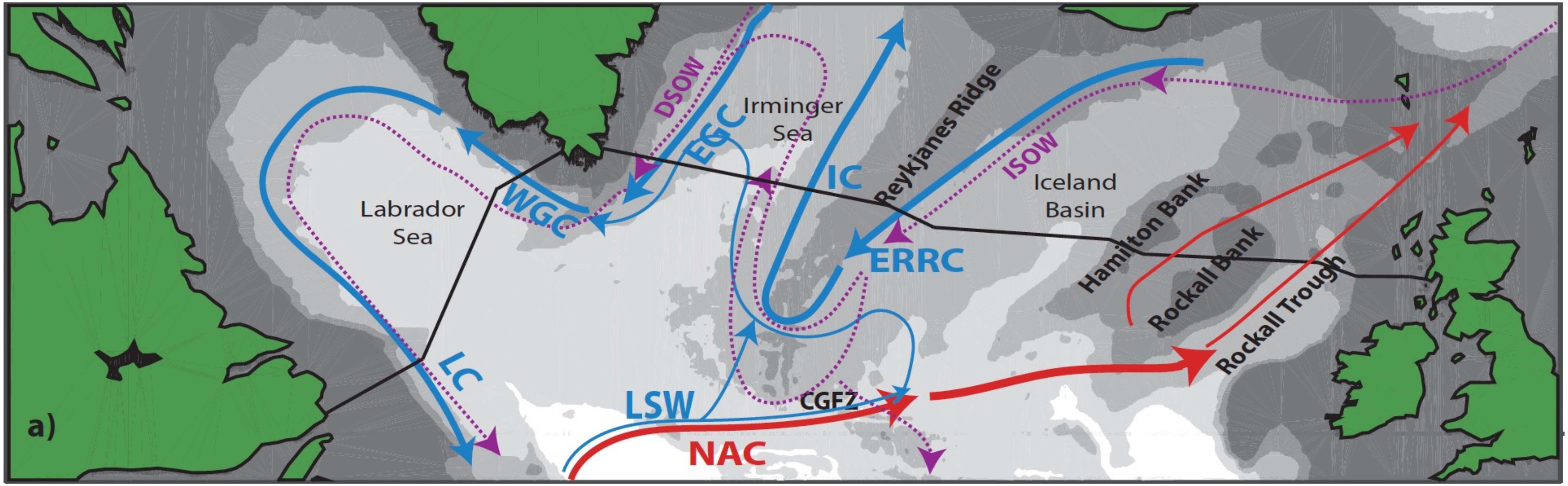
On the (possible) decoupling of ocean ventilation and overturning: Key motivation and early results from GOHSNAP



Jaime Palter and Una Miller, URI
Roo Nicholson, Isabela Les Bras,Hiroki Nagao, and Ellen Park WHOI
Hilary Palevsky, Meg Yoder, and Kristen Fogaren, BC

THE UNIVERSITY OF RHODE ISLAND GRADUATE SCHOOL OF OCEANOGRAPHY

NSF

Take-home messages

1. Ocean deoxygenation can mean life or death (migration, extirpation, or extinction) for many marine animals
2. The ocean has already lost about 2% of its oxygen reservoir
   a. About half of the loss is due to declining solubility
   b. The other half stems from dynamical changes that are poorly understood and missing in many models
3. Many assume an AMOC decline would spell doom for intermediate & deep oxygen in the Atlantic, but ventilation /= overturning
4. We are trying to sort out the role of the Labrador Sea in oxygen ventilation through GOHSNAP (Gases in the Overturning and Horizontal circulation of the Subpolar North Atlantic Program)


Oxygen and life in the ocean

Breathing is hard in the ocean

Percentage of oxygen by volume

Air	Water
21%	3%

Percentage of intake energy for breathing

Mammals	Fish
1-2%	20%

Reference Module in Earth Systems and Environmental Sciences

Encyclopedia of Ecology

https://doi.org/10.1016/B978-008045405-4.00291-3

Climate change tightens a metabolic constraint on marine habitats

Science

Curtis Deutsch,[1*] Aaron Ferrel,[2†] Brad Seibel,[3] Hans-Otto Pörtner,[4] Raymond B. Huey[5]

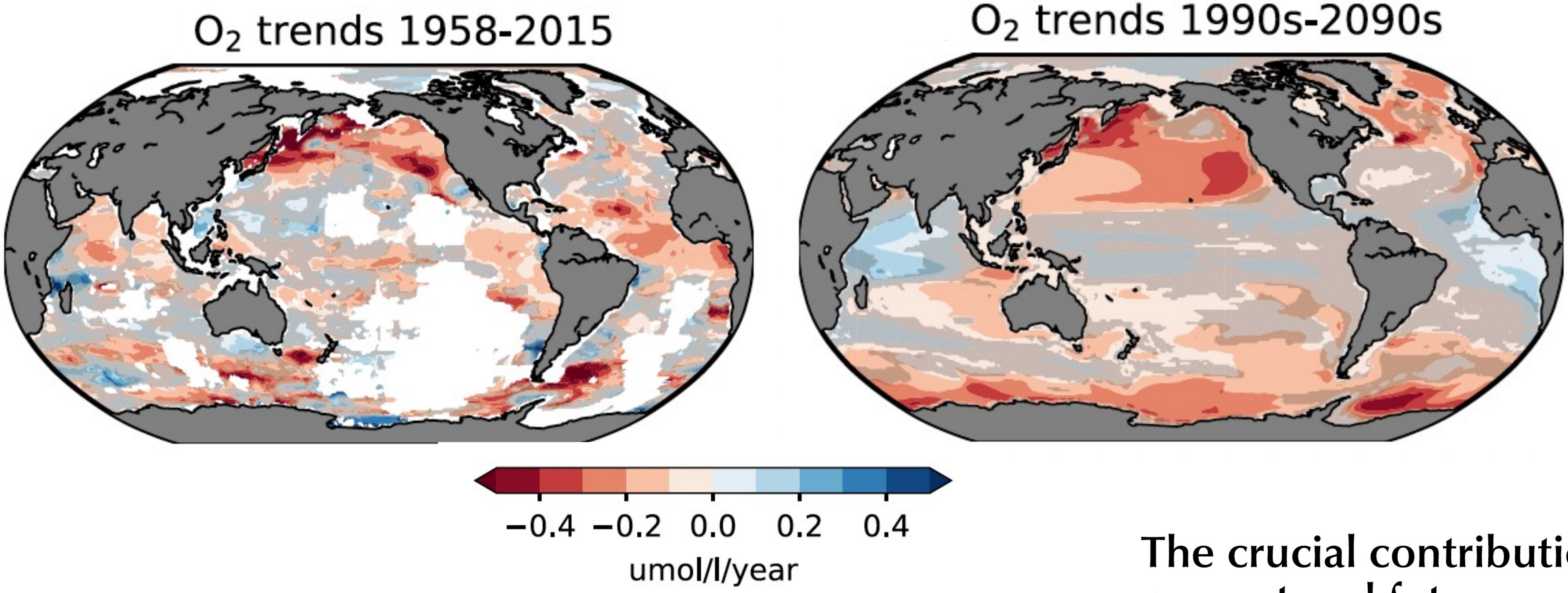
2015 The habitable ocean volume is constricting, given basic metabolic demand of dozens of species.

