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# Insights from developing a coarse-resolution configuration of MOM6

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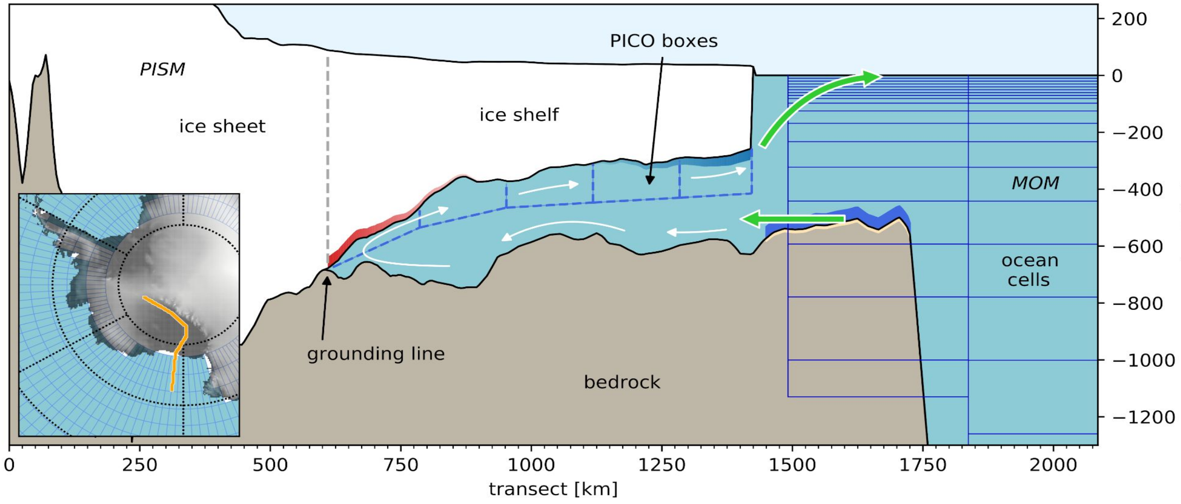
# Background

Why are we doing this?

- Currently developing a new ESM, POEM; requirements include:
  1. Dynamic sea level change (glacial-interglacial)
  2. Changing land-sea mask
  3. Coupling with ice sheet models (PISM-PICO)
- Current MOM5 configuration problematic…
  1. Implementing pts. 1 & 2 would be technically a pain
  2. Model prone to forming NPDW
  3. Significant temperature biases at Antarctic margin




Kreuzer *et al.* 2021

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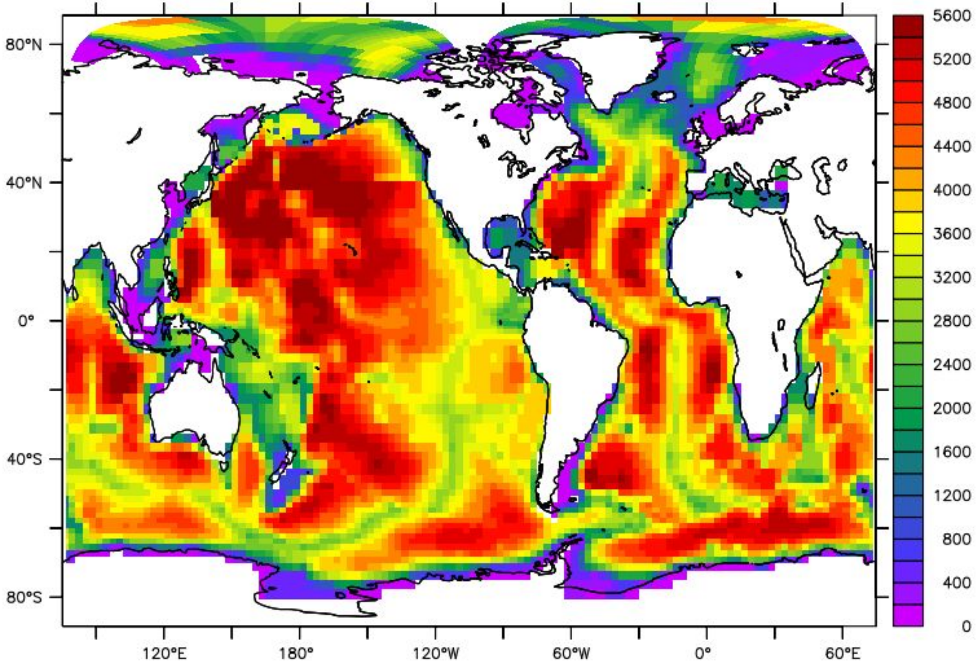
# What does it look like?

- Based upon MOM5 configuration found in CM2Mc (extended to 90S)
- ~3 degrees (narrows to 0.6 deg. at the equator)
- 28 vertical levels (tried both z* and HYCOM)
- Small changes include opening channels (different from MOM5) and differing bathymetry in some places (slightly lower mediterranean outflow, lower NA sill, considerable differences around Antarctica).
- New runoff fields generated using the supplied tool.
- Custom routines for basal melt from floating ice shelves




Bathymetry (m)

# What I can and can't tell you

- Long integration times (1+ week for each scenario), limited computational resources and time (model development was not part of my project) mean this tuning process was not a comprehensive test of the parameter space
- Primary focus was to build from the 1 degree test case and achieve a 'reasonable' AMOC, while dealing with the problems that caused along the way
- I **CAN** tell you, which parameters (that I tested) had the biggest impact in this config.
- I **CAN'T** tell you that this is necessarily true in some configuration of settings I have not tested
- I ran out of time - there is almost certainly room for improvement here

# Current parameter settings

Kh = 20,000
KV = 1.0E-05
DT = 3600
DT_(therm/coupling) = 28000
ALE regridding = True
MEKE = True (using a GM_coeff of 1.0, same for KHTH and KHTR)
KHTH_SLOPE_CFF = 0.01
KHTR_SLOPE_CFF = 0.25

KHTH_MIN = 50.0
KHTH_MAX = 800.0
KHTH_SLOPE_MAX = 0.01

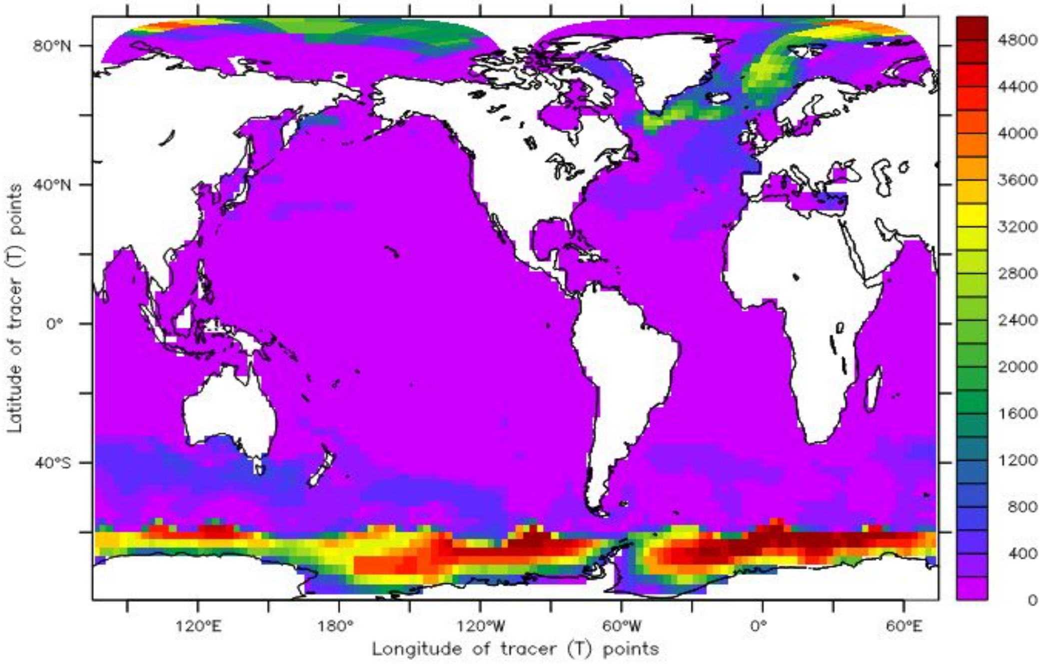
KD = 1.0E-05
KDML = 2.0E-05

HORIZ_VARYING_BACKGROUND = True

Currently simulating ~290 model yrs/day on 32 CPUs
Scenarios were spun-up for 1000-4000 years depending on stability
SIS2 is run with default param. settings.

