Drivers of Sea-Air CO_2 Exchange at the Kuroshio Extension Observatory

Andrea Fassbender, Keith Rodgers,
Christopher Sabine, and Hilary Palevsky

Image: PMEL OCS

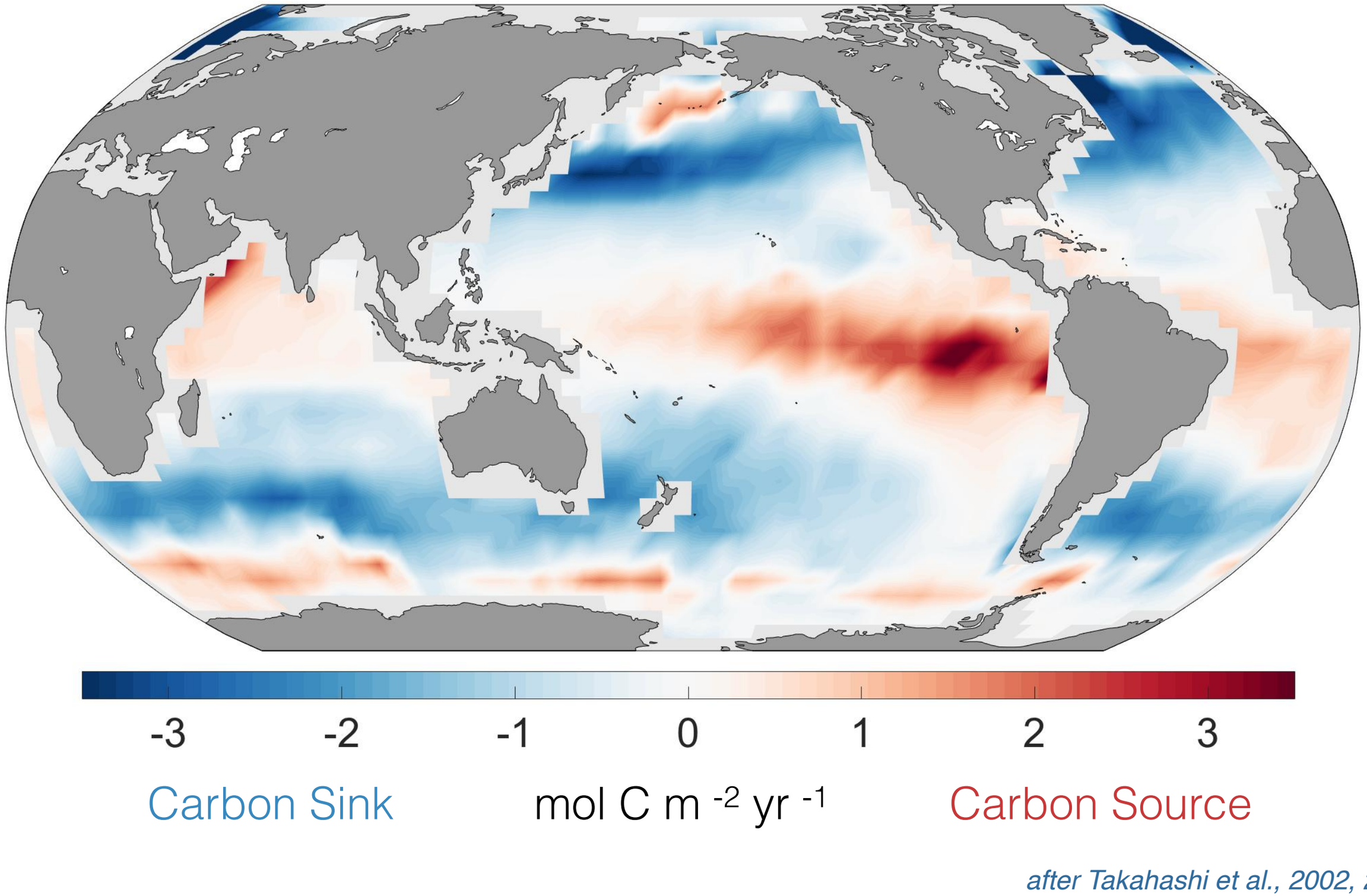
An Increasing Role of Nonlocal Air-Sea CO_2 Exchange in Anthropogenic Carbon Storage(?)

Andrea Fassbender

Image: PMEL OCS

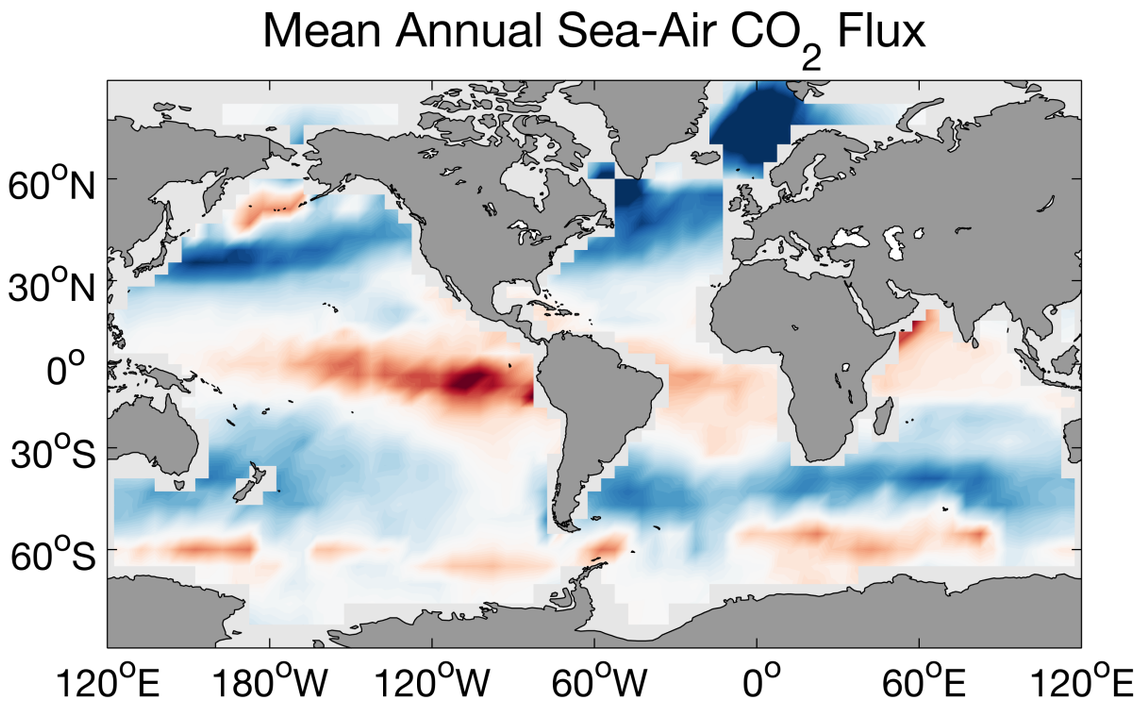
Will the Modern Pattern of Ocean CO_2 Uptake Persist?

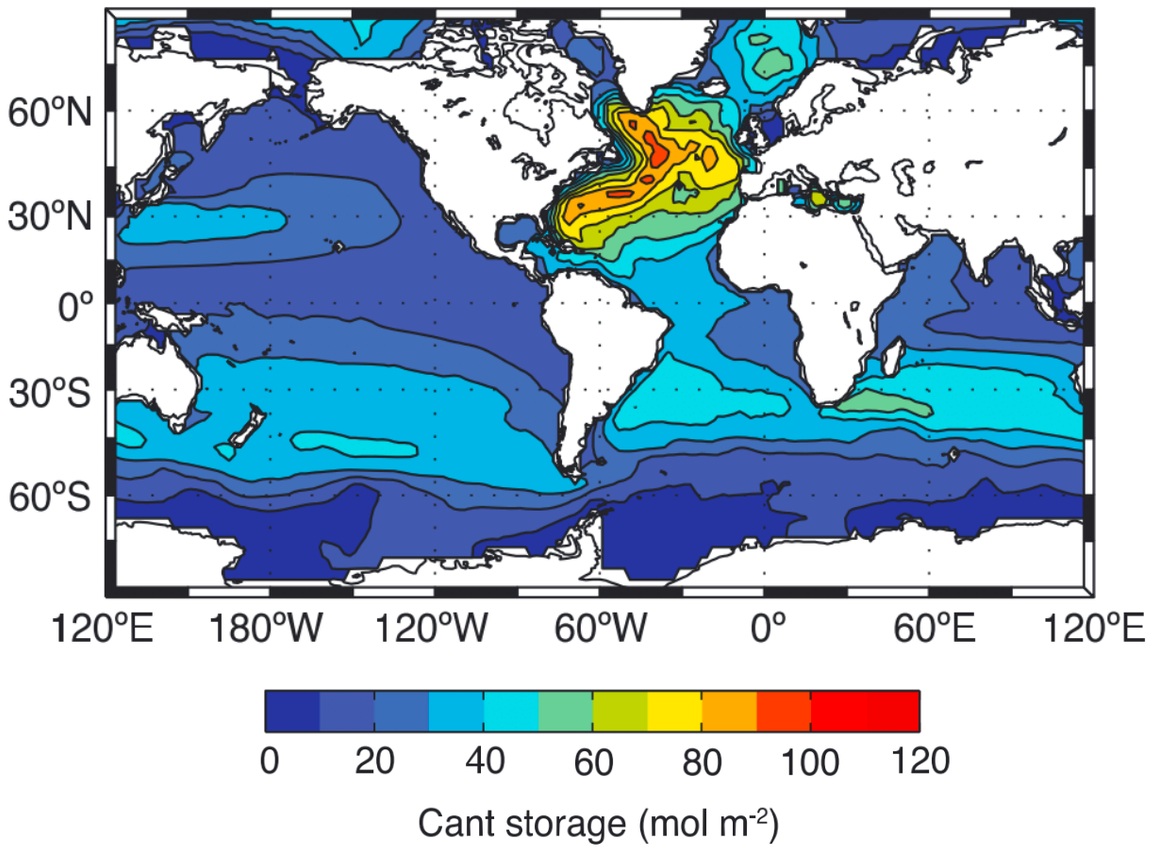
Mean Annual Sea-Air CO_2 Flux



after Takahashi et al., 2002, 2009

Anthropogenic CO_2 Flux Pattern ≠ Storage Rate Pattern





DeVries, 2014 - GBC

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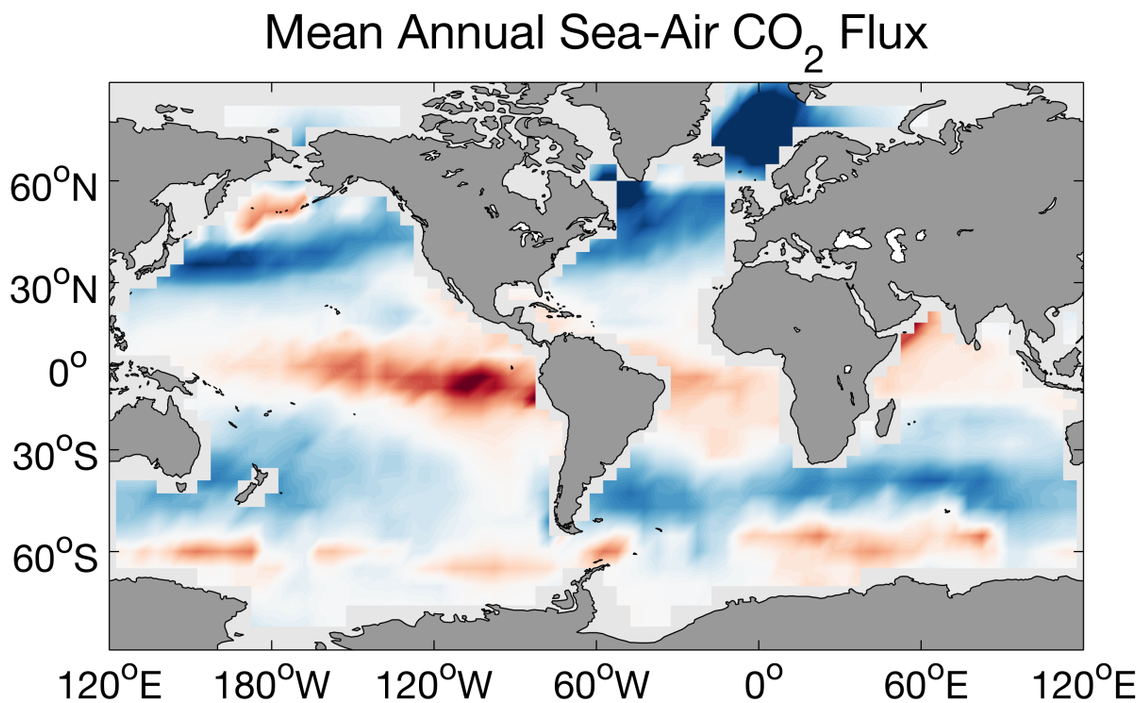

