Computational Modeling Challenges at the Ocean's (Southern) High Latitudes

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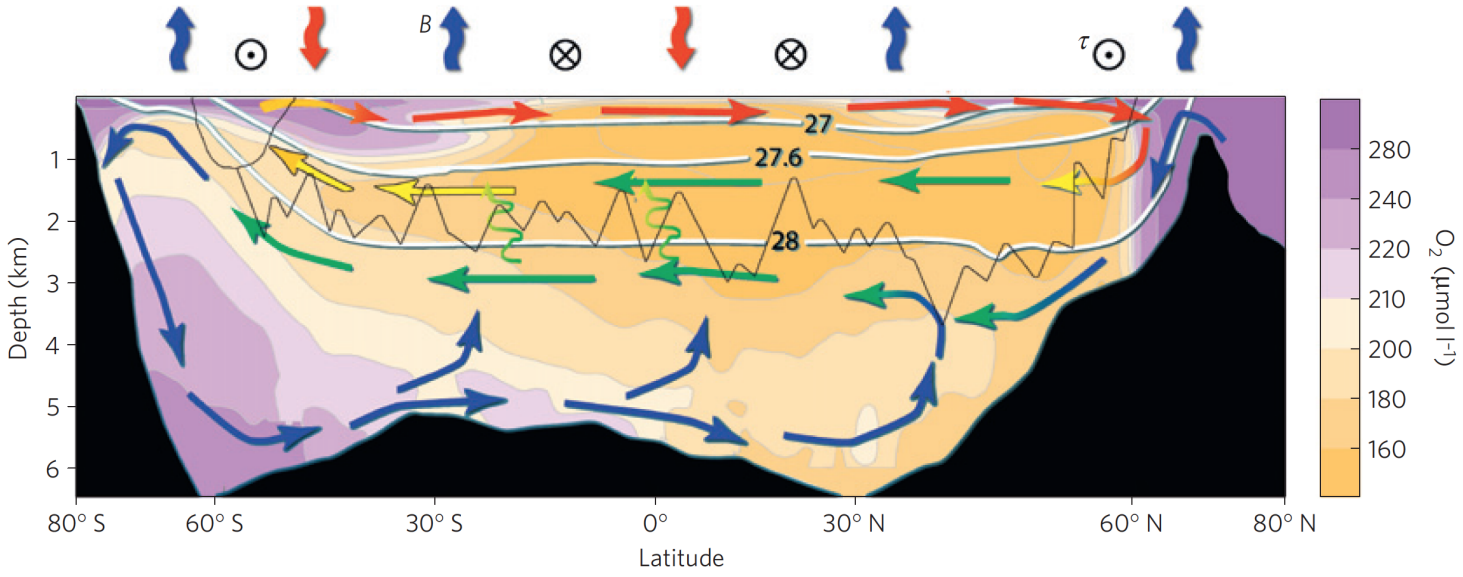
Connection to the global overturning circulation



[Marshall and Speer, 2012]

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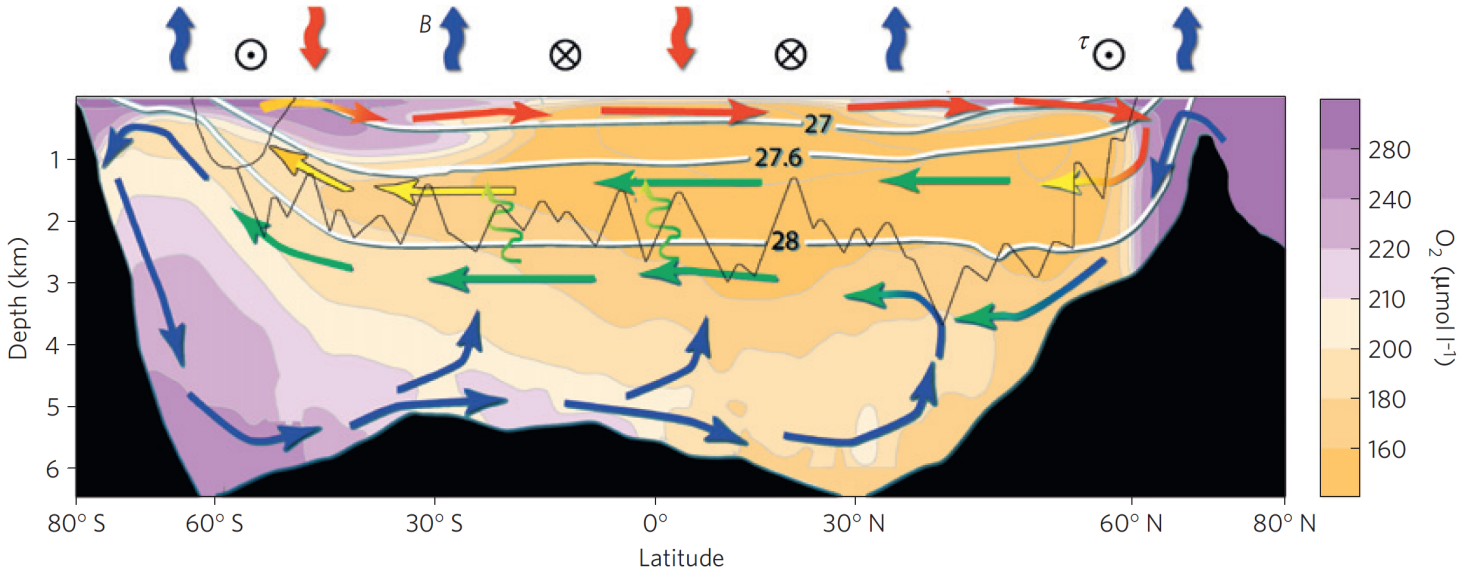

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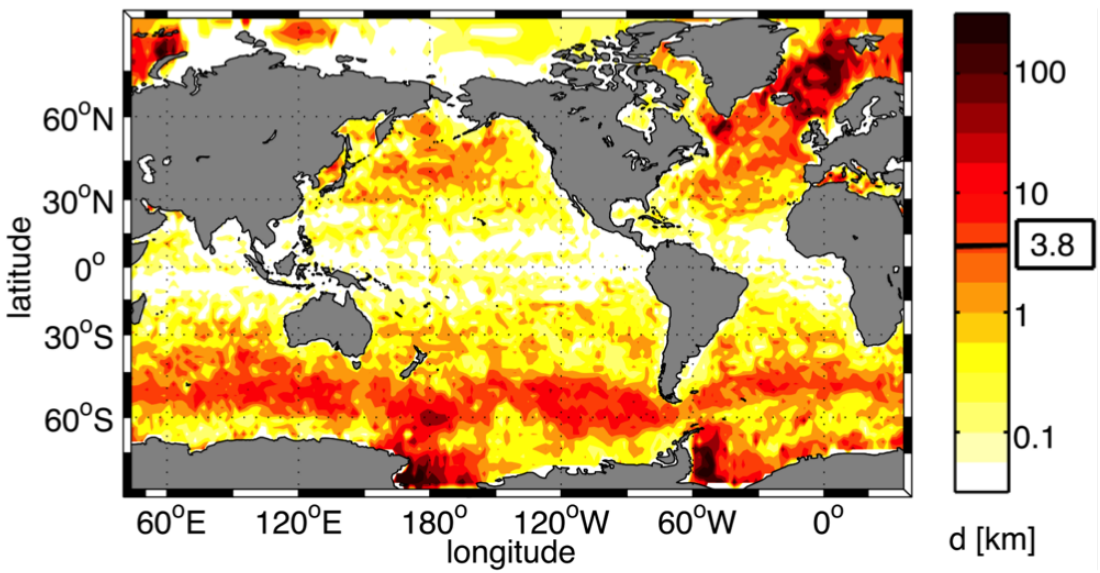
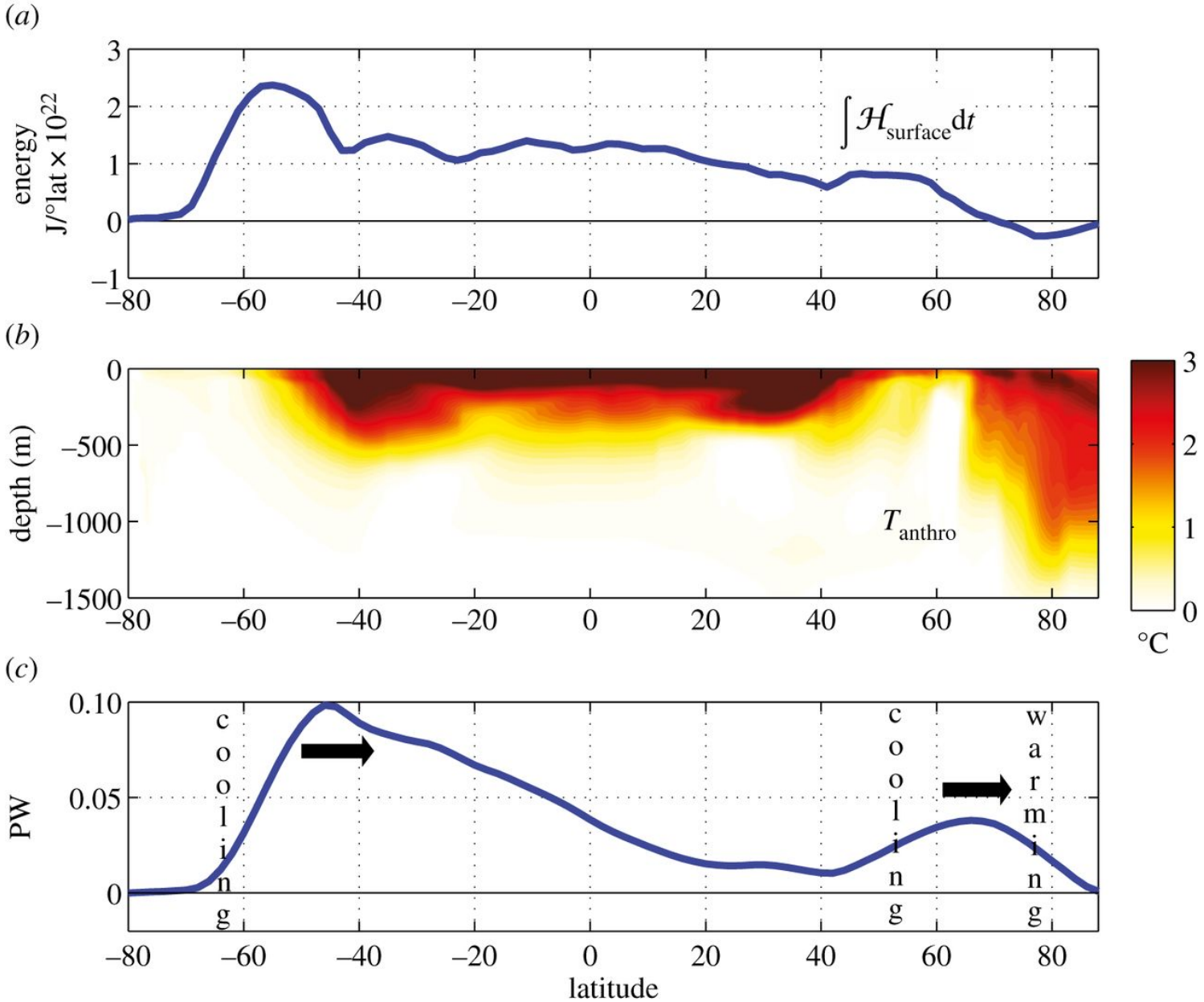