The ocean is losing oxygen

Global oxygen has declined and projected for widespread deoxygenation in coming decades

Historic

RCP8.5 projected



200-600 m average

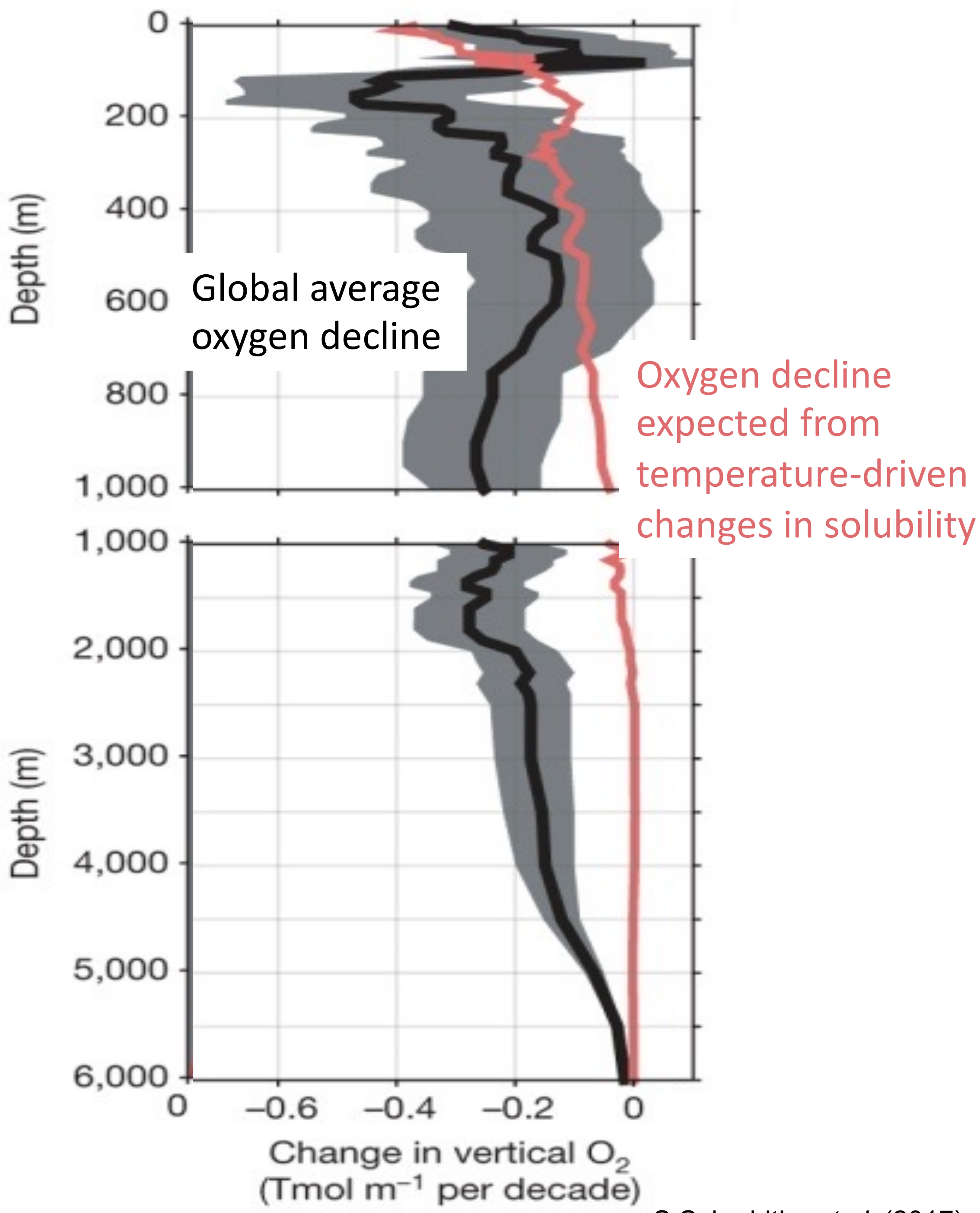
Adapted from Schmidtko *et al.* (2017)
doi:10.1038/nature21399

The crucial contribution of mixing to present and future ocean oxygen distribution

Marina Lévy[a], Laure Resplandy[b], Jaime B. Palter[c], Damien Couespel[a] and Zouhair Lachkar[d]

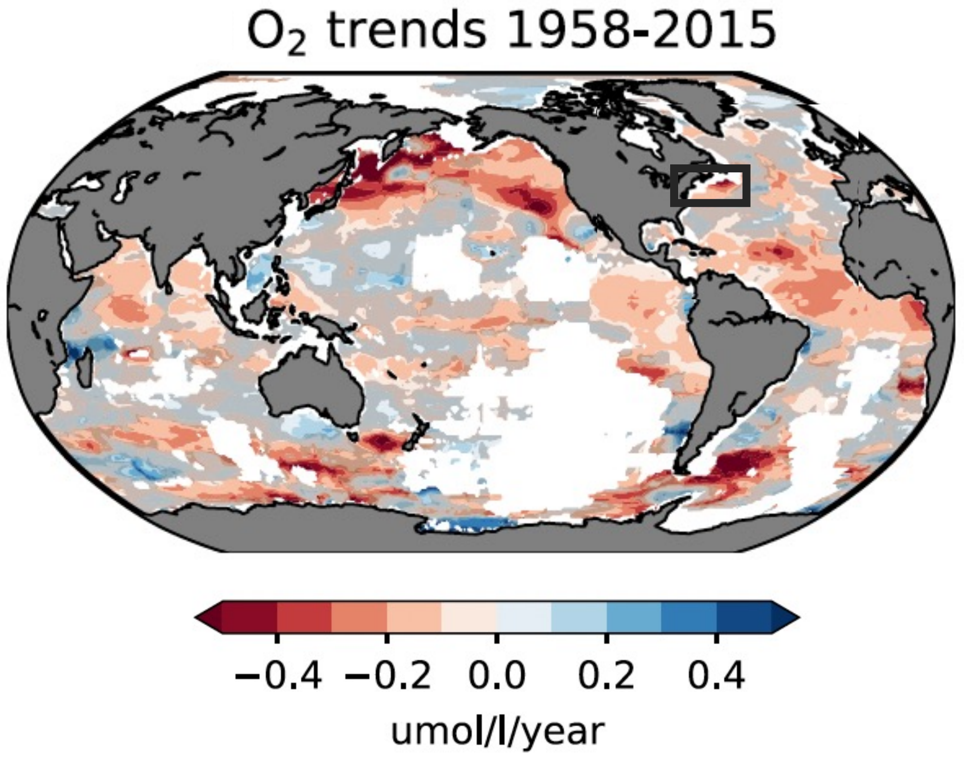
Causes of global oxygen decline not settled