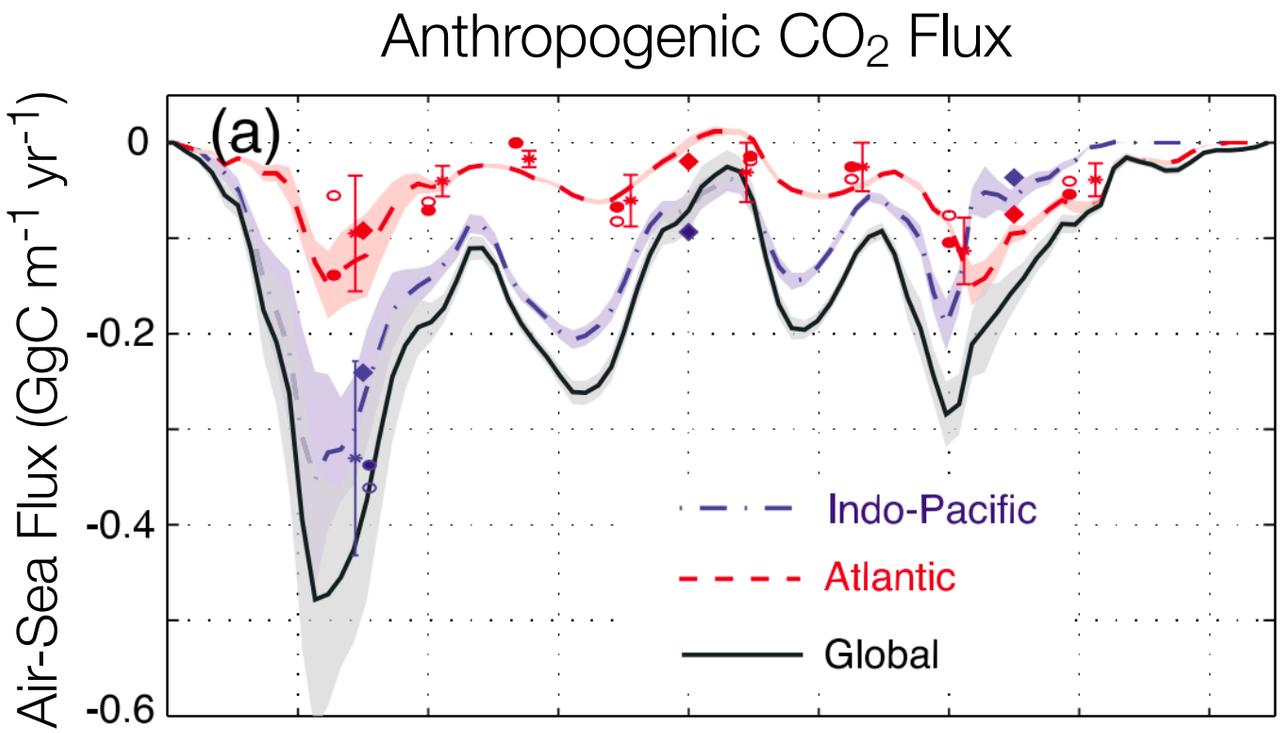

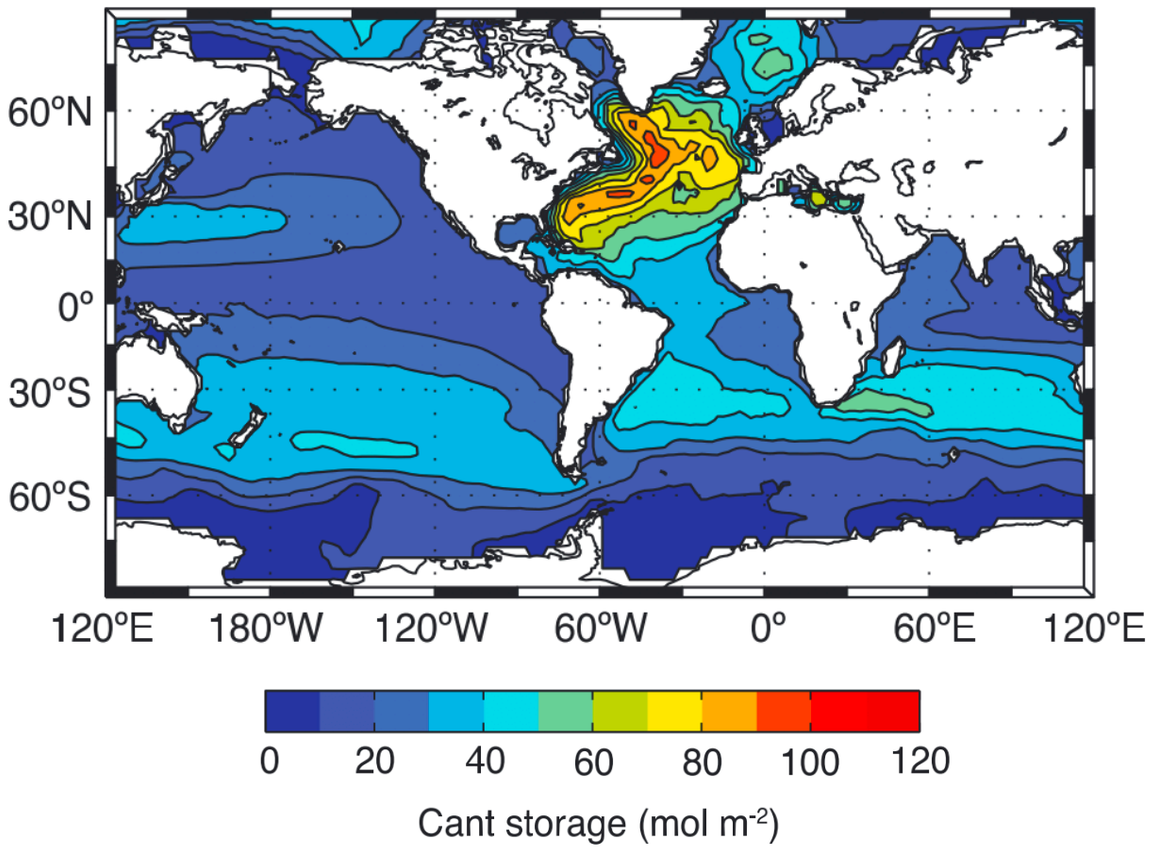

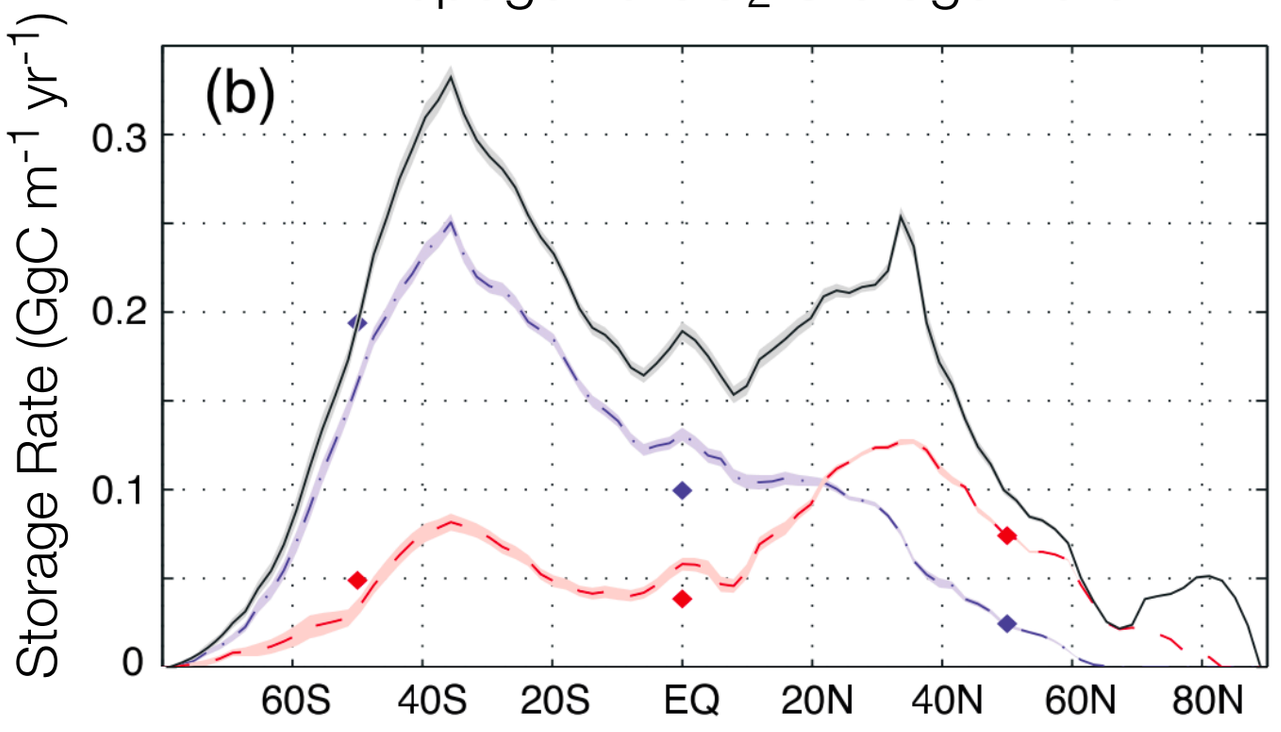

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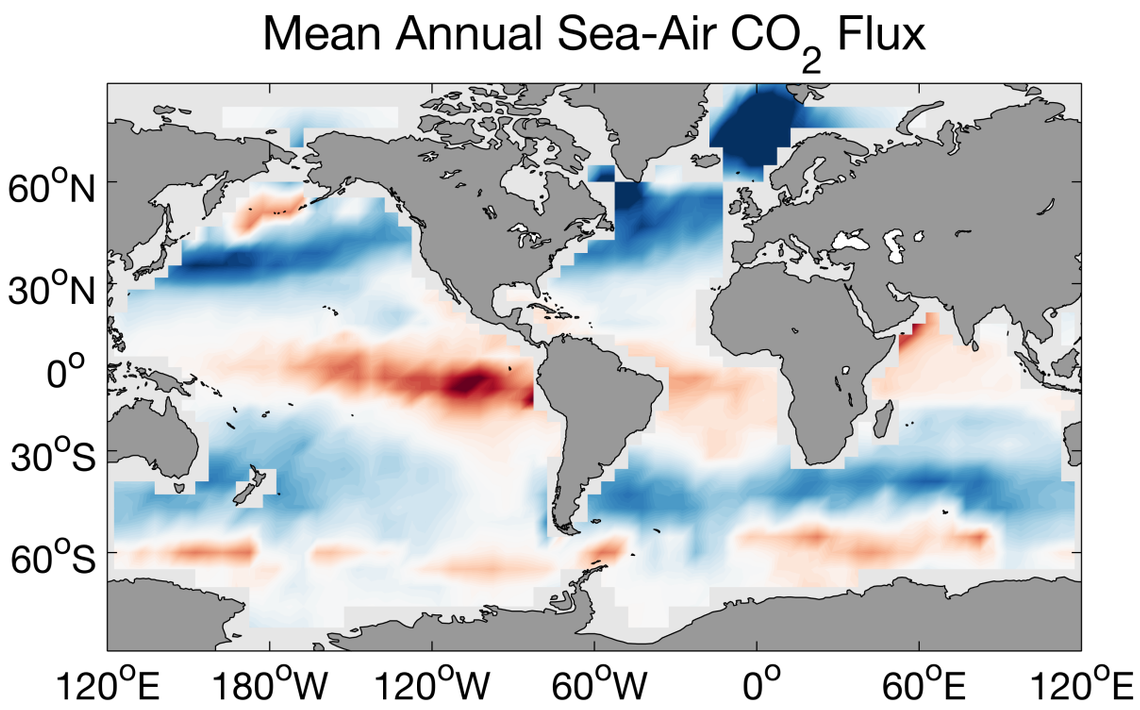

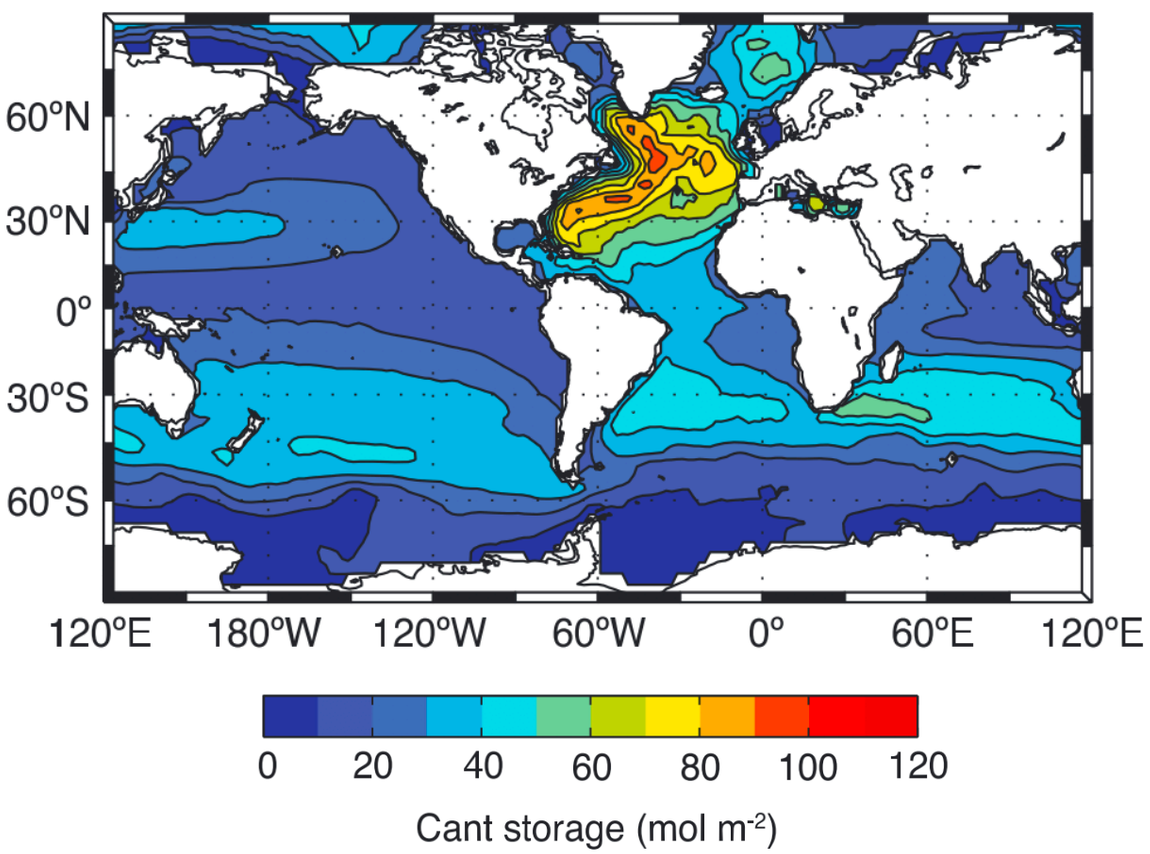

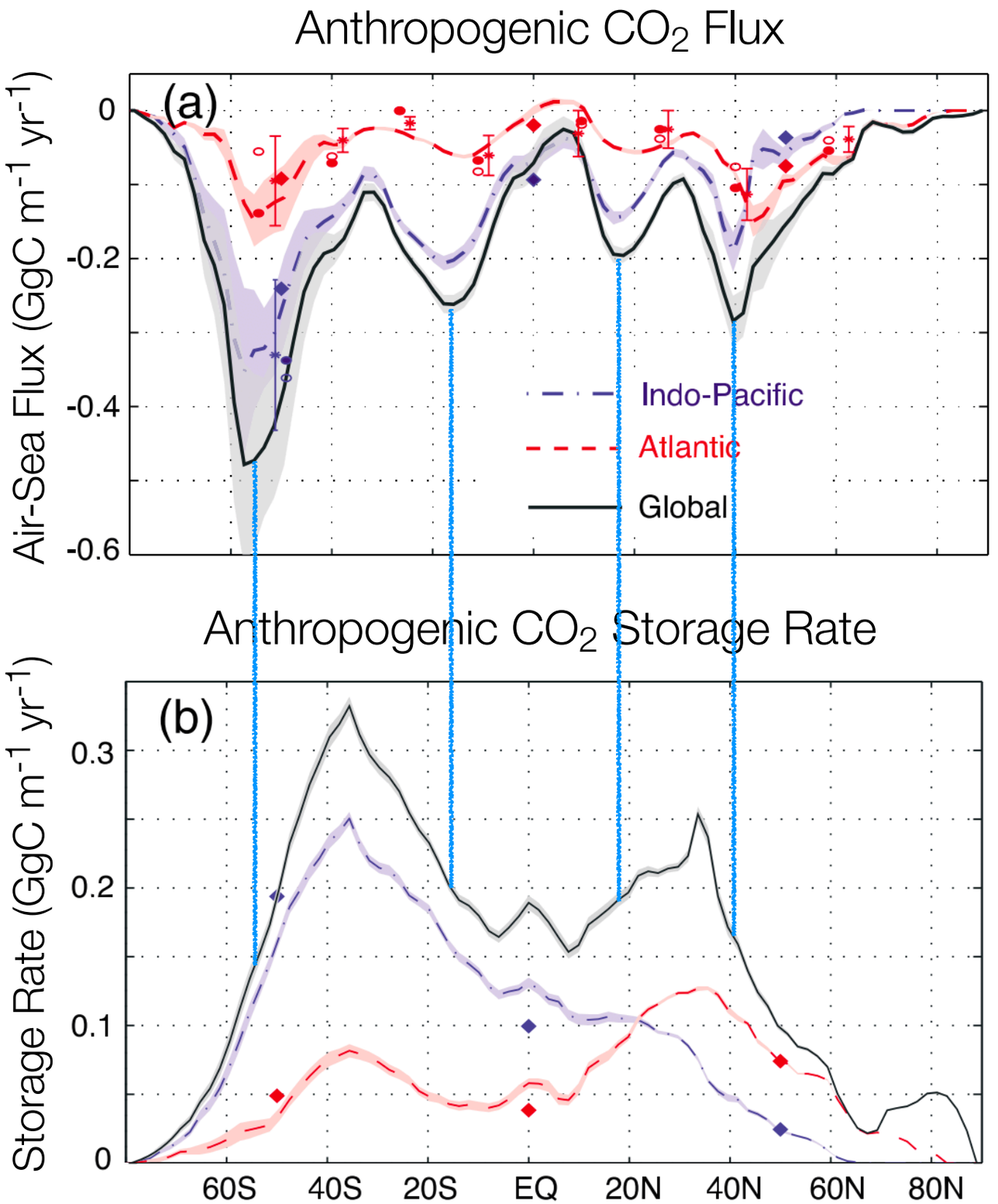

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Natural Variability in Anthropogenic Carbon Storage

