National Oceanography Centre

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Transient tracer-based Investigation of Circulation and Thermal Ocean Change

Pathways and time scales of ocean heat uptake and redistribution in a global ocean-ice model

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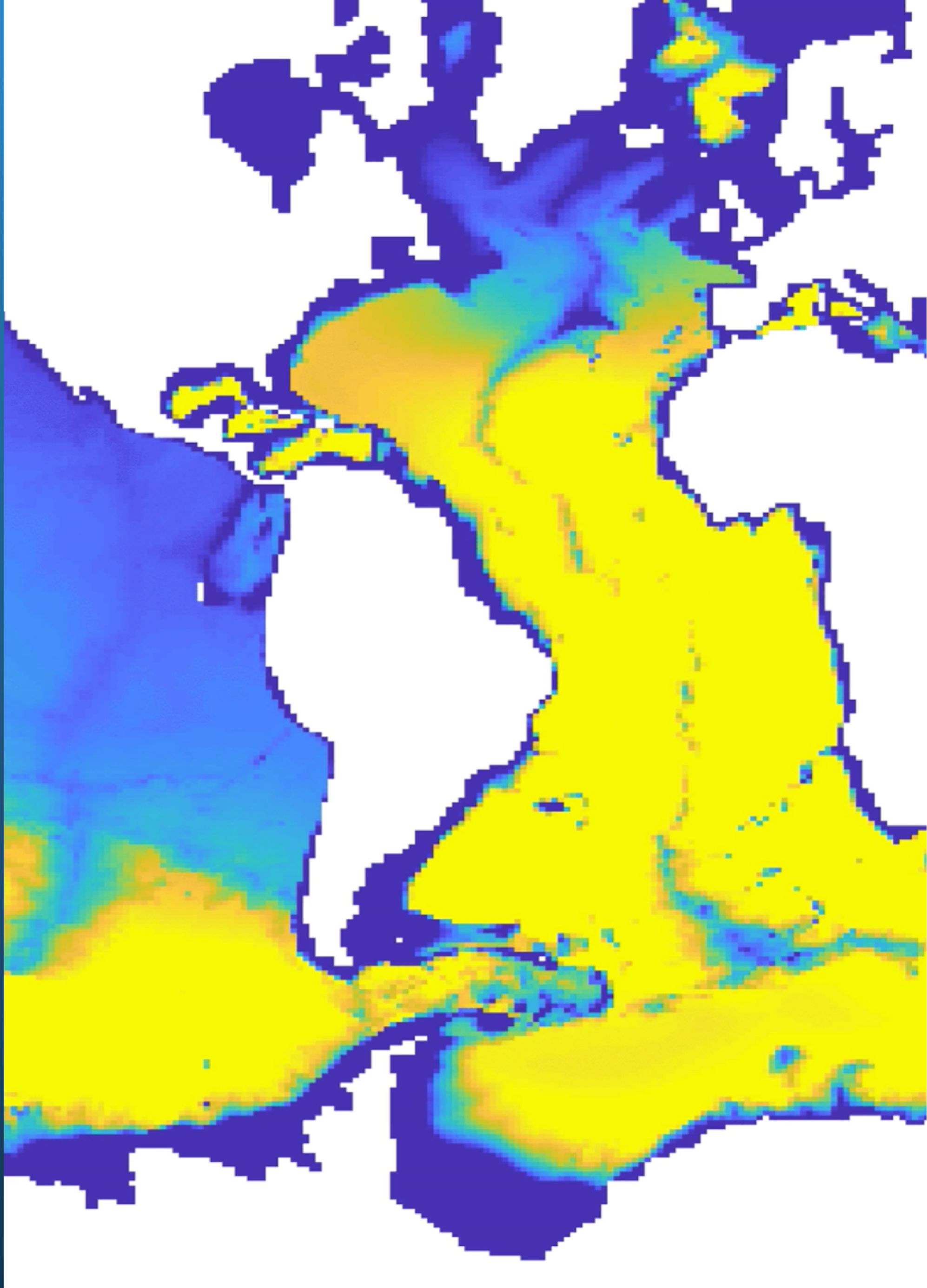
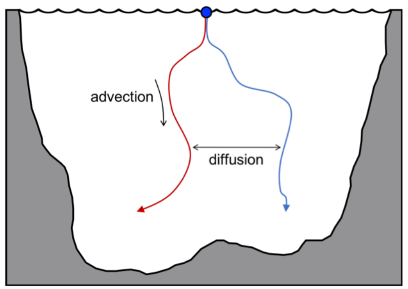


