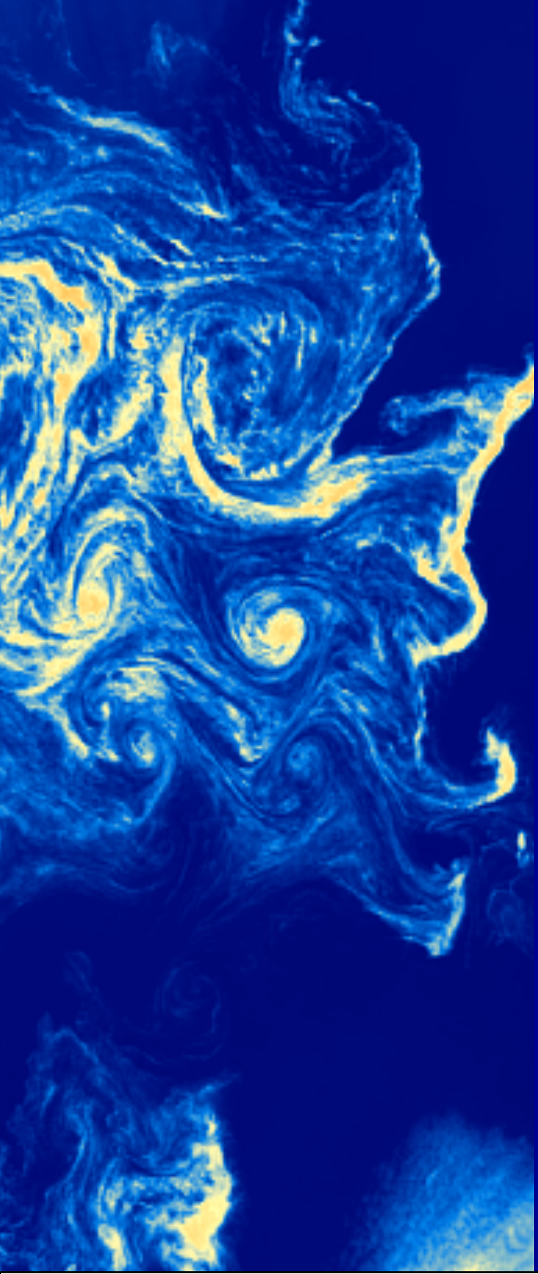

From small whirls to the global ocean

How ocean eddies affect the AMOC

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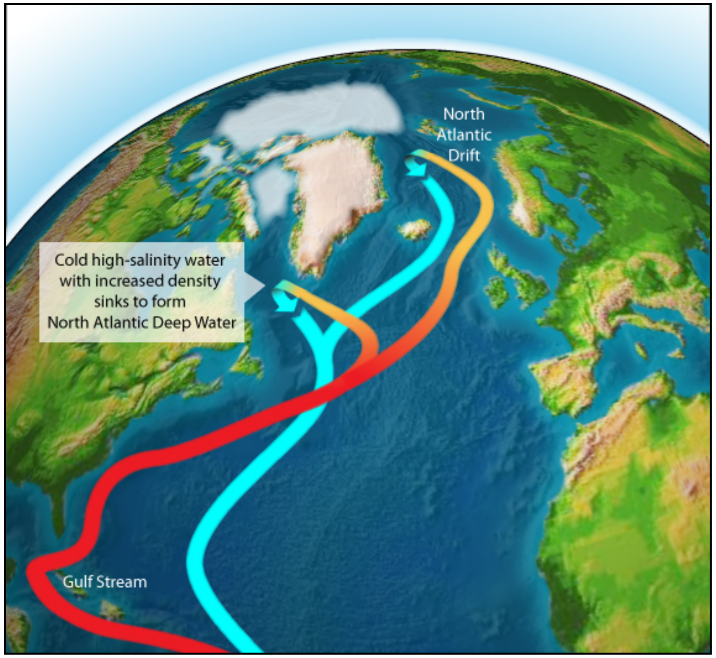
The downwelling branch of the AMOC



- depth space: sinking
- density space: water mass transformation

Do regions of Eulerian sinking and water mass transformation coincide?