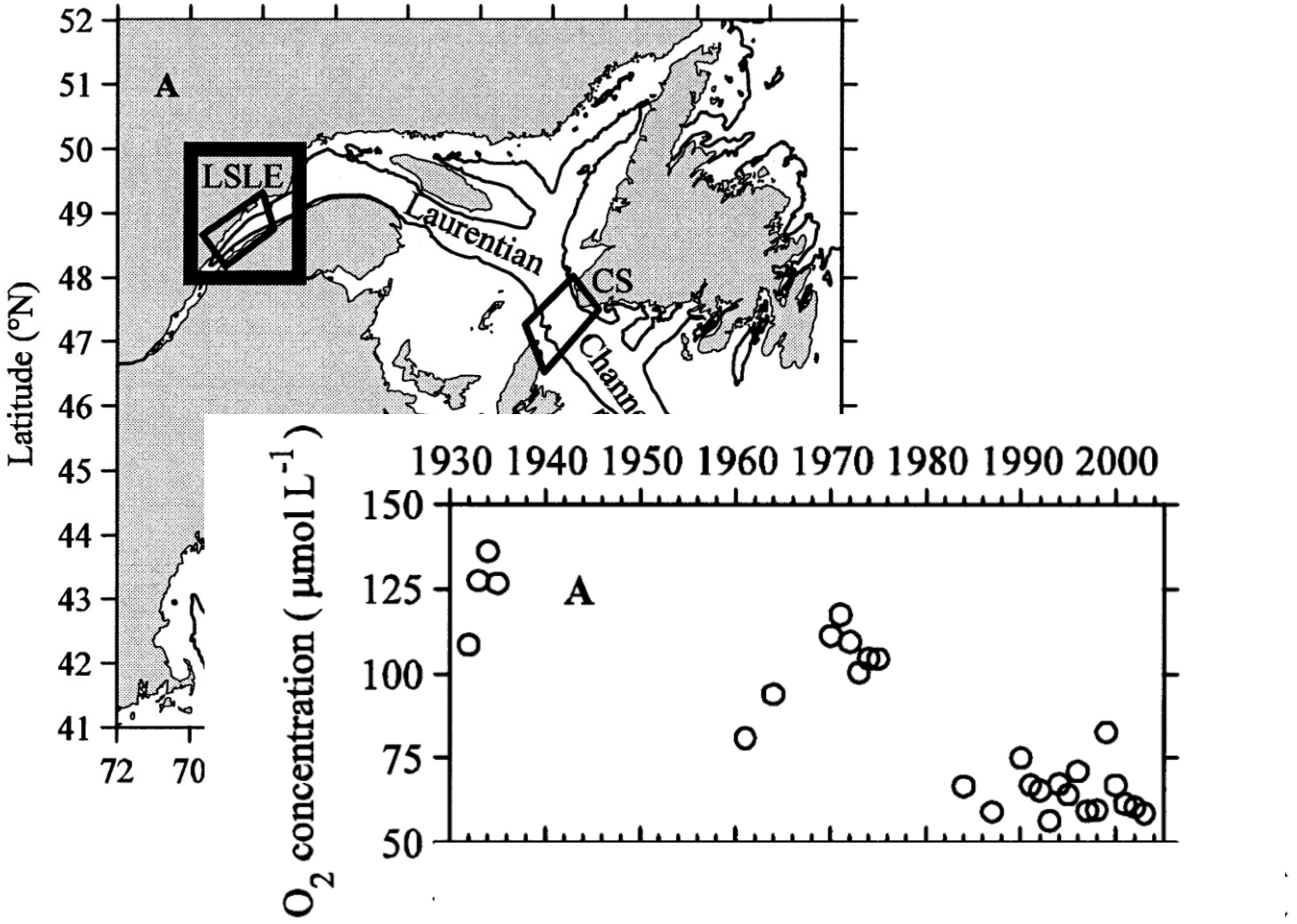
- About half due to warming-induced reduction in solubility
- The other half blamed broadly on changes in ventilation and mixing



S Schmidtko *et al.* (2017) doi:10.1038/nature21399

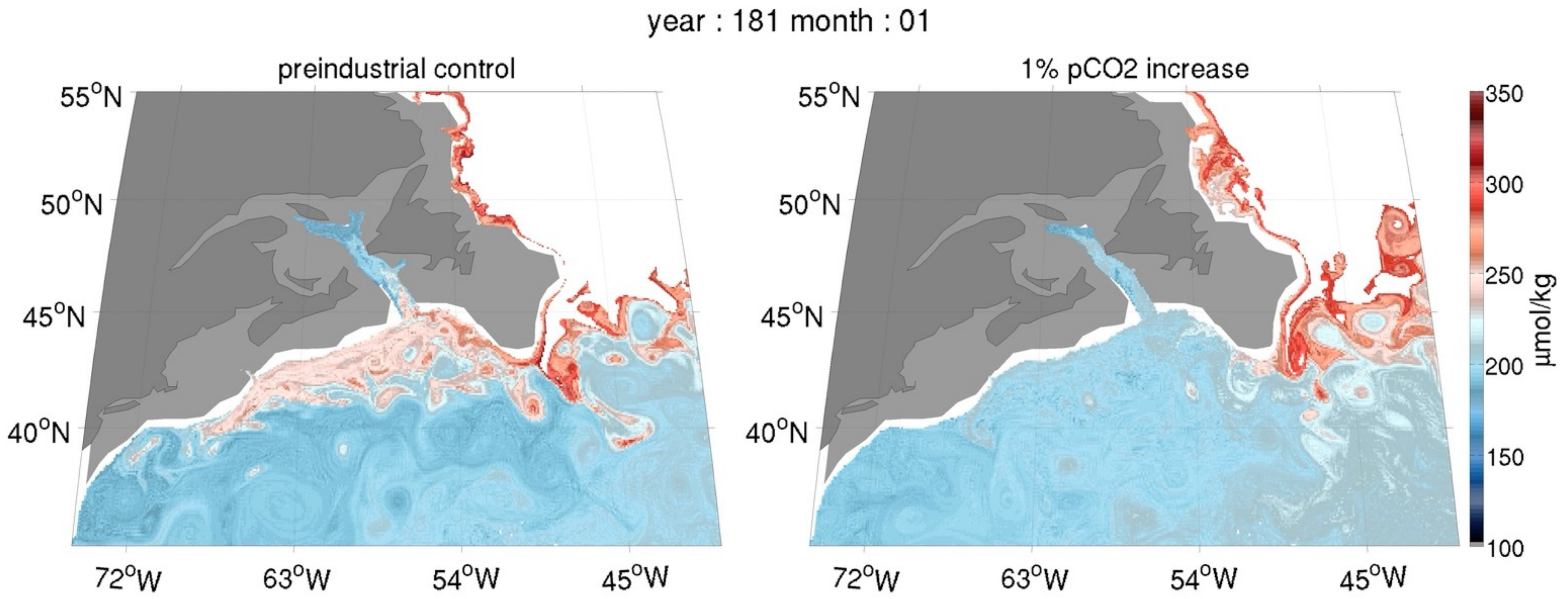
Local rates of deoxygenation can greatly exceed global





Gilbert et al., 2005

Circulation drives a hotspot of declining oxygen along Northwest US and Canadian shelves



GFDL's 1/10° CM2p6 with BLING biogeochemistry, Oxygen on the 27.25 isopycnal, from Claret et al., 2018
See also, Gonçalves Neto 2021, 2023.


What is the role of AMOC on oxygen export?

Gas uptake and transport often assumed linked to AMOC

EN

LETTER

Decline in global oceanic oxygen content during the past five decades

Sunke Schmidtko[1], Lothar Stramma[1] & Martin Visbeck[1,2]

the other hand, a reduction of meridional c
observed globally instantaneously, since a
of oxygenated waters into areas deprived of

Atlantic Ocean circulation is weakening; are our deep-sea ecosystems at threat?