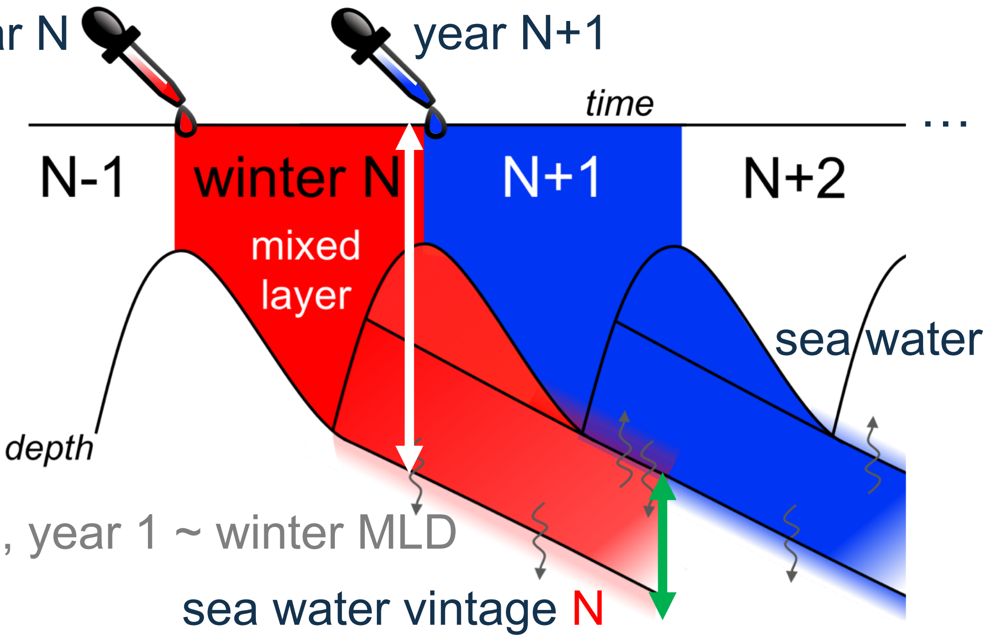
Dye tracer injected globally, after 100 years of simulation

How are tracers ventilated into the ocean's interior?



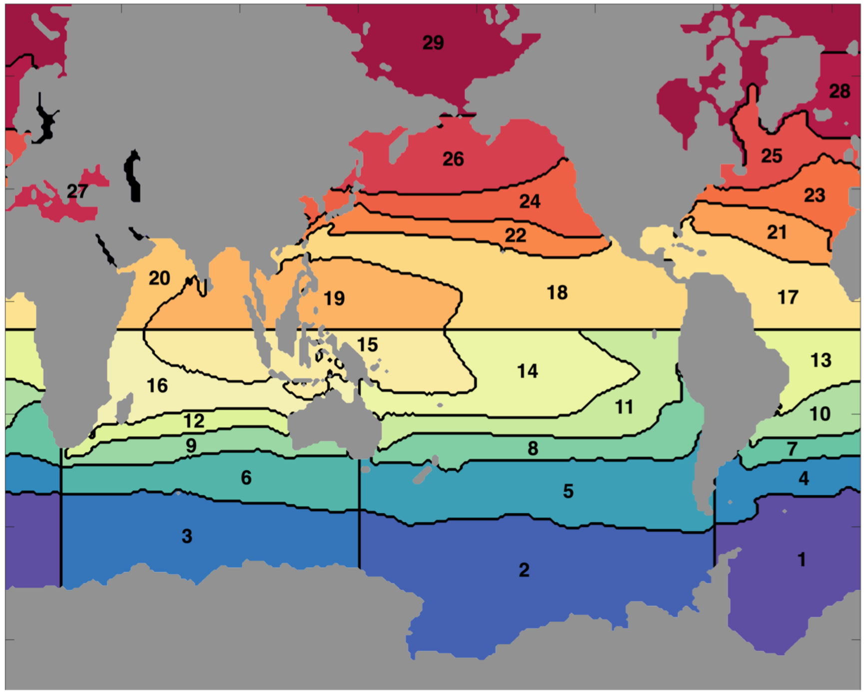
Time:

Injected (surface, winter N, summer to summer) **dye = 1**
Removed (when reaches surface after winter N) **dye = 0**



Space:

29 surface patches (source regions) defined from climatological density following *Khatiwala et al. (2009, 2012)*



Method: ocean-ice simulations where a dye tracer is injected for one year in each surface patch

Experimental setup: model and simulations

Ocean-ice model (NEMO+CICE)
Atmospheric forcing: JRA-55
Resolution: 1º horizontal, 75 vertical levels
300-year spin-up, following OMIP protocol

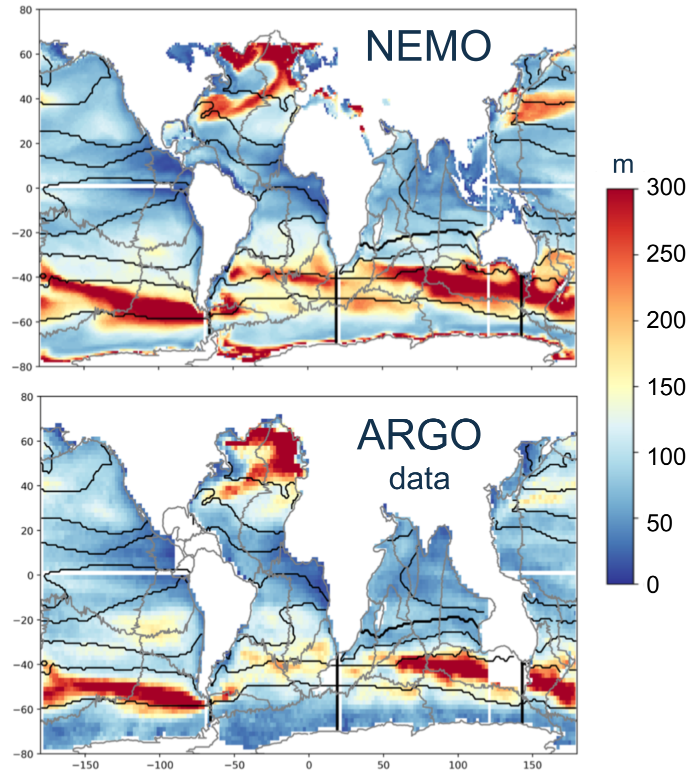
Two main sets of simulations:

- **60-year run** with JRA-55 forcing
  (i.e. 1958-2017)
  Interannual variability – *see example 1*

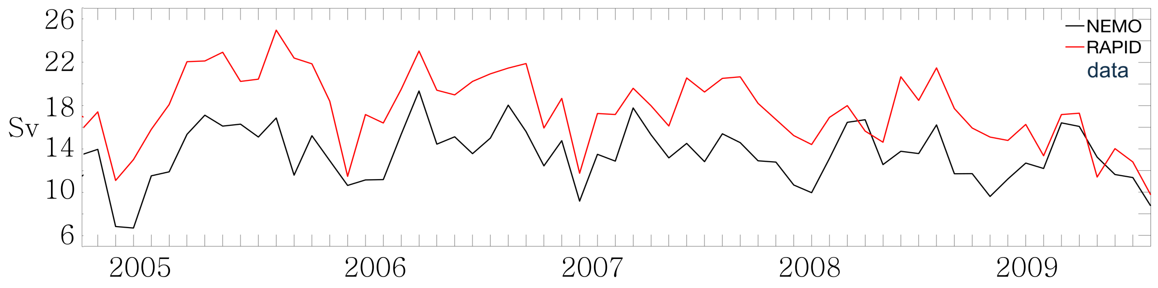
- **218-year run** with repeated forcing
  (i.e. "year 1800" to 2017)
  Long time scales – *see example 2*