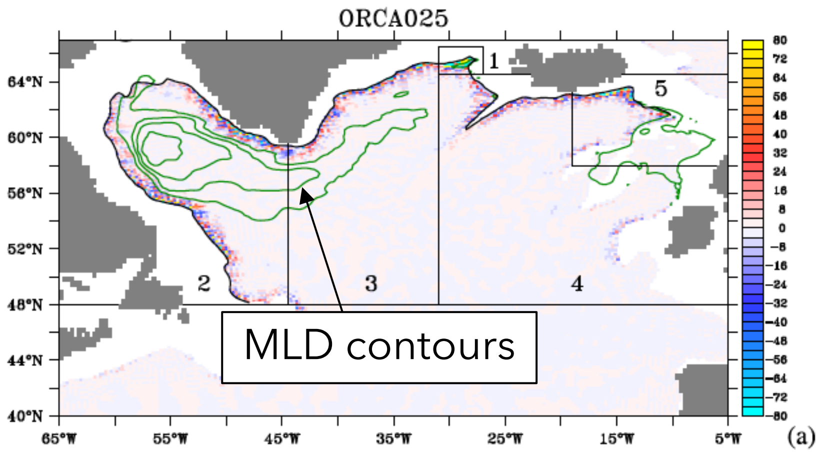
Are isopycnal and diapycnal processes in the boundary current and interior connected?

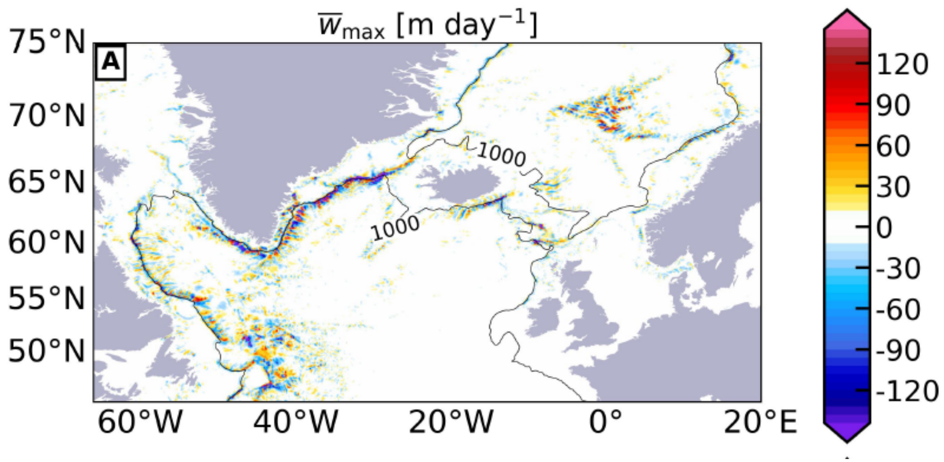
Approach: combined analyses of idealized and realistic models

Focus: marginal seas (not overflows)