For comprehensive list of parameters, link to data at the end…

# Problems along the way…




Mixed layer depth (delta rho = 0.03) (m)

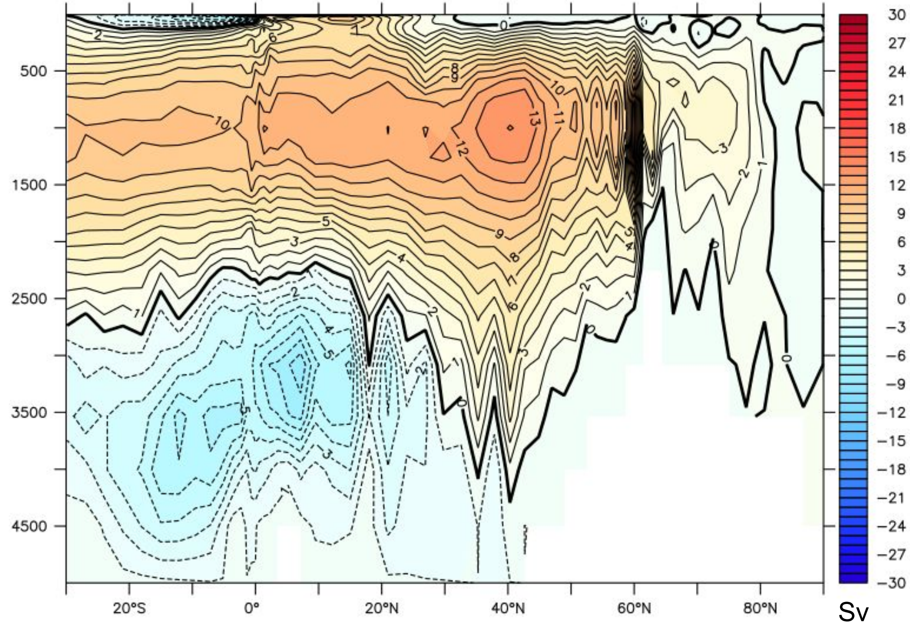
- It's considerably slower than MOM5 (our MOM5 config. achieves ~1000 model years/ day)
- Exact reasons still under investigation (eq. of state?)
- Dt is limited to ~1hr 50 mins due to coriolis implementation in C-grid. Anything slower and high latitude regions convect excessively.

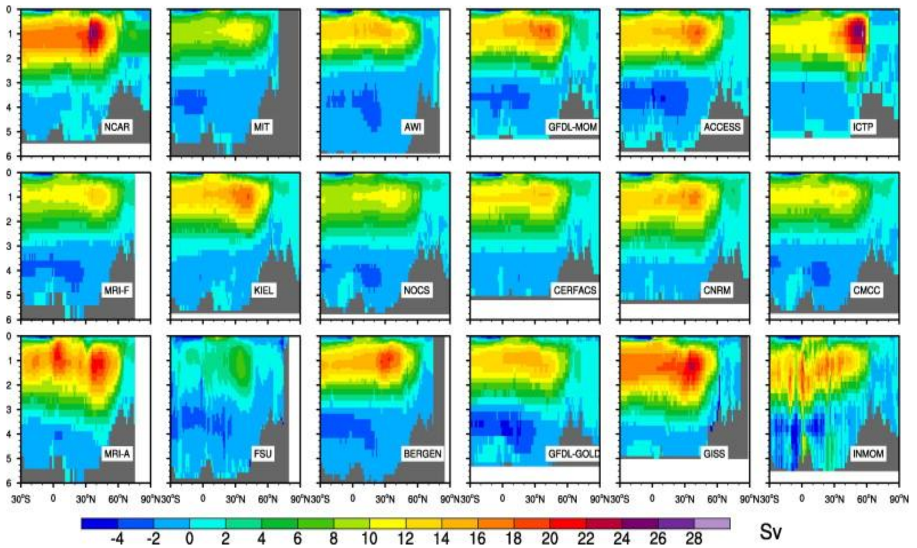
Bob Hallberg's explanation can be found here

# What does it look like?  AMOC is quite weak

Results from a 4000 yr run, 20yr means (aside from MLD - decadal max)

AMOC (Sv)




Danabasoglu *et al.* 2014

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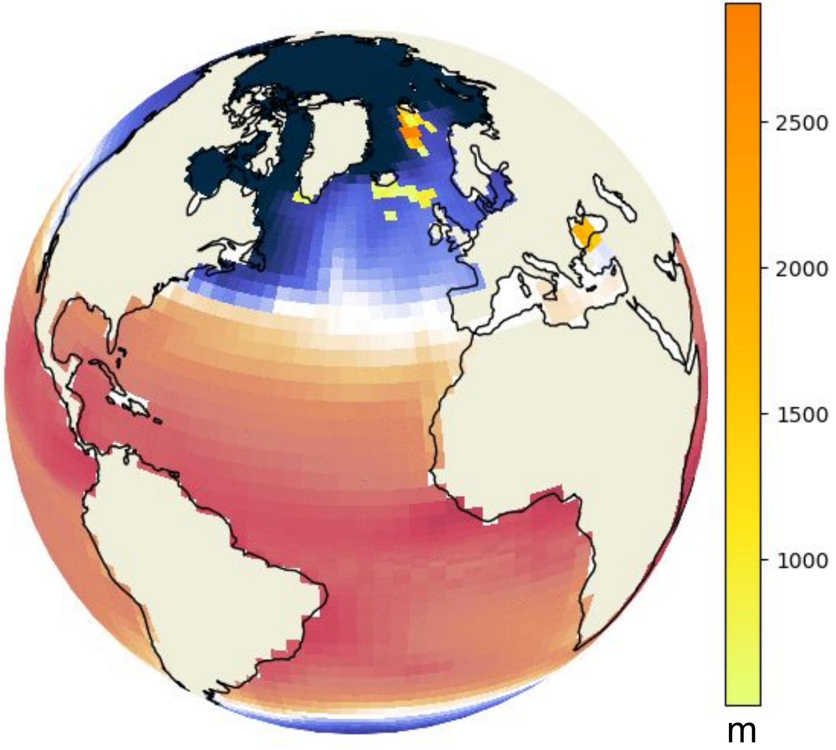
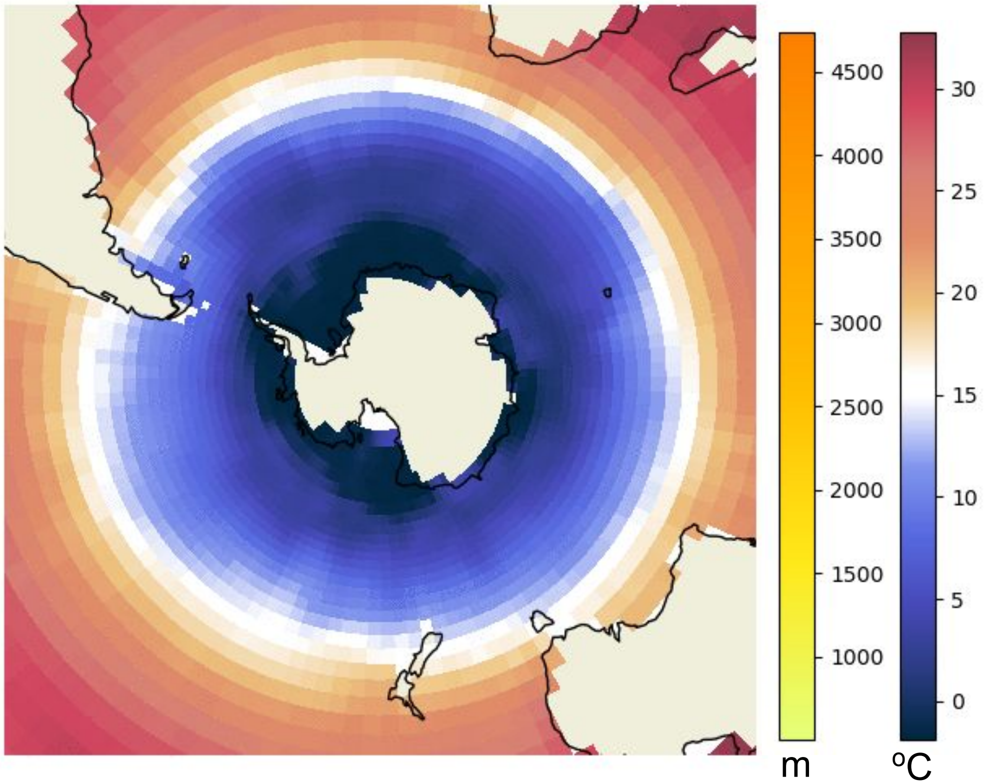
# What does it look like? (cont.) - SSTs and MLD (>500m)