All: dye tracers released from 29 patches

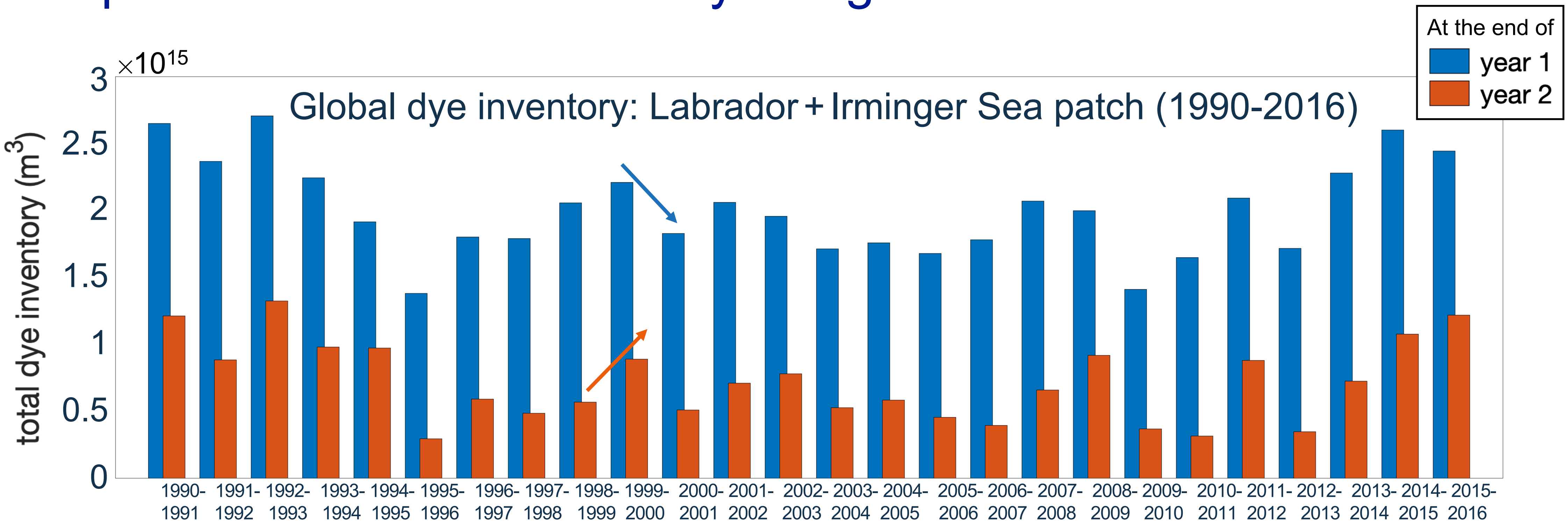
Winter mixed layer depth (MLD)



Atlantic Meridional Overturning Circulation (26ºN)