(1) Sinking occurs near boundaries

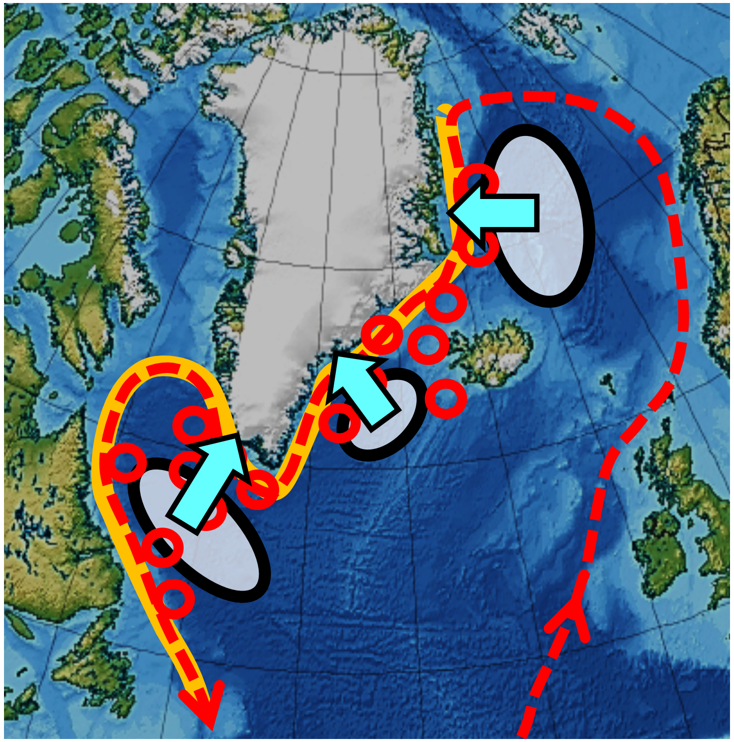
- convection = mixing (water mass transformation) ≠ sinking
- geostrophy prevents large-scale sinking in the interior; ageostrophic effects allow for sinking near the boundary (different vorticity balance) - Spall and Pickart (2001)
- **This is indeed what happens in ocean models (figure)**
- **The sinking occurs below the mixed layer** so is not associated with local water mass transformation - Bruggemann and Katsman (2019); Georgiou et al (2019)





mean w at depth of AMOC maximum (~1000m); in m/day
Katsman et al (2018) – ORCA 0.25°, Sayol et al. (2019) – POP 0.1°

(2) Eddy activity connects convection regions to boundary (currents)



Eddies govern the cycle of convection & restratification (Gelderloos et al 2011)

<u>Hypothesis: </u>eddies facilitate the exchange of waters between boundary current-interior **and link convection regions to the boundary (current)** and allow convected waters to be exported via the boundary current

➔ Process studies using highly idealized models of marginal seas characterized by a dense interior and a buoyant boundary current.

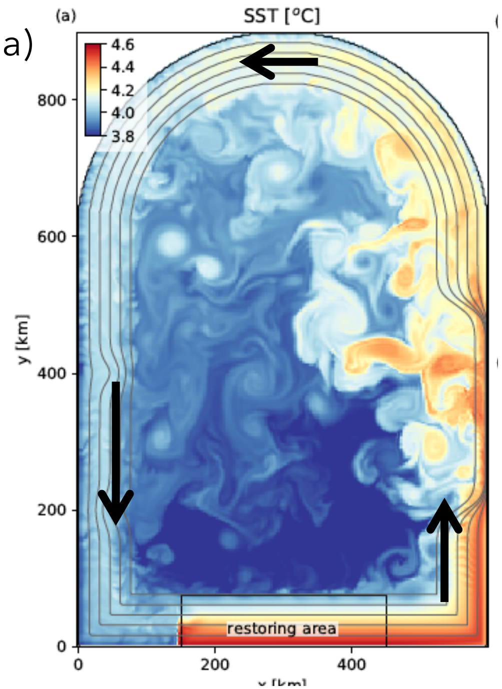
Bruggemann and Katsman (2019);

Georgiou et al (2019, 2020)