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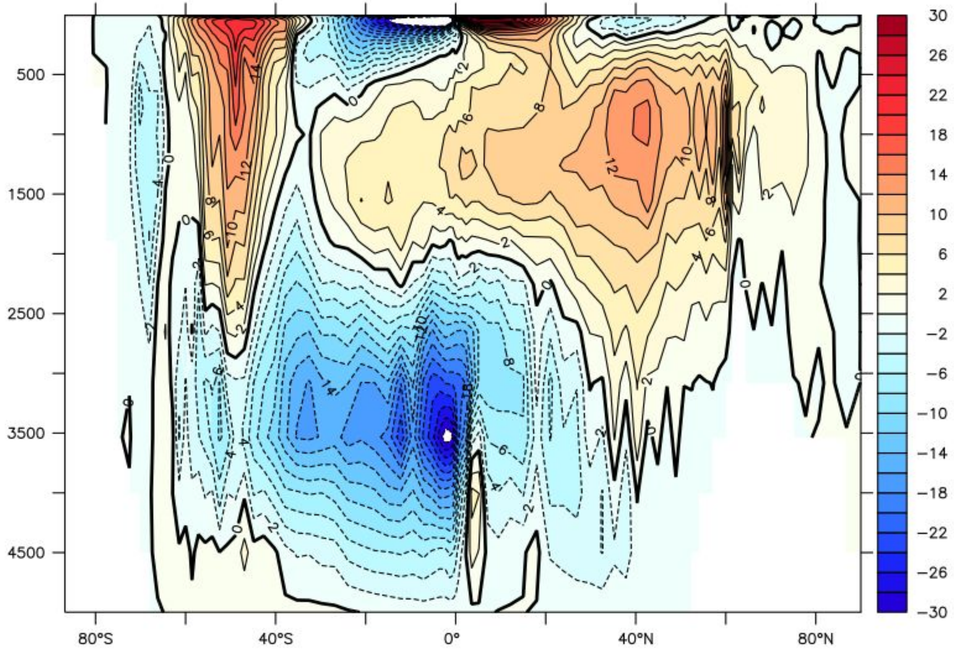
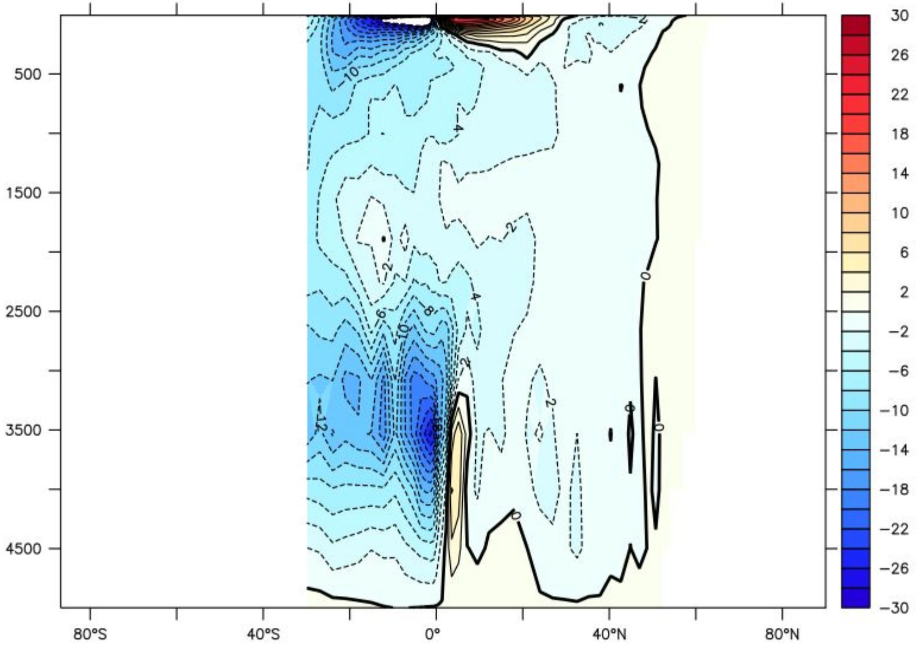
# Problems along the way…

Strong equatorial cell in deep Pacific

GMOC (Sv)

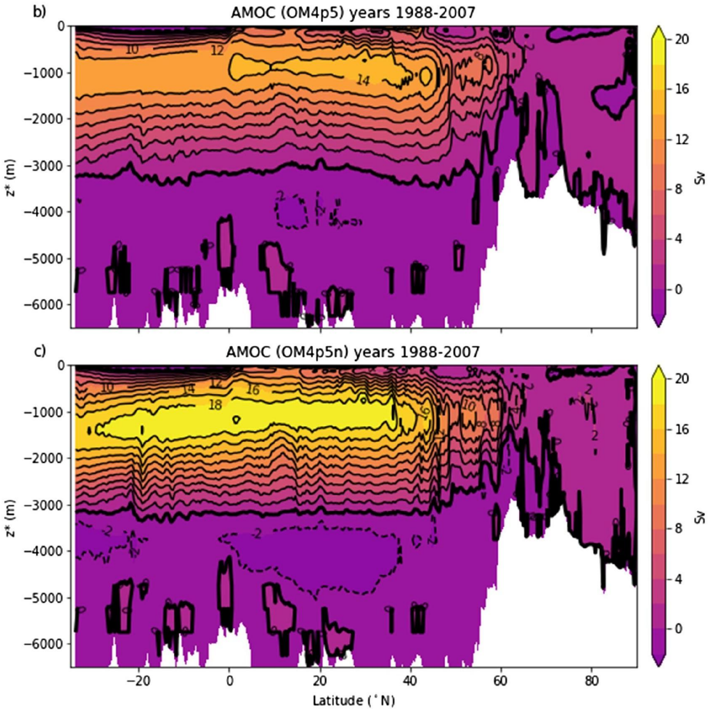



Pacific-Indian ocean transport (Sv)

