Amplified subsurface signals of ocean acidification

and the implications for interior ocean ecosystems

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Session 8

October 31, 2024

marine ecosystem stressors: warming & deoxygenation

nature geoscience

REVIEW ARTICLE

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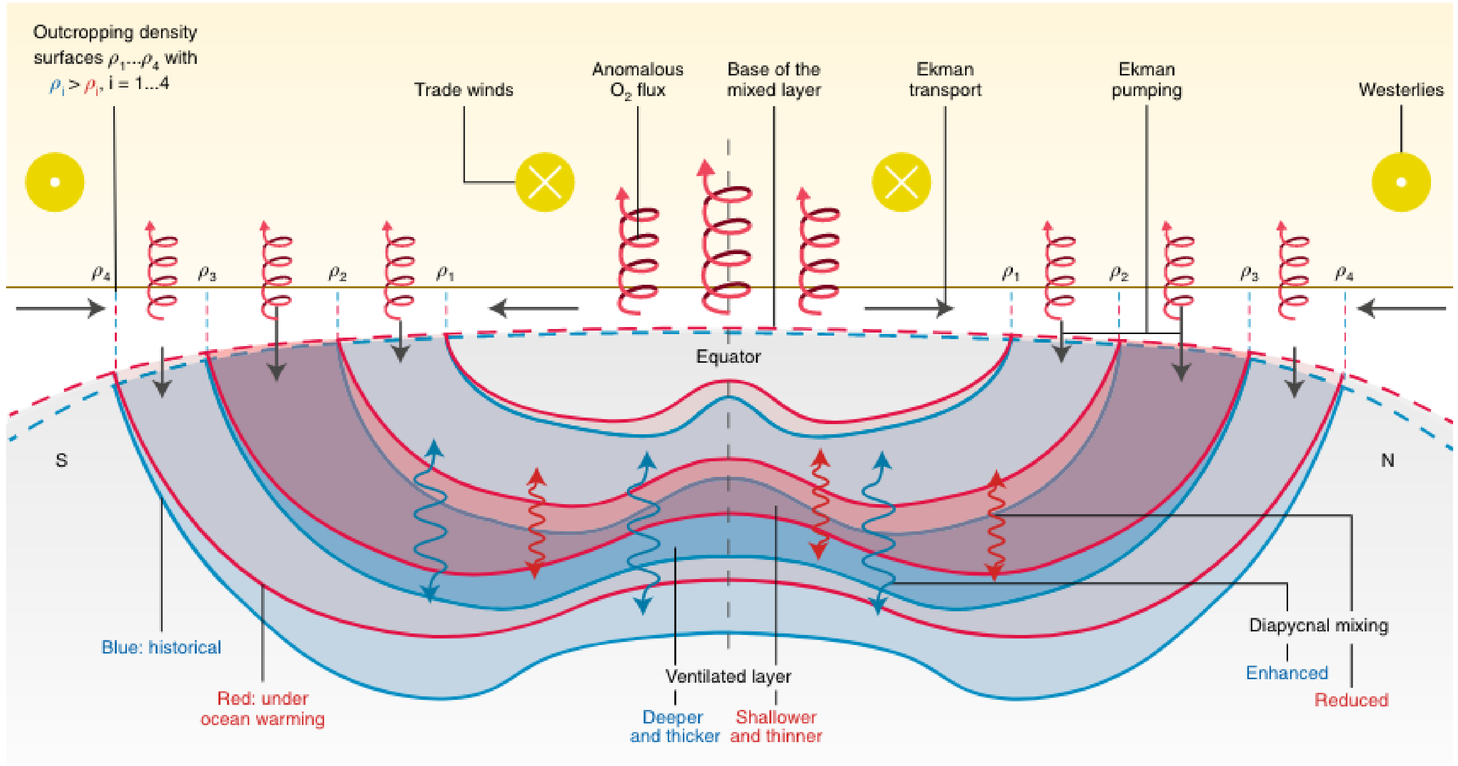
Drivers and mechanisms of ocean deoxygenation

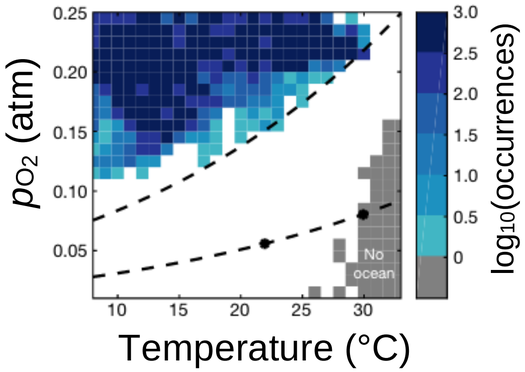
Andreas Oschlies[1,2*], Peter Brandt[1,2], Lothar Stramma[1] and Sunke Schmidtko[1]



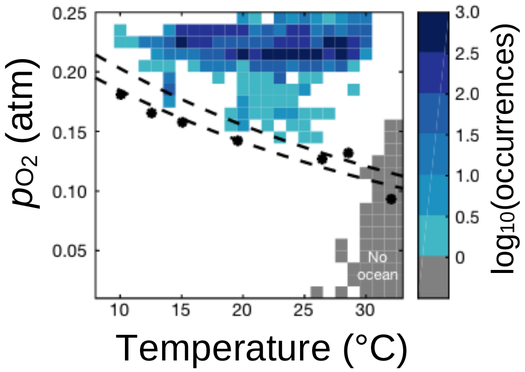
"Warming is considered a major driver: in part directly, via solubility effects, and in part indirectly, via changes in circulation, mixing and oxygen respiration."

Metabolic trait diversity shapes marine biogeography

Deutsch et al., 2020 - Nature



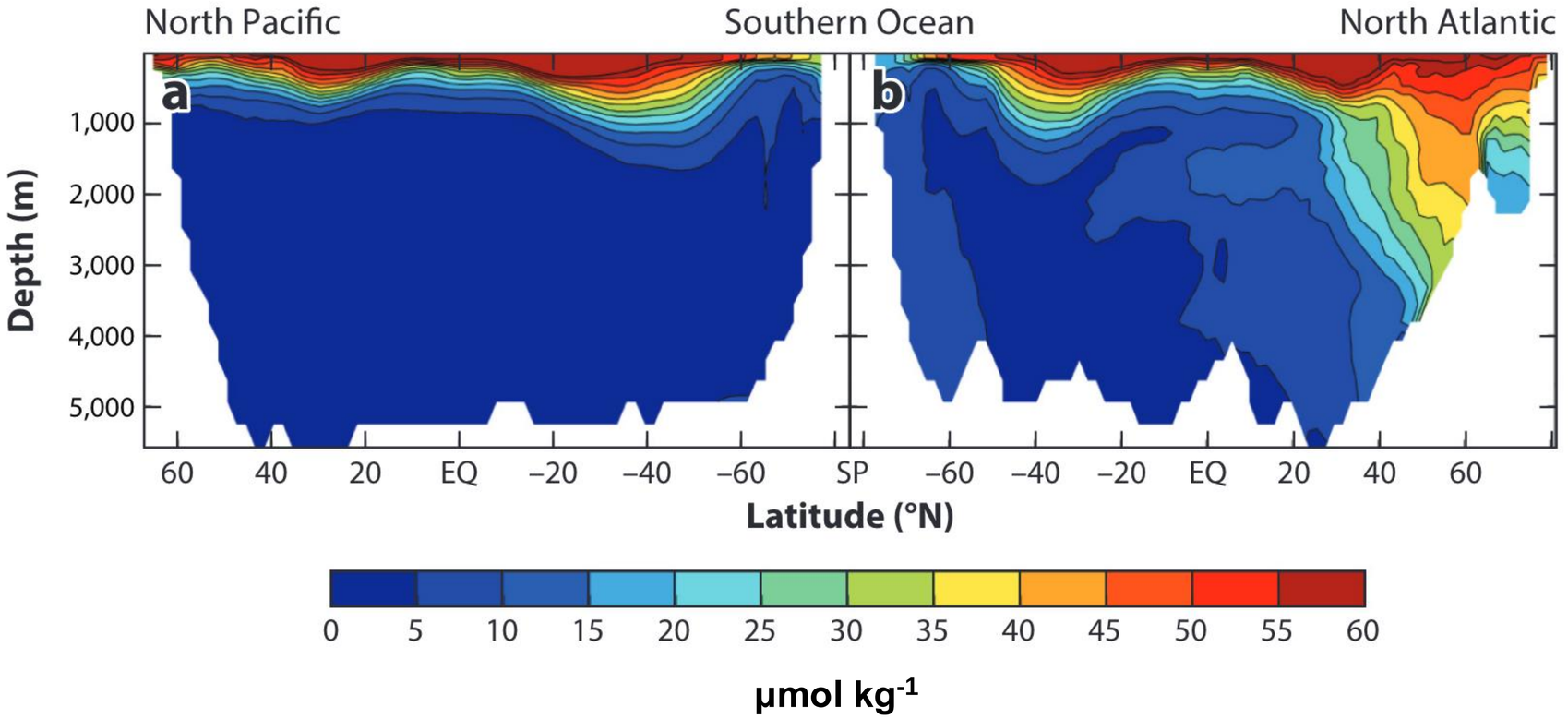
habitat of Summer flounder (subtropical eastern Atlantic)



habitat of Sea squirt (cosmopolitan tunicate)