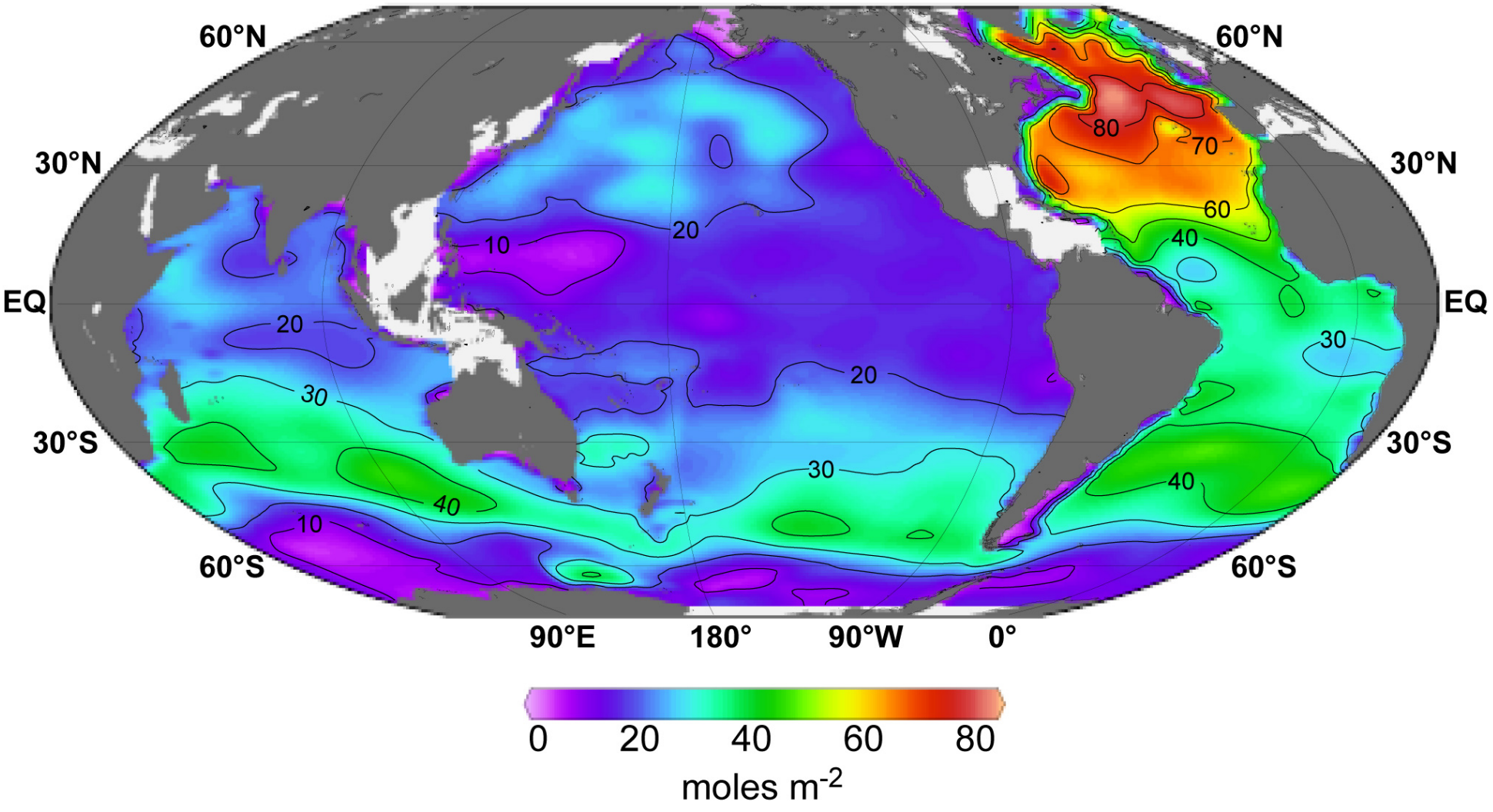
[Gebbie and Huybers, 2011]

Heat uptake



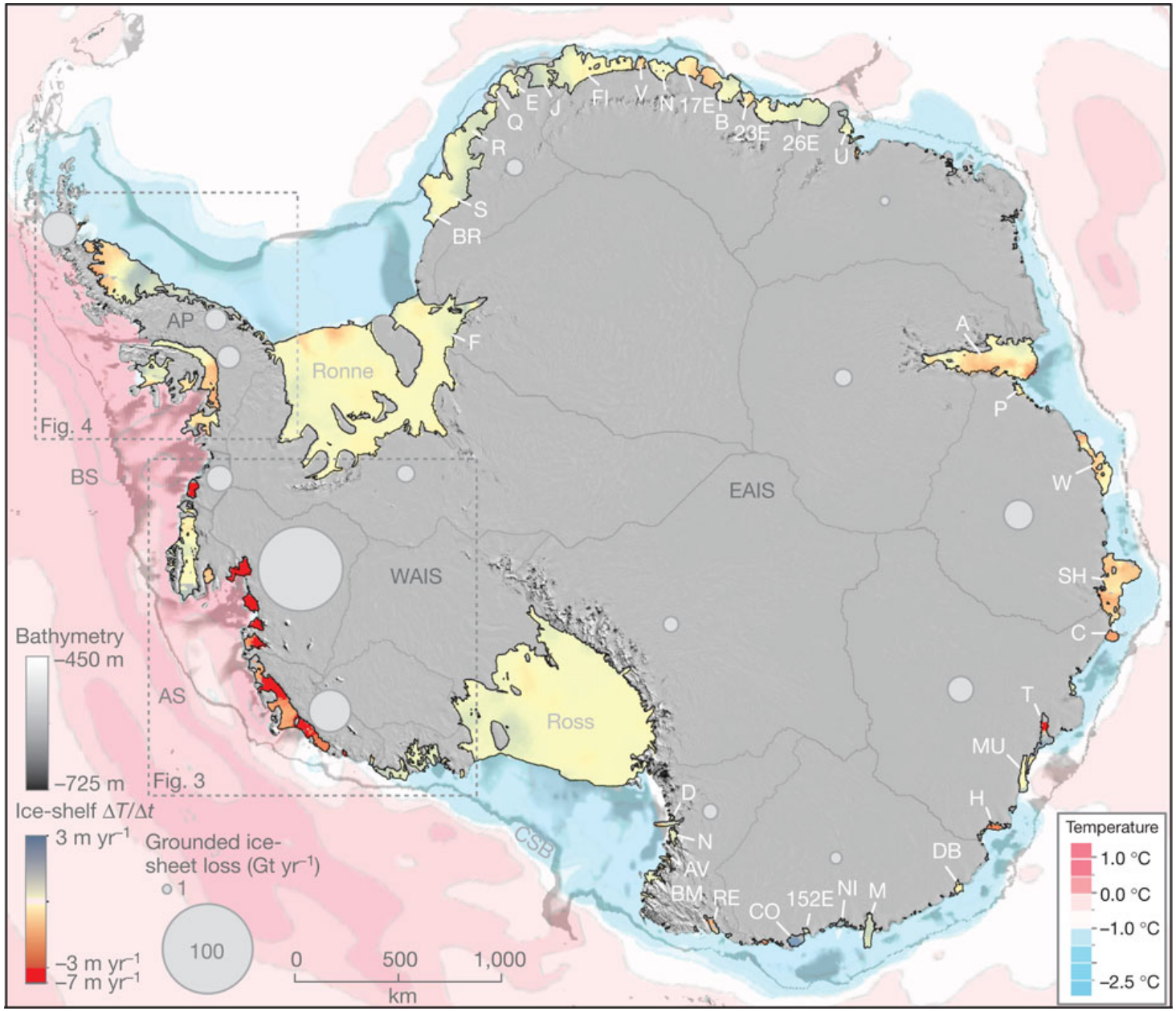
[Marshall et al., Phil. Trans. Roy. Soc. A 2014]