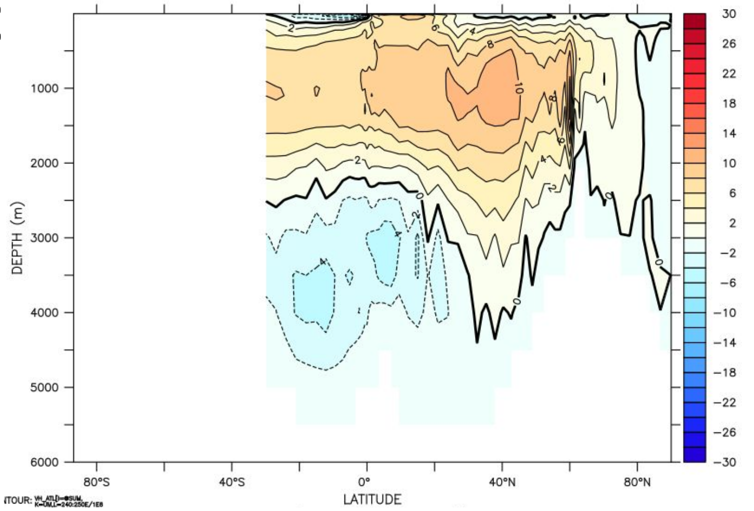


# GM consistently weakens AMOC

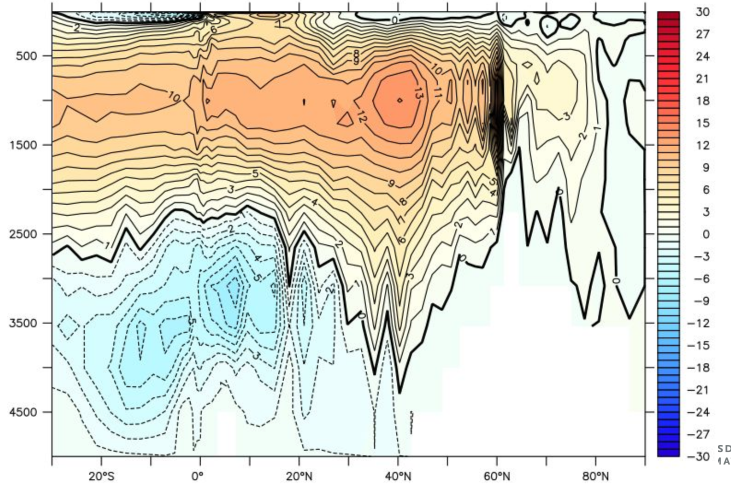
GM on vs. off (0.5 degree)




Adcroft *et al. 2019*



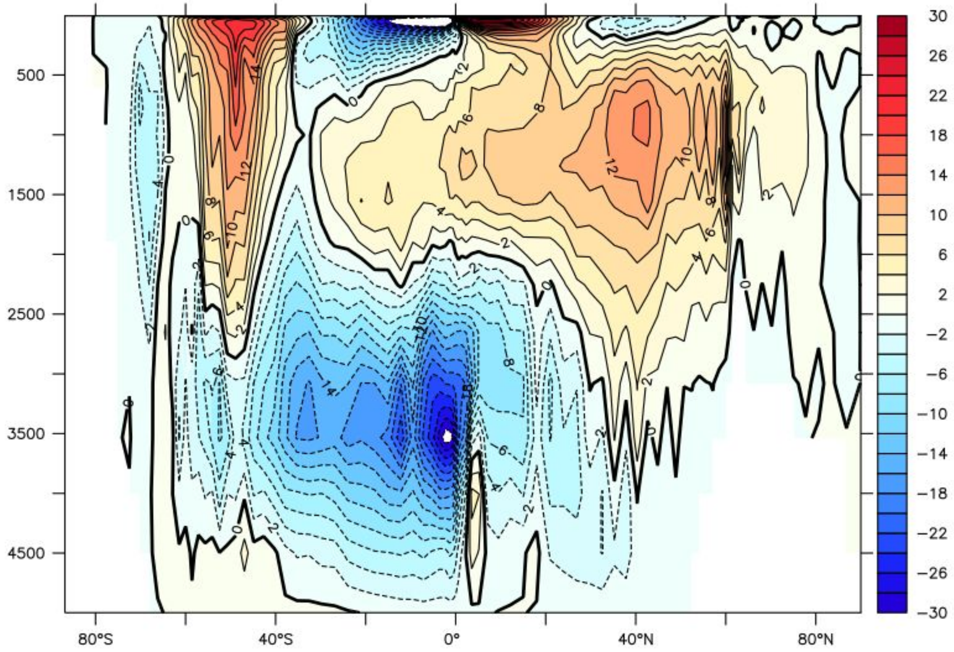

KHTH_SLOPE_CFF = 0.25



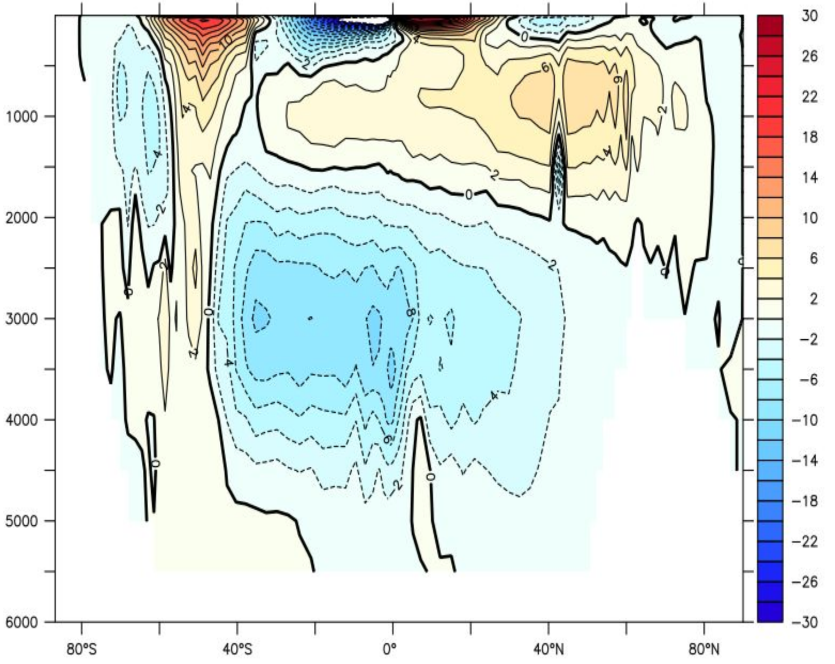
KHTH_SLOPE_CFF = 0.01

# GM consistently weakens AMOC

KHTH (variable) - min. 50 m/s2




KHTH = 1000

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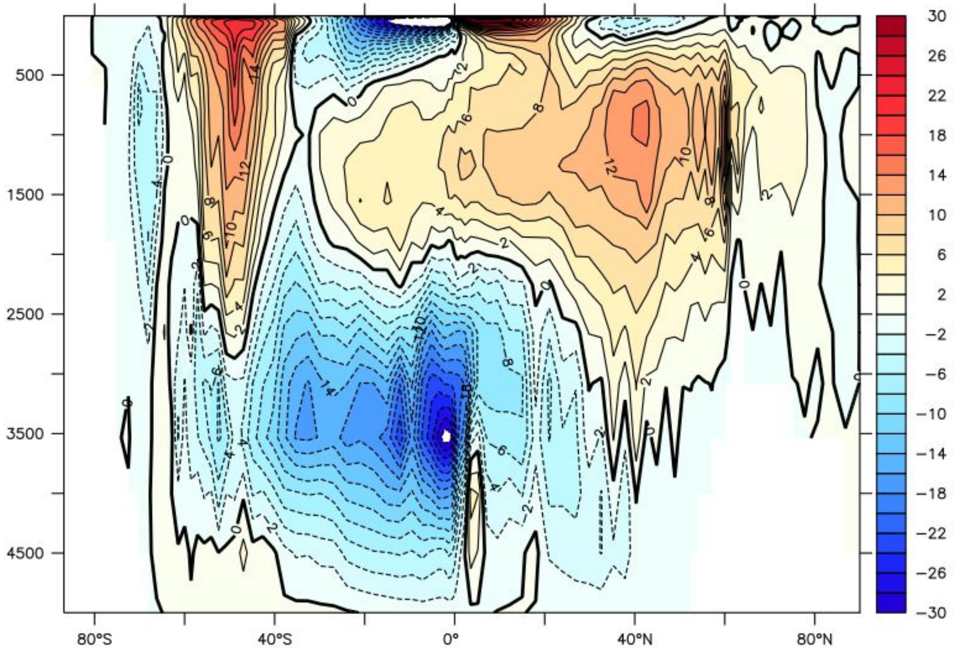