Example 1: interannual variability in high latitude ventilation



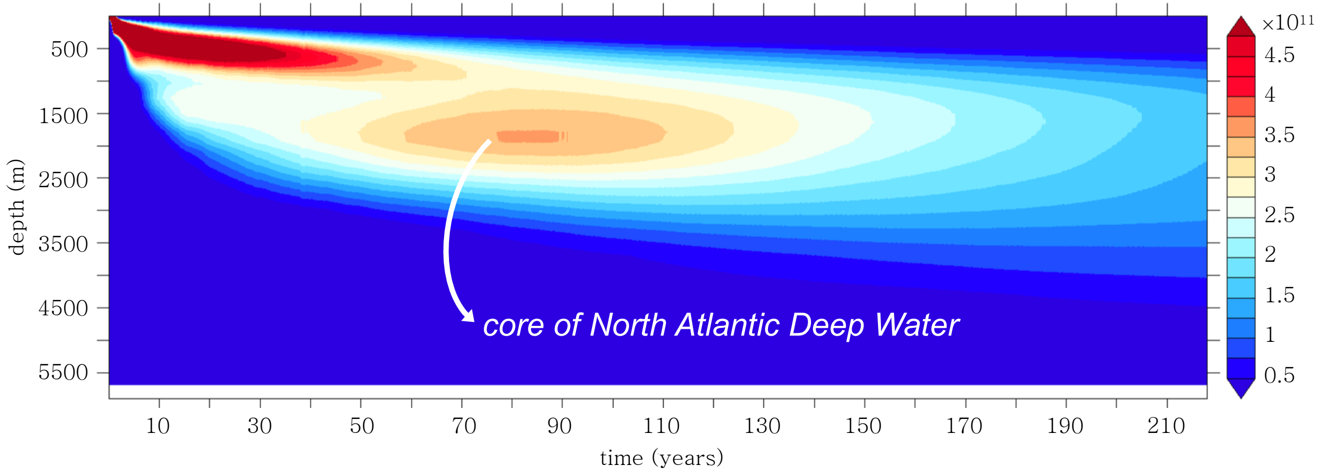
Strong interannual variability (compares favourably with observations) as expected from MLD's strong response to surface forcing (air-sea fluxes) in these regions (year 1 ~ MLD variability)

But after year 1, a reduction in MLD (convection) during the following cooling season ↘ allows more subduction of water from the previous year in year 2 ↗ (and subsequent years?)

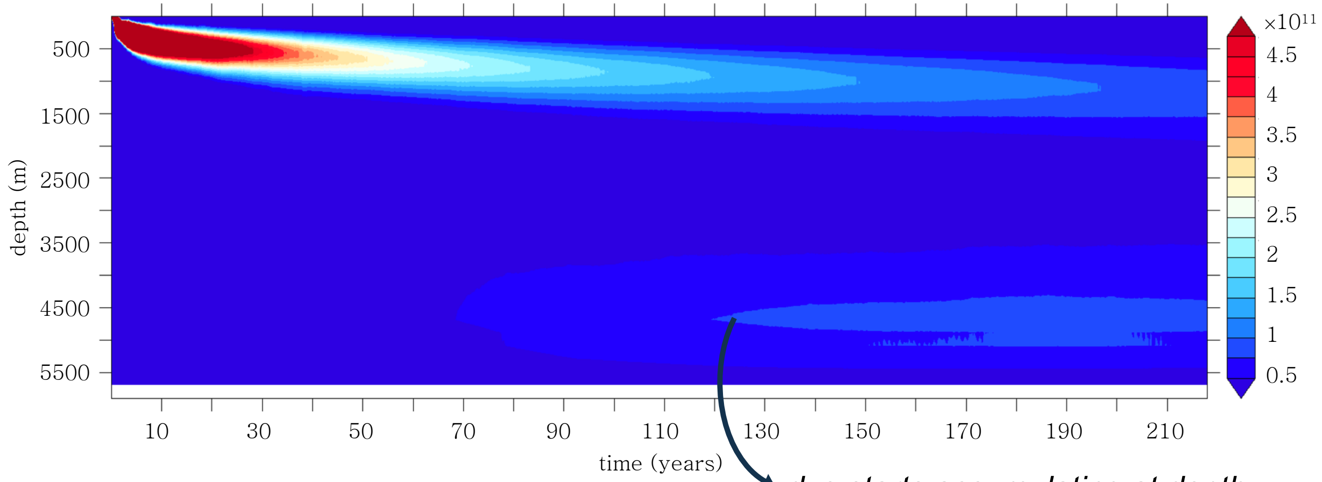
There are some exceptions – interplay between convection in Labrador vs Irminger Sea?