Carbon uptake



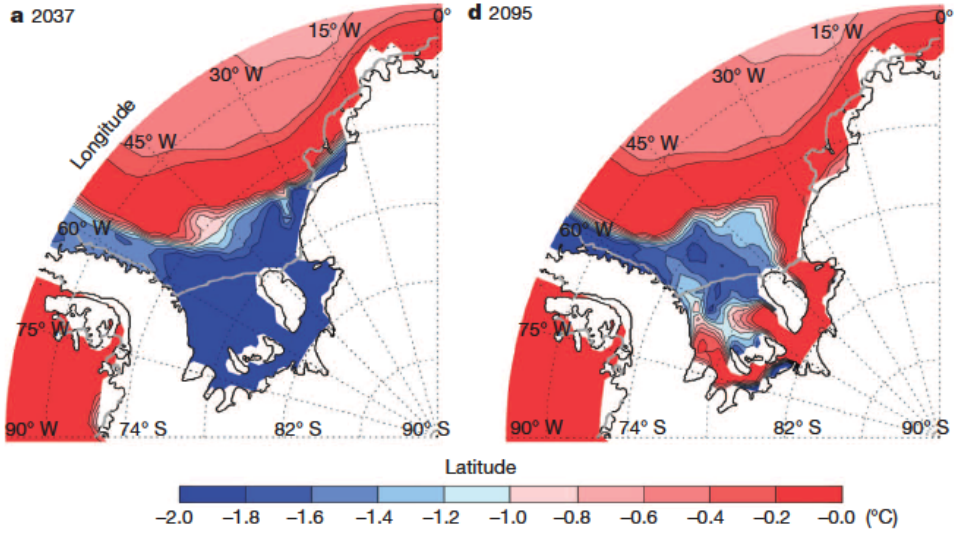
Water column anthropogenic carbon inventory in 1994 from Sabine et al. [2004]

Ice sheet retreat and sea level rise



[Pritchard et al., Nature 2012]

Even “cold” ice shelves may be vulnerable



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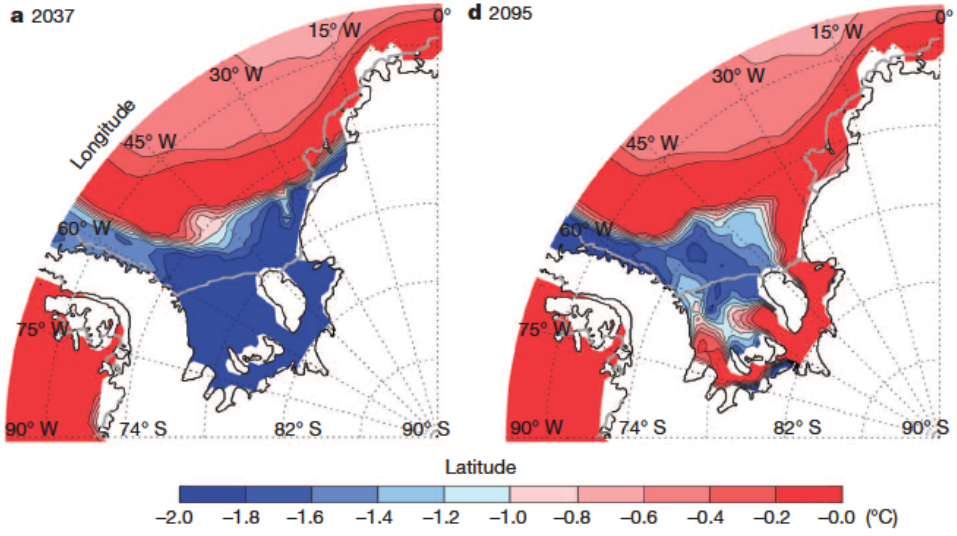

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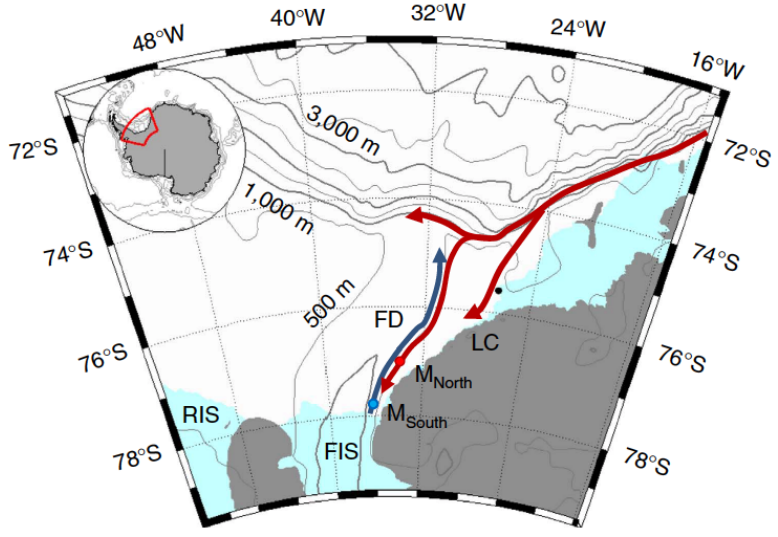
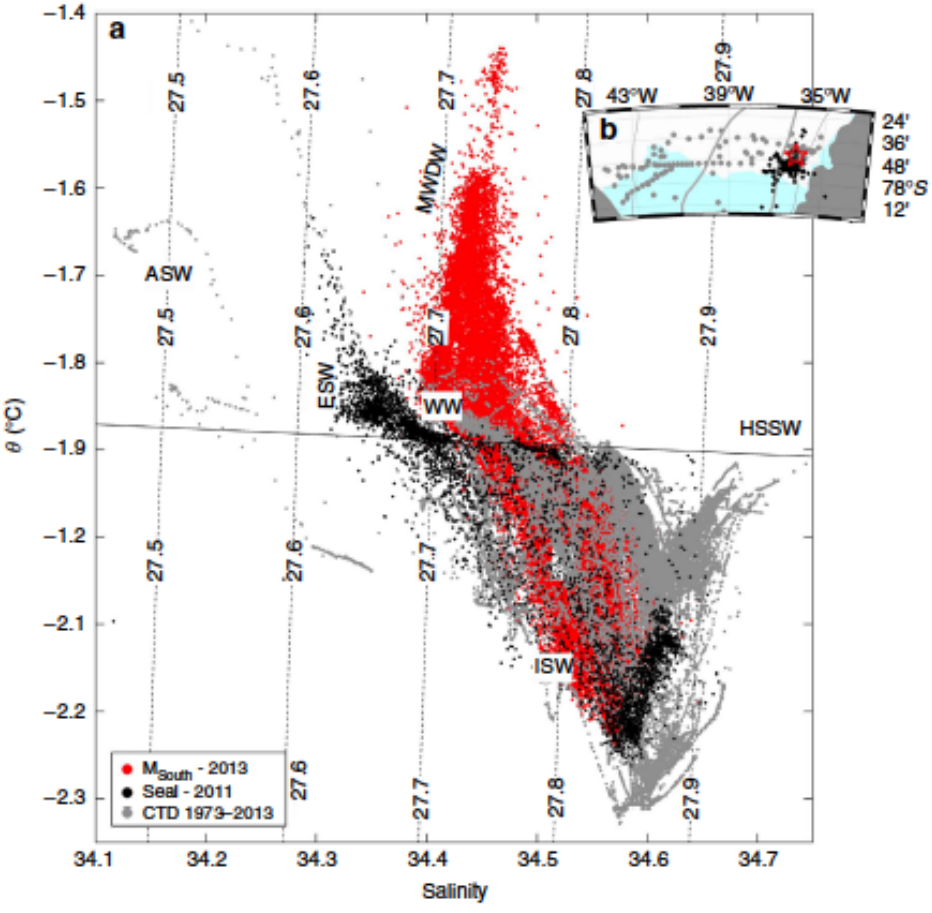
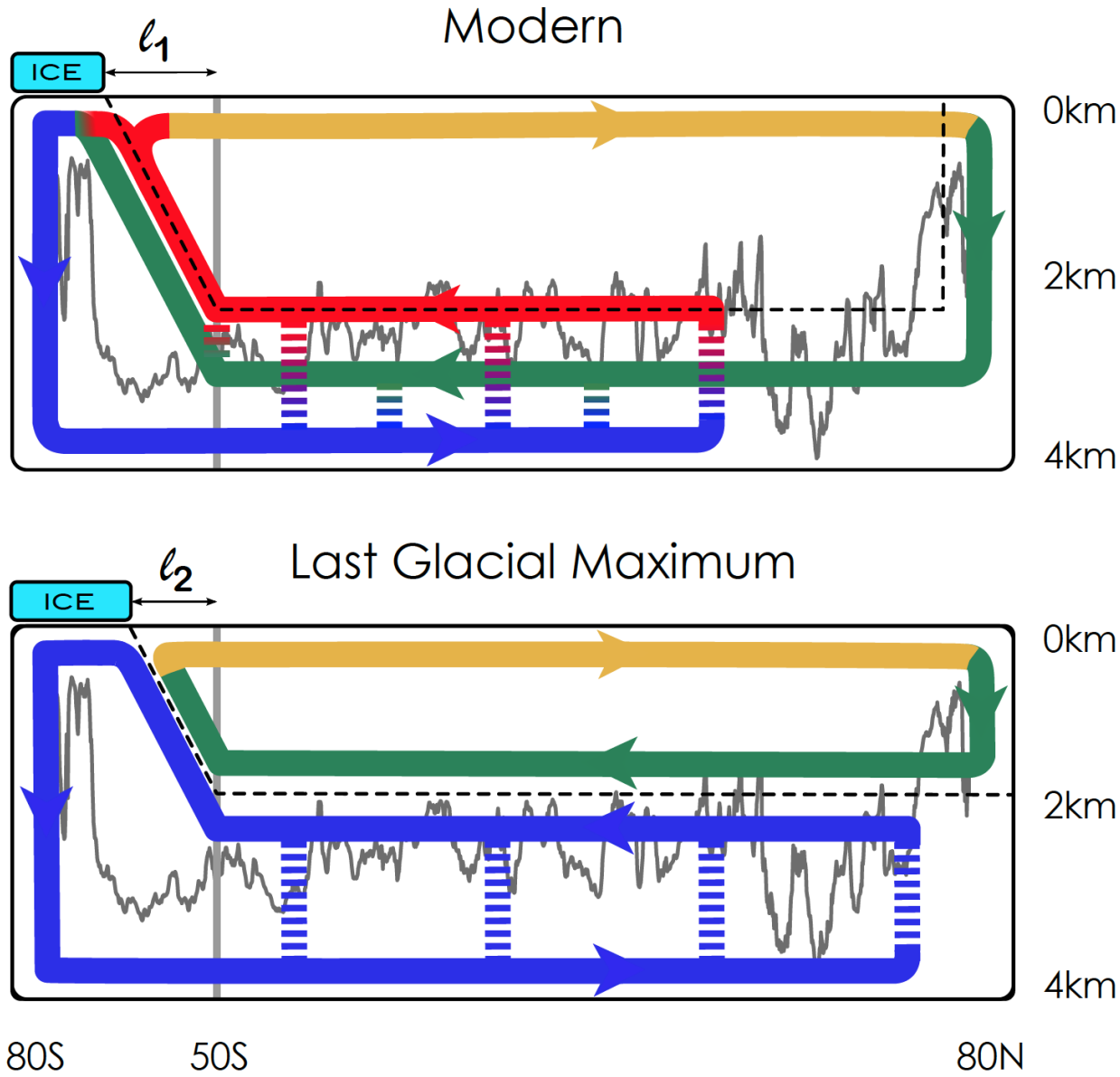