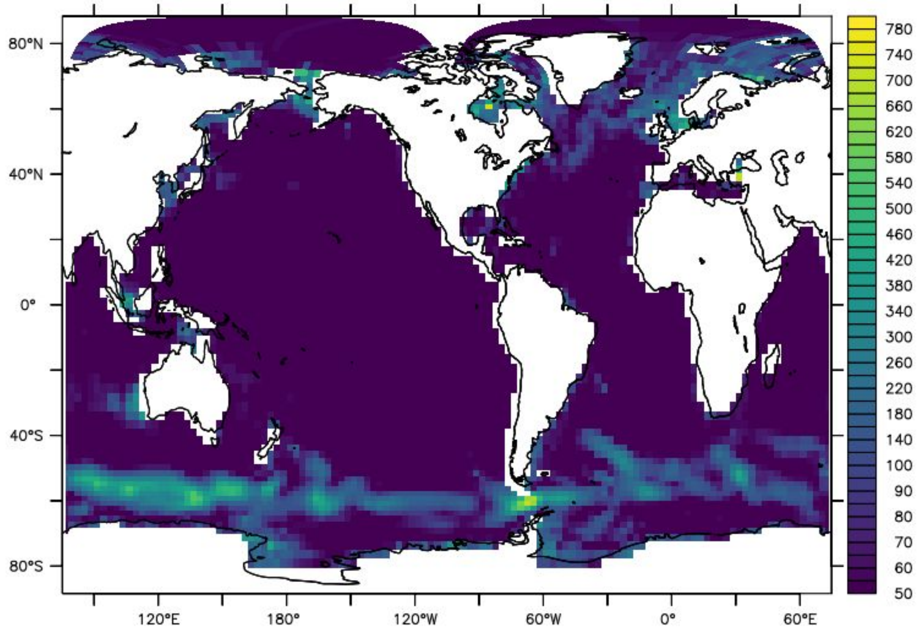

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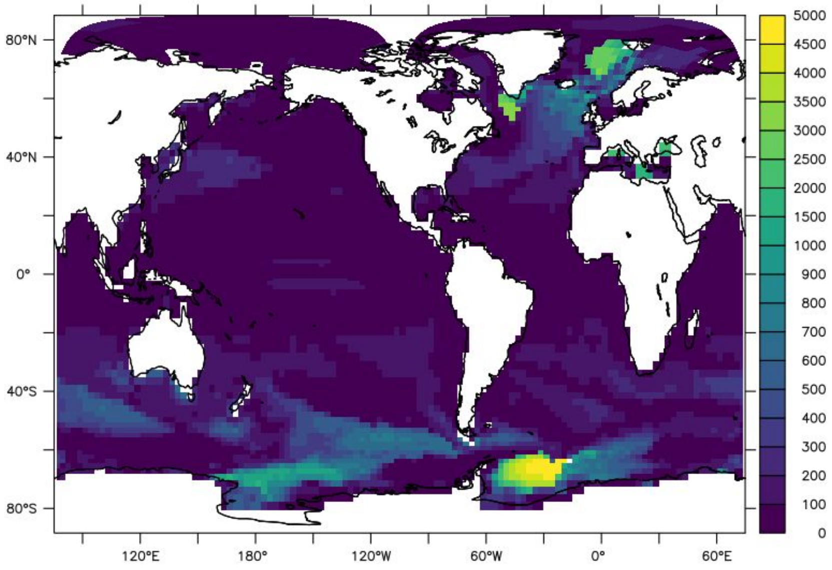


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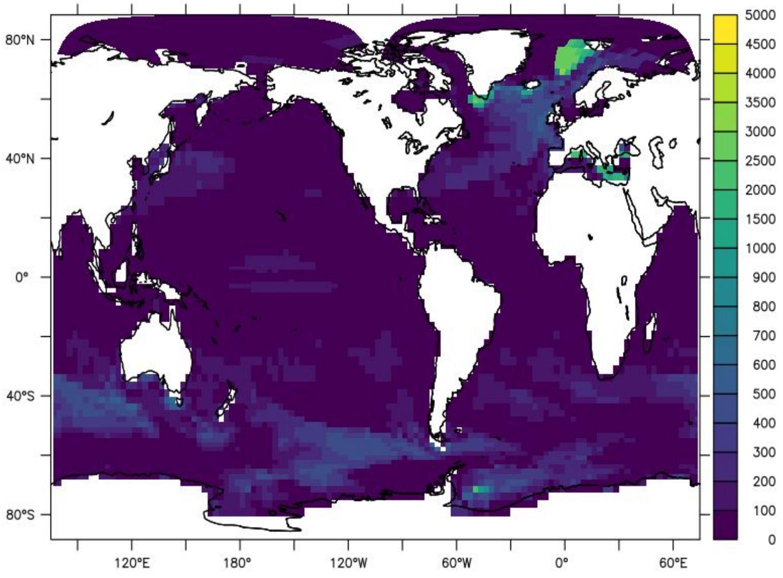
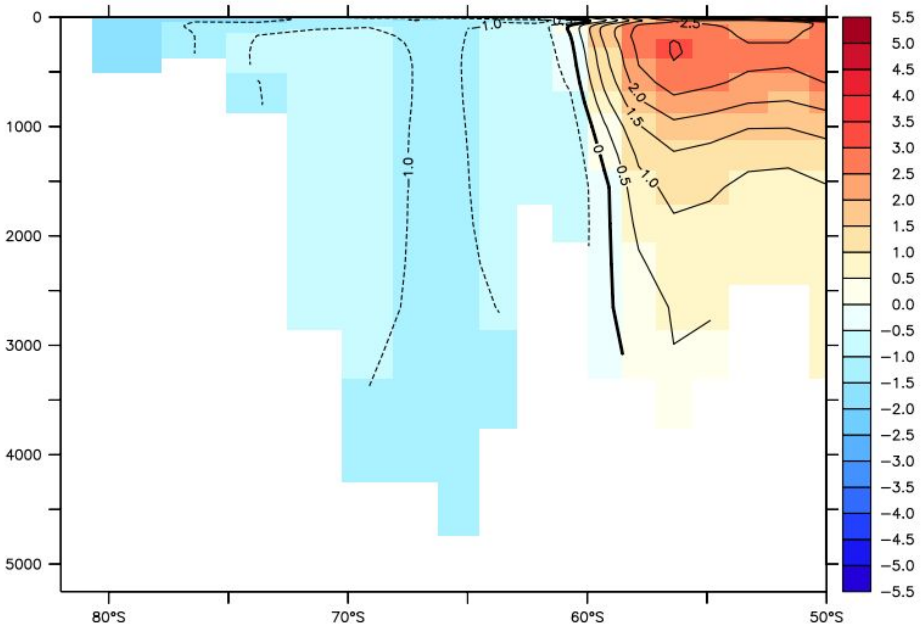
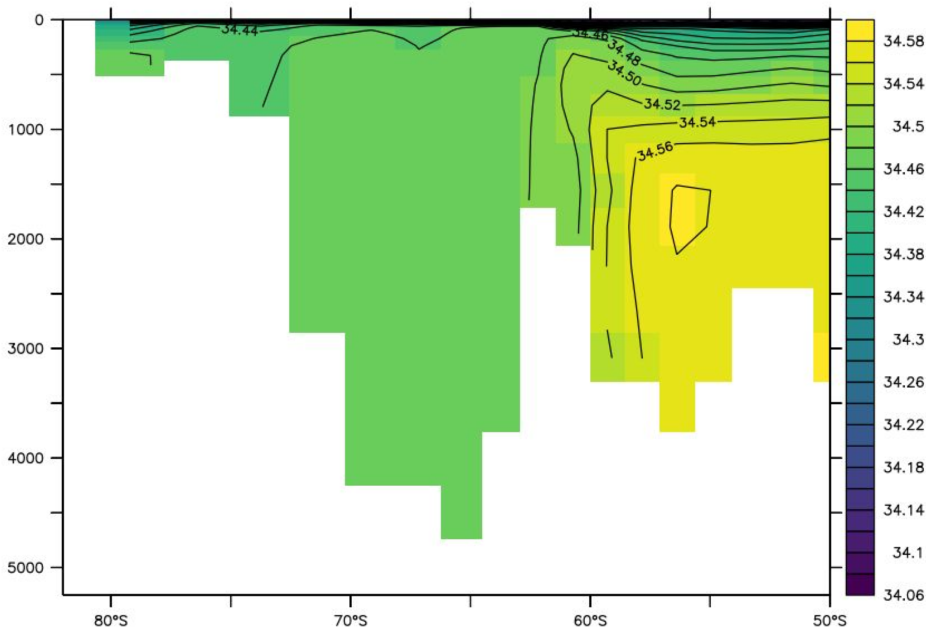