Published: 13 January 2013

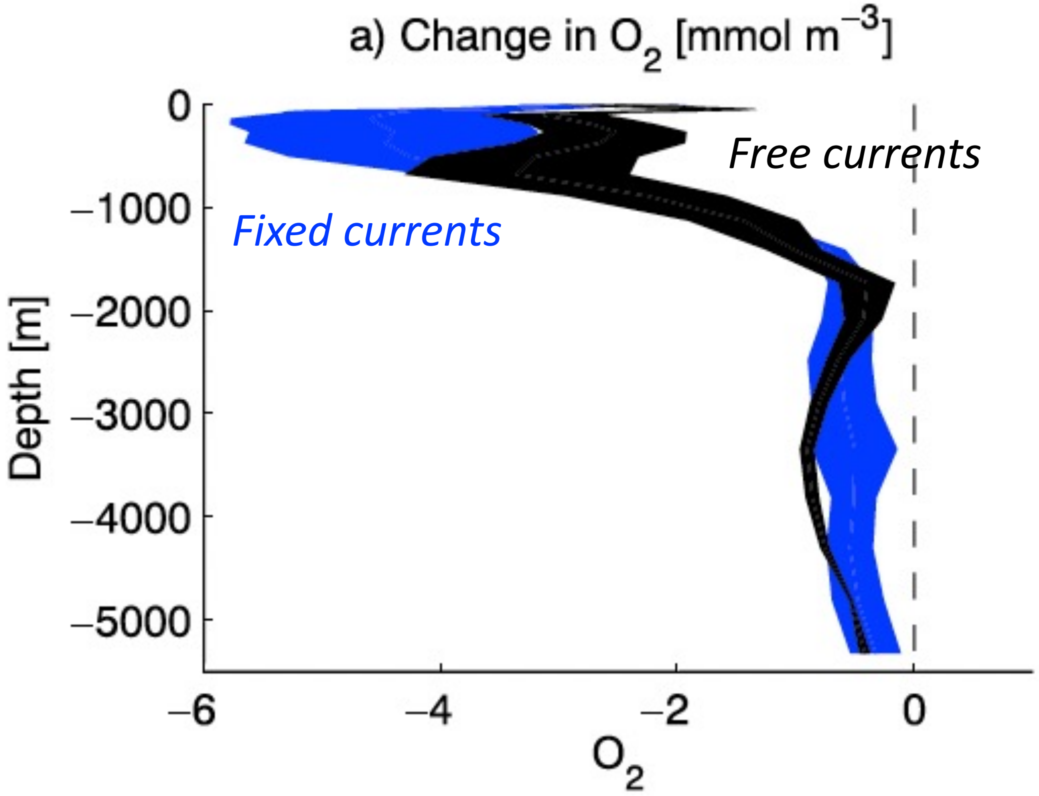
Atlantic Ocean CO_2 uptake reduced by weakening of the meridional overturning circulation

Fiz F. Pérez, Herlé Mercier, Marcos Vázquez-Rodríguez, Pascale Lherminier, Anton Velo, Paula C. Pardo, Gabriel Rosón & Aida F. Ríos

Nature Geoscience **6**, 146–152 (2013) | Cite this article

Idealized modeling experiments suggest slowing AMOC does not cause rapid deoxygenation

- Model with increasing atmospheric CO_2 at 1% per year till doubled
- In one ensemble of simulations (*Free Currents*), we let everything evolve as normal
- In the second ensemble ("Fixed Currents"), we swapped in the ocean velocity field from the control simulation
- AMOC declined by 25% in "Free Currents," but deep oxygen changed little in the Atlantic, because respiration is so slow
- Simulations with circulation response had LESS oxygen loss overall (see figure)



Palter and Trossman 2017, Global Biogeochemical Cycles

AMOC and ventilation are not the same

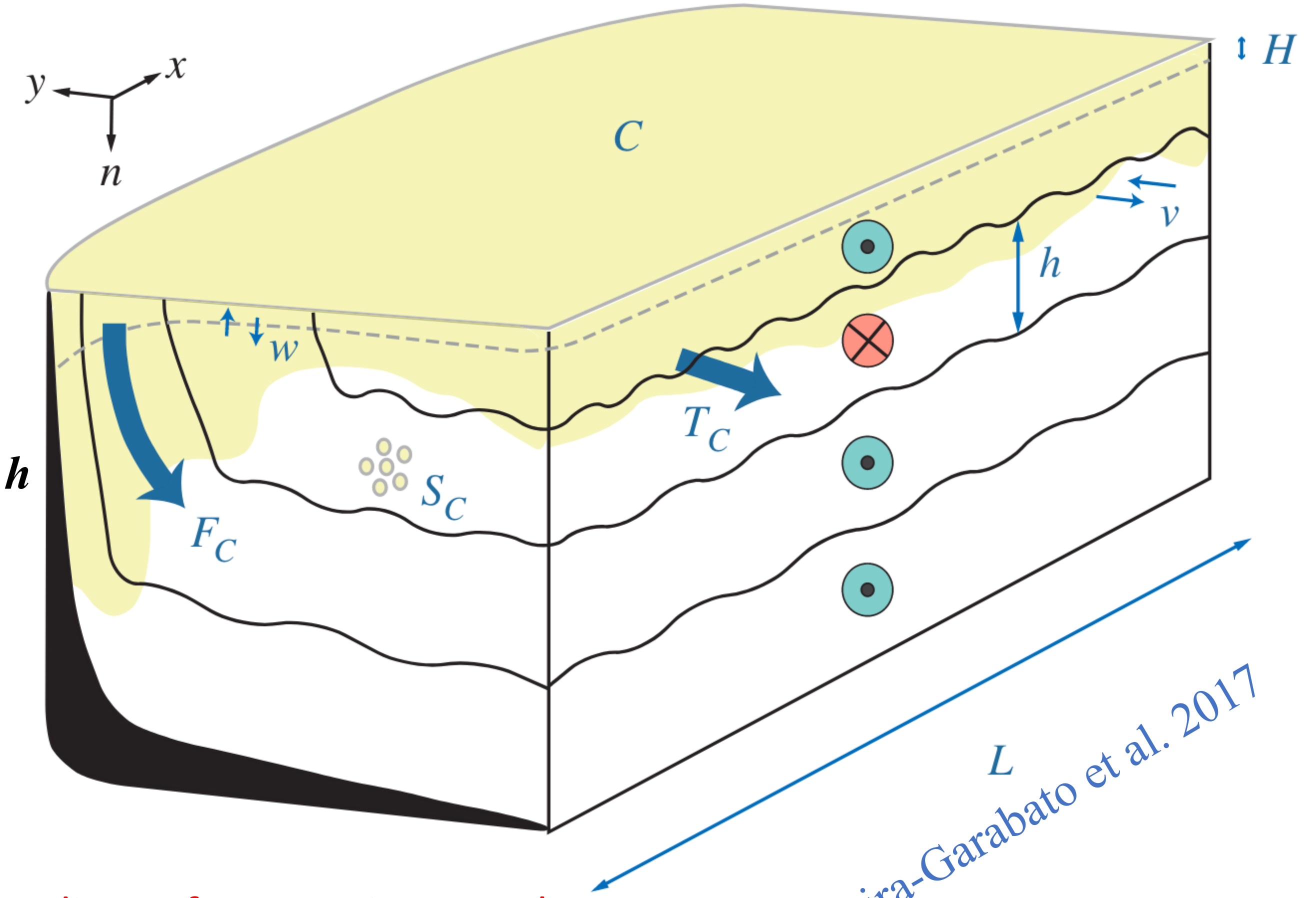
Basin-scale ventilation: The zonally-integrated transport, T_c, of a tracer sourced in the atmosphere (e.g. O_2, CO_2, CFC) summed on density levels

$$T_C = \int_0^L \int_1^N v(x,n,t)h(x,n,t)C(x,n,t)\mathrm{d}x\mathrm{d}n,$$

$\boldsymbol{v}$, meridional velocity on each isopycnal layer, N, of thickness, $\boldsymbol{h}$
$\boldsymbol{C}$, tracer concentration at ML base