[Darelius et al., Nat. Commun. 2016]

Dense water export and glacial cycles



[Ferrari et al., PNAS 2014]

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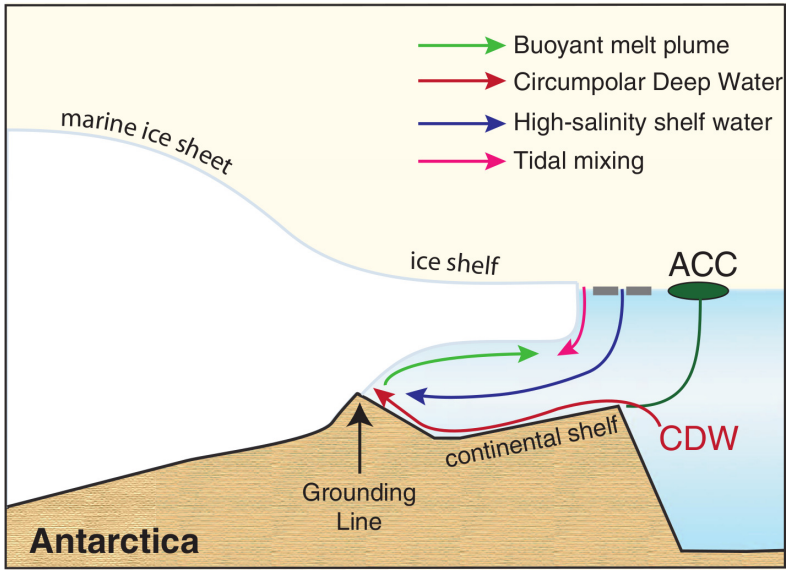
Ocean-ice shelf interaction is critical



[Joughin et al., Science 2012]

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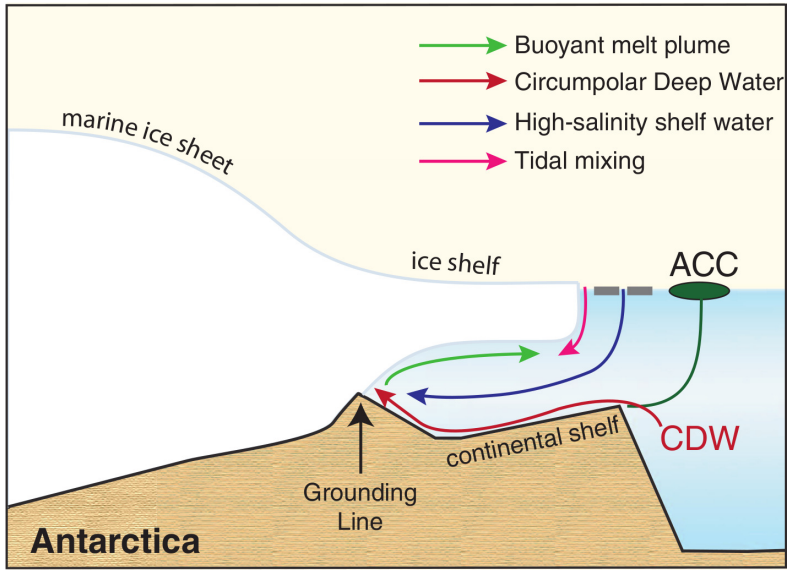

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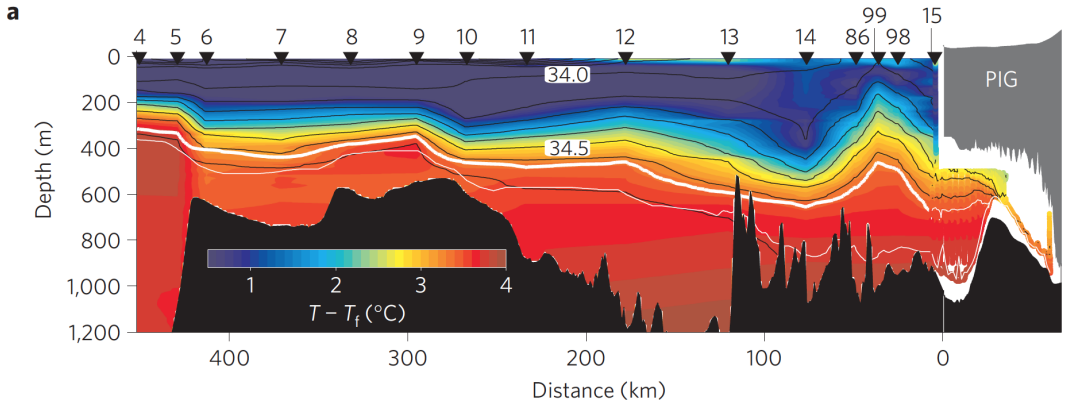

[Jacobs et al., Nature Geosci. 2011]