# Weddell Sea convection with low GM

Temp at 42W °C




Salt at 42W psu

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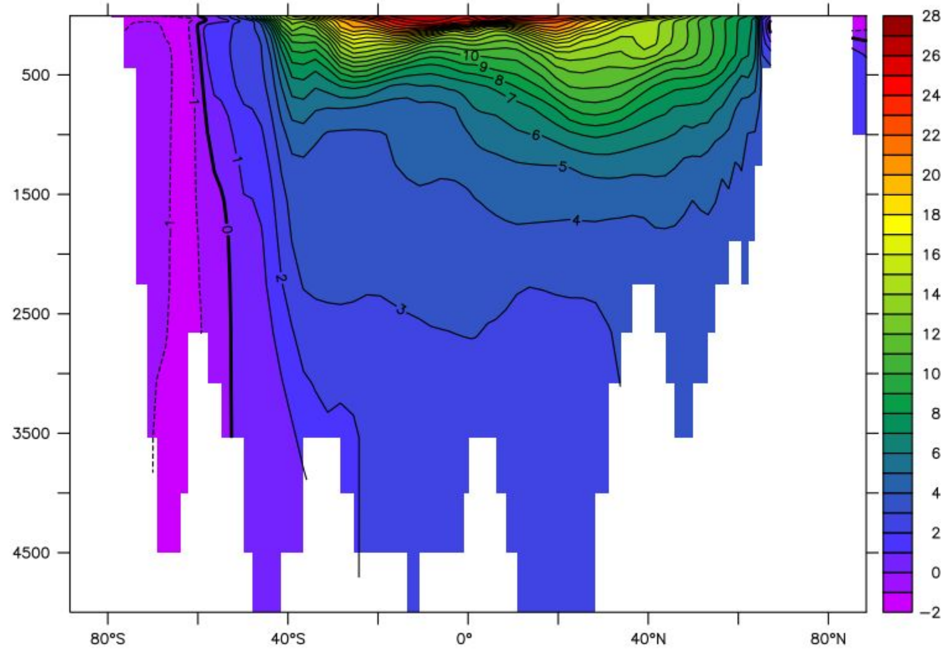
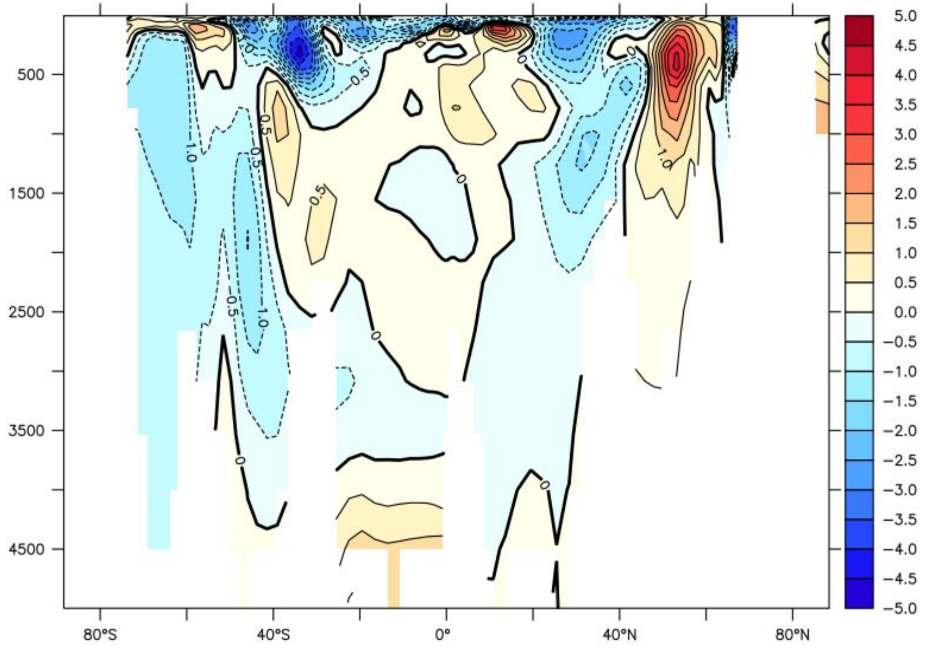
# Temp. and Salinity