NAO Variability Modulates Subtropical Mode Water CO_2 Sink

- Bates et al., 2002 - Letters to Nature
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  Changes in mode water C_{anthro} inventories are primarily due to changes in water mass volumes driven by variations in water mass transformation rates rather than local air-sea CO_2 exchange.
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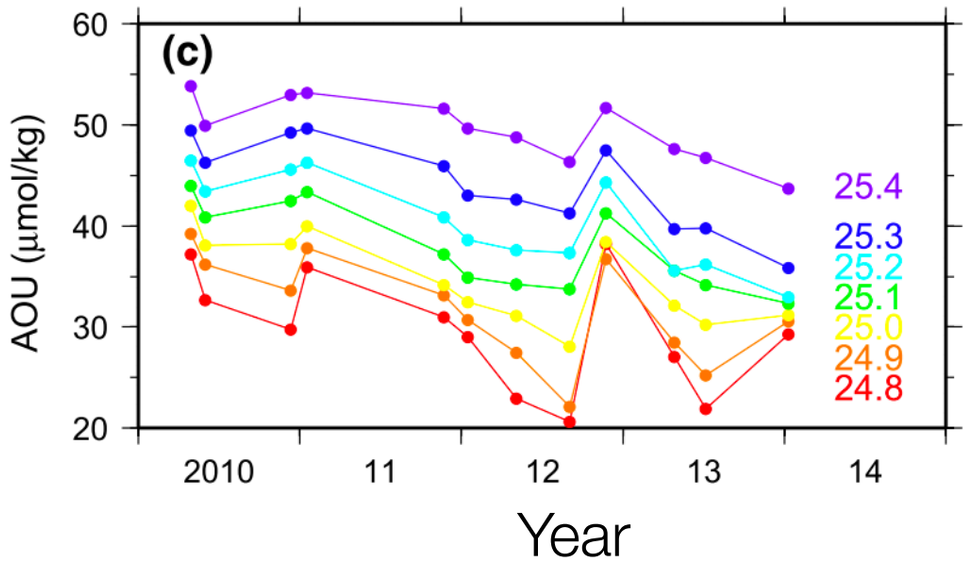