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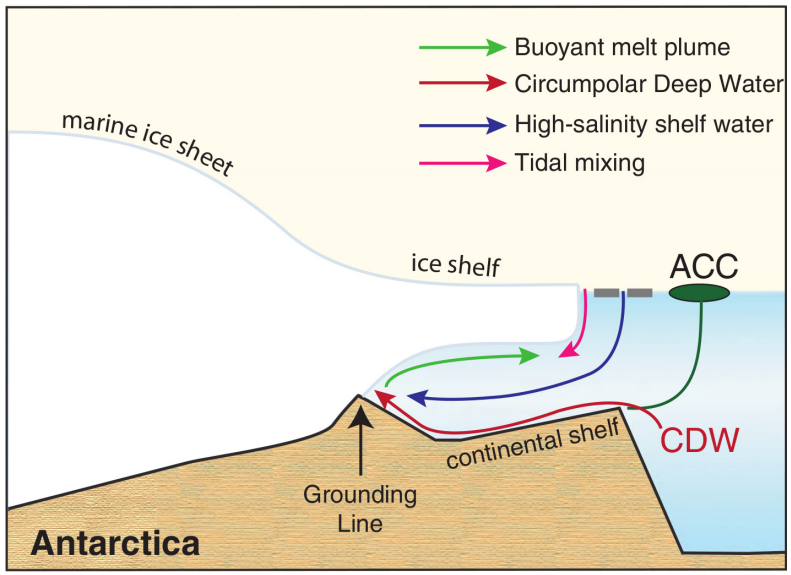

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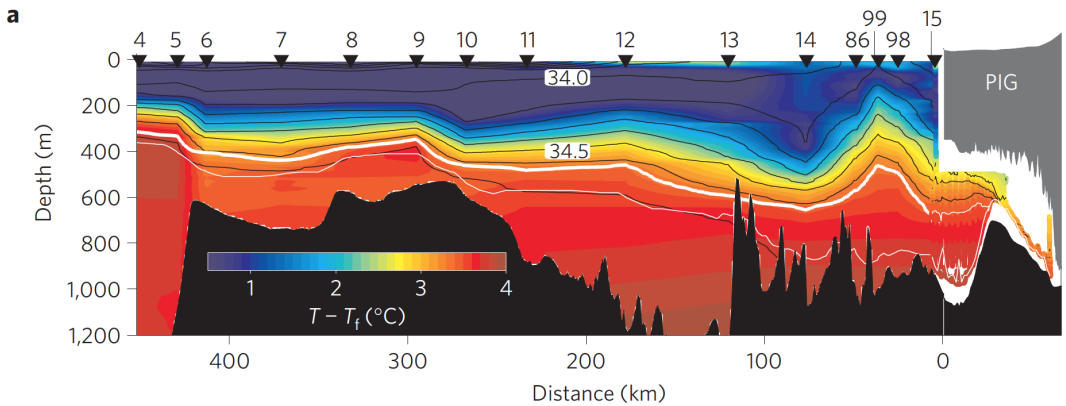

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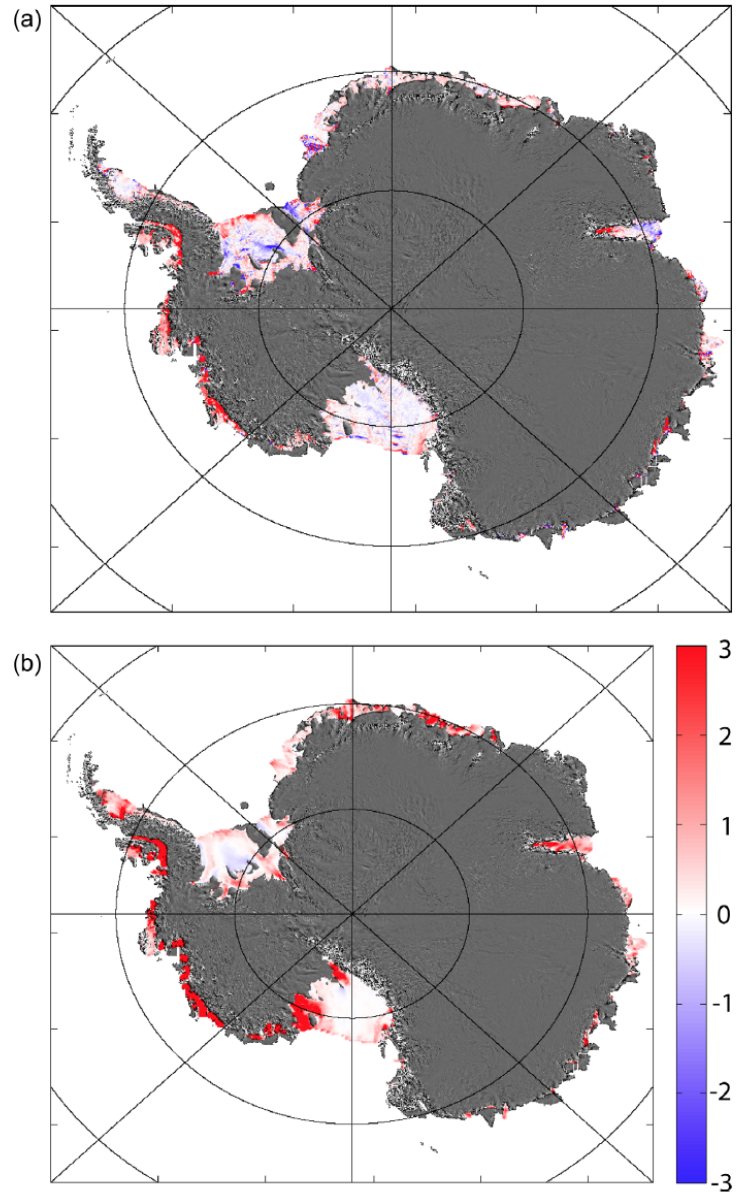

[Schodlok et al., J. Geophys. Res. Oceans 2016]