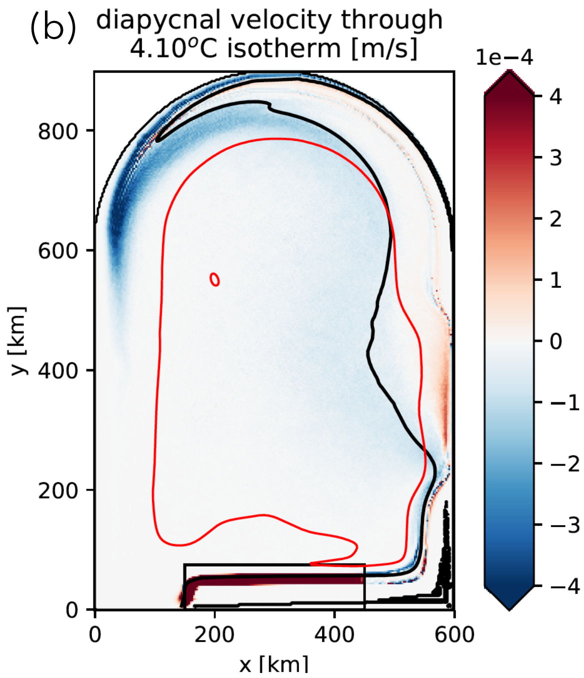
Example: highly idealized marginal sea

The boundary current loses buoyancy along the perimeter (atmosphere, lateral eddy fluxes) and -as the cross-shore density gradient reduces- this reduces the baroclinic transport. This suggests a downward diapycnal transport in the boundary current (Straneo 2006). **This is indeed seen in the model (figure b)**

(a)



(b)



(a) SST snapshot shows eddies form in the east.

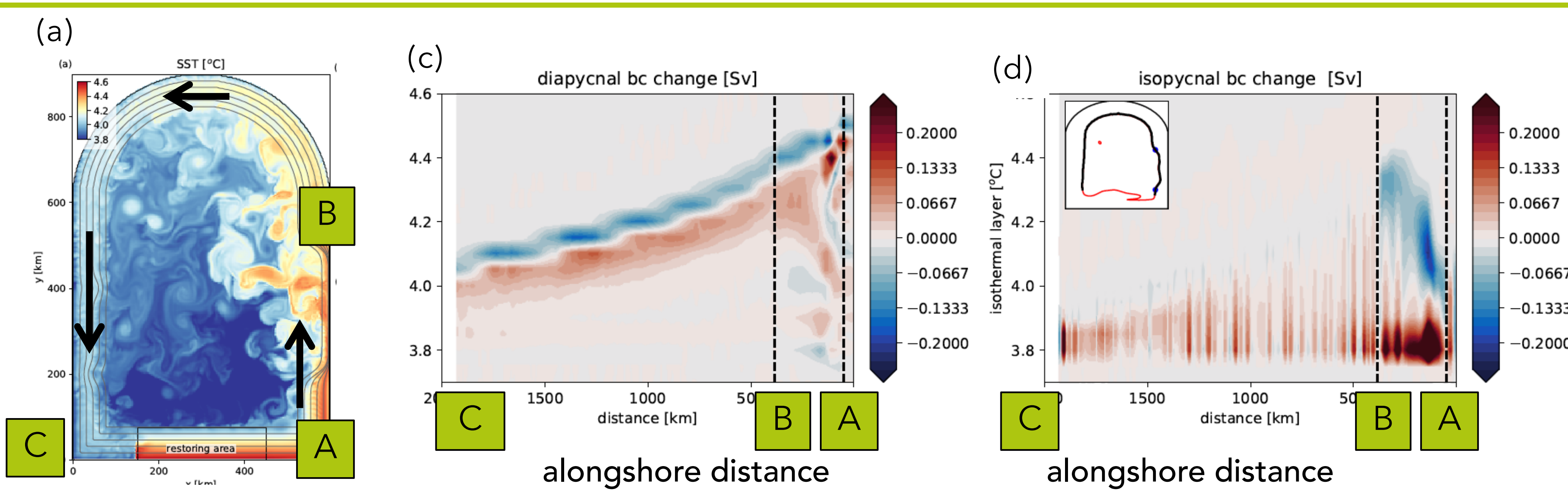
(b) downward diapycnal transport occurs downstream of the eddy-shedding region, in the boundary current (blue shading)

Bruggemann and Katsman (2019)