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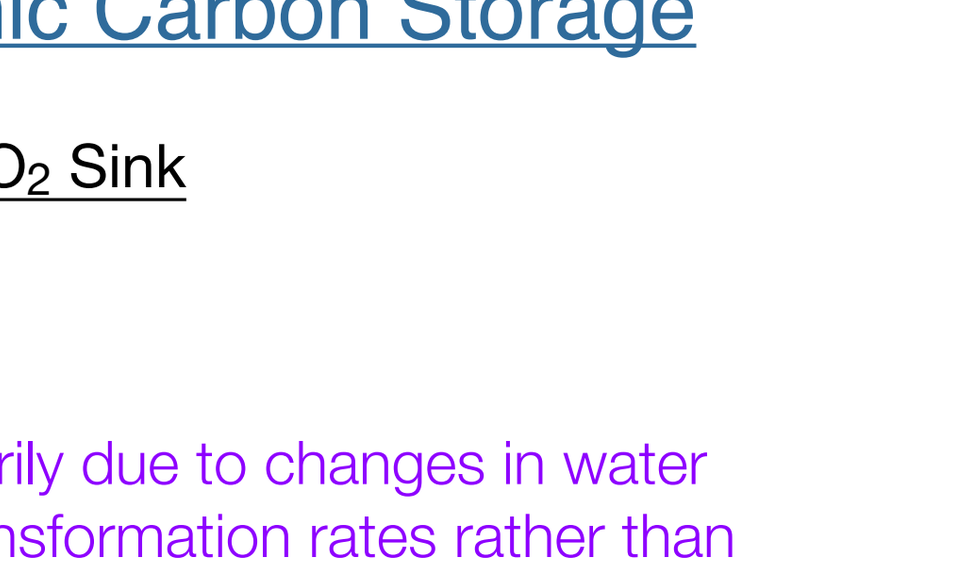

Global Perspective

- DeVries et al., 2017 - Letters to Nature

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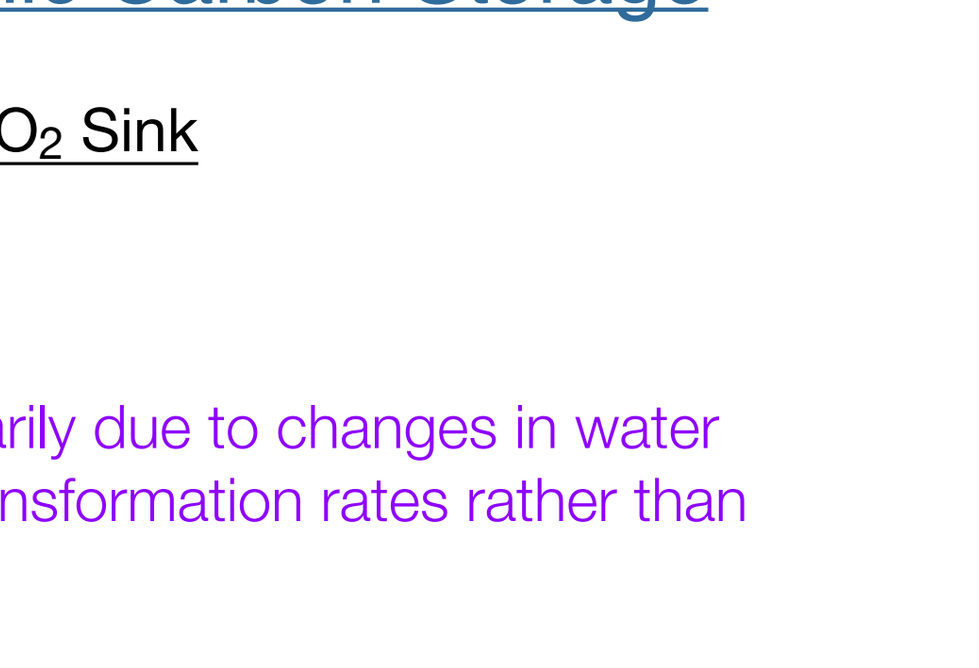
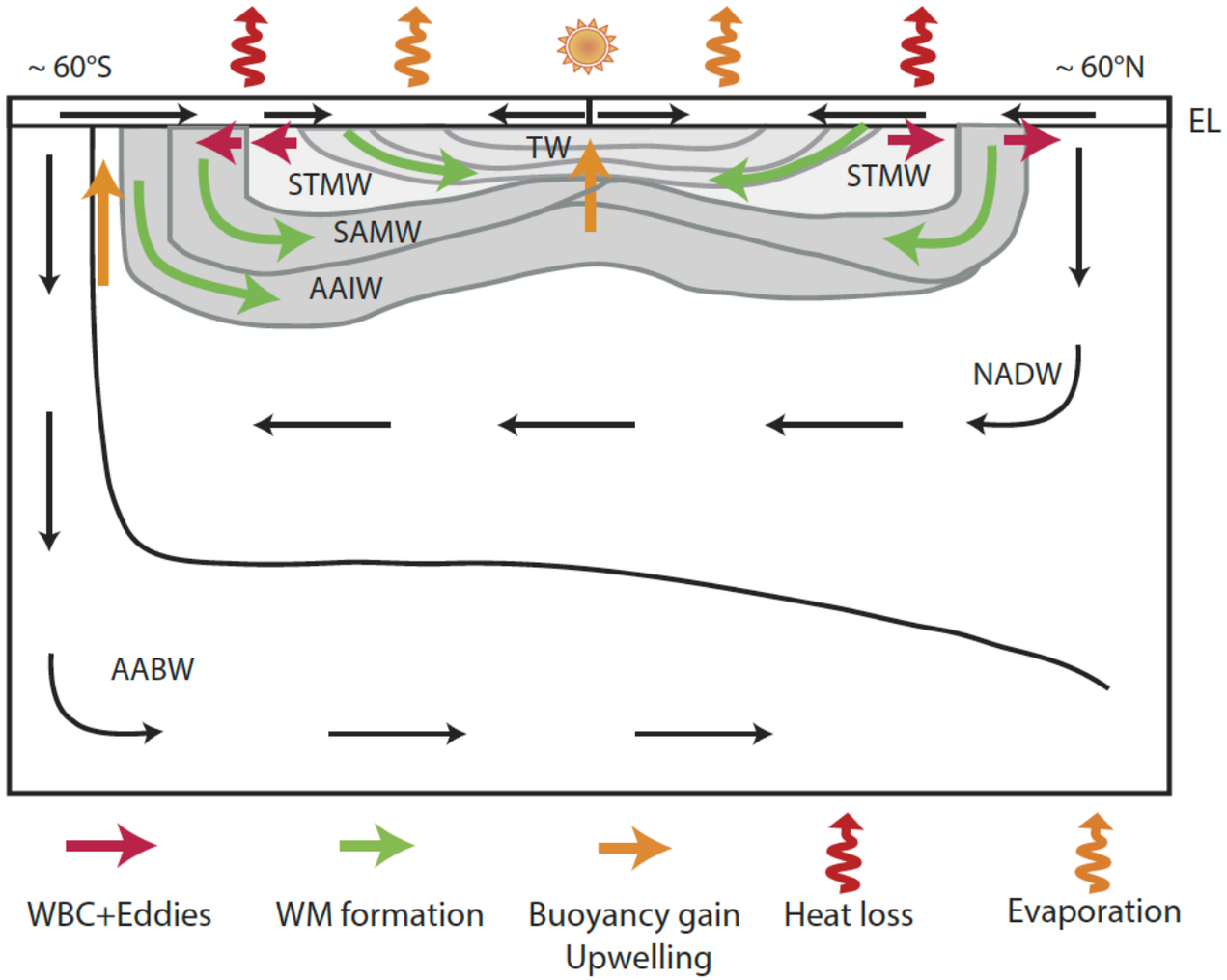


Shallow Overturning Circulation & Carbon Storage



The shallow overturning circulation ($\sigma<27.0$) and intermediate waters ($27<\sigma<27.5$) contain as much as 63-86% of the global anthropogenic carbon inventory, yet occupy only 27.1% of the global ocean volume.

Iudicone et al., 2016 - Sci. Reports

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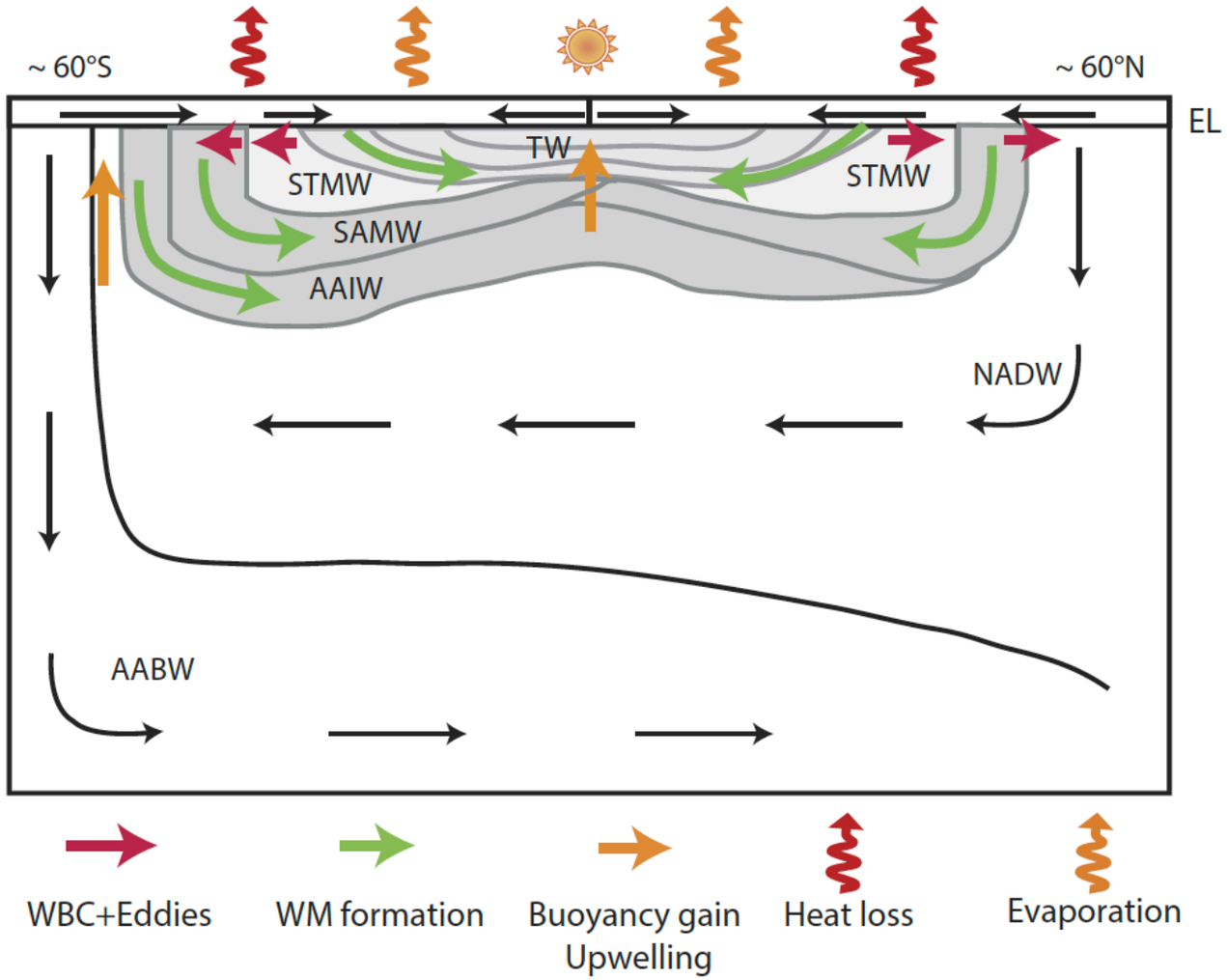

