Size Matters: Another Reason Why the Atlantic is Saltier than the Pacific

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The Meridional Overturning Circulation



- Wind-driven upwelling in the Southern Ocean pumps waters up & north lacksquare
- Diffusive upwelling in all oceans pumps deep water up lacksquare
- Deep water formation occurs in North Atlantic (saltier), but not North Pacific

Why is the Atlantic the preferred sinking site?

Observations: salinity zonally and vertically averaged above 800m



High salinity in North Atlantic enables sinking

Why is Atlantic saltier than **Pacific?**

MITgcm setup



- Domain is 210^o-periodic, 4000m deep
- Surface wind stress, relaxation temperature and freshwater flux are zonally uniform
- Low-diffusivity regime $\kappa_v = 2 \times 10^{-5} \text{m}^2/\text{s}$ \bullet
- 1 degree resolution
- GM parametrization $\kappa_{GM} = 500 \text{m}^2/\text{s}$

ROC streamfunction



- Narrow basin sinking is preferred
- Same amount of transport crosses equator regardless of sinking location

$$\psi(y,\tilde{b}) = \frac{1}{T} \int_0^T \int_0^{L_x} \int_{-H}^0 (v + v_{GM}) \mathcal{H} \left[b(x,y,z,t) - \tilde{b} \right] \, \mathrm{d}z \, \mathrm{d}z$$

Lower freshwater flux over wide basin



Why is the northward MOC transport independent of sinking location?



- Amount of sinking must be equal to amount of upwelling \bullet
- Amount of upwelling is independent of sinking location
- Amount of sinking is independent of sinking location \bullet
- Northward transport in "sinking" basin is 15Sv \bullet





Zonally averaged salinity anomaly from abyssal value, depth averaged above b_m



Red is the sinking basin

Blue is the nonsinking basin

- For wide sinking, salinity is barely above abyssal value
- For wide sinking, difference between salinities is very small

Wide sinking is coerced by reducing freshwater input in NH of wide basin by 0.06Sv





Zonally averaged tracer anomaly from abyssal value, depth averaged above b_m



Red is the sinking basin

Blue is the nonsinking basin

- Wide sinking is unstable for zonally uniform freshwater flux

Passive tracer is forced with zonally uniform freshwater flux



Passive tracer is advected with same velocity field as salinity

Sinking region

• Tracer concentration in narrow basin is higher than in wide basin for both MOC states • For wide sinking, tracer concentration in wide basin is barely above abyssal concentration



Velocity in the sub polar gyre (SPG) is the sum of gyres + MOC velocities



- Southward western boundary current in wide SPG is larger than in narrow SPG \bullet
- Differences in velocity field cause differences in salinity field \bullet





Depth-integrated velocity in sinking basin above b_m

Western boundary current brings fresh water southward



- Arrows are direction, colors are magnitude ullet
- \bullet
- Western boundary current is northward to about 45N for wide sinking lacksquare

Zero meridional current at western wall

Western boundary current is northward to about 57N for narrow sinking

Salinity in SPG sets sinking distribution Depth-average salinity/tracer anomaly above the isopycnal b_m (colors) Sinking





Conclusions

- sinking occurs if the freshwater flux into the wide basin is reduced by 0.06Sv.
- sinking than for wide sinking.
- The western boundary is fresher in the wide basin than in the narrow basin. Therefore sinking does not occur on the western boundary of the wide basin.
- Freshwater spreads eastward and suppresses sinking in the wide basin.

The greater width of the Pacific and the advection of salinity by the warm route may inhibit deep-water formation in the Pacific, even if buoyancy flux into the north Atlantic increases (e.g. from Greenland ice melt).

Jones, C.S. and Cessi, P. Interbasin transport of the meridional overturning circulation (2016) JPO. Jones, C.S. and Cessi, P. Size matters: another reason why the Atlantic is saltier than the Pacific. Submitted to JPO

• Wide-basin sinking is not possible with zonally uniform surface freshwater flux. Wide-basin

• The size of the basin determines the transport of the SPG western boundary current. The northward western boundary current in the sinking basin extends further north for narrow