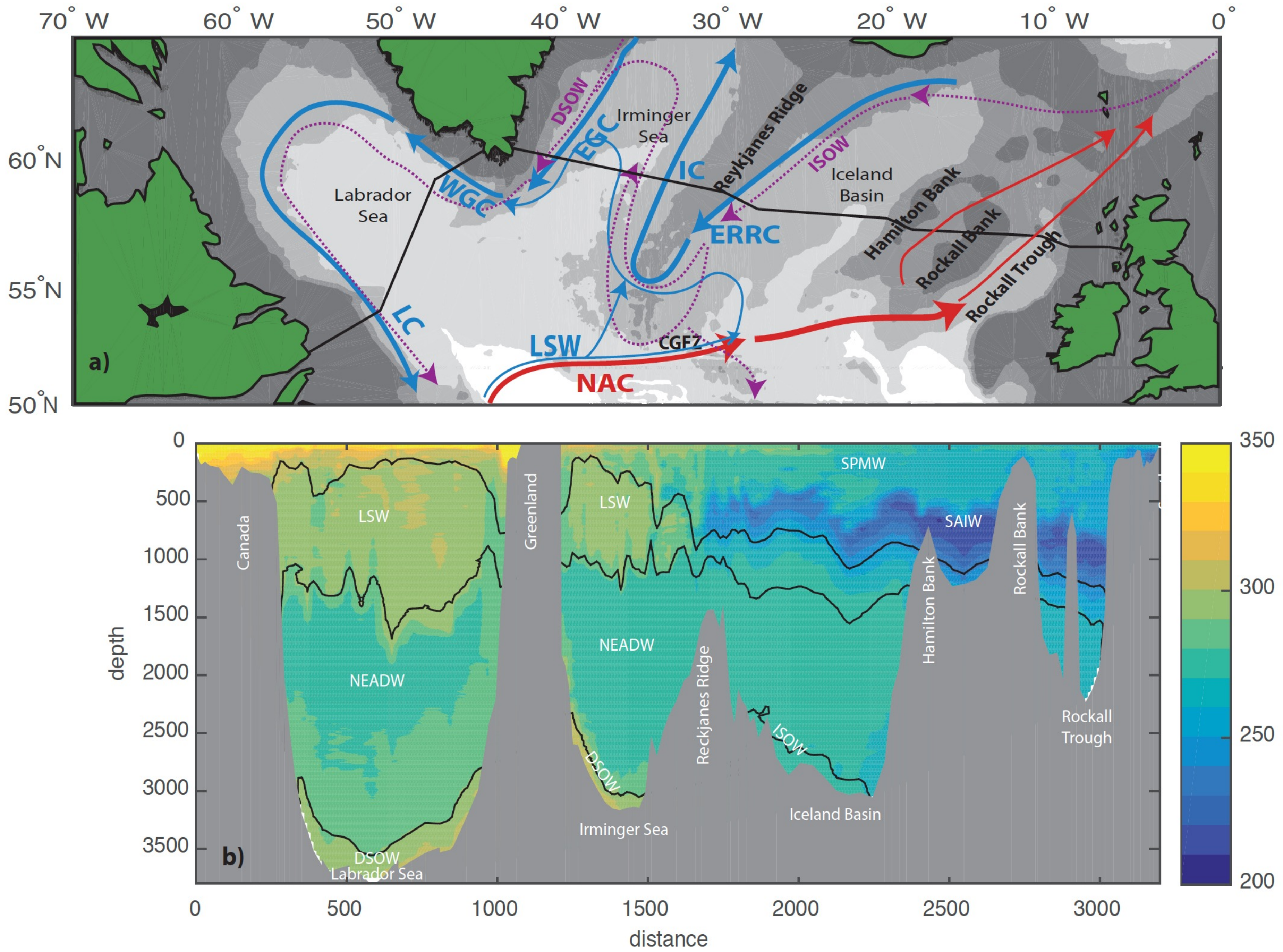
Overturning: The meridional volume transport, zonally integrated and cumulatively summed on density levels

$$\psi = \int_0^L \int_1^N v(x,n,t)h(x,n,t)dxdn$$



A zonal gradient of C on an isopycnal can lead to meaningful differences between ventilation and overturning

From Naveira-Garabato et al. 2017



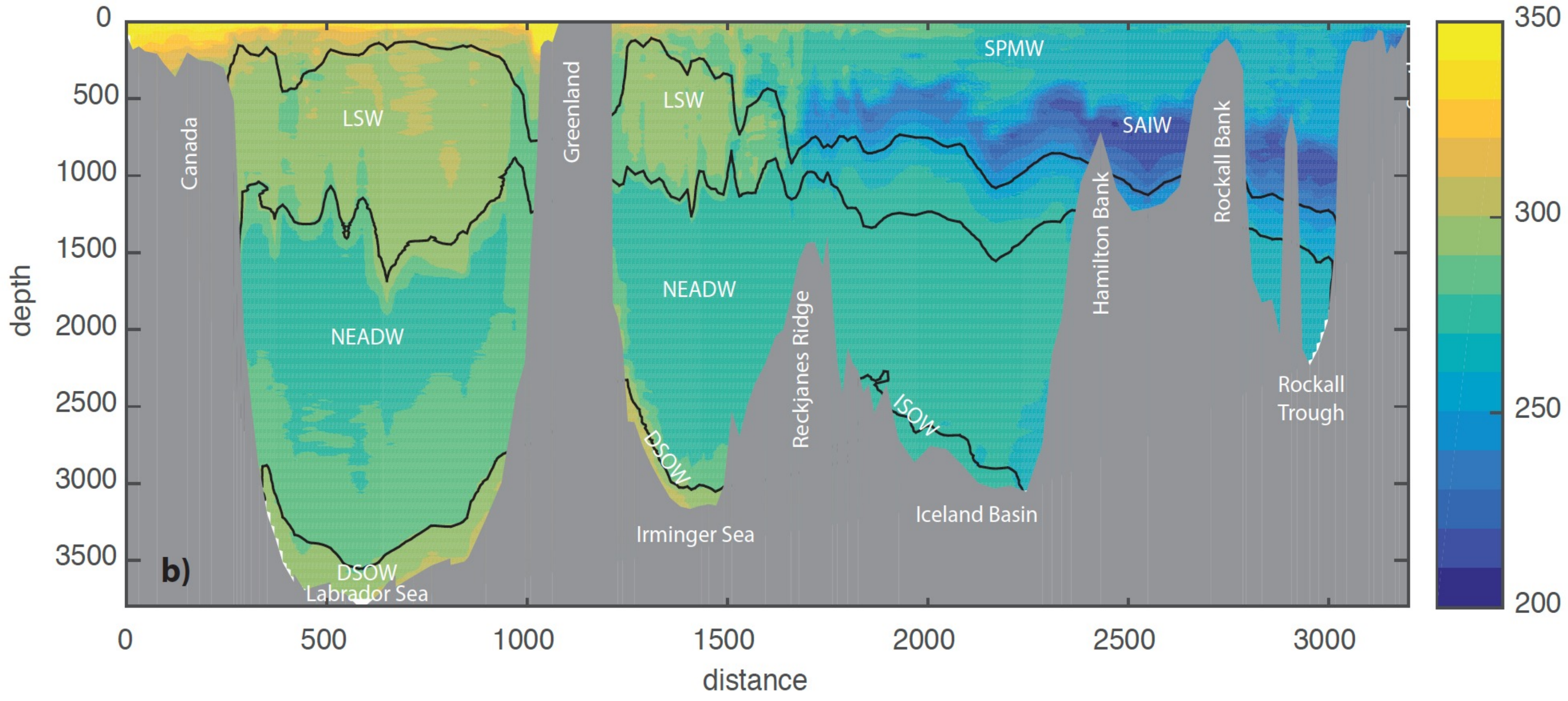
Oxygen highest in the Labrador Sea Water and Denmark Strait Overflow Water
Gradients apparent on isopycnals