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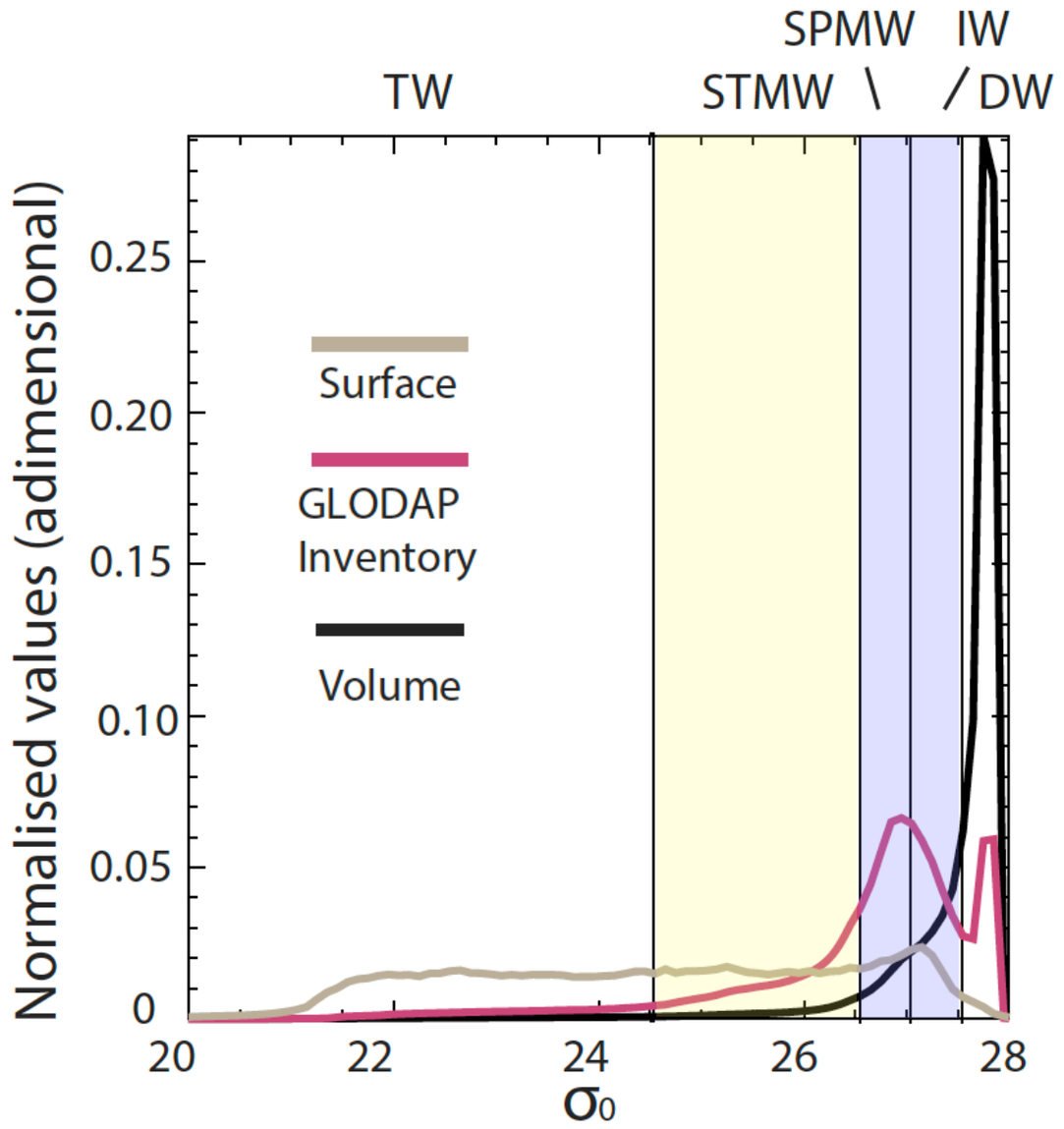
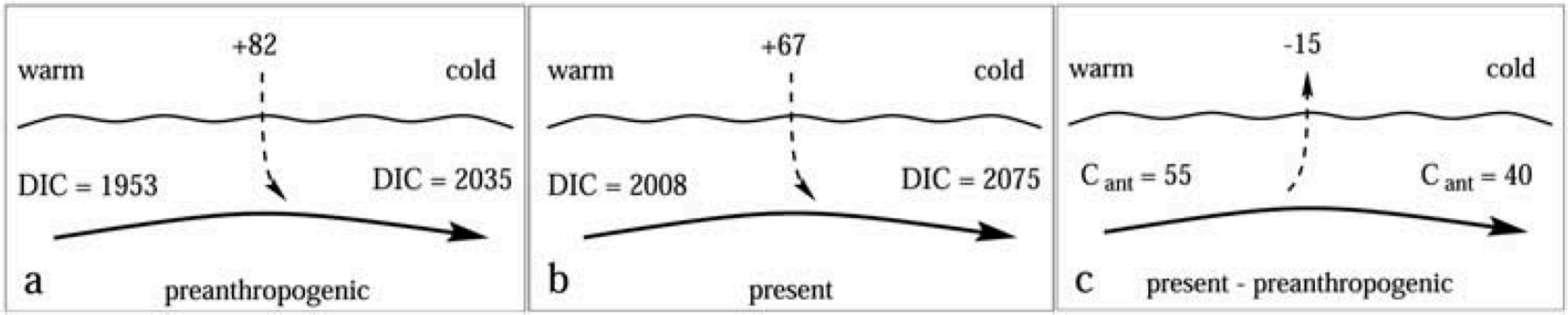
More than 50% of subpolar mode water formation sources are subtropical.

Iudicone et al., 2016 - Sci. Reports



The Role of Nonlocal Anthropogenic Carbon Fluxes



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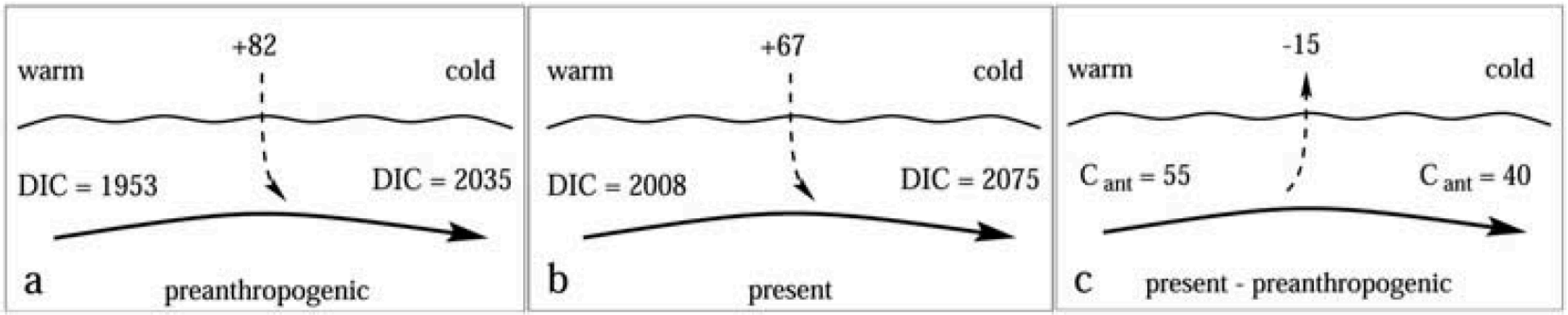

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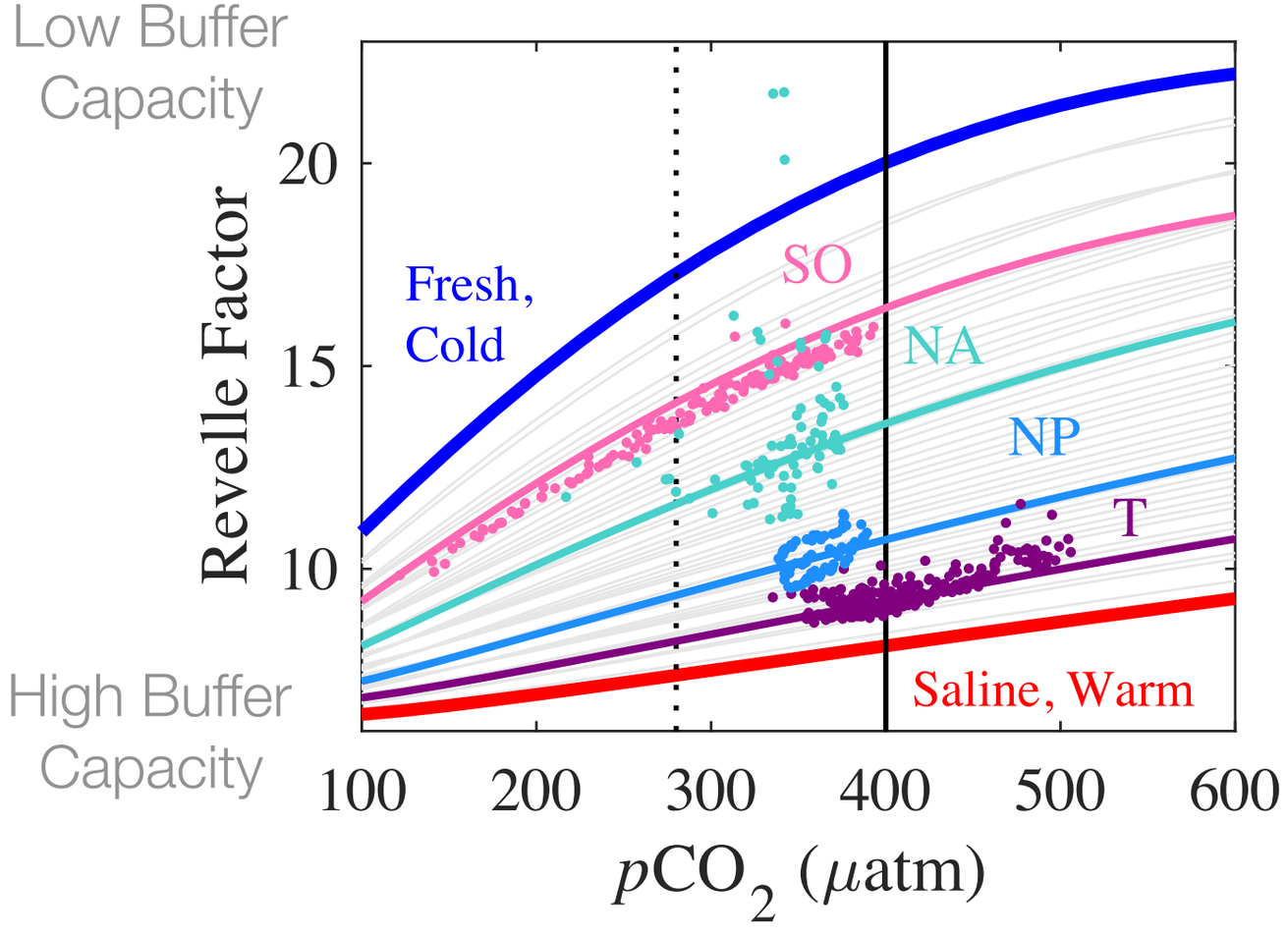