Example 2: Atlantic vs Pacific variability on long(er) time scales

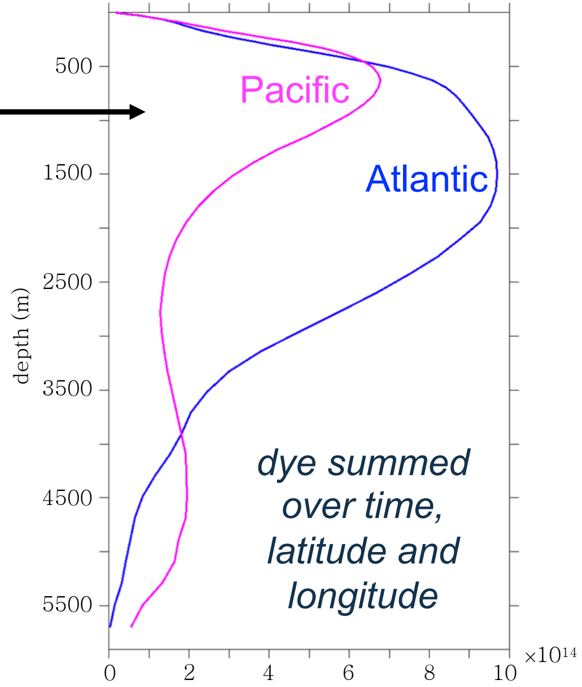
Time evolution of latitudinally-integrated dye along a mid-Atlantic cross section (here: summed only between 40ºN-40ºS) as function of depth



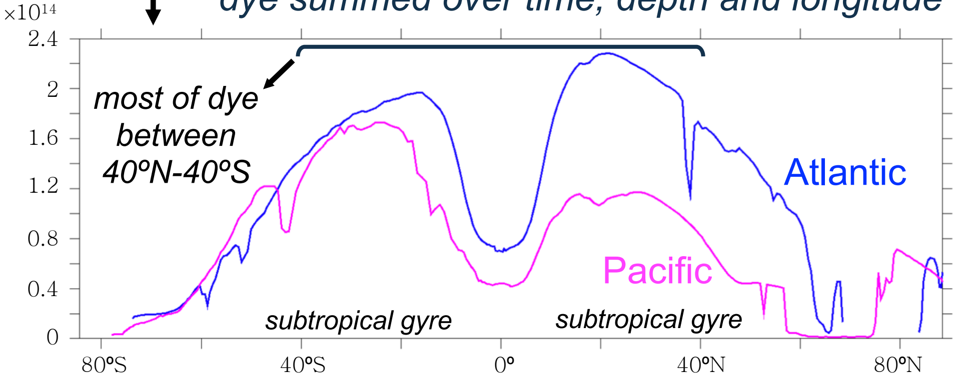
mid-Pacific cross section (40ºN-40ºS only)



Here the dye is summed along full north-south cross sections in the centre of the Atlantic and Pacific basins: summing the dye mimics the distribution of a passive tracer that accumulates over time



dye summed over time, depth and longitude



Summary and conclusions

Simulations with dye tracers that are “tagged” based on year and region of origin.
Aim: heat as a passive tracer (similarly to carbon, e.g. *Khatiwala et al., 2009, 2012*)

Dye is summed to mimic the distribution of a passive tracer that cumulates over time.
Initial results from two main sets of simulations:

Interannual variability: strong response to atm forcing in Labrador/Irminger Sea and tracer’s subduction strongly depends on convection during following cooling season.

Long timescales: largest amount of dye found in subtropical gyres – slow ventilation.

Atlantic: more dye accumulates between ~1000-2000m (on this time scale) i.e. NADW
Pacific: more dye accumulating in the abyssal ocean below ~4000m (after ~100 years)

Northern Hemisphere: ~ twice as much dye accumulates in the Atlantic than Pacific.
Southern Hemisphere: accumulation is similar in the Atlantic and Pacific.

Next: more direct interpretation/application to ocean heat uptake and redistribution.
But results/analysis are applicable to any passive tracer in the ocean.

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