marine ecosystem stressors: acidification

Anthropogenic Carbon

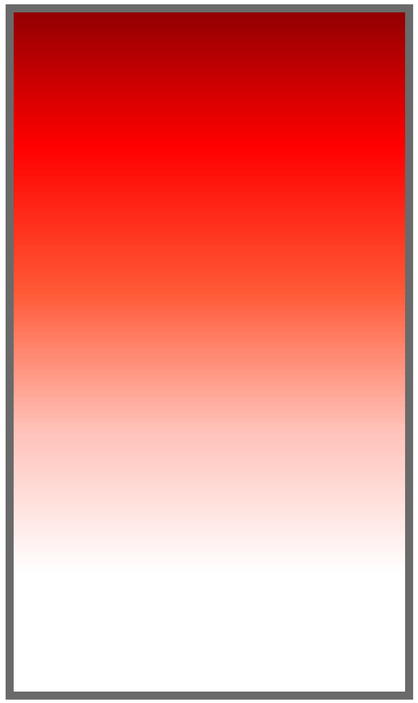


DeVries et al., 2022

surface intensified changes

Increasing Temp & C_{anth}

Surface



Deep

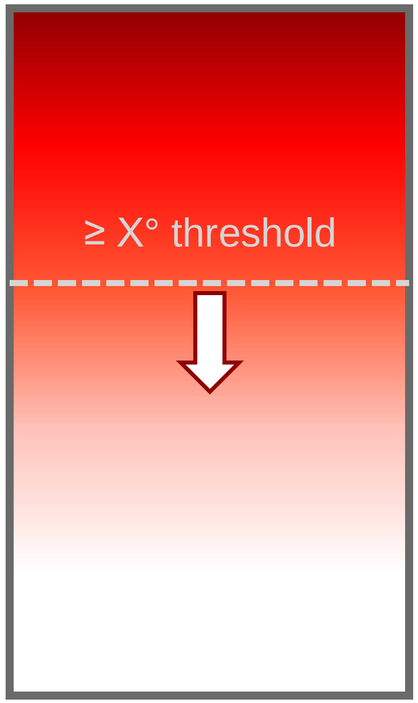
Decreasing pH & Ω_{Ar}

Decreasing Oxygen

threshold migration in opposite directions

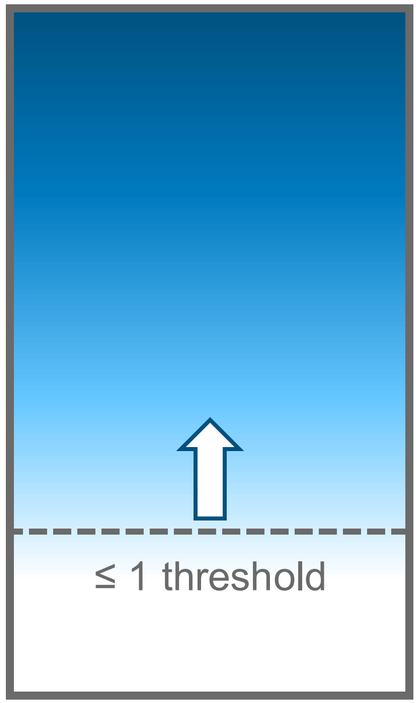
Increasing Temp & C_{anth}

Surface

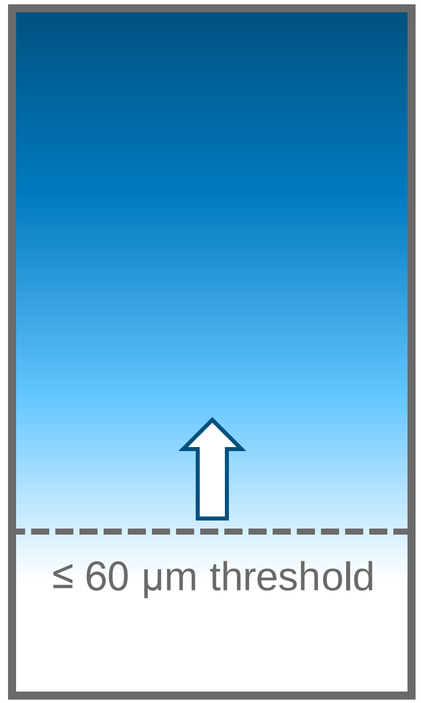


Deep

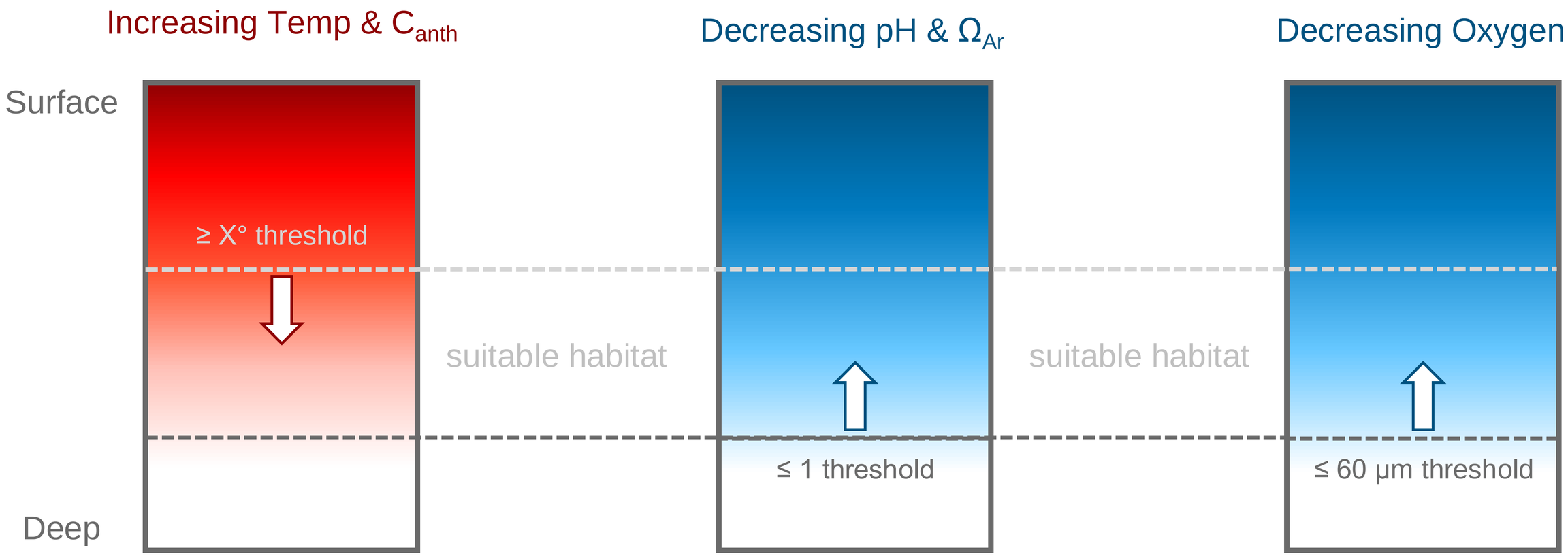
Decreasing pH & Ω_{Ar}



Decreasing Oxygen

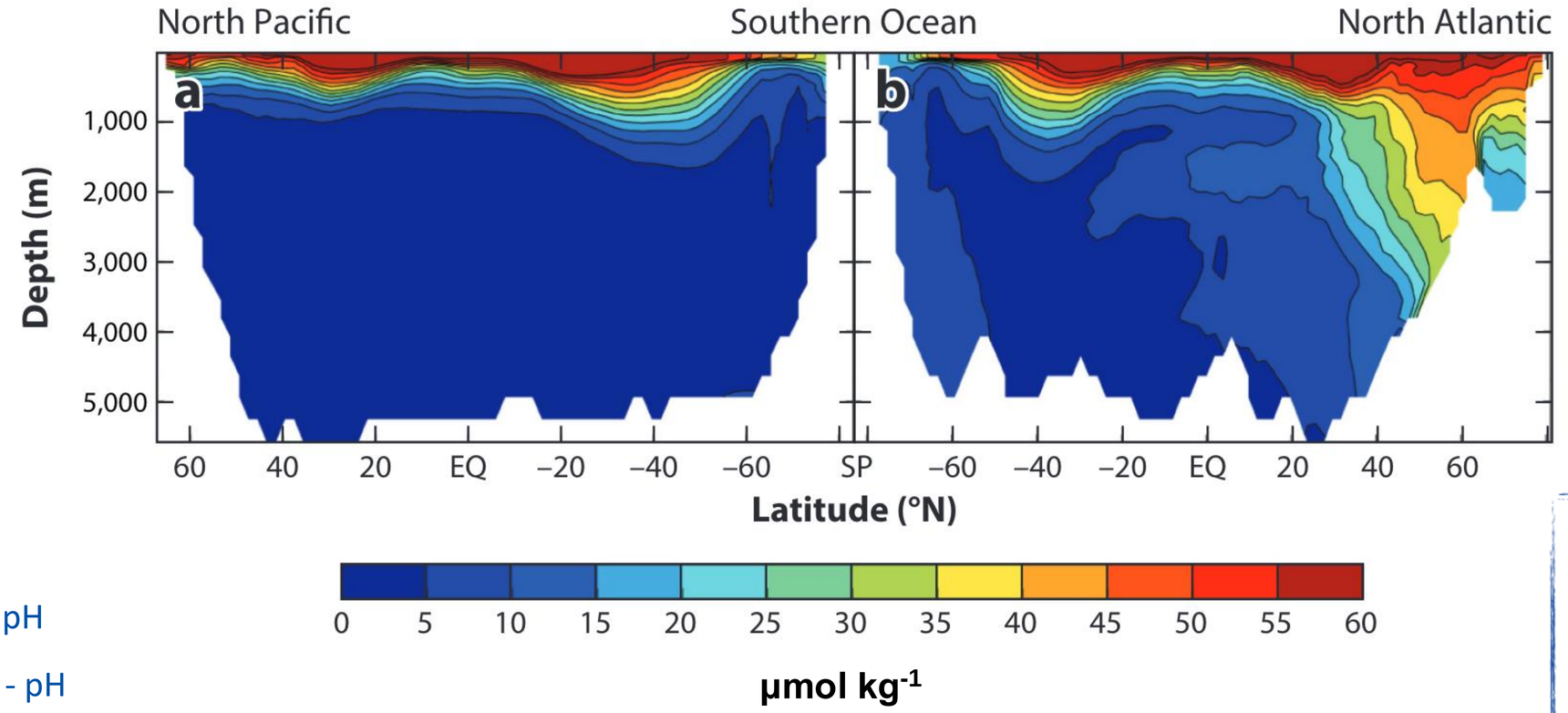


compression of suitable habitat



ocean acidification (OA) is largely considered a surface intensified process

Anthropogenic Carbon



Carter et al., 2019 - pH

Lauvset et al., 2020 - pH

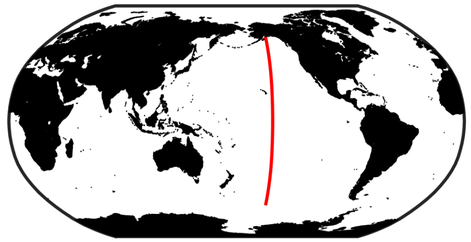
Fassbender et al., 2021 - pH, $[H^+]$

Arroyo et al., 2022 - pH, Ω_{Ar}, pCO_2, $[H^+]$, RF

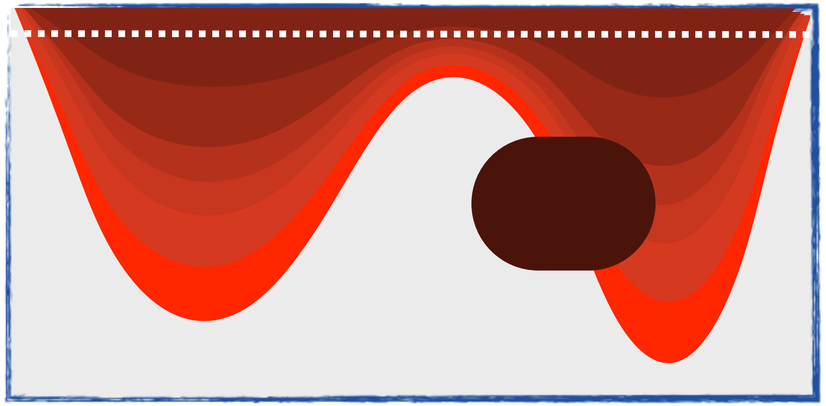
Data Source:
GLODAPv2.2016b mapped data product
(Lauvset et al., 2016)

DeVries et al., 2022

are amplified subsurface signals of OA ubiquitous?

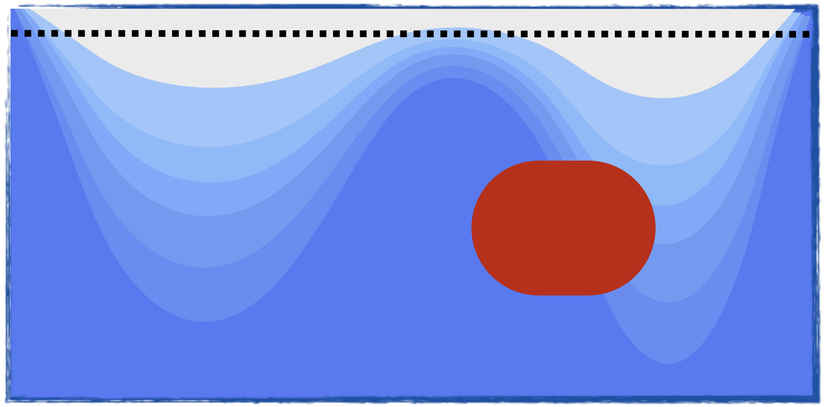


$\Delta\Omega_{Ar}^{Cant}$



C_{ant} = anthropogenic carbon

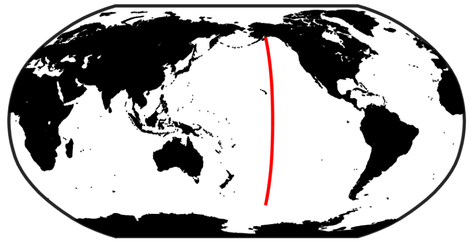
$\Delta\Omega_{Ar}^{Cant} - \overline{\Delta\Omega_{Ar}^{Cant}}\,|_{0\text{-}50\ m}$



smaller than upper 50 m change

larger than upper 50 m change

are amplified subsurface signals of OA ubiquitous?