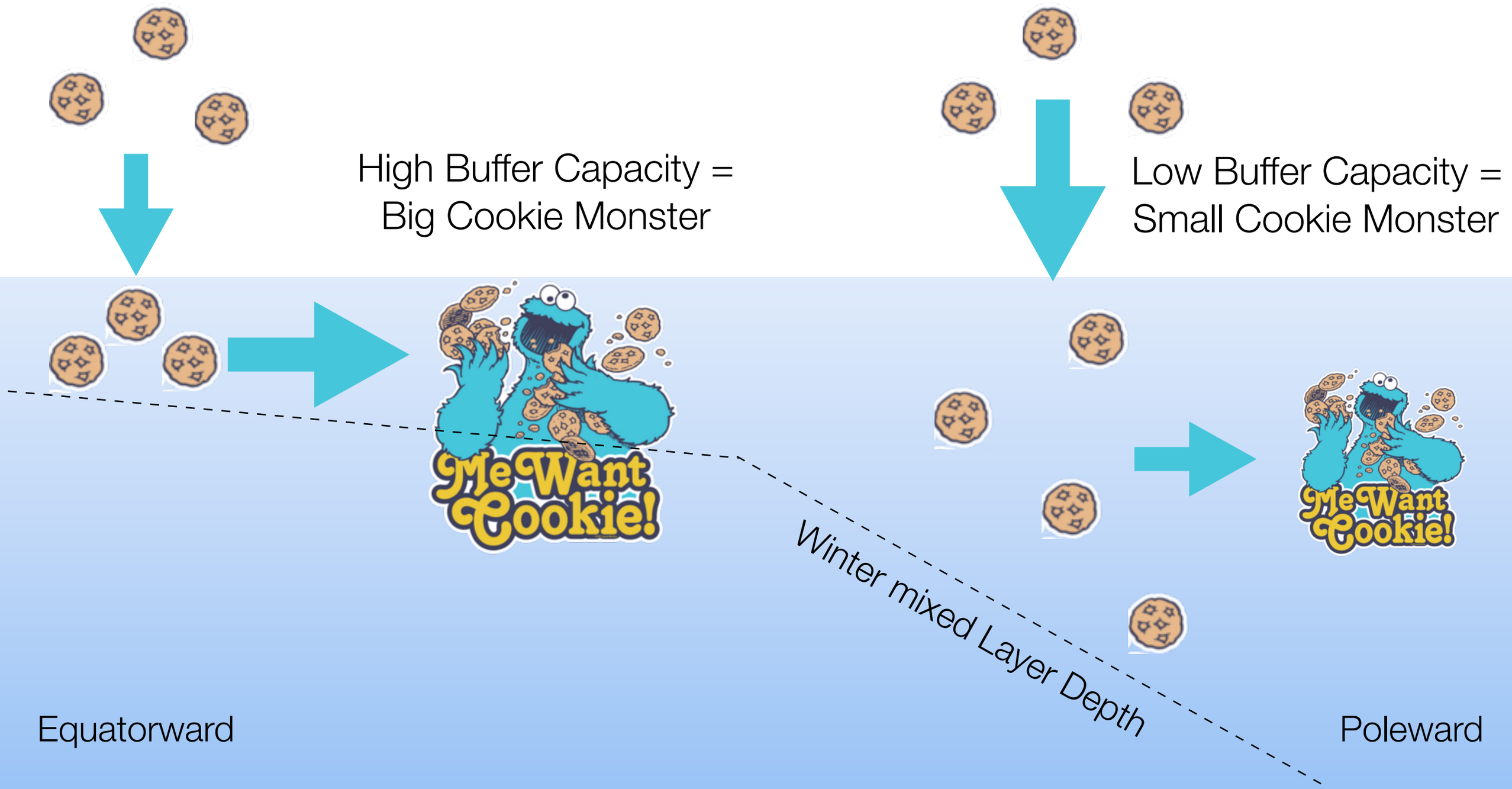
This may suggest a reduction in the role of sea-air fluxes during northward transport over time.

Which means the source water carbon characteristics may become even more important for anthropogenic carbon storage.

Fassbender et al., 2017 - GRL

This Can Be Summarized Best Using Cookie Monster…

Anthropogenic carbon is more concentrated in low latitude waters due to shallower mixed layers and more efficient carbon uptake (or higher buffer capacities)



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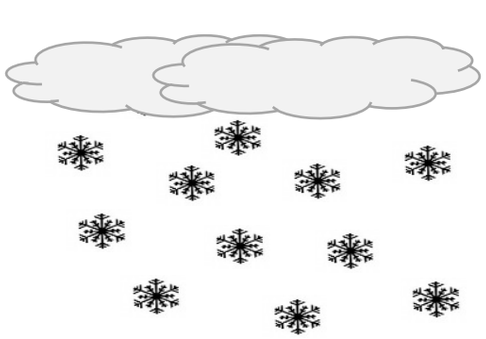
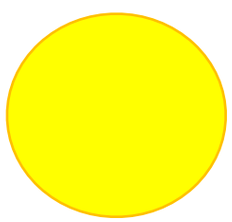
Growth in the Revelle Factor may lead to a decline in the meridional DIC gradient

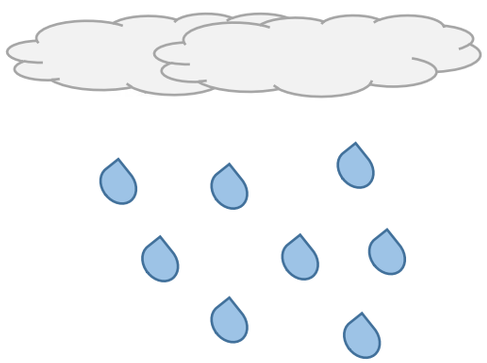
High Buffer Capacity =
Big Cookie Monster

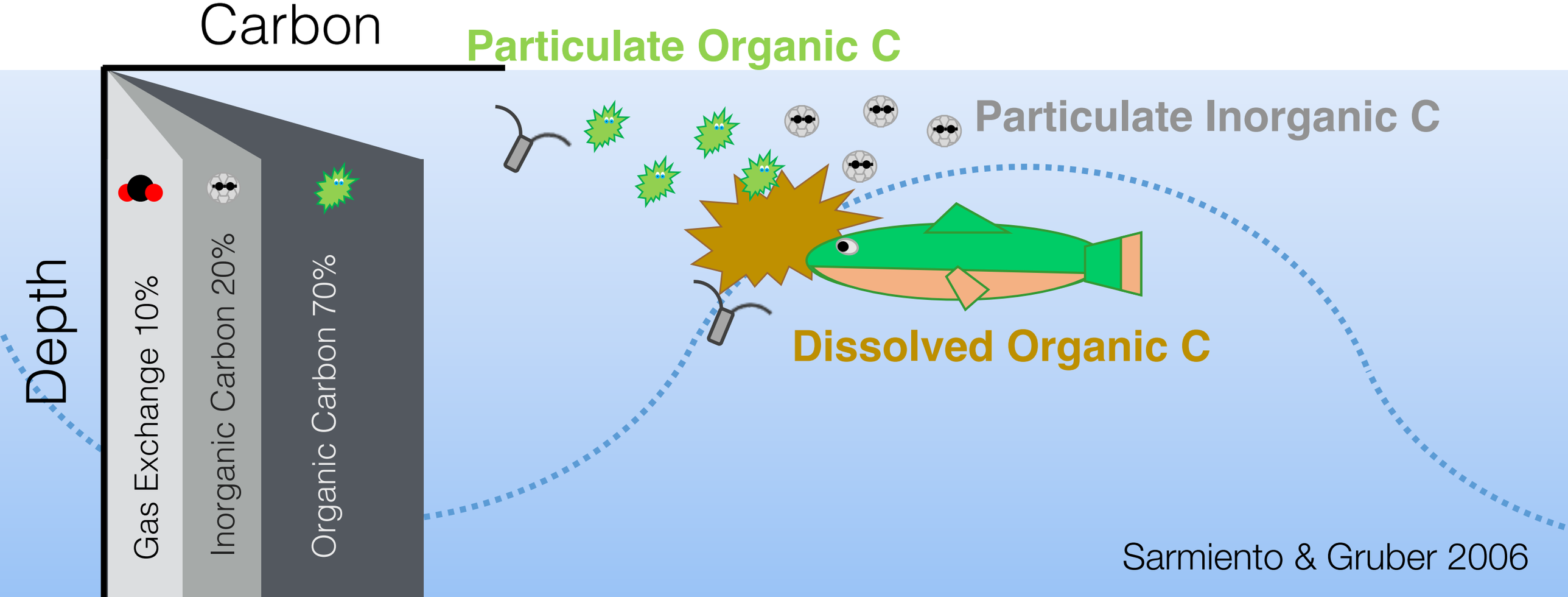
Low Buffer Capacity =
Small Cookie Monster

Consideration of Natural Carbon Cycling

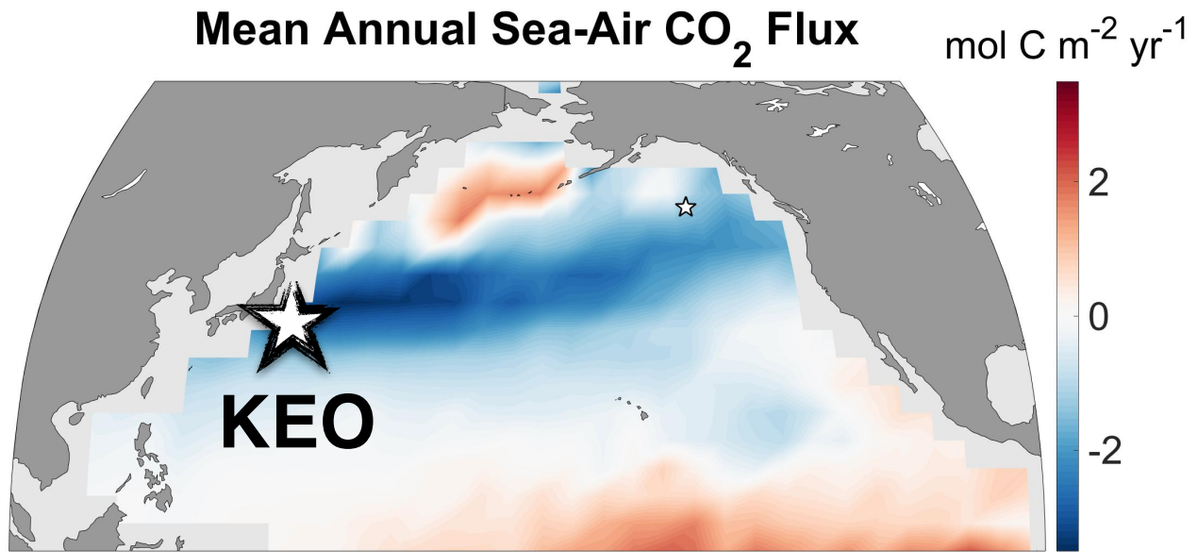








How Does Ocean Physics Influence Carbon Export?