Data from the 2014 OSNAP cruise JR302, kindly provide by Penny Holliday

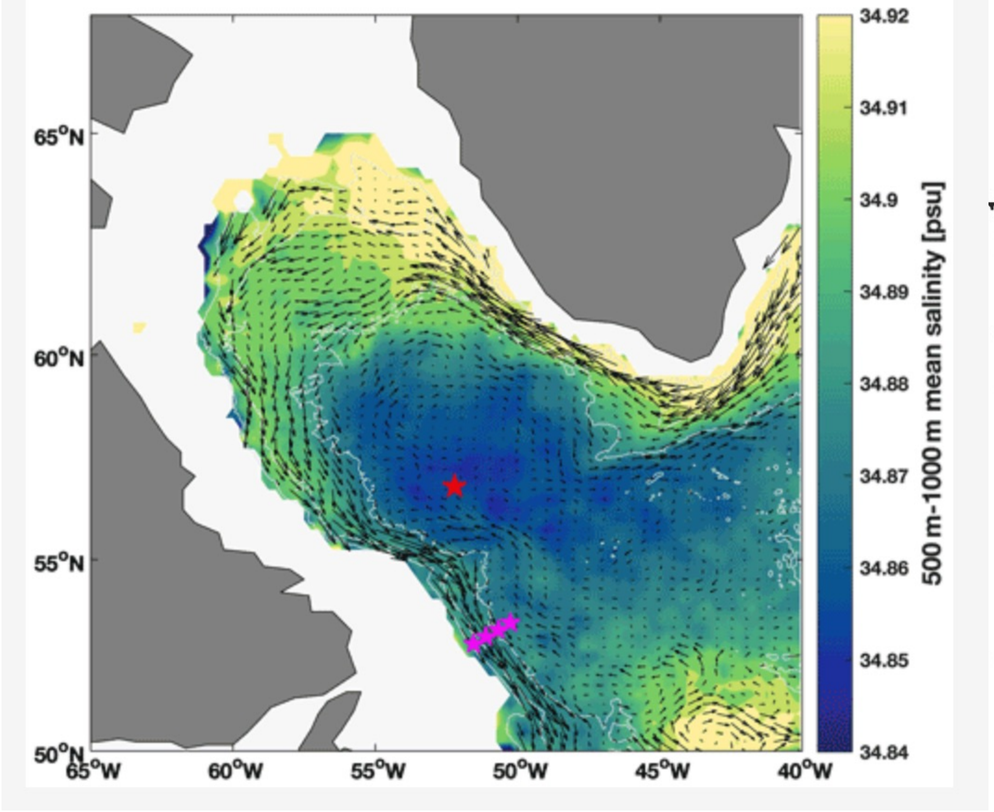
Labrador Sea appears to be important for oxygen ventilation (even if less so for overturning)

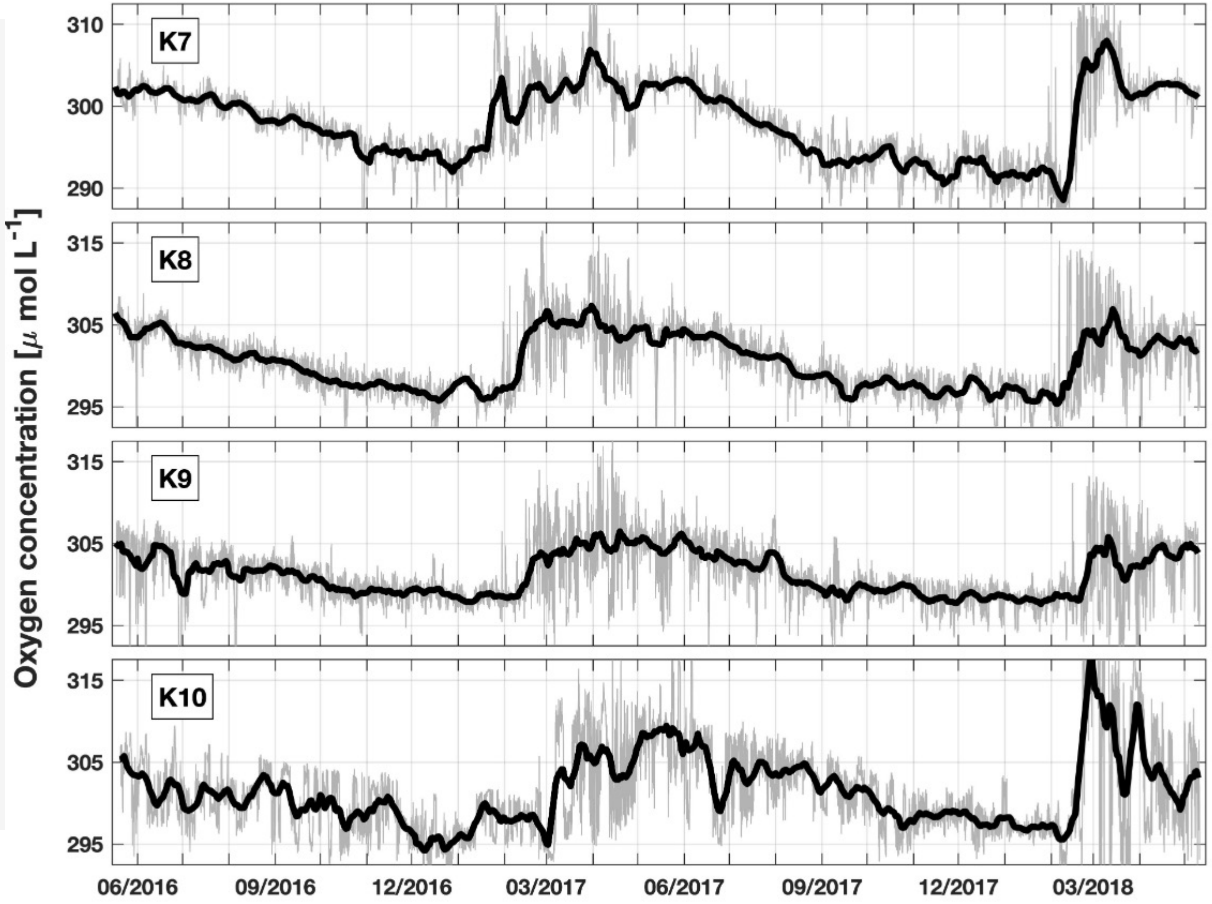
- Caveat: Oxygen transports are sensitive to choices about volume transport
- Net Oxygen export from eastern subpolar North Atlantic is mainly due to the LSW being better oxygenated than thermocline waters in the North Atlantic Current (but where did this oxygen enter the ocean?)

Oxygen transport across section: -14 Tmol O_2 -15 Tmol O_2



Hydrographic snapshots miss seasonality and may underestimate trans-basin gradients