Anthropogenic carbon induced changes by the year 2002 relative to the mean change in the upper 50 m

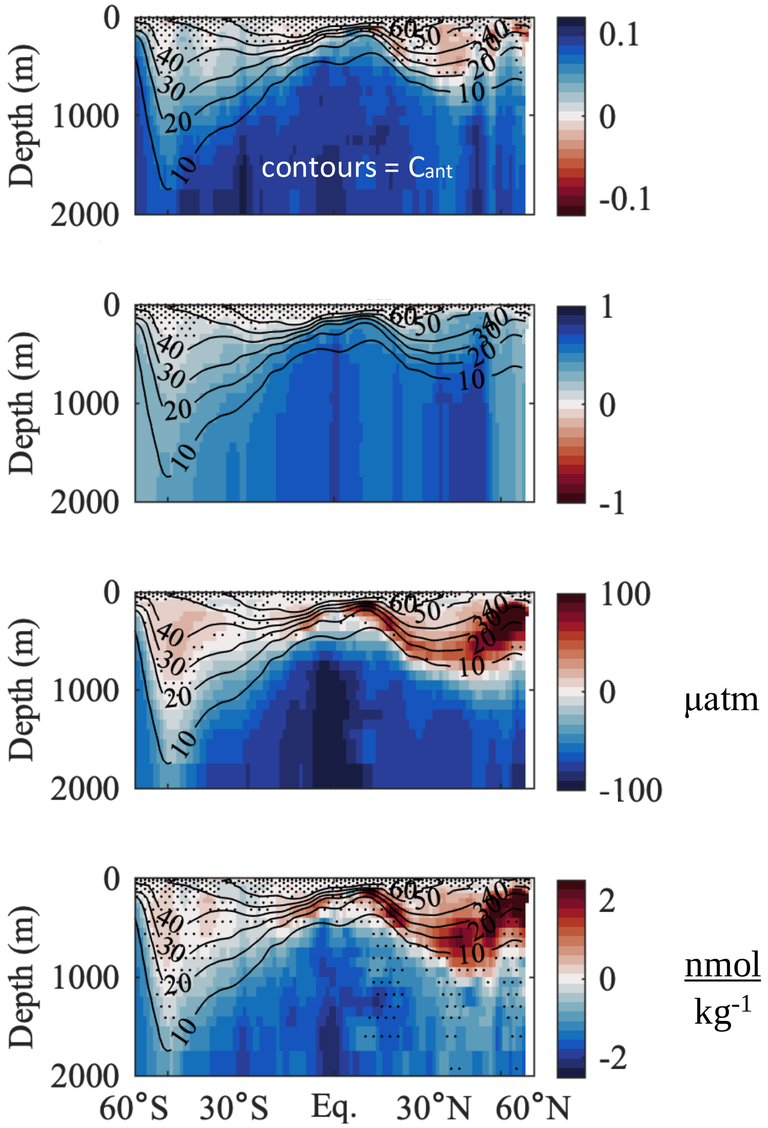
Pacific

pH

Ω_{Ar}

*p*CO2

$[H^+]$



smaller than upper 50m change

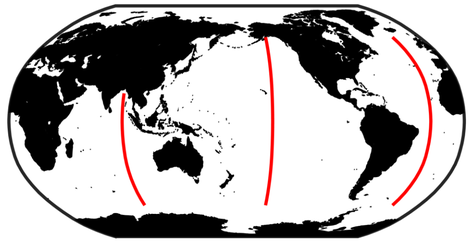
larger than upper 50 m change

Data Source:
GLODAPv2.2016b mapped data product
(Lauvset et al., 2016)

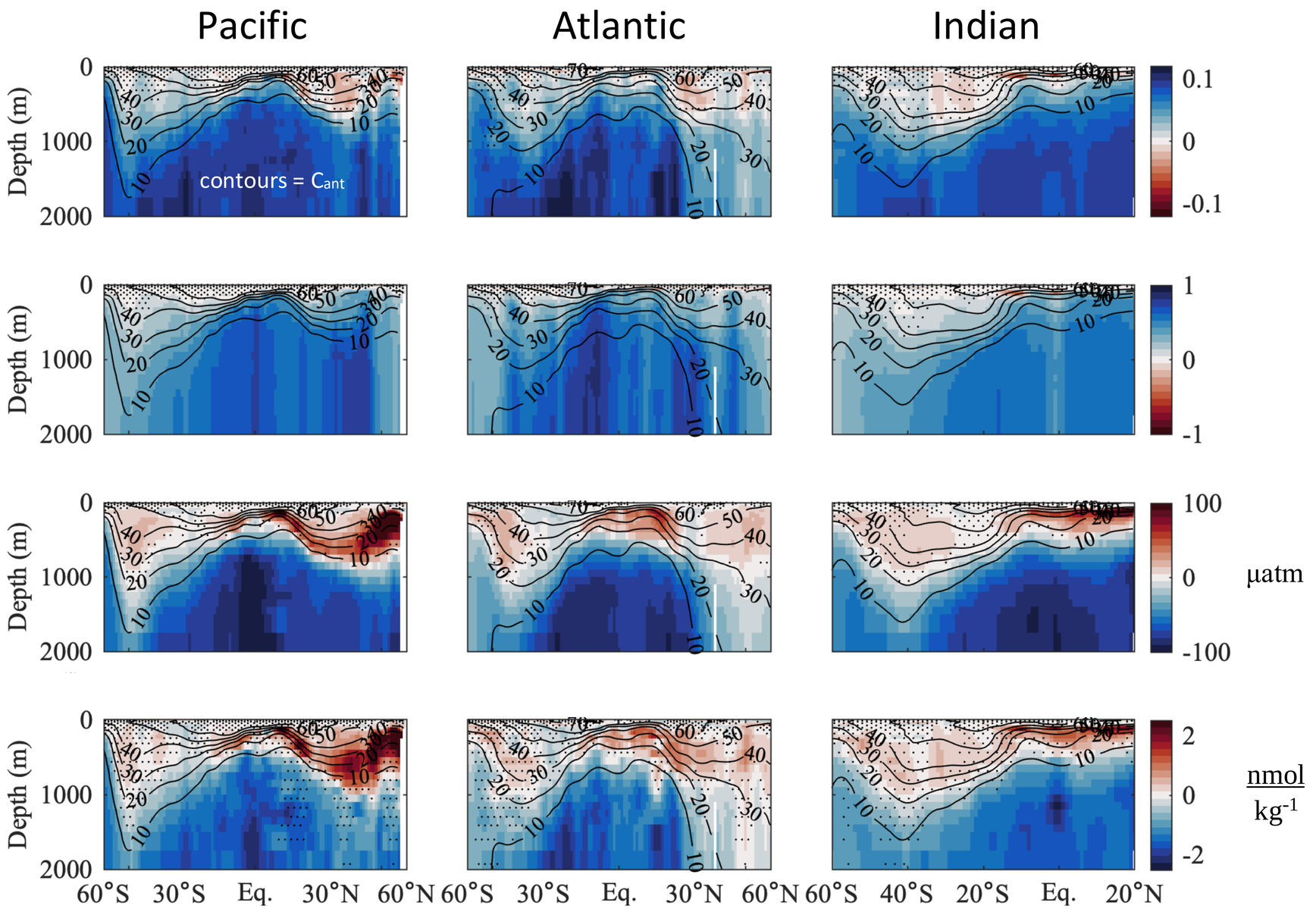
Fassbender et al., 2023 (GBC)

$pH = -\log_{10}([H^+])$

amplified subsurface changes to *p*CO2, [H$^+$], & pH are global



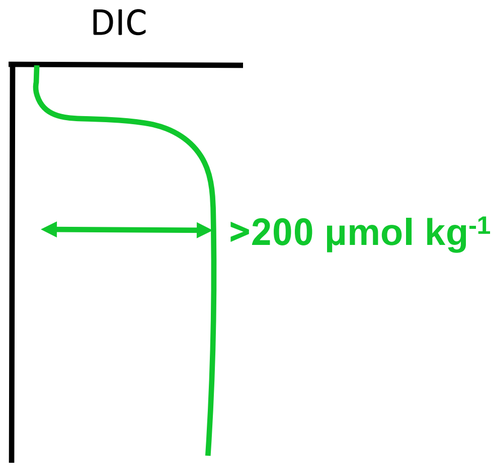
Anthropogenic carbon induced changes by the year 2002 relative to the mean change in the upper 50 m

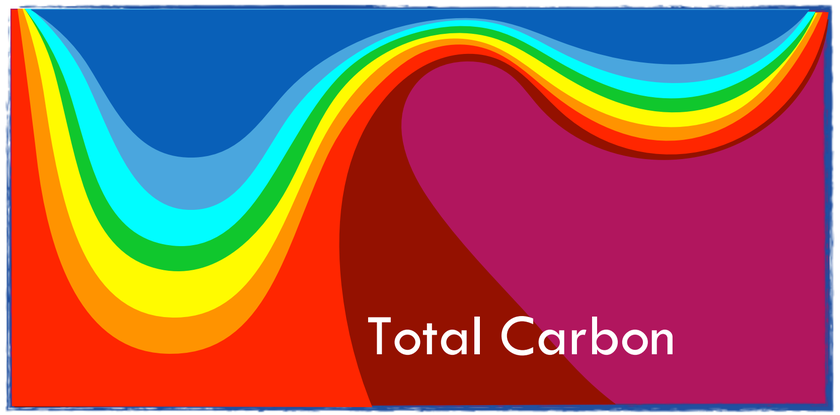


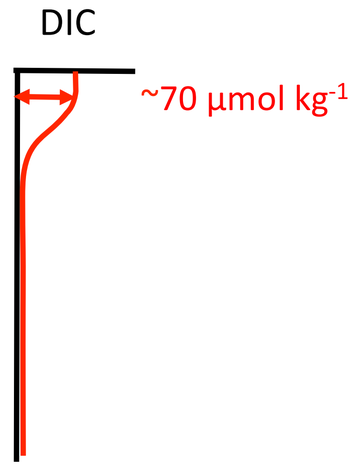
Fassbender et al., 2023 (GBC)

pH = -log$_{10}$([H$^+$])

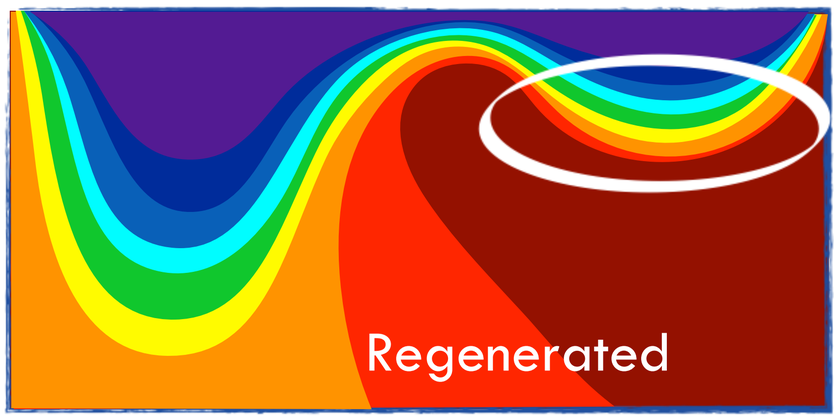
hypothesis: widespread effect from interior ocean carbon pool interactions