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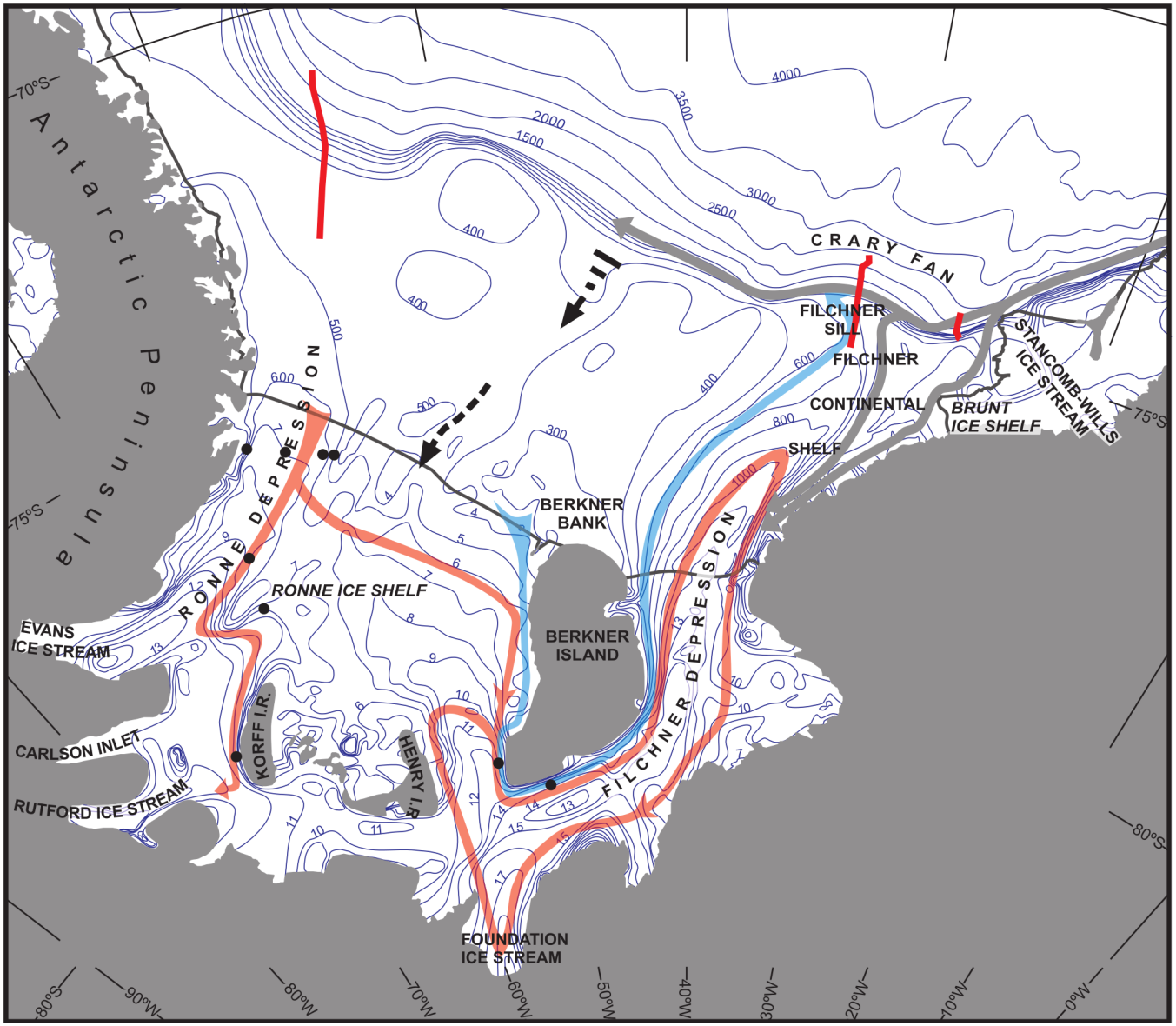
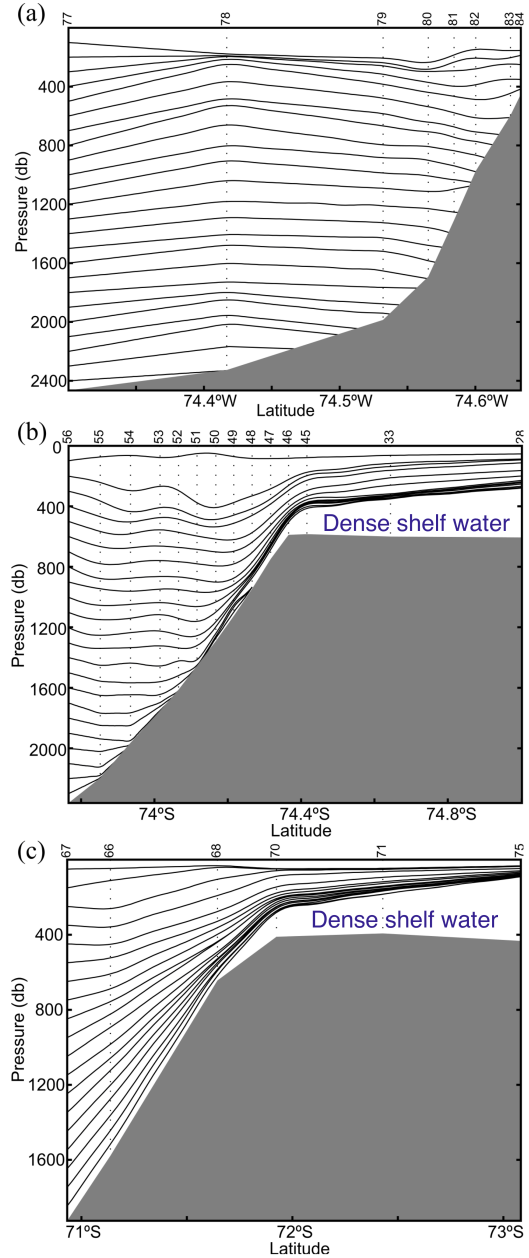
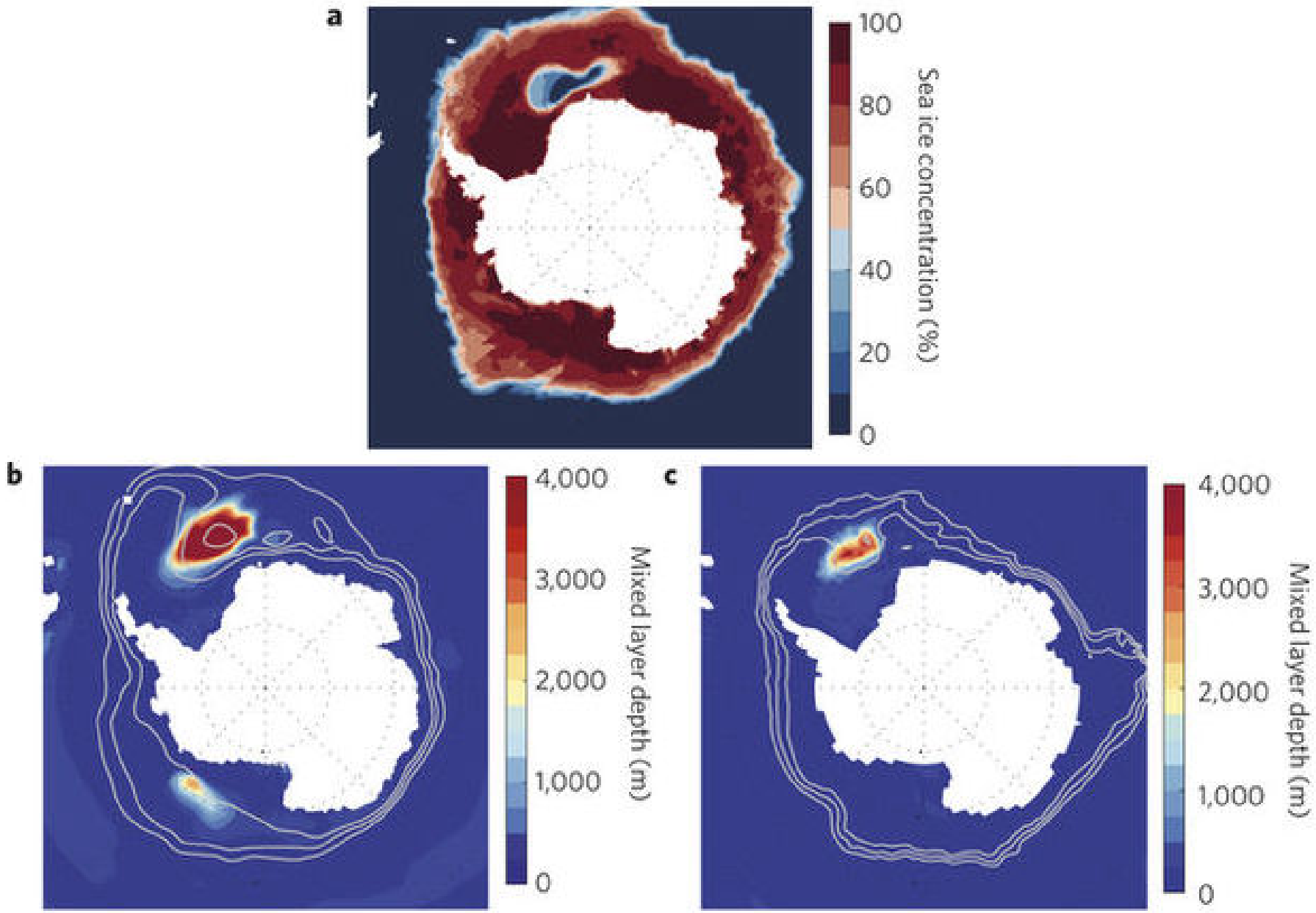




[Nicholls et al., Rev. Geophys. 2009]

Dense water formation in climate models



[de Lavergne et al., Nature Commun. 2014]