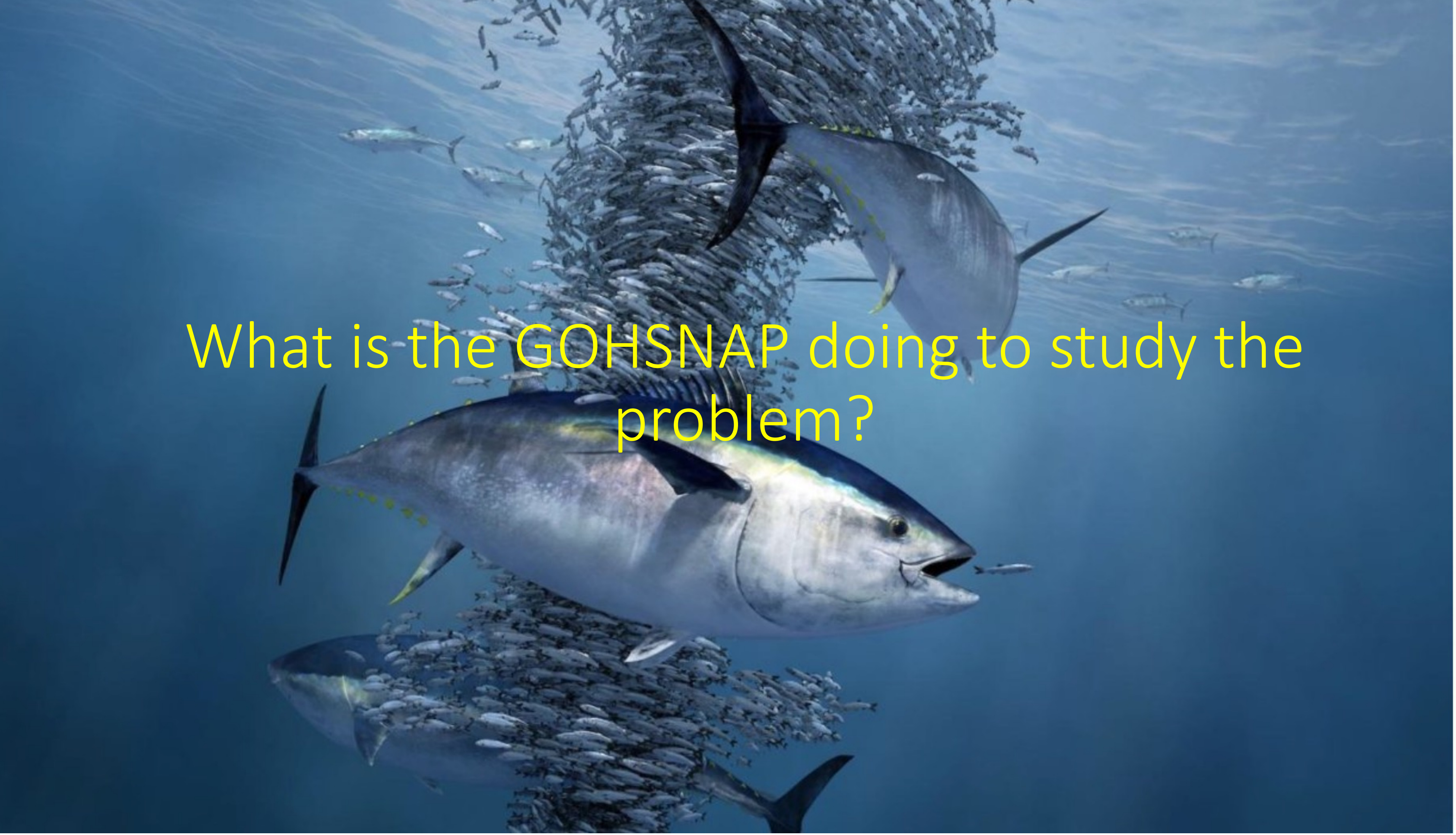




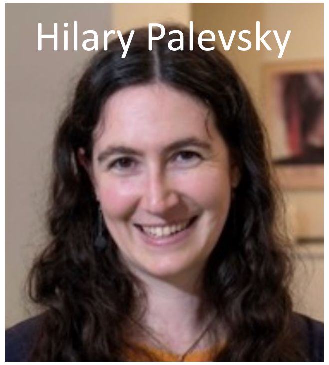
Oxygen time series from moored instruments at 610 m, western Labrador Sea, magenta stars on map

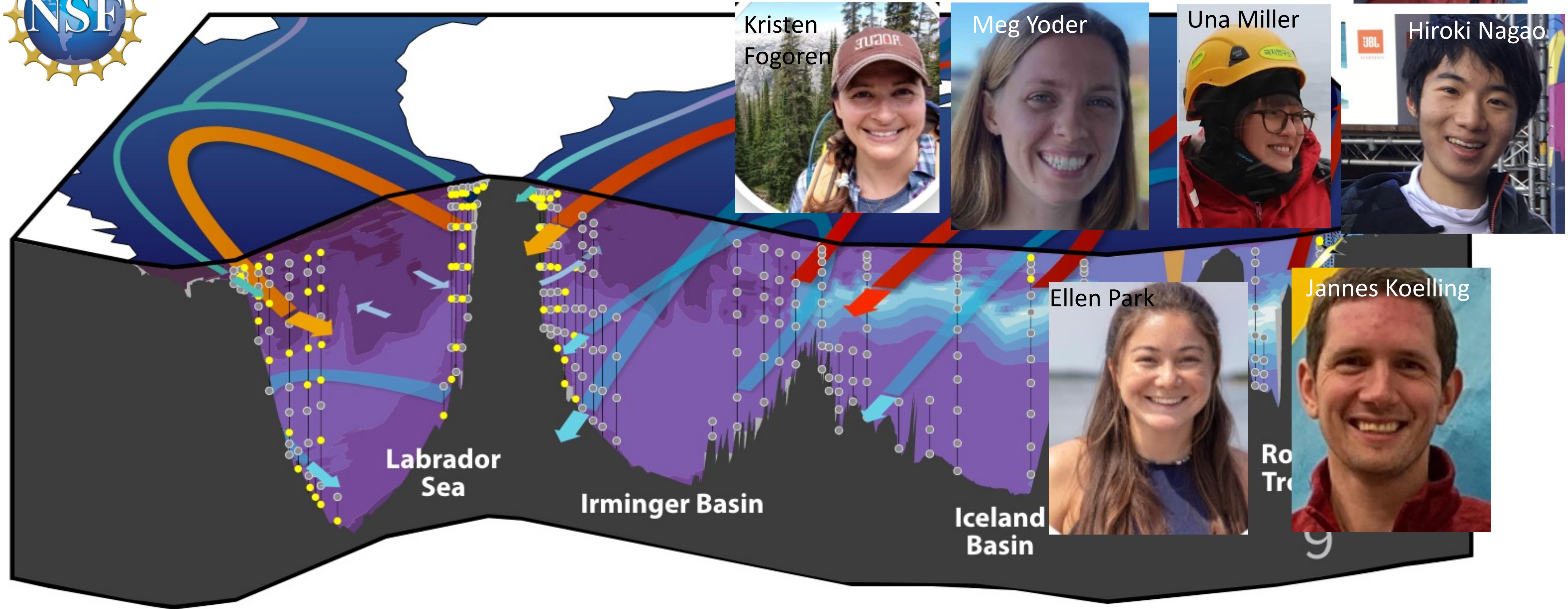
From Koelling et al 2022, Biogeosciences.

What is the GOHSNAP doing to study the problem?



GOHSNAP and Friends

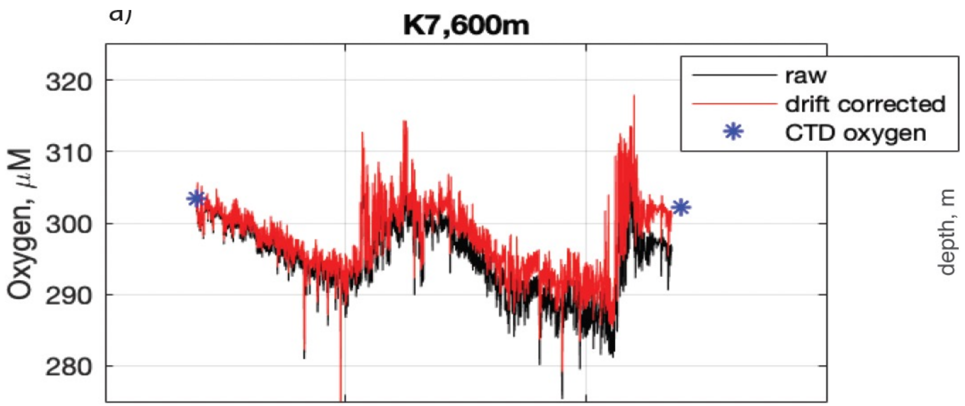




Johannes Karstensen and Doug Wallace   Isabela Les Bras   Schematic by Penny Holliday