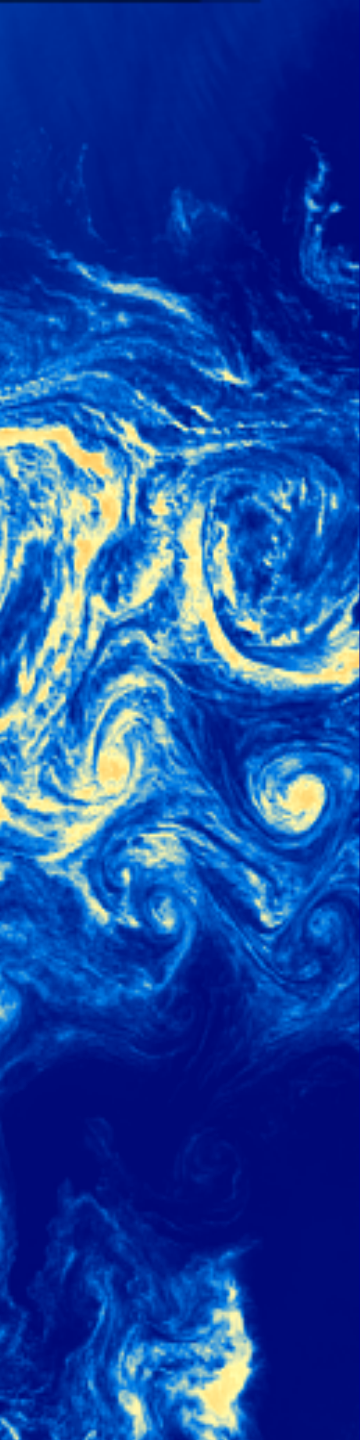
Example: highly idealized marginal sea

But if everything happens in the boundary current, how does dense water formed in the interior leave the marginal sea?

It appears that in addition to (c) diapycnal mixing in the boundary current, there is a (d) **strong exchange with the interior along isopycnals** that peaks in the eddy-shedding region (between [A] and [B]). The exchange **replaces lighter (warmer) boundary current waters by denser (colder, convected) waters**



Changes in boundary current transport analyzed in alongshore direction due to (c) diapycnal mixing and (d) exchange along isopycnals (Bruggemann and Katsman, 2019)