Representation of paleo ocean circulation

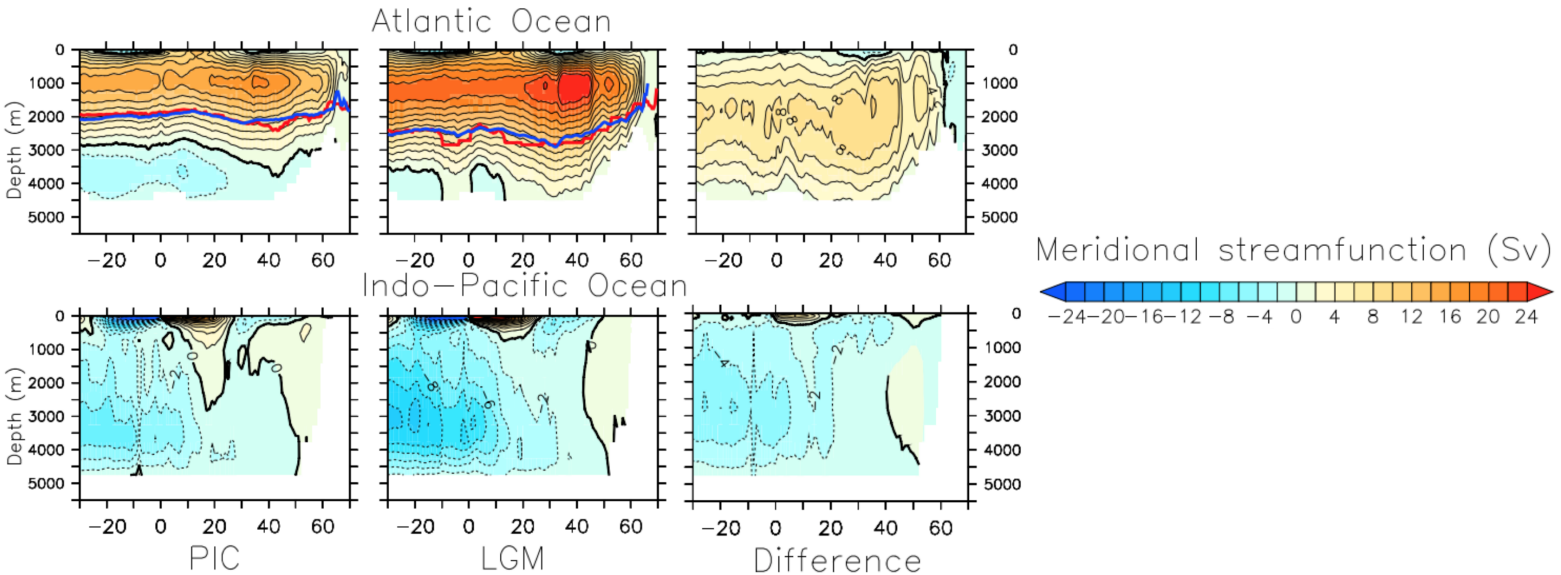


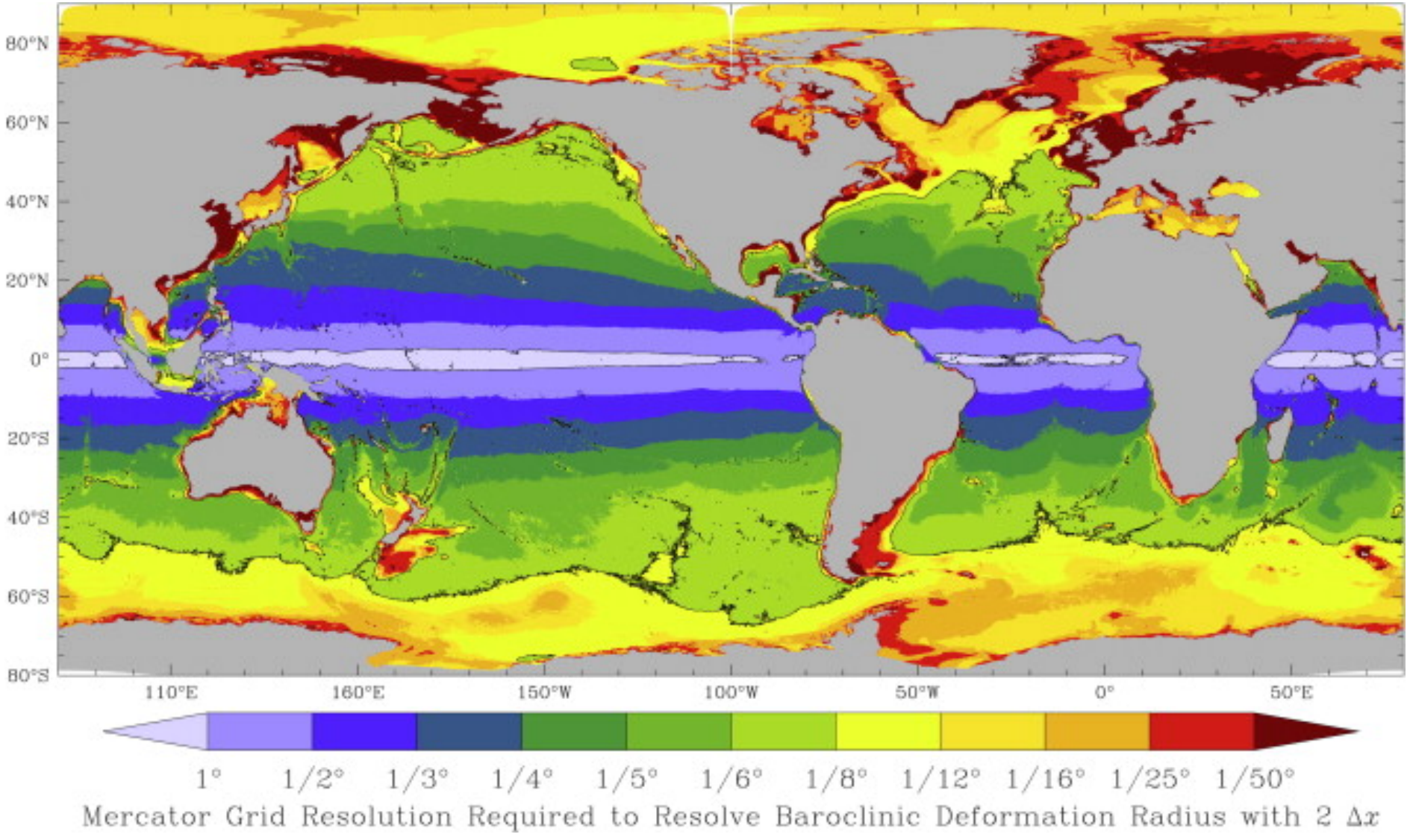
Table 1. Maximum Transport and Depth of the AMOC at 25°N Calculated by PMIP3 Models, in Their PIC and LGM Simulations, and Percentage of Increment Between the Two Periods[a]

Model	PIC (Sv)	LGM (Sv)	Change (%)	PIC Depth (m)	LGM Depth (m)	Change (%)
CCSM4	19.69	21.53	9	2608	2333	−10
GISS	16.92	22.32	32	2055	2273	11
CNRM	13.03	22.74	74	1735	3230	86
MPI	18.19	21.37	17	1963	1993	01
MIROC	13.56	22.07	63	1795	2745	53
MRI	14.82	21.76	47	2193	3363	53
FGOALS	23.02	31.64	37	1965	2940	50
IPSL	12.64	23.04	82	2238	2980	78
Mean	16.48	23.31	41	2069	2732	32

[a]Bottom row is the multimodel mean.

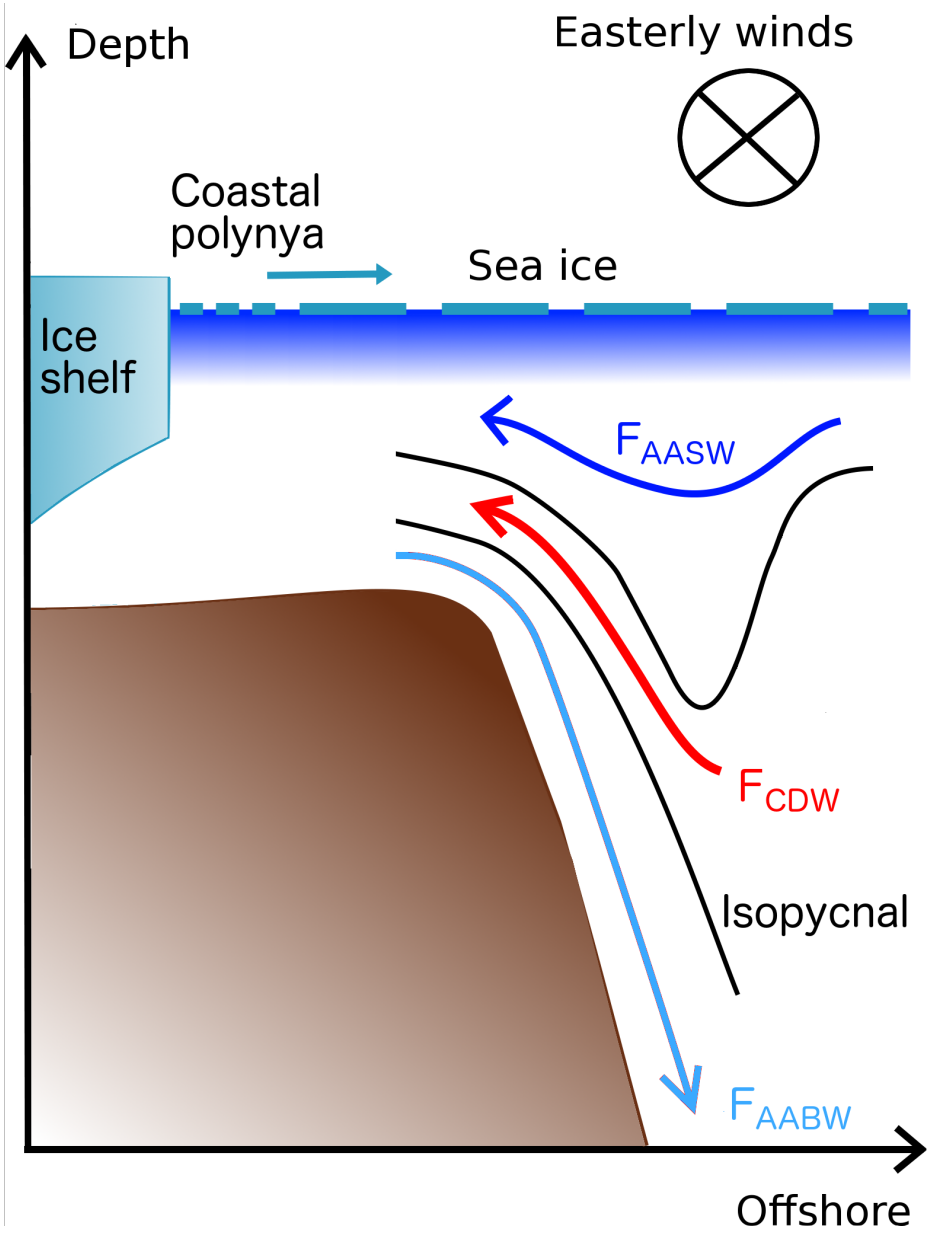
[Muglia and Schmittner, Geophys. Res. Lett. 2015; see Sun et al., Geophys. Res. Lett. 2018]

Ocean model resolution constraints



[Hallberg, Ocean Modell. 2013]