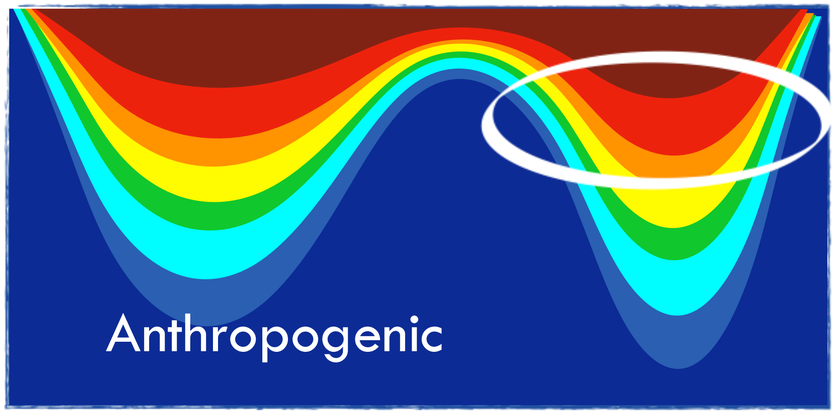




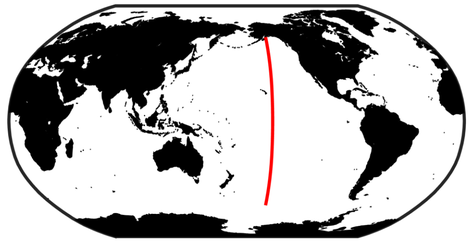
Natural

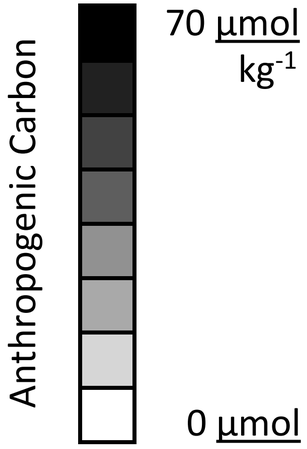


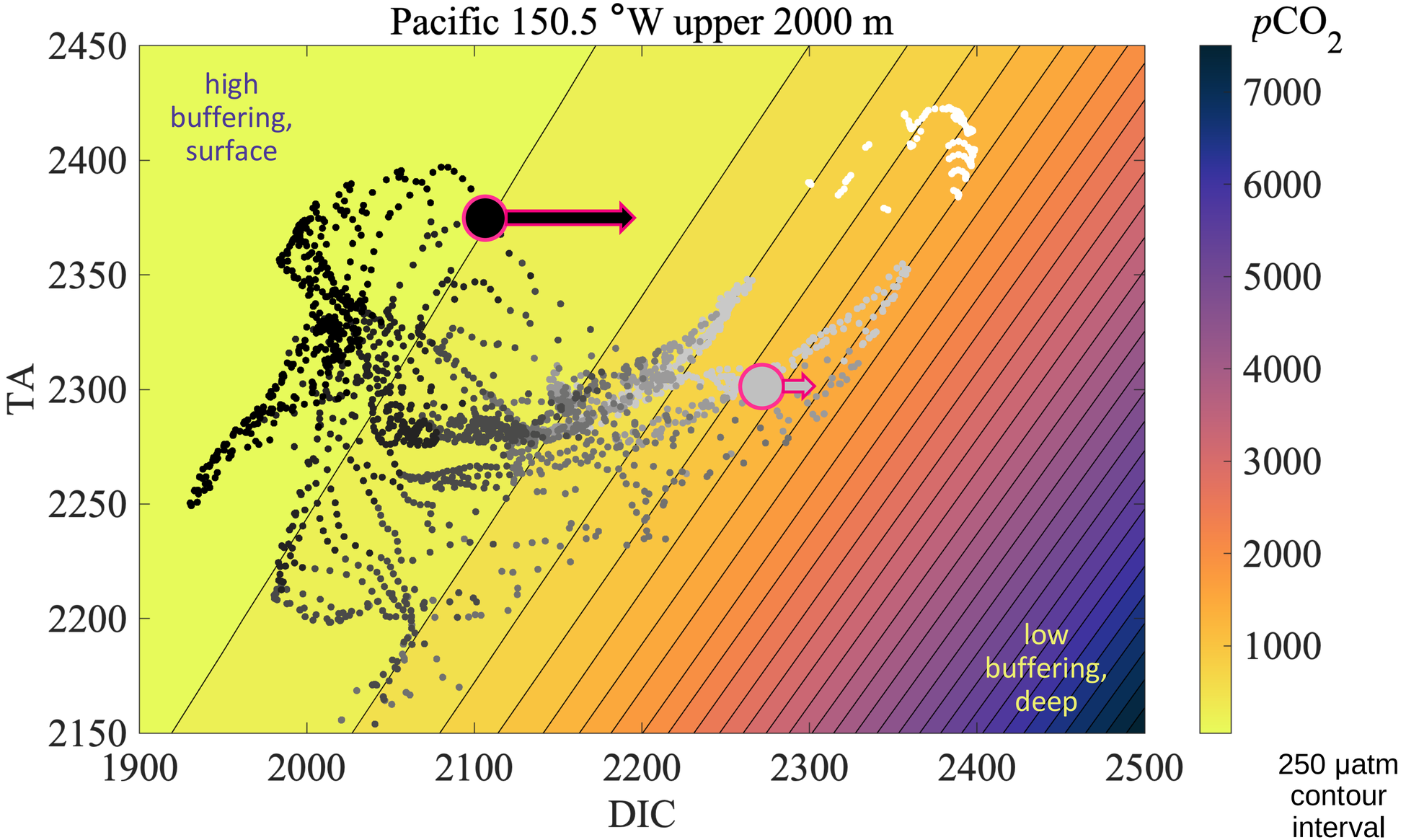
Anthropogenic



carbonate system nonlinearities

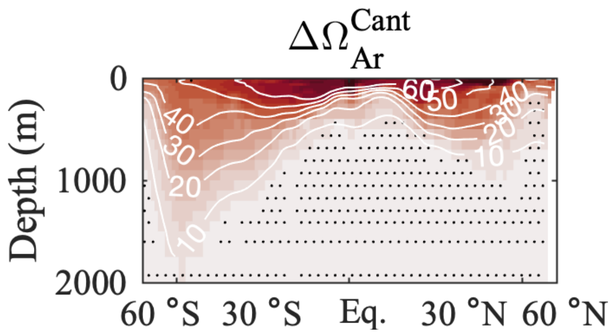


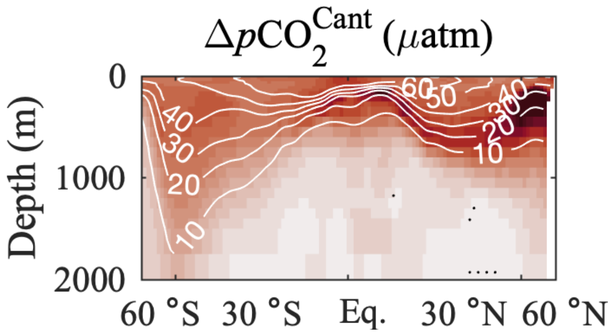




Fassbender et al., 2023 (GBC)

implications: OA complicates vertical structure of interior ocean stressors





Increasing Temp & C_{anth}

Surface

≥ X° threshold

Deep

Decreasing Ω_{Ar}

≤ 1 threshold

Decreasing pH & Increasing $[H^+]$ & pCO_2

≥ 1000 µatm threshold

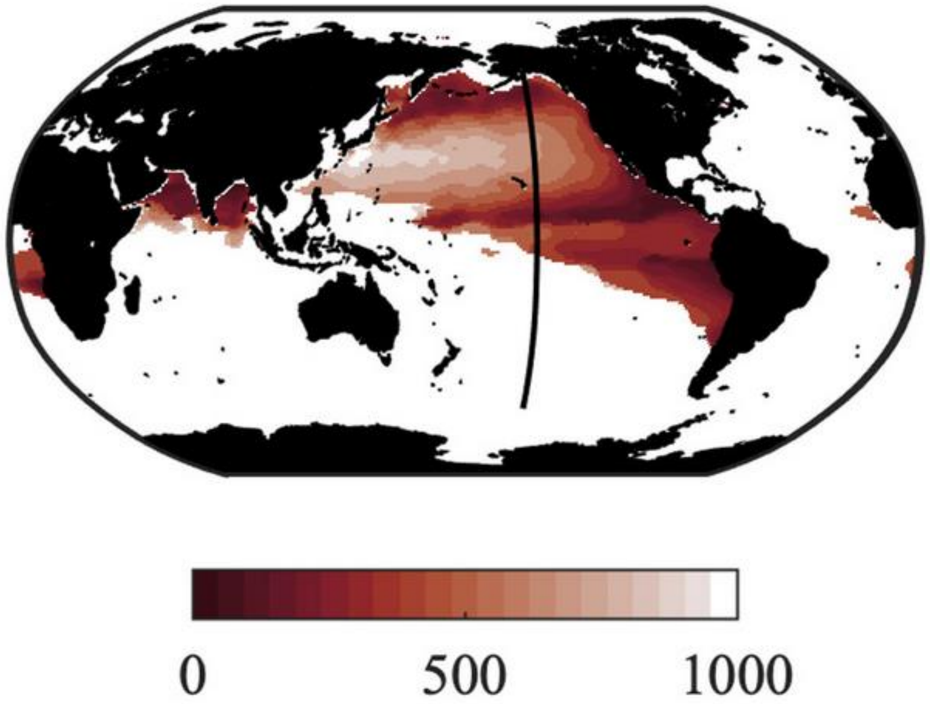
Decreasing Oxygen

≤ 60 µm threshold

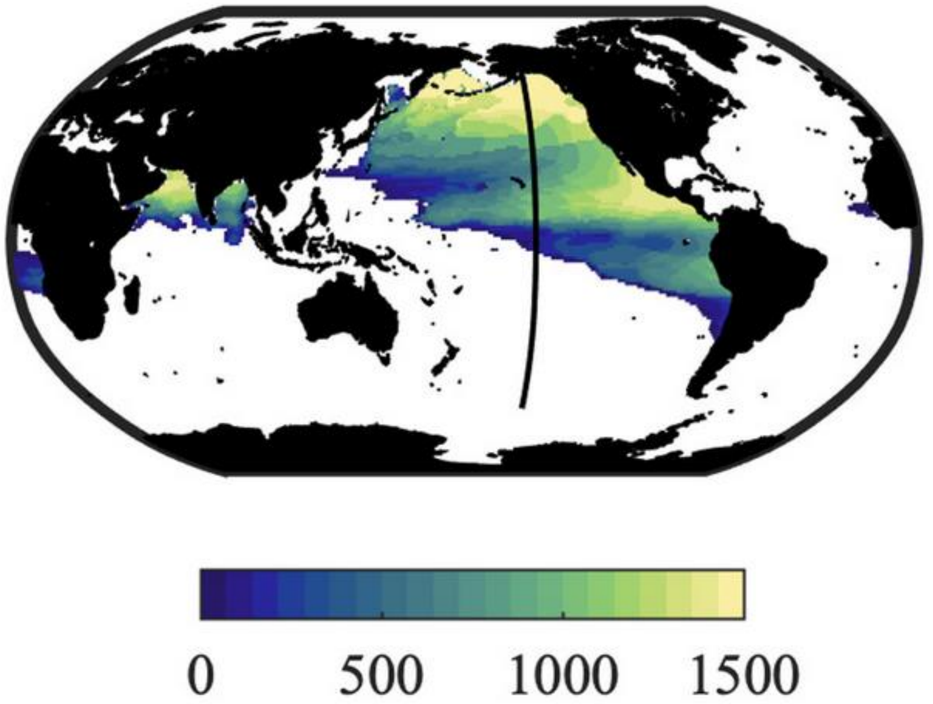
implications: overlapping stressors

growing volume of water experiencing multiple environmental stressors

Hypercapnia Horizon (m)



Hypoxia-Hypercapnia Overlap Thickness (m)



Hypoxia: $O_2 \leq 60$ µmol kg^{-1}

Hypercapnia: $pCO_2 \geq 1000$ µatm

Fassbender et al., 2023 (GBC)

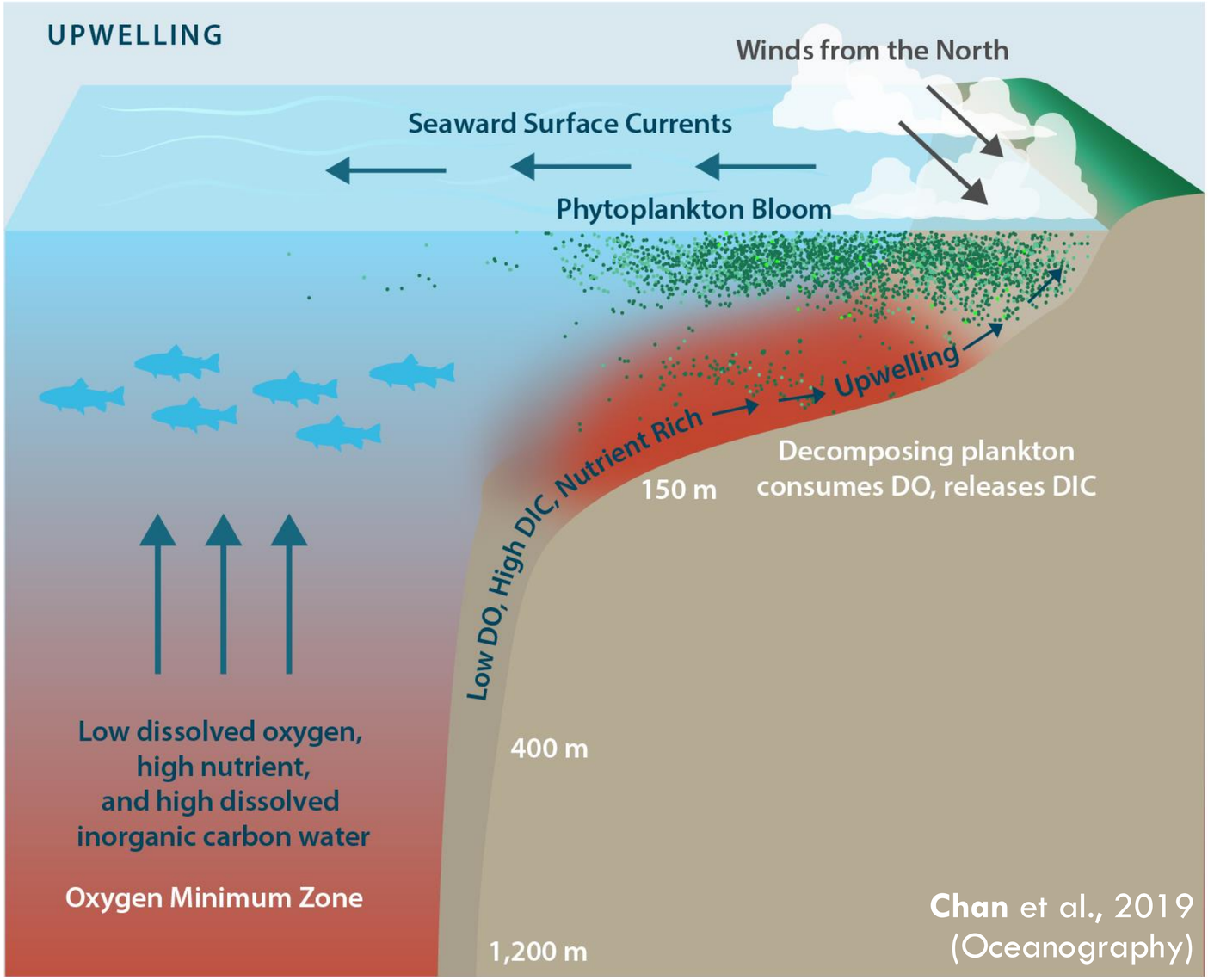
implications: reconsider perspectives on upwelling region exposure