Temperature (34W) °C

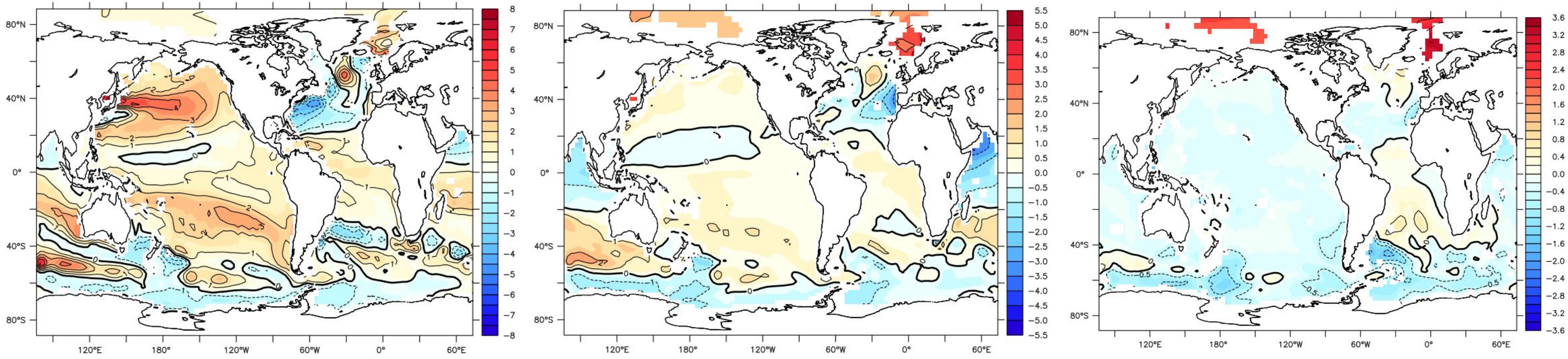



Temperature (34W) wrt. WOA18



# Temp. and Salinity

Temperature $^{o}$C wrt. WOA18




500m

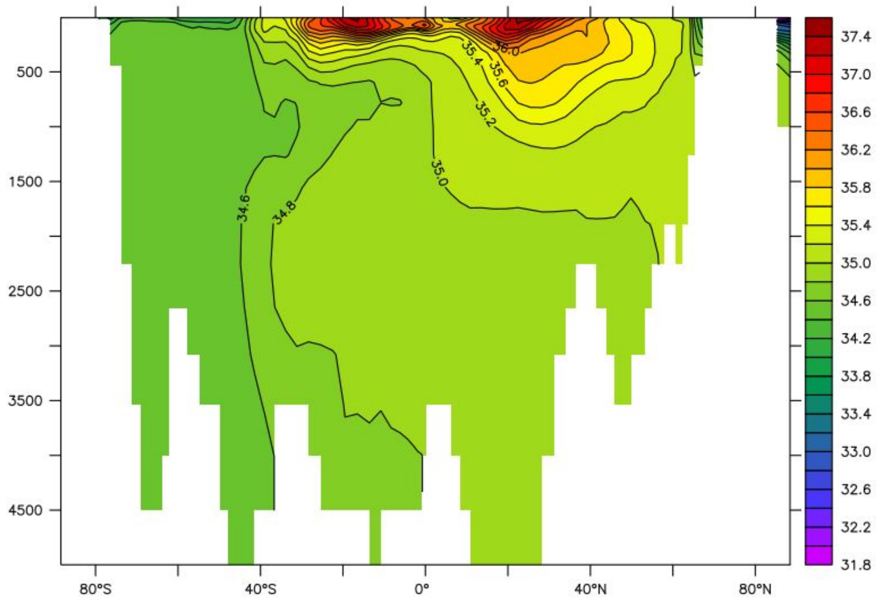
1000m

2000m

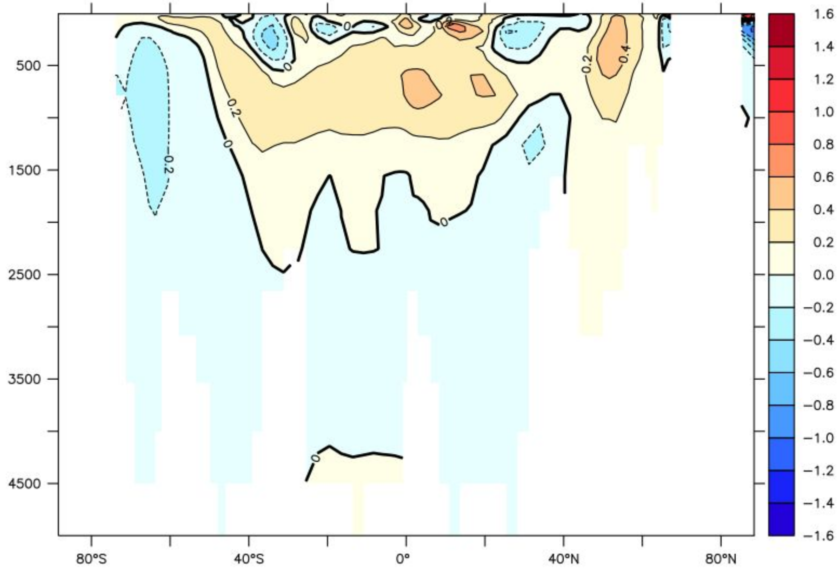
- Southern ocean, cooler than obs. (for the most part) along with the entire ocean below ~2500m
- Exception is the Arctic, which is consistently far too warm
- Unable to fix this via either tuning or SST restoring

# Temp. and Salinity

Salinity (34W) psu




Salinity (34W) wrt. WOA18

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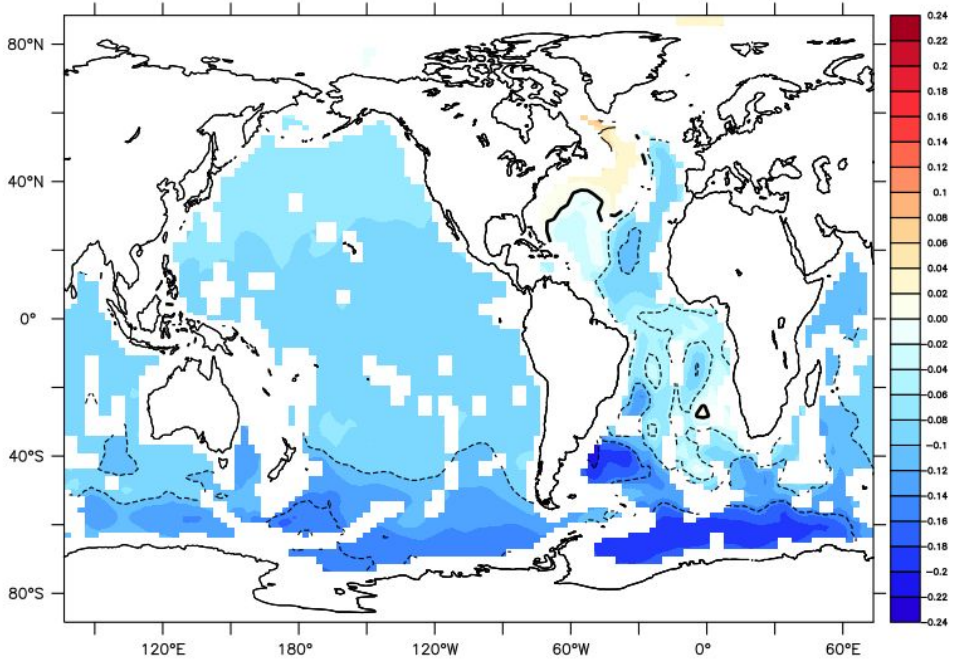
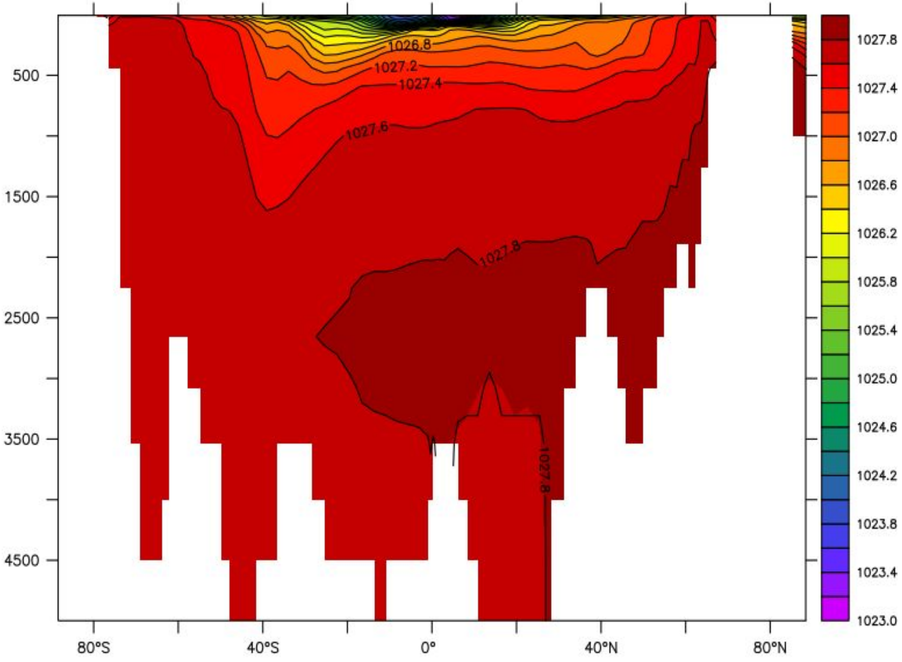
# Temp. and Salinity

Salinity (psu) at 3000m wrt. WOA18

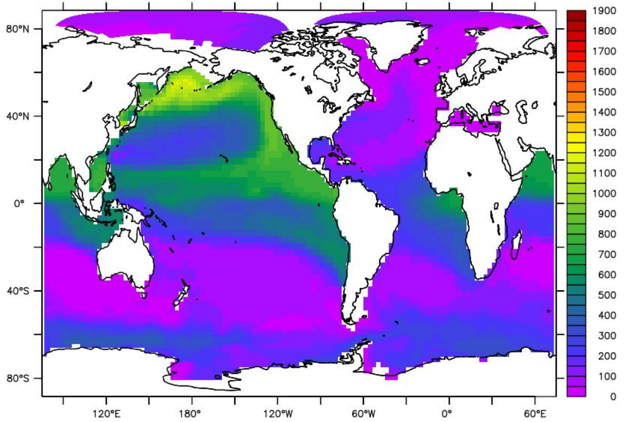



Potential density (34W) (kg/m3)