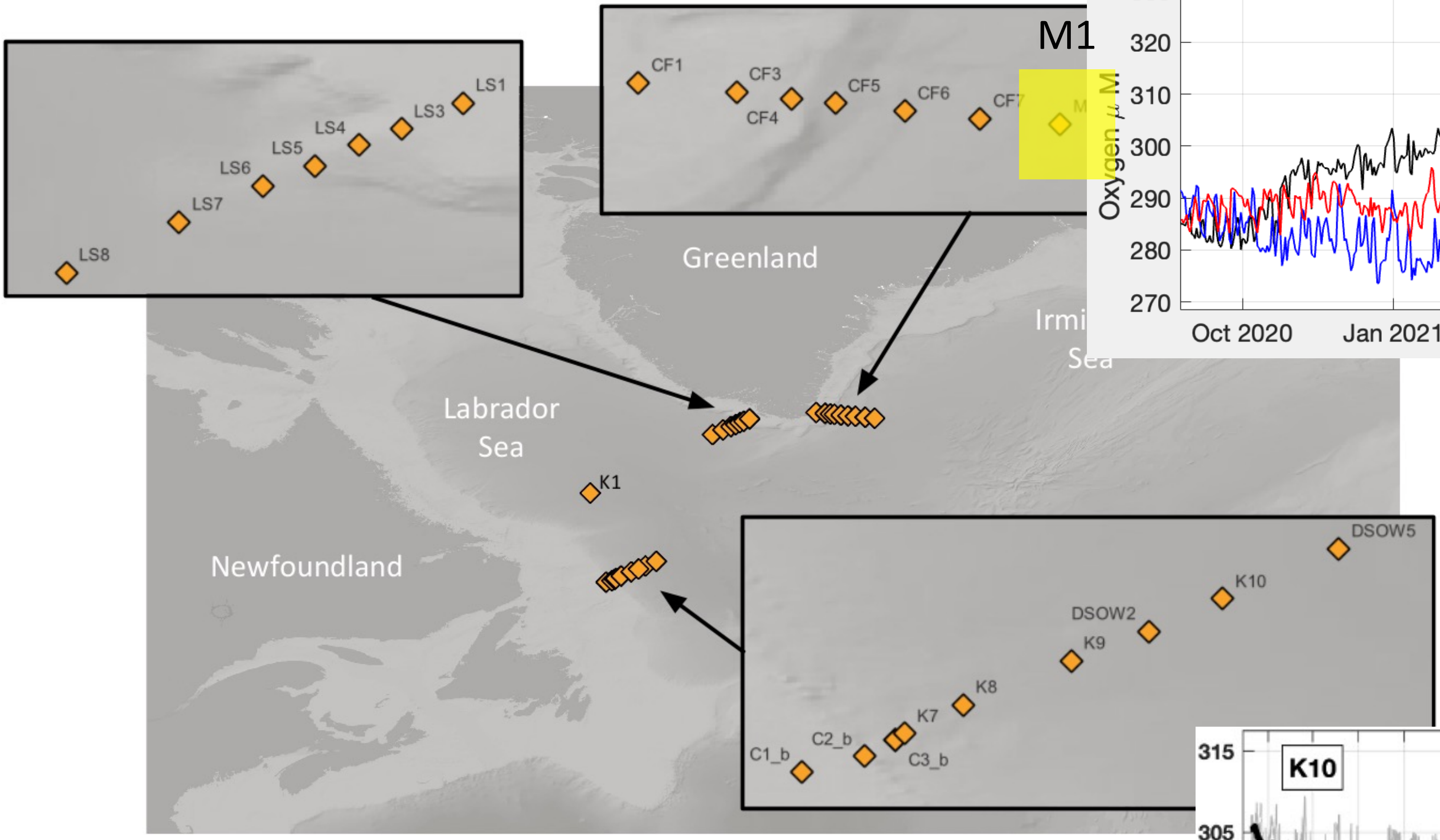
Oxygen calibration is a crucial (and painstaking) process

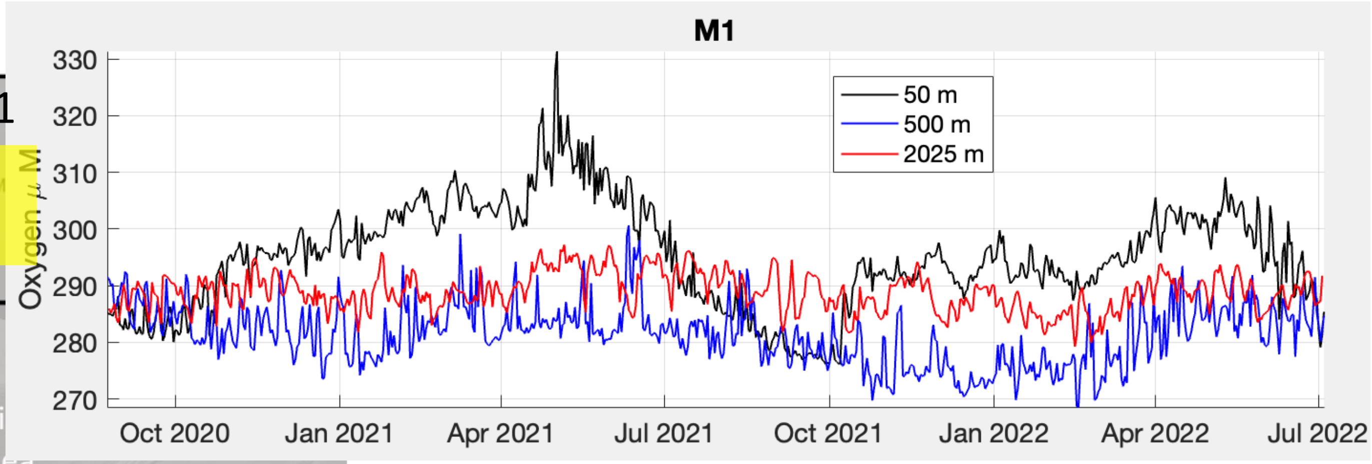
- Ship's CTD oxygen sensor must be calibrated with Winkler titrations of bottle samples (ideally processed on the ship and with many bottles)
- Winkler-calibrated CTD-oxygen then used to compare with sensor "caldips" and co-located calibration casts
- Must correct pressure compensation effect and fast and slow components of drift



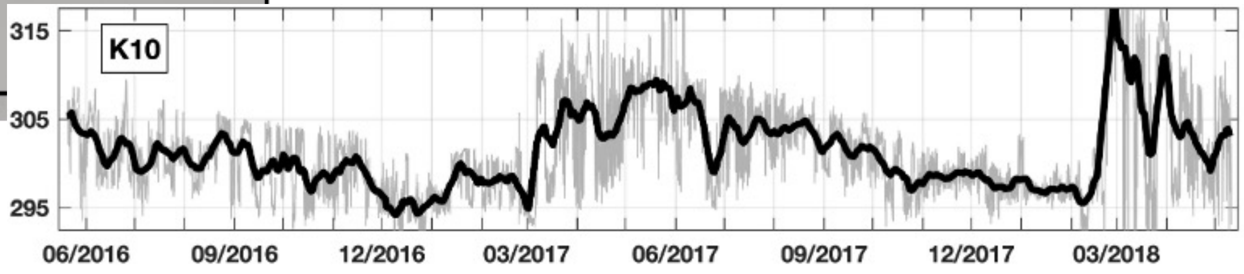
Aanderaa optodes with RBR loggers strapped to rosette for caldip

First calibrated time series:





Seasonality in Irminger Sea barely penetrates to 500 m, in contrast to Labrador Current array



Figures by Una Miller

Up next:

Finish careful QA/QC of all sensor data

Create gridded $O_2(x,z,t)$ field

Combine with OSNAP's v(x,z,t) field to get transports and net export from the basin

Understand everything

In summary:

1. Ocean deoxygenation can mean life or death for many marine animals
2. The ocean has already lost about 2% of its oxygen reservoir
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Thank you