Potential flaw in the hypothesis that organisms in upwelling regions are more tolerant to OA due to natural variability

Arroyo et al., 2022

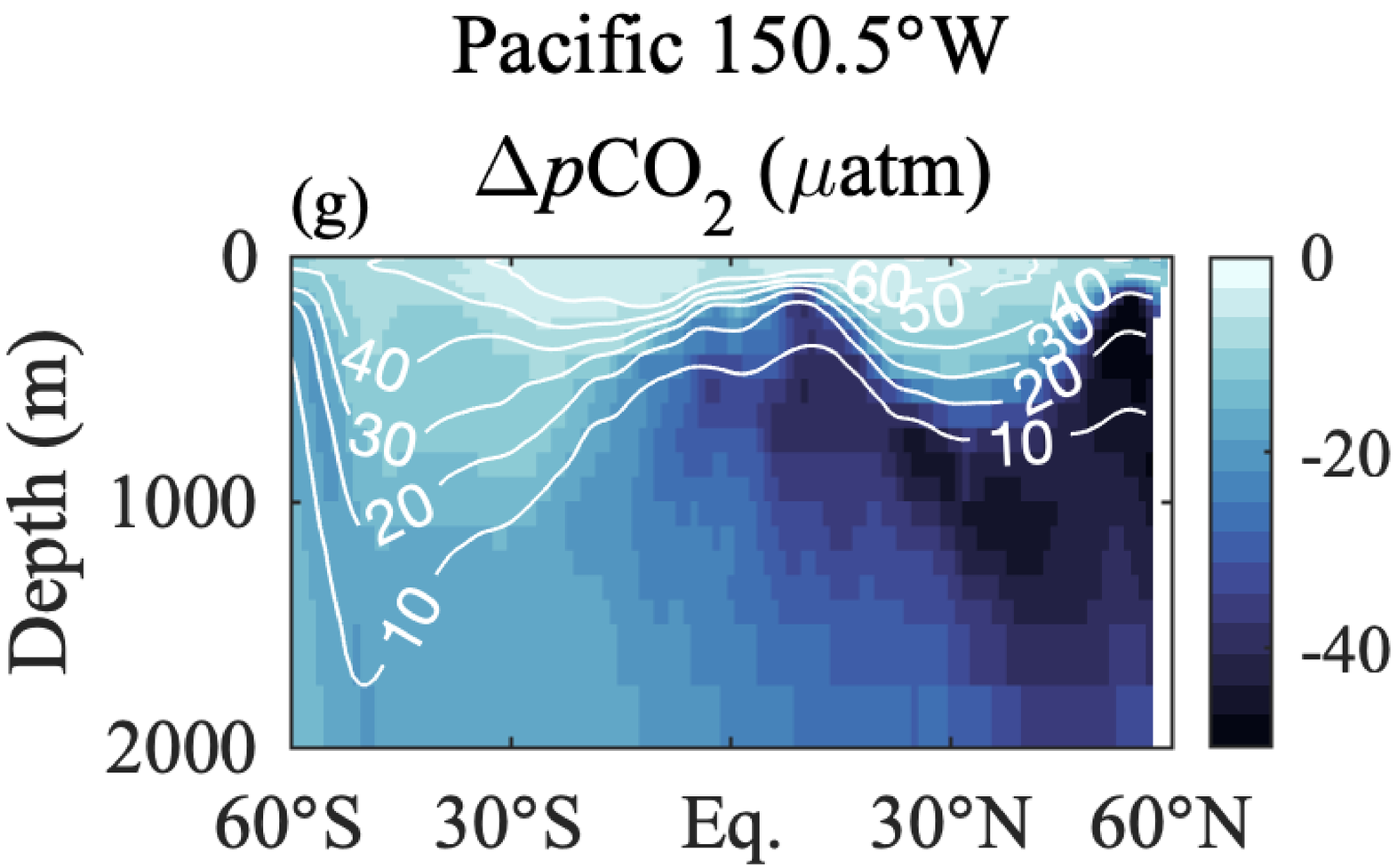
scan me!

Mar Arroyo
PMEL/UCSC
Graduate Student



Fassbender et al., 2023 (GBC)

implications: consequences and co-benefits of mCDR

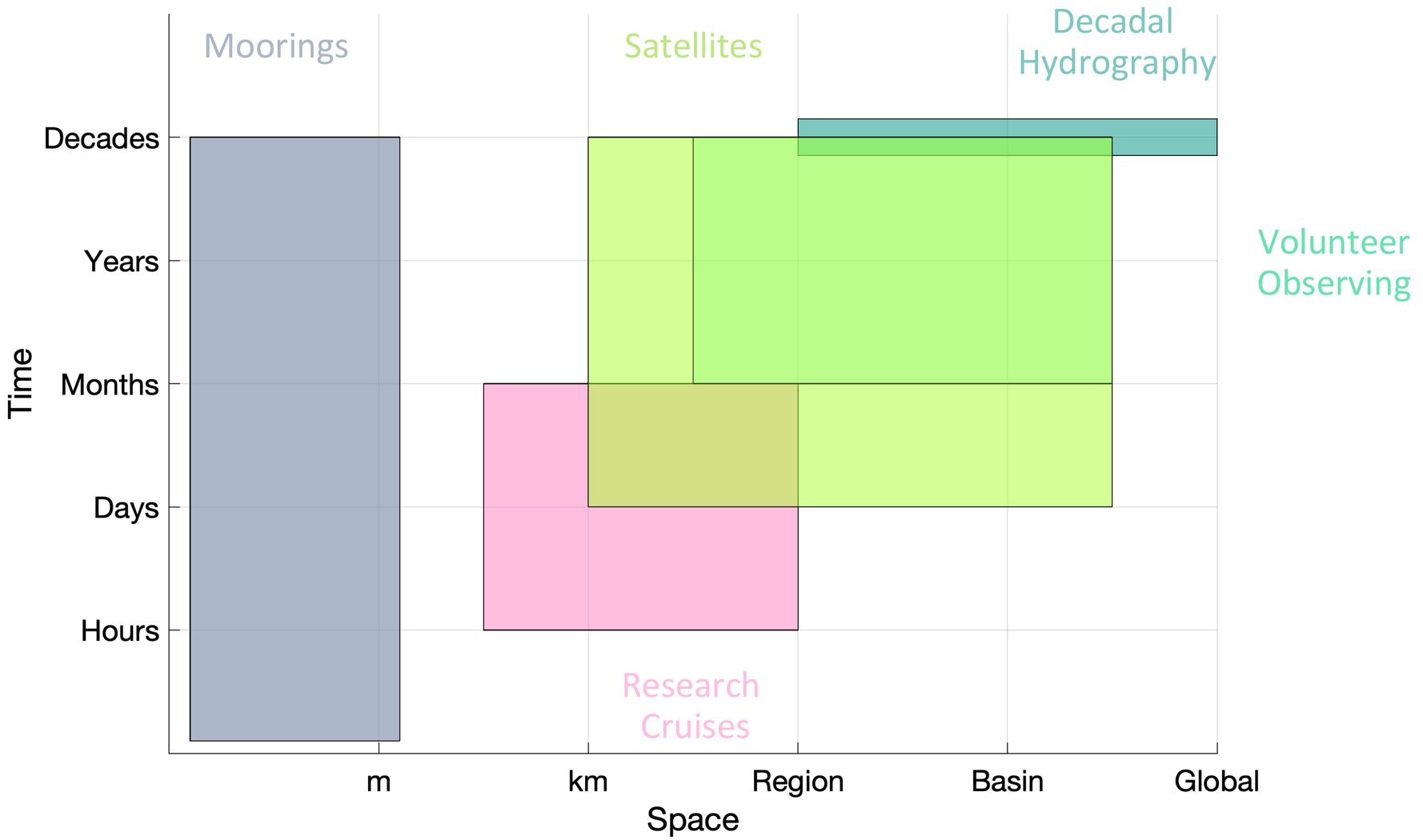


pCO_2 change associated with adding 5 µmol kg^{-1} DIC and 10 µmol kg^{-1} TA throughout the entire water column (mimicking $CaCO_3$ dissolution).

scan me!

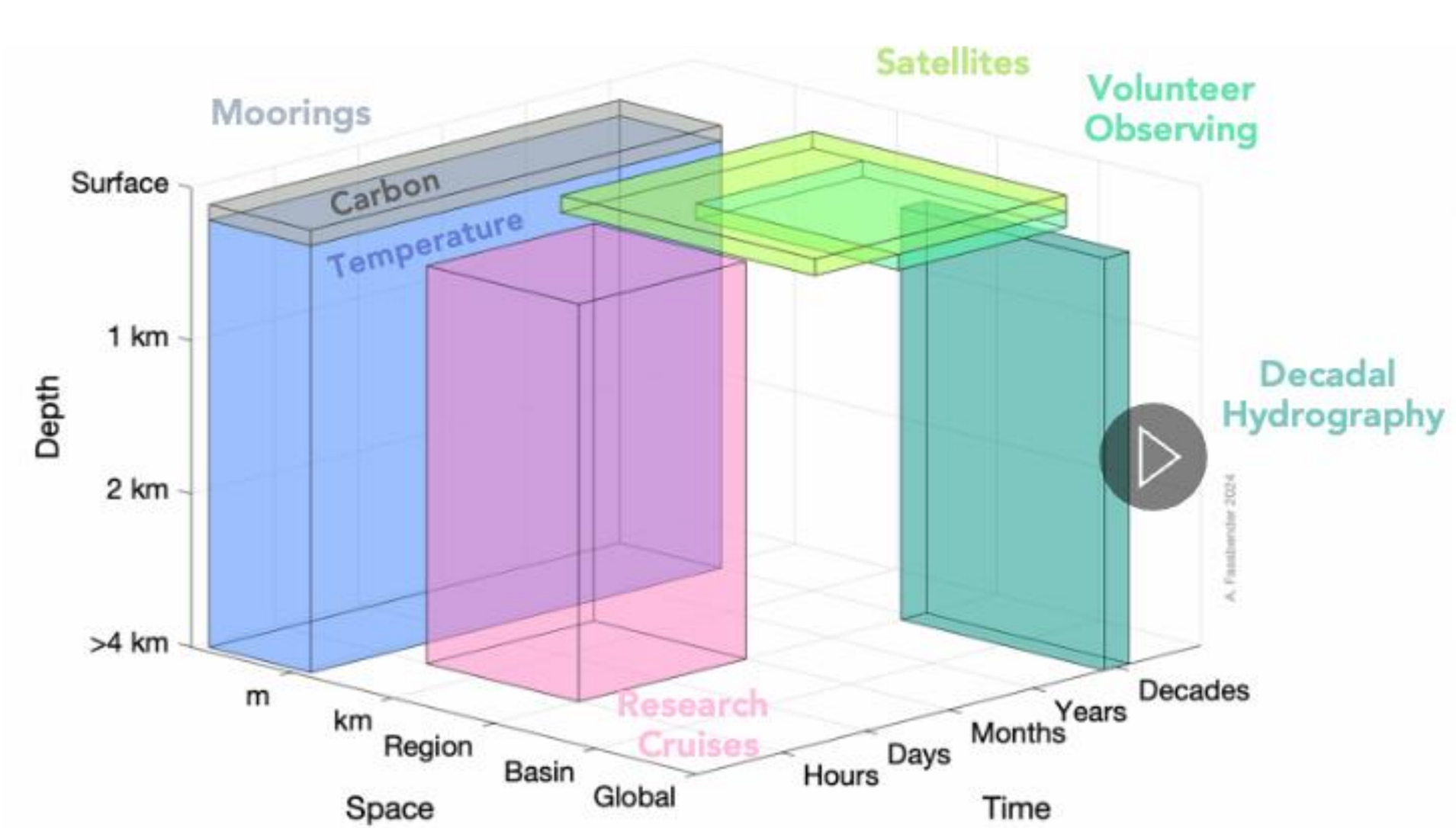
Fassbender et al., 2023 (GBC)