Complex 3D view on sinking and overturning in marginal seas

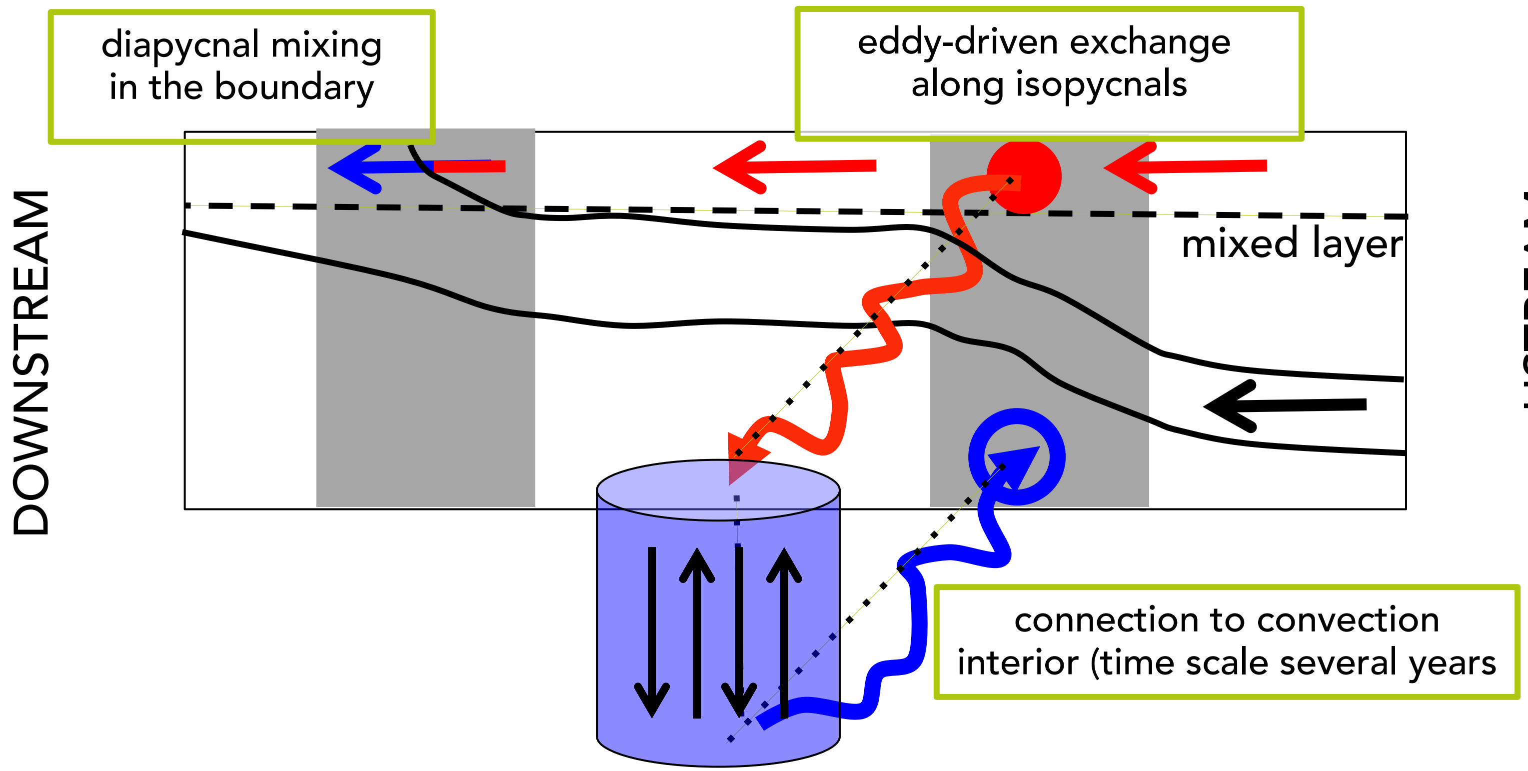
Eulerian sinking peaks in the boundary current, in eddy-rich regions, and below the mixed layer

Diapycnal mixing occurs in the interior of the marginal sea, and further downstream in the boundary current

A pathway exists for upper boundary current waters from the boundary current into the convection area and back. These waters get denser through diapycnal mixing in the interior, the cross-shore movement is along isopycnals in both directions

The presence of a strong eddy field is crucial for this exchange between boundary current and interior

Complex 3D view on sinking and overturning in marginal seas



Schematic of unfolded boundary current and interactions with the interior from Brüggemann & Katsman (2019), after Straneo (2006).

This 3D view has been confirmed by Lagrangian analyses in idealized models (Georgiou et al 2020) and in realistic models (in progress; see Display D2750 – EGU2020-22348)

Recent papers on our work

- Katsman et al 2018 - Sinking of Dense North Atlantic Waters in a Global Ocean Model: Location and Controls. J. Geophys. Res. Oceans, 123(5):3563–3576, 2018
- Bruggemann and Katsman 2019 - Dynamics of downwelling in an eddying marginal sea: contrasting the Eulerian and the isopycnal perspective . J. Phys. Oceanogr., 49:3017–3035, 2019
- Georgiou et al 2019 - On the interplay between downwelling, deep convection and mesoscale eddies in the Labrador Sea. Ocean Modelling, 135:56–70, 2019
- Sayol et al 2019 - Seasonal and regional variations of sinking in the subpolar North Atlantic from a high-resolution ocean model. Ocean Science, 15(4), 2019
- Georgiou et al 2020 - Pathways of the water masses exiting the Labrador Sea: The importance of boundary–interior exchanges, Ocean Modelling, 101623.

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