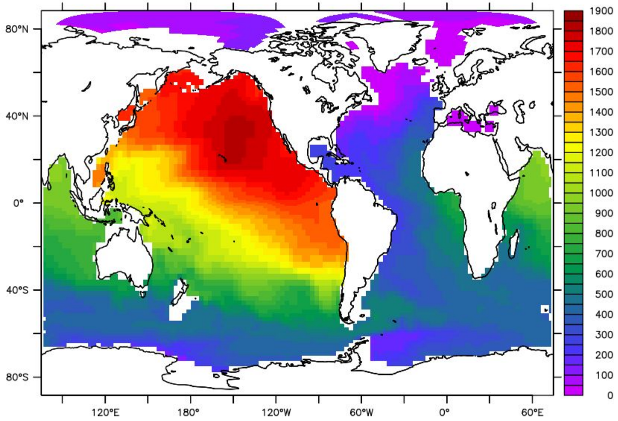


# What does it look like? (cont.) - Water mass age

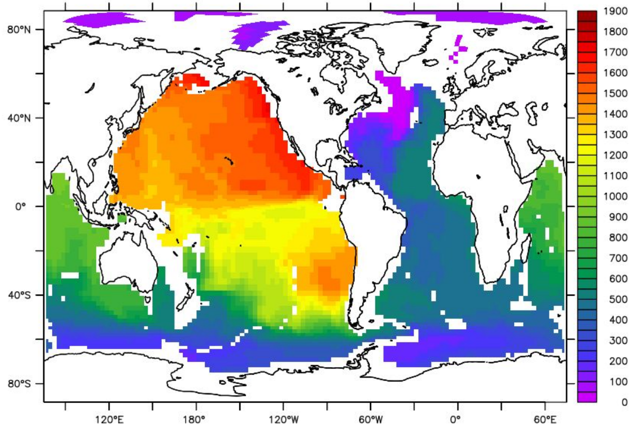
500m



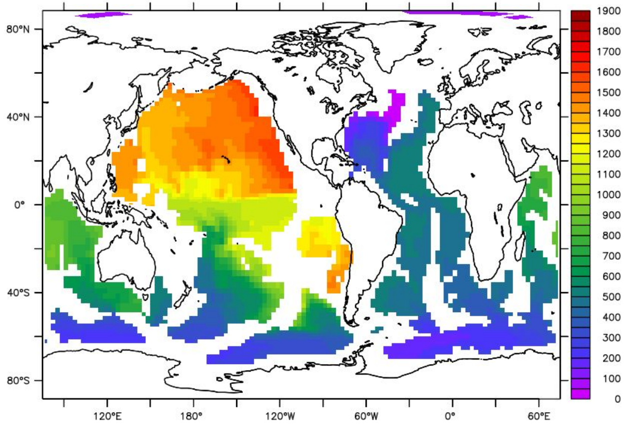

1500m




3000m




4000m



# Summary

- MOM6 is slower than MOM5 (physics + time-stepping limitations)
- MOM6 struggles to simulate large scale overturning correctly. Using ‘reasonable’ values for parameters, AMOC is far too weak and AABW is consistently too strong.
- It appears that thickness diffusion is primarily responsible.
- Producing a reasonable AMOC comes with a host of compromises and biases.
- Different approach needed? (is 3 degrees simply too coarse? Varying resolution more trouble than it’s worth?)

# Summary

- MOM6 is slower than MOM5 (physics + time-stepping limitations)
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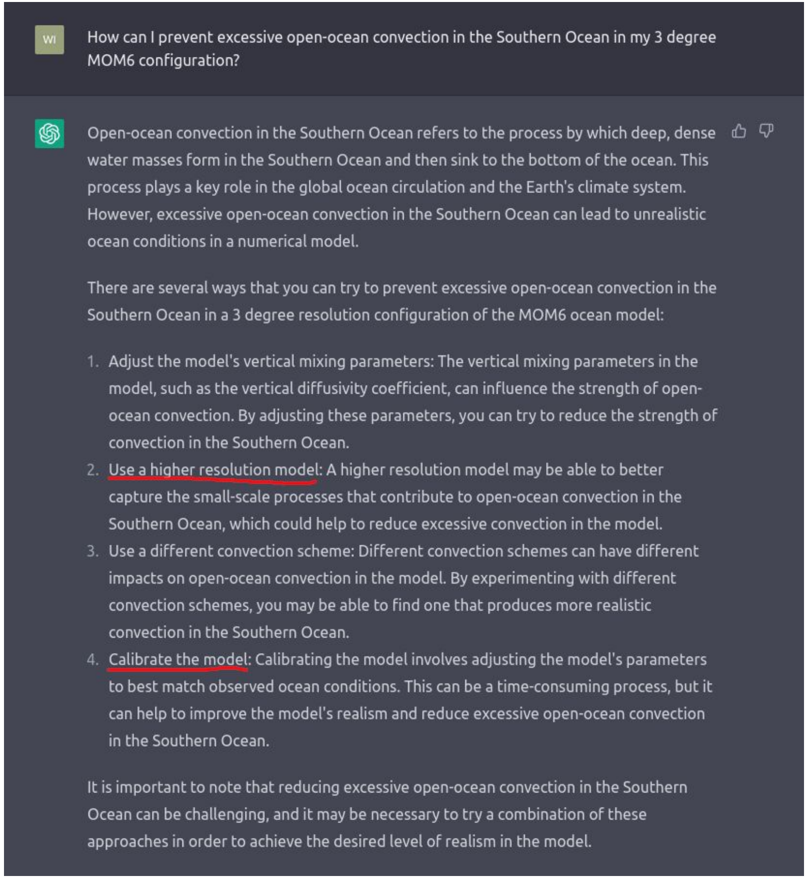
- It appears that thickness diffusion is primarily responsible.
- Producing a reasonable AMOC comes with a host of compromises and biases.
- Different approach needed? (is 3 degrees simply too coarse? Varying resolution more trouble than it’s worth?)
- AI (ChatGPT) won’t save us.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How can I prevent excessive open-ocean convection in the Southern Ocean in my 3 degree MOM6 configuration?

Open-ocean convection in the Southern Ocean refers to the process by which deep, dense water masses form in the Southern Ocean and then sink to the bottom of the ocean. This process plays a key role in the global ocean circulation and the Earth's climate system. However, excessive open-ocean convection in the Southern Ocean can lead to unrealistic ocean conditions in a numerical model.

There are several ways that you can try to prevent excessive open-ocean convection in the Southern Ocean in a 3 degree resolution configuration of the MOM6 ocean model:

1. Adjust the model's vertical mixing parameters: The vertical mixing parameters in the model, such as the vertical diffusivity coefficient, can influence the strength of open-ocean convection. By adjusting these parameters, you can try to reduce the strength of convection in the Southern Ocean.
2. Use a higher resolution model: A higher resolution model may be able to better capture the small-scale processes that contribute to open-ocean convection in the Southern Ocean, which could help to reduce excessive convection in the model.
3. Use a different convection scheme: Different convection schemes can have different impacts on open-ocean convection in the model. By experimenting with different convection schemes, you may be able to find one that produces more realistic convection in the Southern Ocean.
4. Calibrate the model: Calibrating the model involves adjusting the model's parameters to best match observed ocean conditions. This can be a time-consuming process, but it can help to improve the model's realism and reduce excessive open-ocean convection in the Southern Ocean.

It is important to note that reducing excessive open-ocean convection in the Southern Ocean can be challenging, and it may be necessary to try a combination of these approaches in order to achieve the desired level of realism in the model.

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With thanks to the MOM6 dev. team, Michael Eby, Andy Hogg, Sarah Ragen (and others).

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http://www.pik-potsdam.de/~huiskamp/MOM6c/

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