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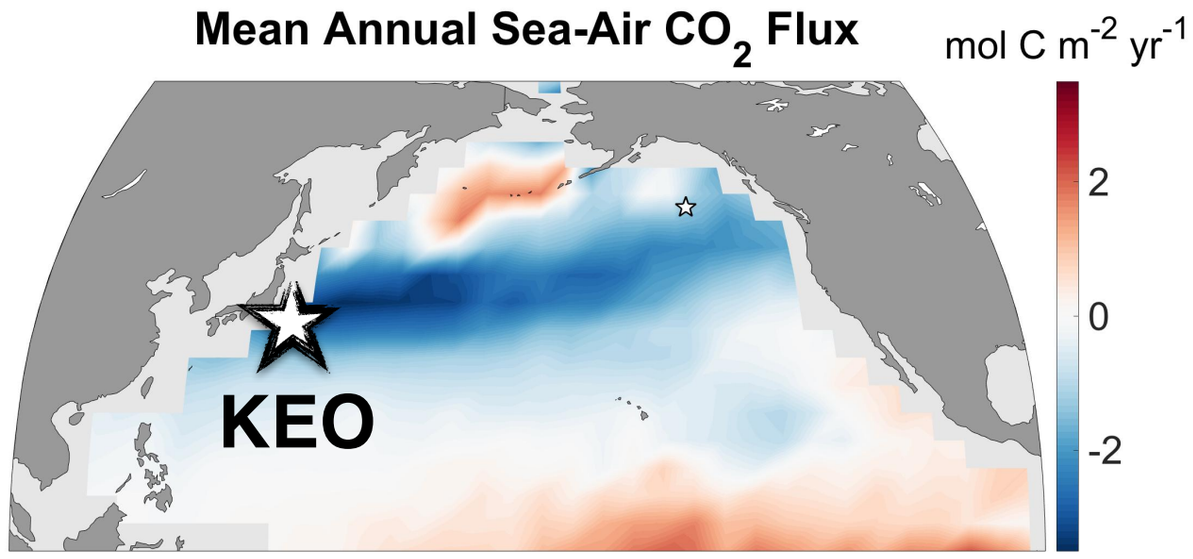

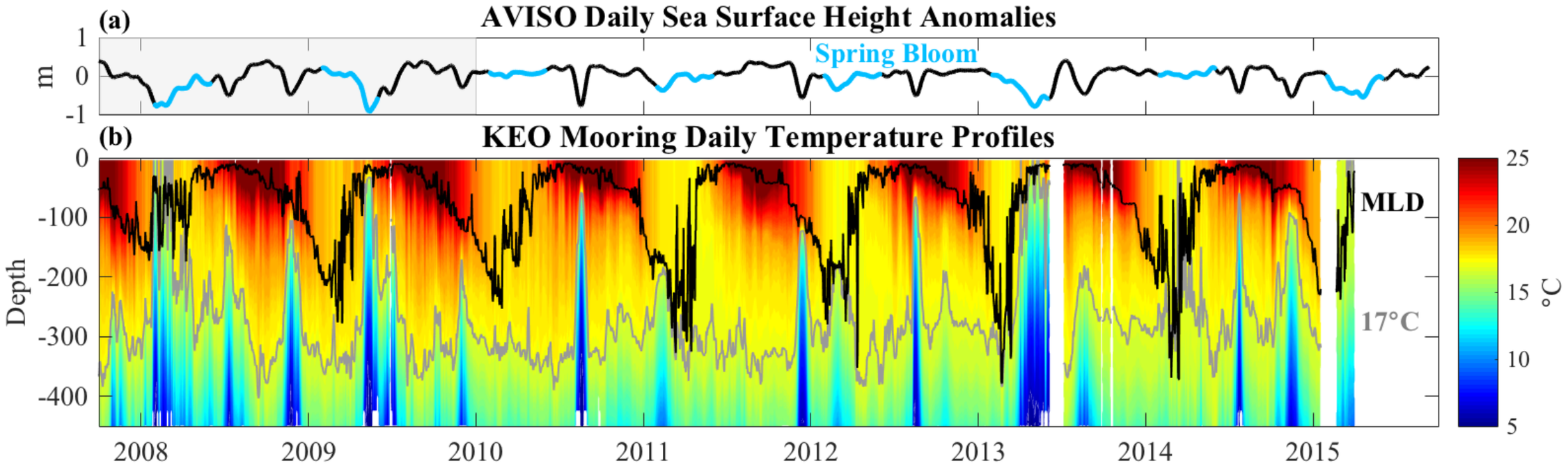

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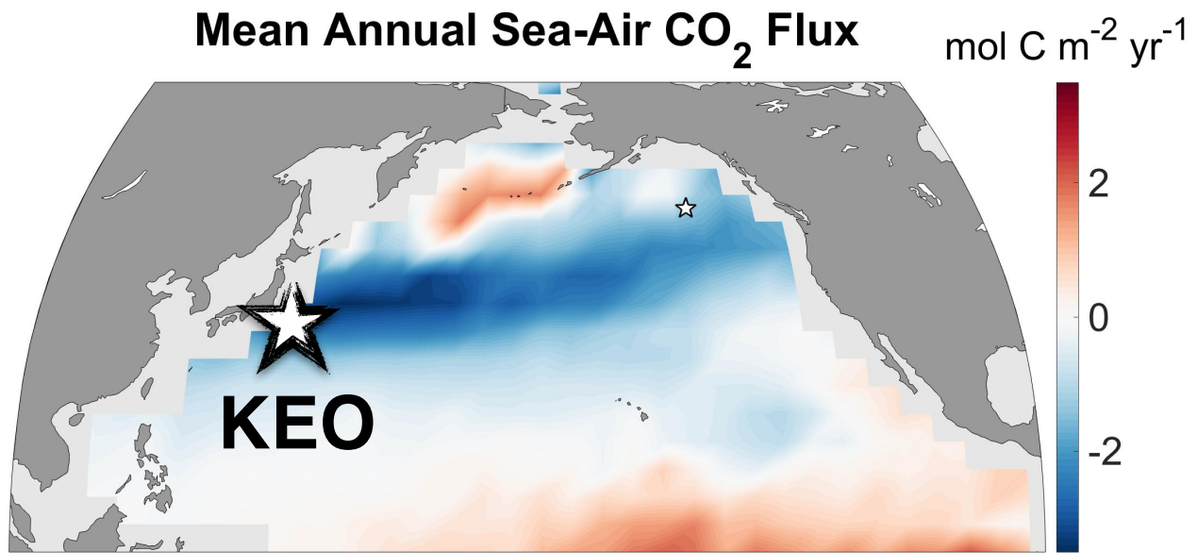
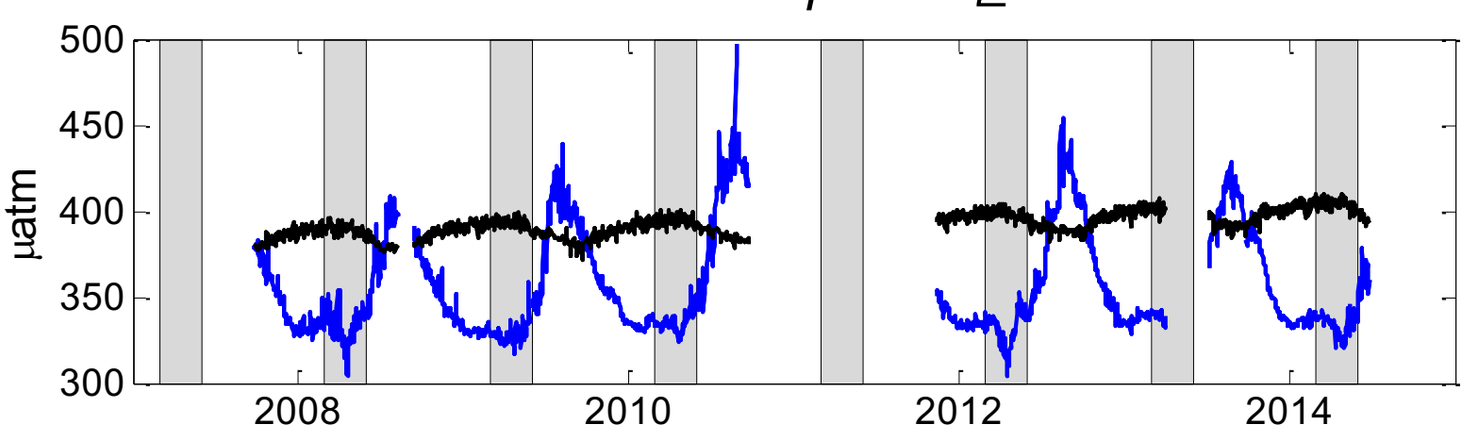
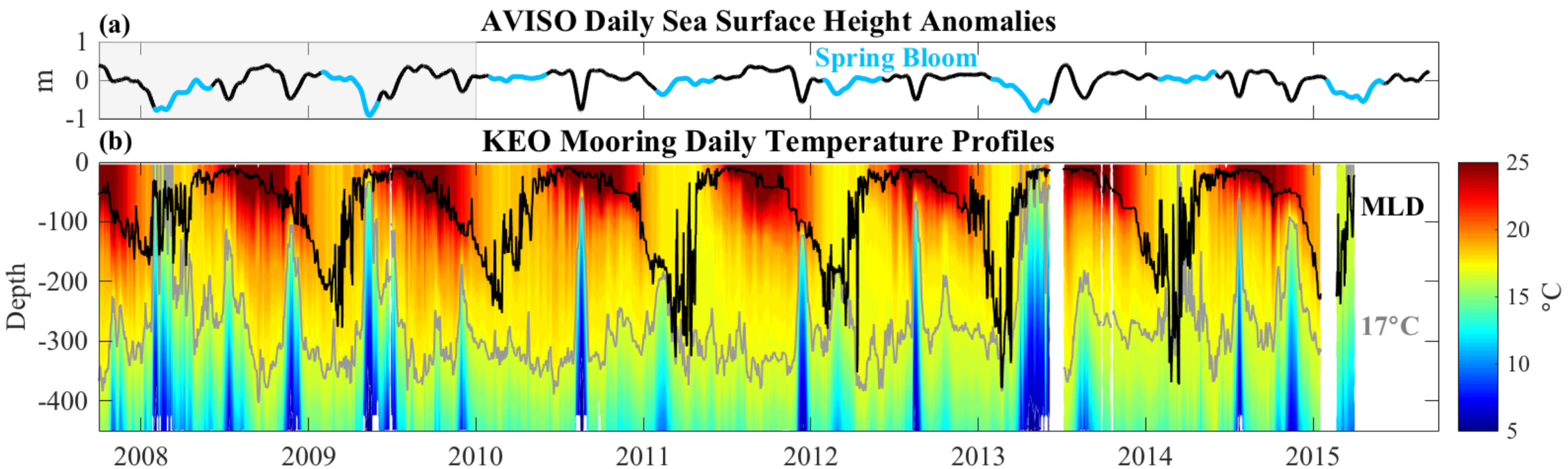
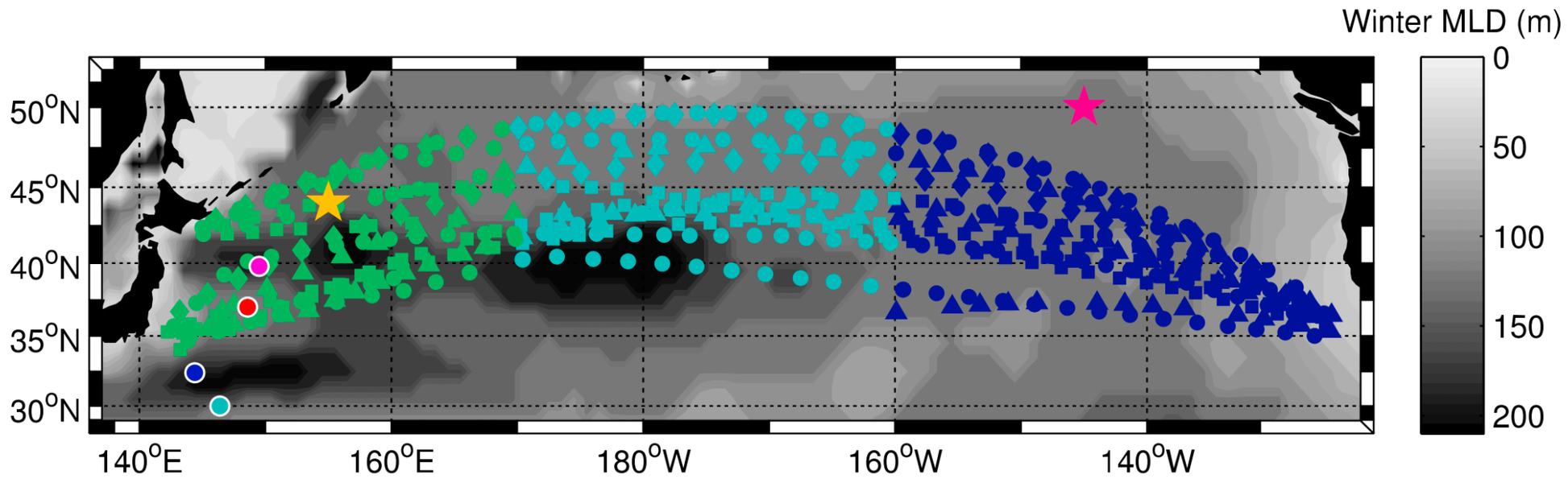
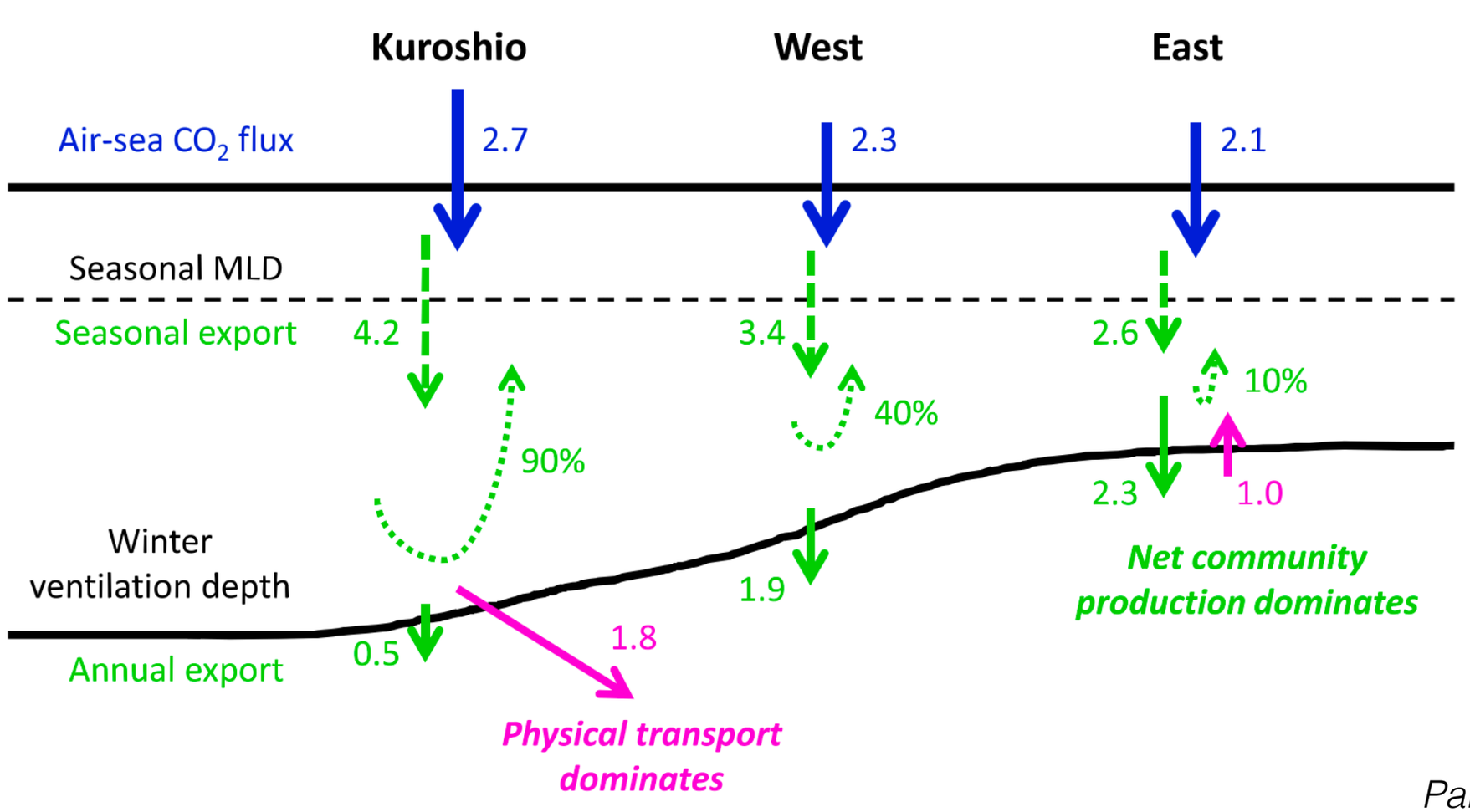






