WW Characterisation …

Intro:

* SO significance in MOC and global climate system.
  + Tilting isopycs driving upwelling
  + water mass formation and transformation
* What is WW? Why is it important?
  + Final stage of upper limb upwelling in MOC
  + Blocks UCDW
* Description of current lit around WW
  + limited or dated
  + theory is also important! Include some of those papers
    - <https://empslocal.ex.ac.uk/people/staff/gv219/classics.d/Anderson_Gill75.pdf> ? not directly WW but definitely SO upwelling.

Notes:

* ABT (and but therefore)
* agreement, contradiction, consequence
* arousal and fulfilment

**SO significance (MOC):**

Notes:

The Southern Ocean (SO, 50°S) is integral to the climate system; it absorbs vast quantities of anthropogenic carbon dioxide and heat (cite…) through its central role in global overturning circulation. The wind stress imposed on the ocean causes upwelling (downwelling) poleward (equatorward) of the maximal wind stress (cite?). This is associated with tilting isopycnals and setting the geostrophic eastward Antarctic Circumpolar Current (ACC) (cite …), which facilitates inter-ocean transport of water.

These same winds drive an equatorward transport of the surface ocean.

water mass formation is a key feature in the SO.

This upwells naturally CO2-rich and warm deep waters. Antarctic Winter Water (WW) acts as a conduit in the upper limb of overturning circulation to transform deep waters to Antarctic Intermediate Water (AAIW) through entrainment.

**SO signif attempt # 2:**

The continental configuration around the Southern Ocean (SO) allows for strong and persisting circumpolar westerlies, which help in setting the geostrophic eastward flowing Antarctic Circumpolar Current (ACC). South of the ACC is a region of upwelling due to strong winds and intense eddy-driven mixing, which tilts density surfaces to rise to the upper ocean. Subsequently, warm and naturally CO2-rich deep waters are brought to the ocean surface via spiraling pathways [1], which are transformed into intermediate waters via Antarctic Winter Water (AAWW, henceforth WW) [2]. Mixing of deep water into the surface results in CO2 outgassing and surface warming in the polar SO. Therefore, summertime WW acts as a barrier to the interior deep water, with WW thickness and erosion rates directly impacting rates of overturning as well as arresting CO2 outgassing and surface warming.

**Describe Winter Water:**

Antarctic winter water, WW, is a surface water mass capping the upper limb of overturning circulation south of the Polar Front [3] and exhibits an annual cycle.

WW is formed in the wintertime mixed layer (wML), where an intensely cold atmosphere drives ocean surface cooling and sea ice formation, causing a cold and deep wML to form. from

The cold layer caps the warm circumpolar deep water (CDW) and remains stable in the water column (counter-intuitively) due to a feedback relationship between warm and saline CDW entrainment and sea ice melt [4].

WW subsequently subducts when the atmosphere changes to a positive heat flux melting the sea ice and warming the surface ocean. Consequently, a warm-cold-warm layer comprising of surface layer water-WW-CDW forms. The WW is eventually eroded largely due to upper-bound fluxes (cite Iss’s paper in prep/submission/review?)

**Winter Water state of literature:**

**Hypothesis:**

[1] V. Tamsitt *et al.*, ‘Spiraling pathways of global deep waters to the surface of the Southern Ocean’, *Nat. Commun.*, vol. 8, no. 1, p. 172, Aug. 2017, doi: 10.1038/s41467-017-00197-0.

[2] D. G. Evans, J. D. Zika, A. C. Naveira Garabato, and A. J. G. Nurser, ‘The Cold Transit of Southern Ocean Upwelling’, *Geophys. Res. Lett.*, vol. 45, no. 24, Dec. 2018, doi: 10.1029/2018GL079986.

[3] H.-M. Park, E. Charriud, and M. Fieux, ‘Thermohaline structure of the Antarctic Surface Water/Winter Water in the Indian sector of the Southern Ocean’, *J. Mar. Syst.*, vol. 17, no. 1–4, pp. 5–23, Nov. 1998, doi: 10.1016/S0924-7963(98)00026-8.

[4] E. A. Wilson, S. C. Riser, E. C. Campbell, and A. P. S. Wong, ‘Winter Upper-Ocean Stability and Ice–Ocean Feedbacks in the Sea Ice–Covered Southern Ocean’, *J. Phys. Oceanogr.*, vol. 49, no. 4, pp. 1099–1117, Apr. 2019, doi: 10.1175/JPO-D-18-0184.1.