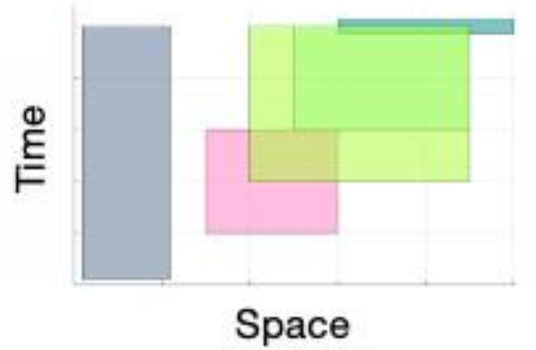
conventional observing platforms for ocean carbon and temperature



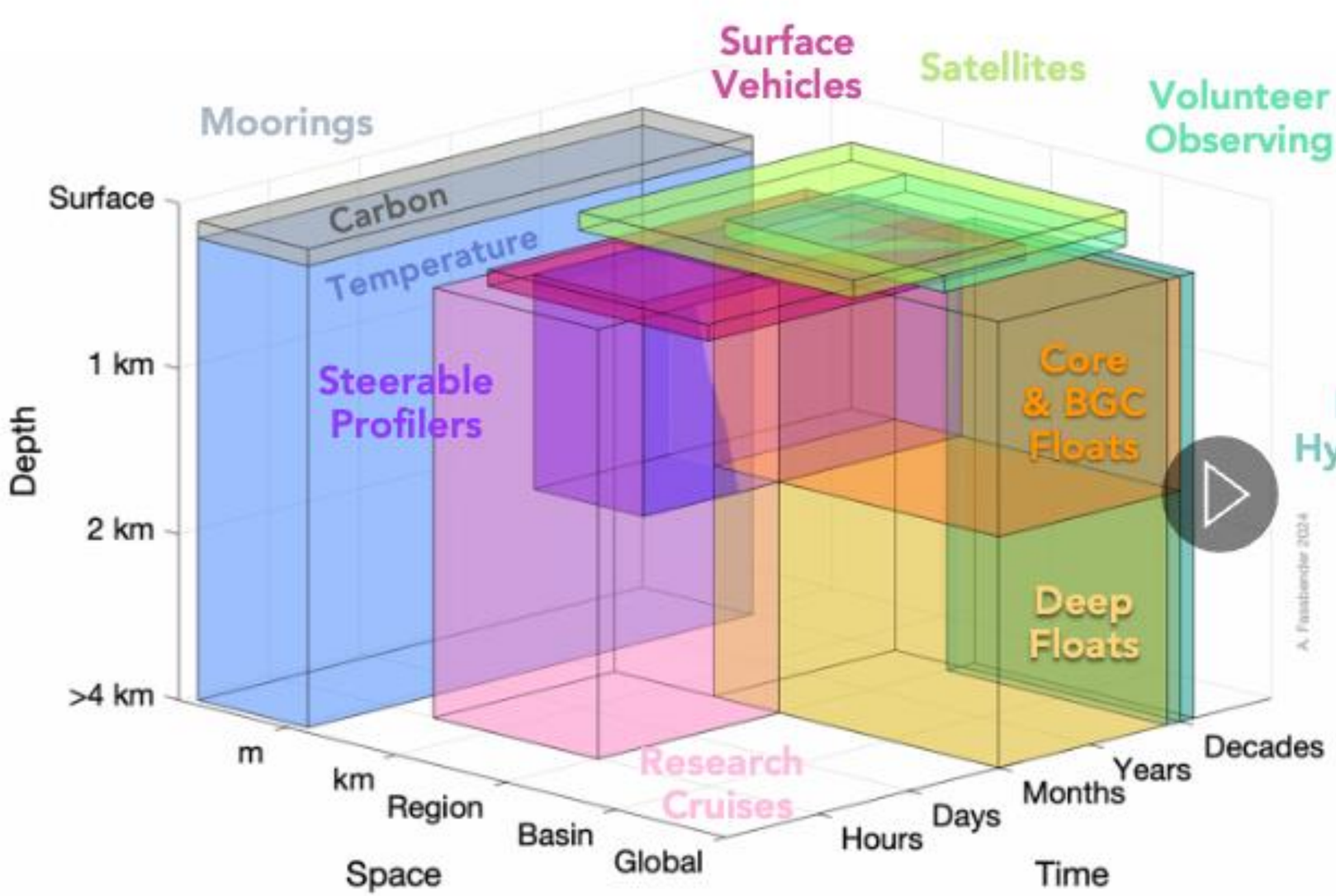
adapted from Bushinsky et al., 2019

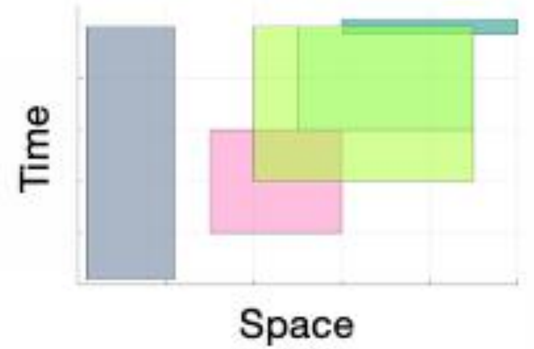
conventional observing platforms for ocean carbon and temperature

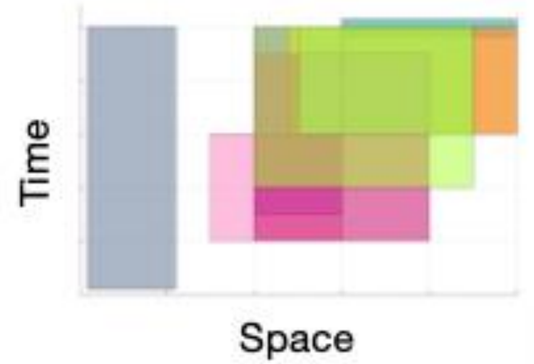




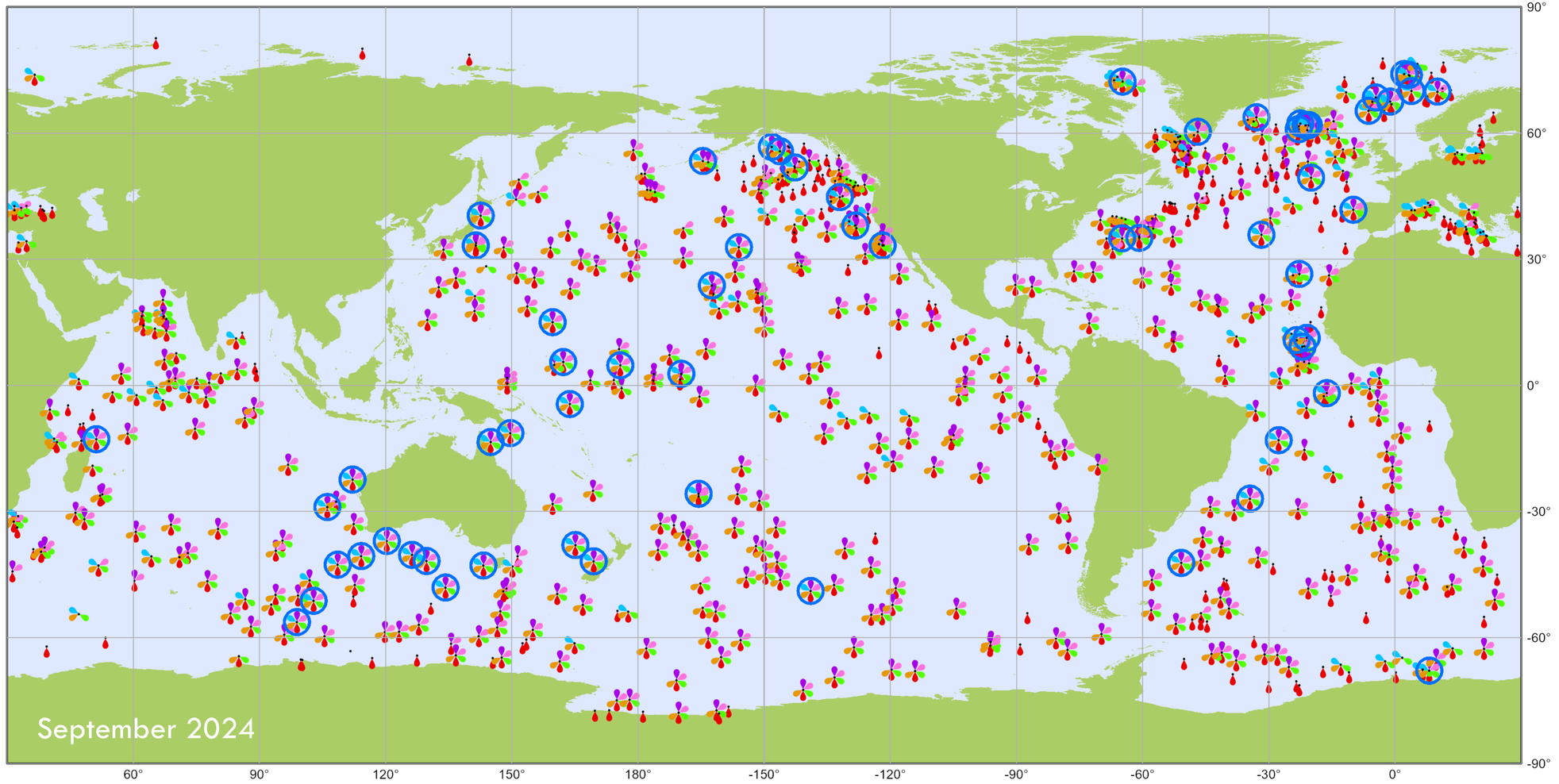
autonomous observing platforms for ocean carbon and temperature