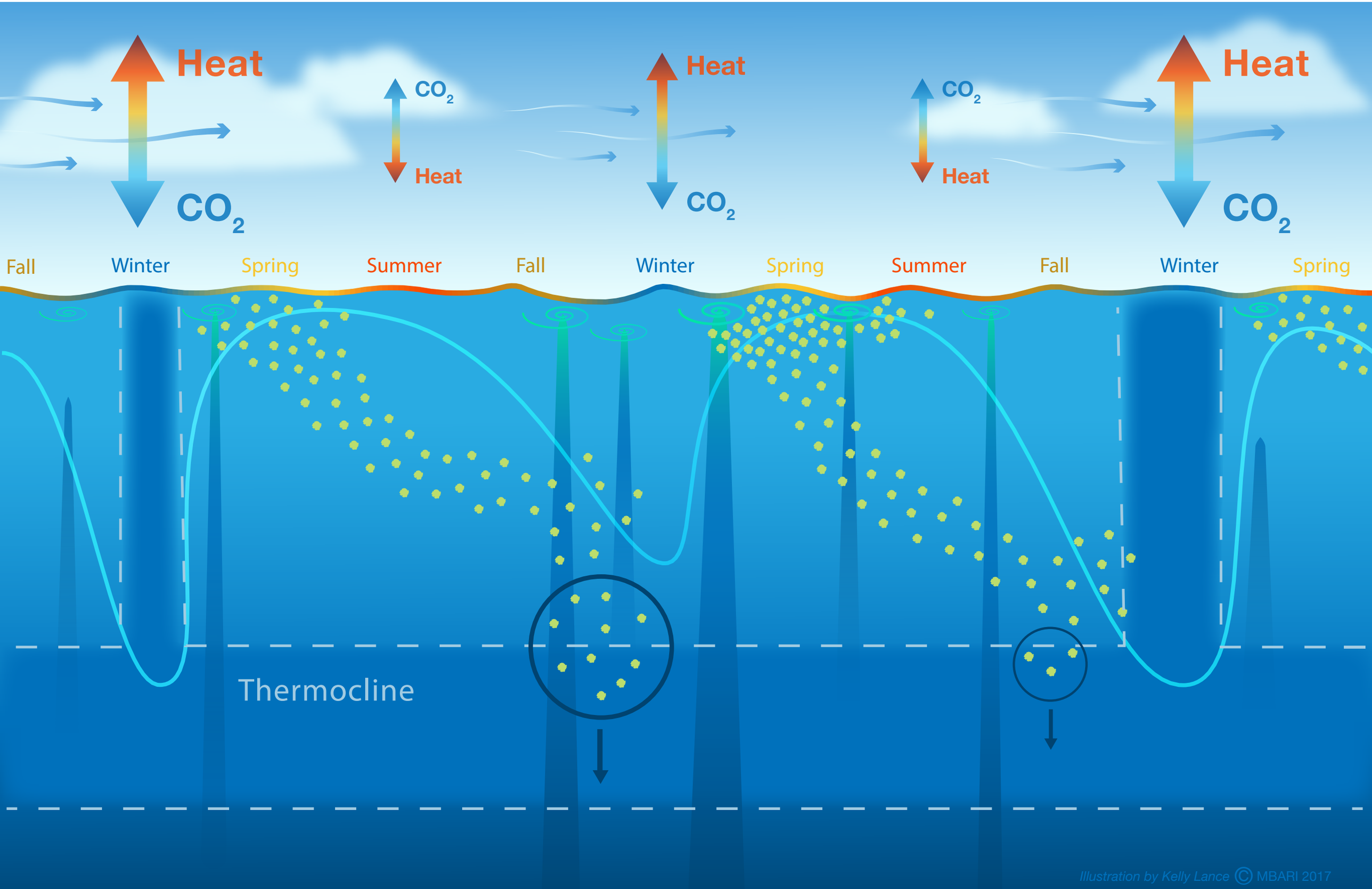
Mixed Layer Depth Constraints on Carbon Export





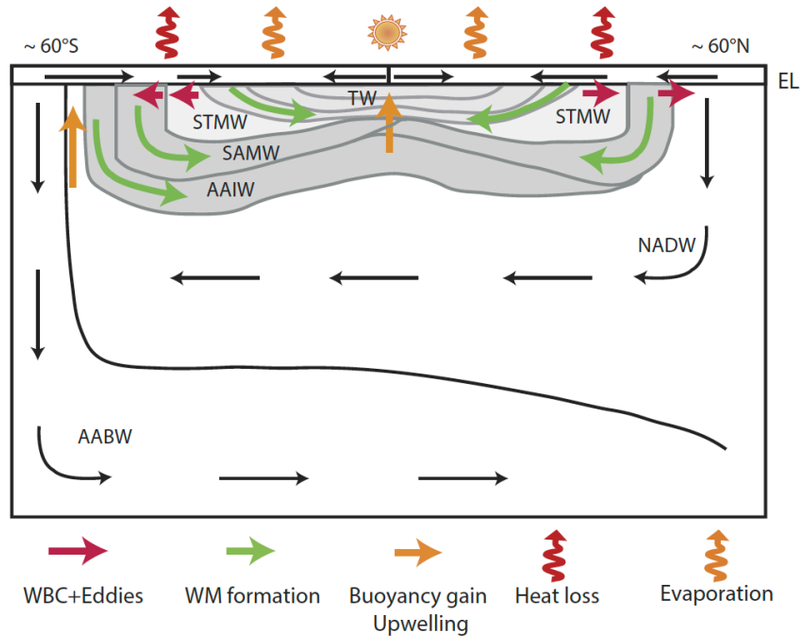
Palevsky et al., 2017

KE Jet Dynamics and Carbon Export



Take Home Messages

1. Anthropogenic carbon storage mediated by the shallow overturning circulation is heavily dependent on mode and intermediate water formation rates.



2. Anthropogenic carbon uptake in subtropical source waters is important and may begin to play an even larger role in anthropogenic carbon storage, relative to subpolar waters.

= larger and larger Cookie Monster relative to high latitudes

3. Consideration of future ocean circulation and biological changes is needed.