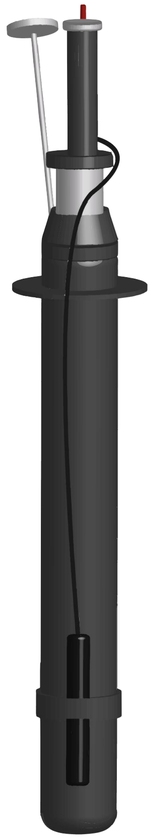


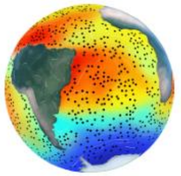




Biogeochemical (BGC) Argo array implementation status







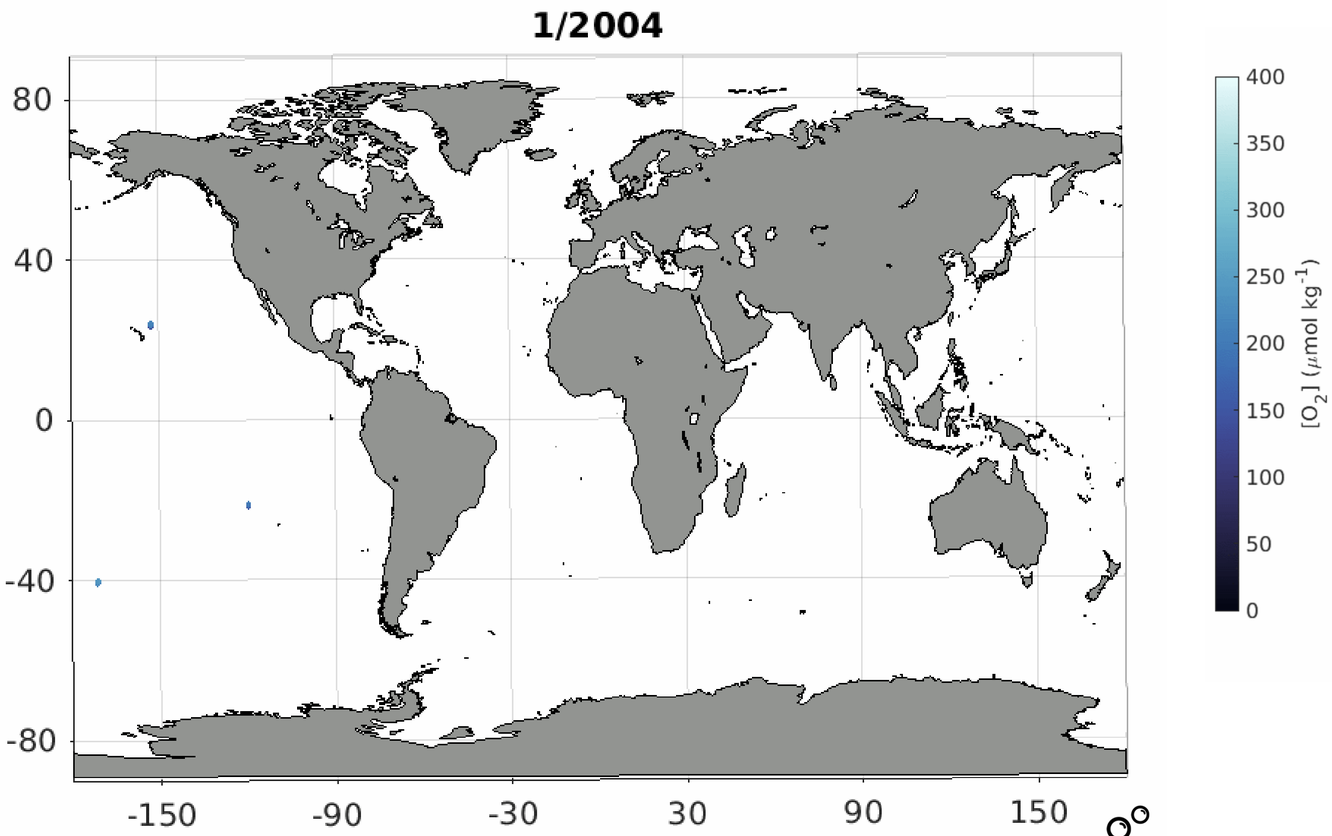
2024-10-04

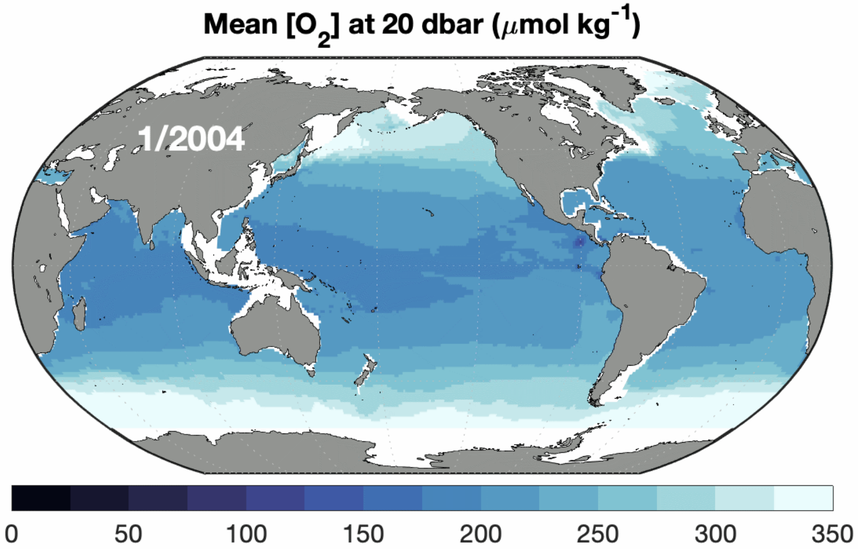
Operational Floats (689)
Suspended particles (462)
Downwelling irradiance (143)
pH (375)
Nitrate (365)
Chlorophyll a (462)
Oxygen (682)
Full BGC Floats (62)

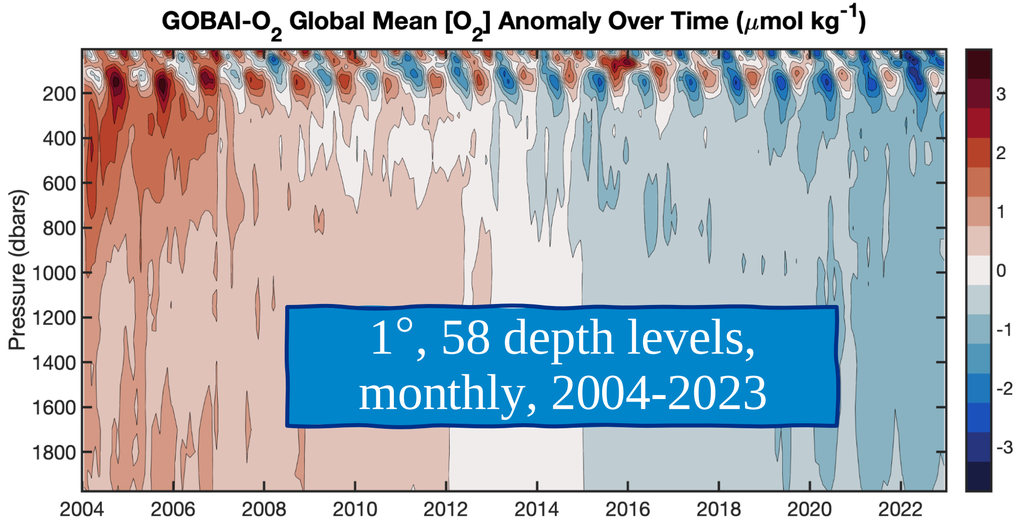
andrea.j.fassbender@noaa.gov | PICES 2024 Session 8

BGC Argo data synthesis: oxygen

Jonathan Sharp
PMEL/CICOES
Research Scientist







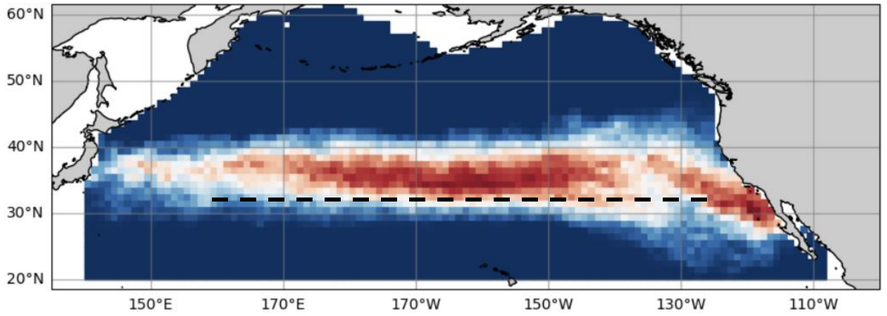
GOBAI-O_2

scan me!

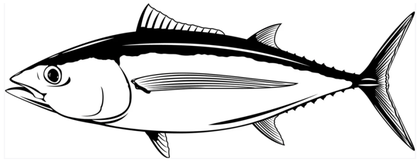
BGC Argo application: species distribution modeling

Mary Margaret Stoll
UW Grad Student

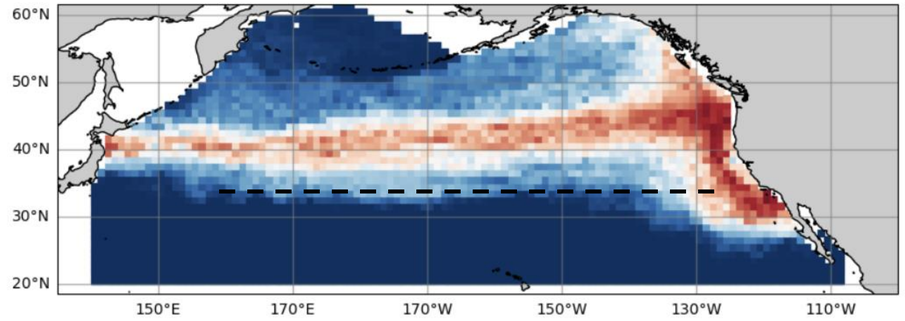
Winter



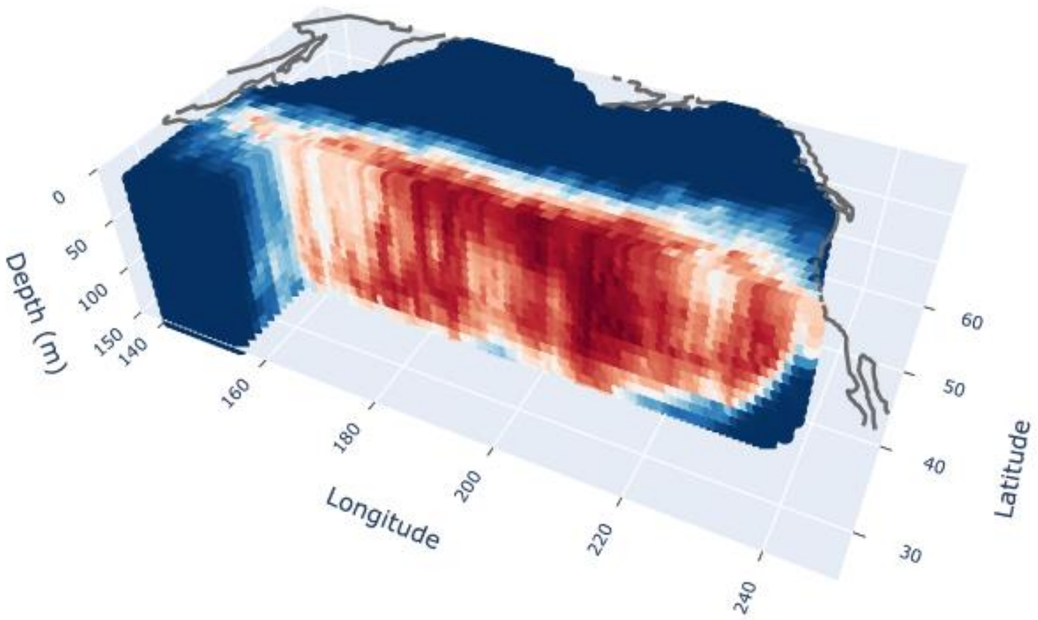
Albacore tuna
(*Thunnus alalunga*)

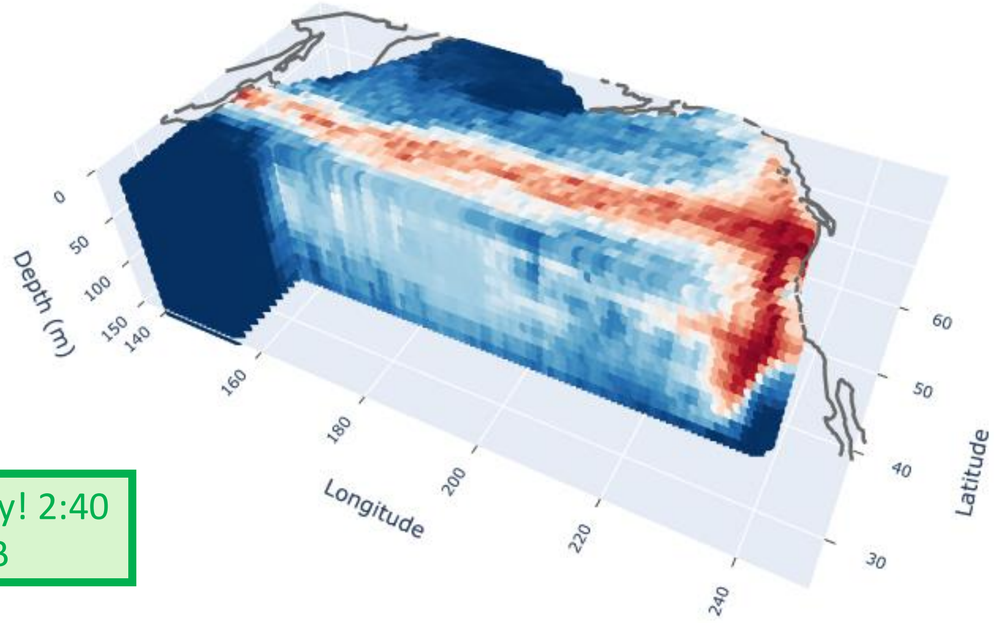


Summer



Mean Probability of Occurrence

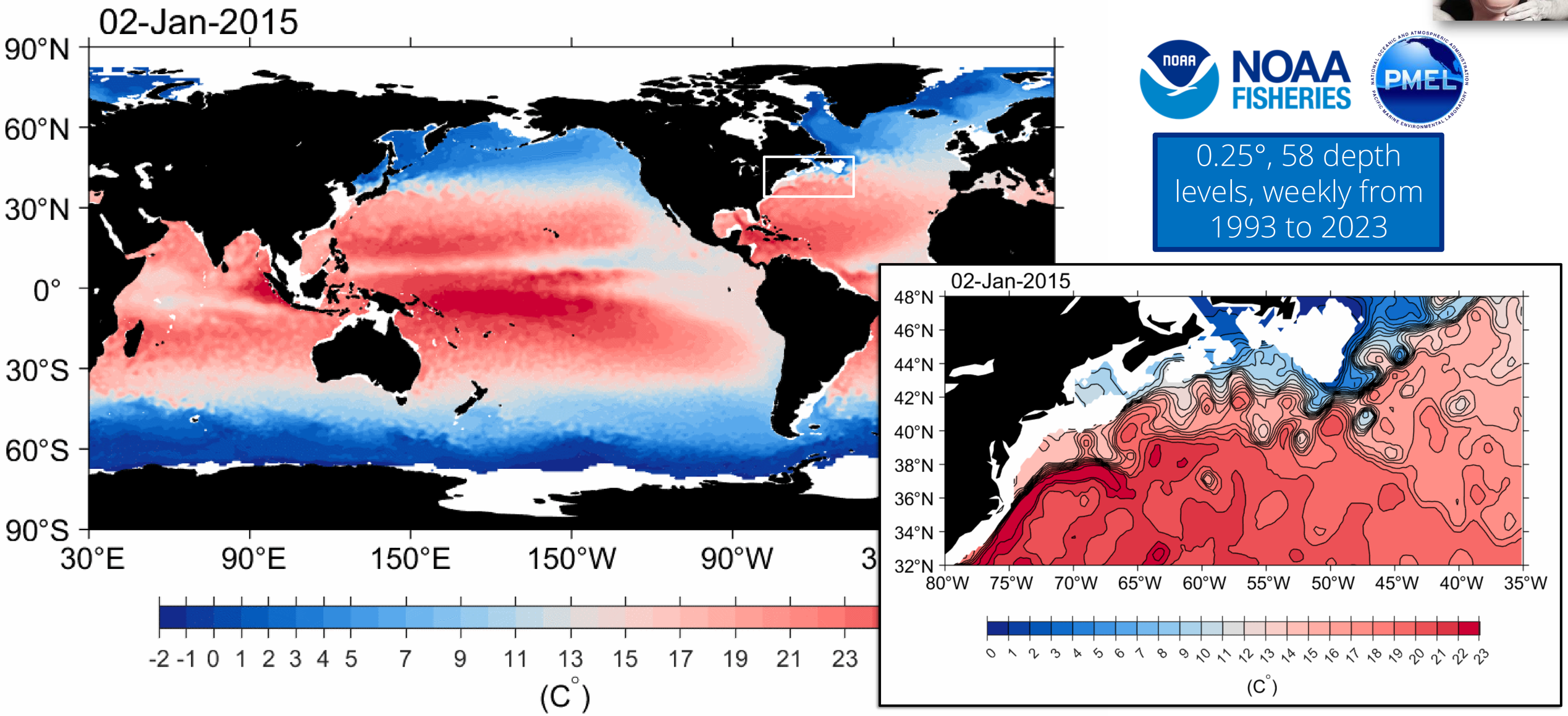




PICES Session 4 → Today! 2:40 pm, room 304 A/B

future of Argo data synthesis products: T & S

John Lyman
PMEL/CIMAR
Research Scientist



NOAA FISHERIES

PMEL

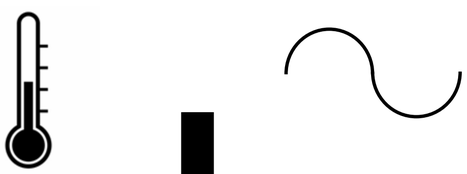
0.25°, 58 depth levels, weekly from 1993 to 2023

dynamically served Argo data synthesis products

Satellite 2D Inputs

Temperature

Sea Surface Height



Mapped 4D Outputs

Temperature

Salinity

PMEL Argo-Based Products:

T, S, O_2, NO_3^-, & Carbon

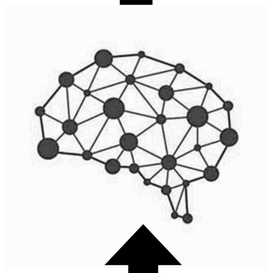
0.25°, 58 depth levels, weekly

Mapped 4D Outputs

Oxygen

Nitrate

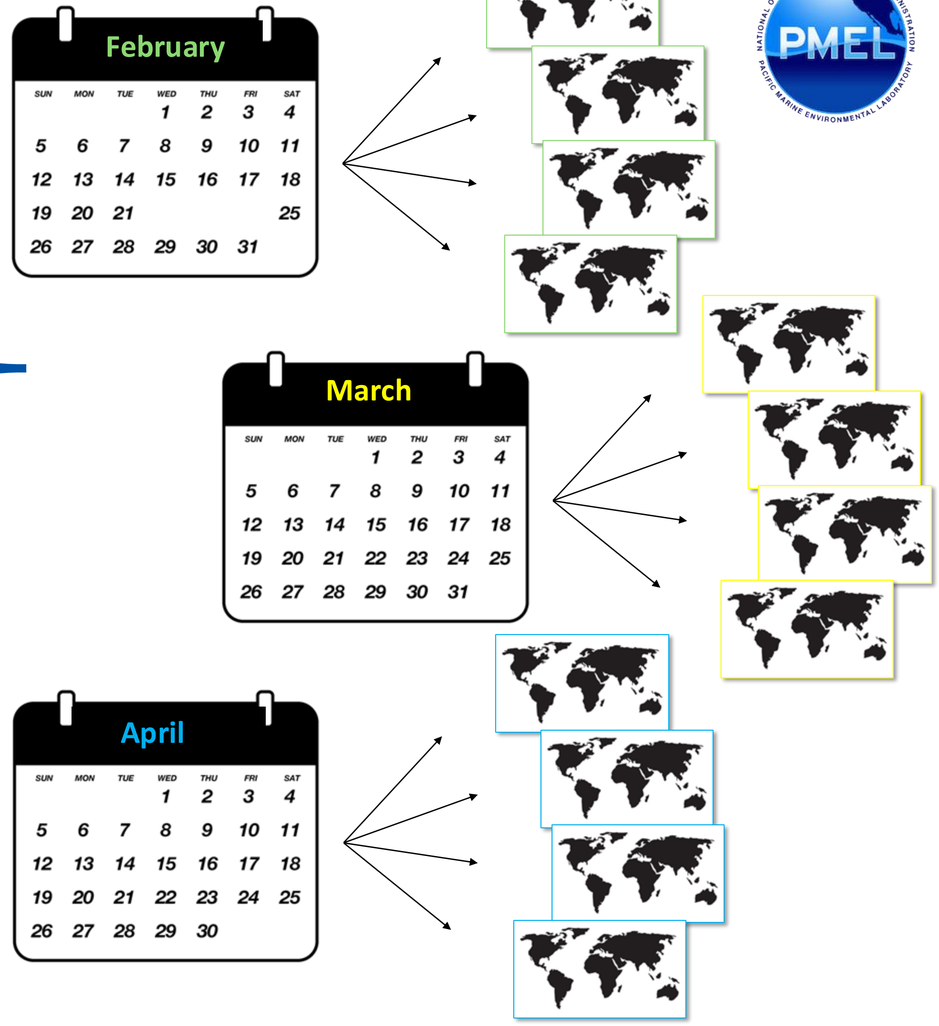
Carbon



Other Inputs

SOCAT - SURFACE OCEAN CO2 ATLAS -

monthly releases of weekly maps



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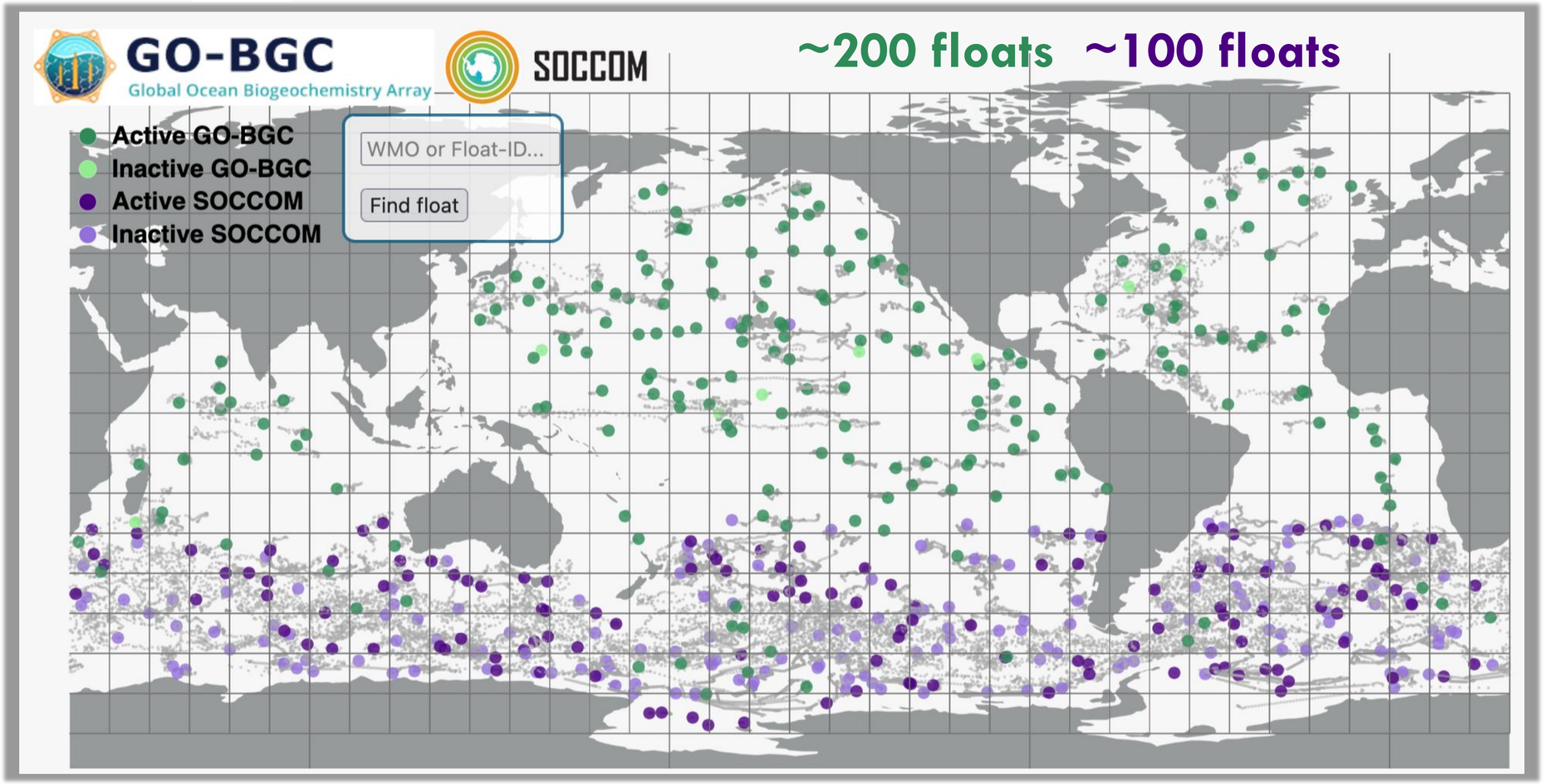
U.S. BGC Argo outlook…the cliff

2027



U.S. BGC Argo largely implemented via NSF projects with end dates

SOCCOM funded through 2027 (few new floats)

GO-BGC fund through 2026 (500 float array)

Argo is for everyone. Check out our data access & visualization toolboxes in MATALB, R, & Python

GitHub

U.S. Argo consortium

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