Eddy processes at the Antarctic margins



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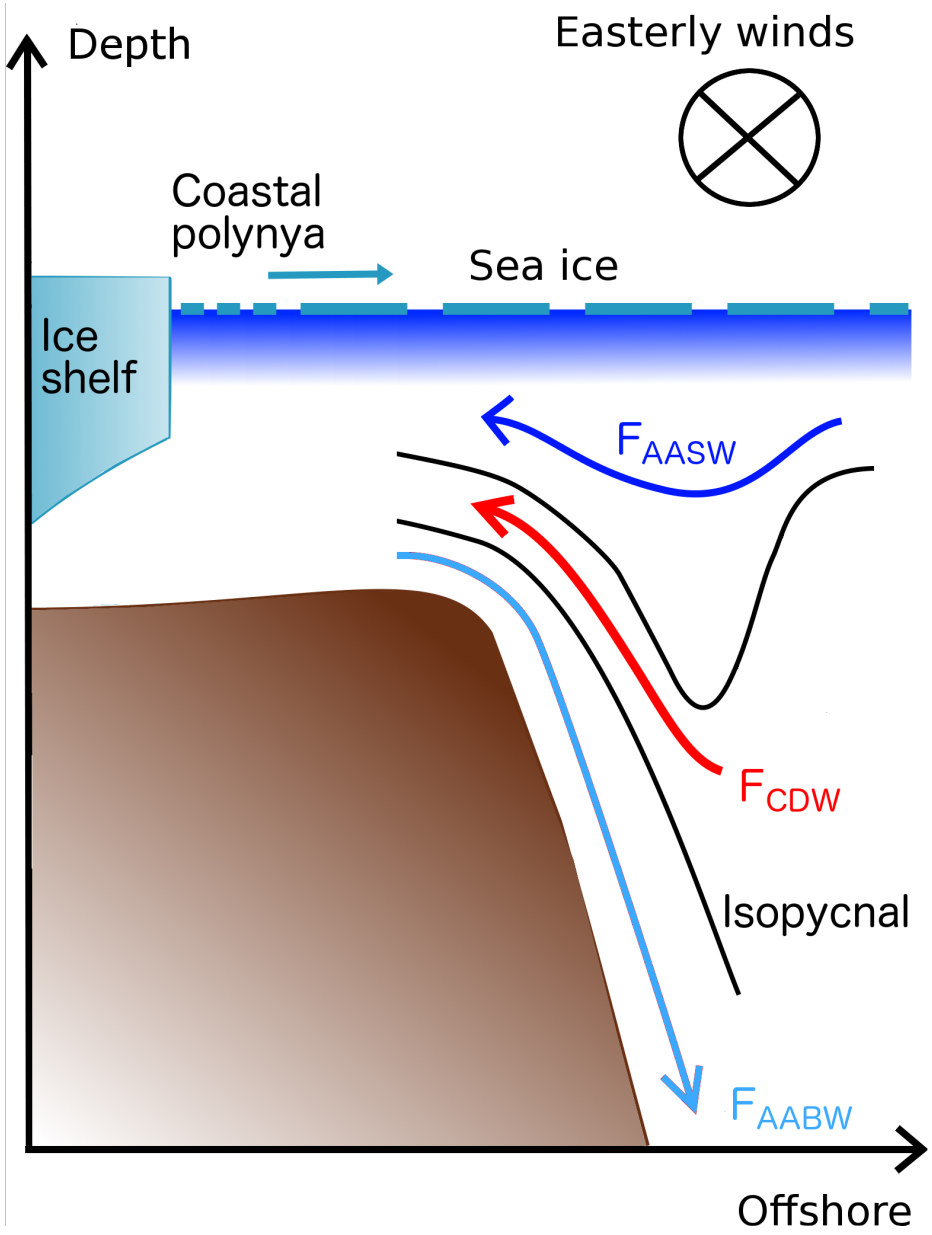

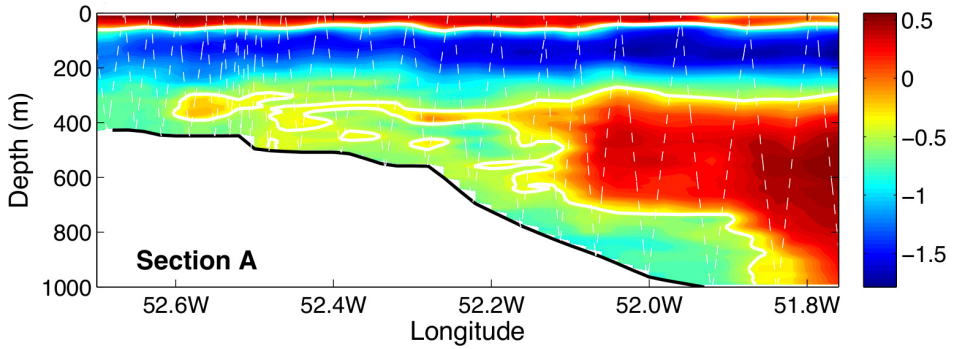

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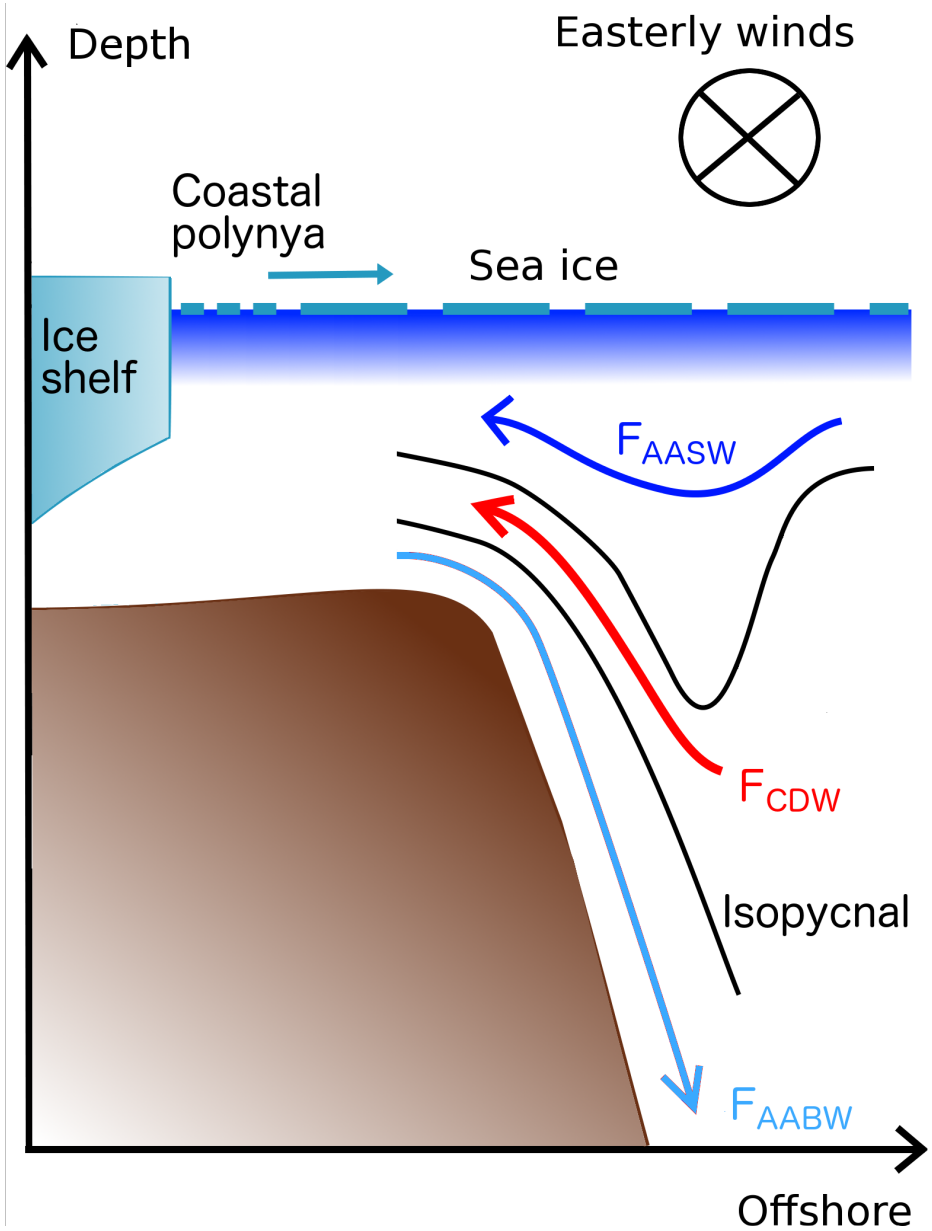

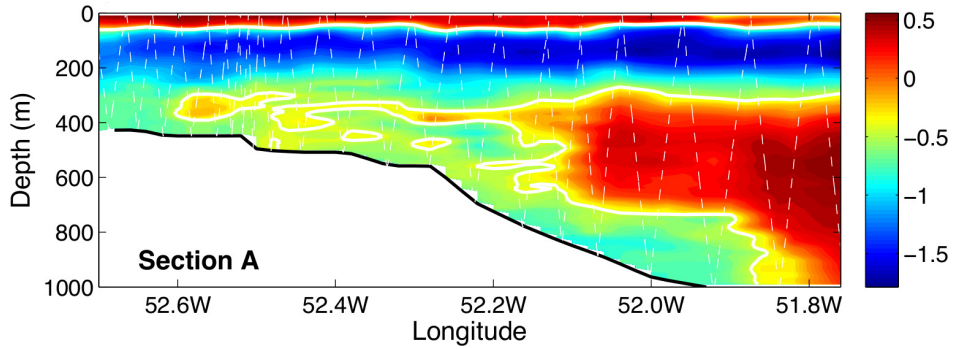

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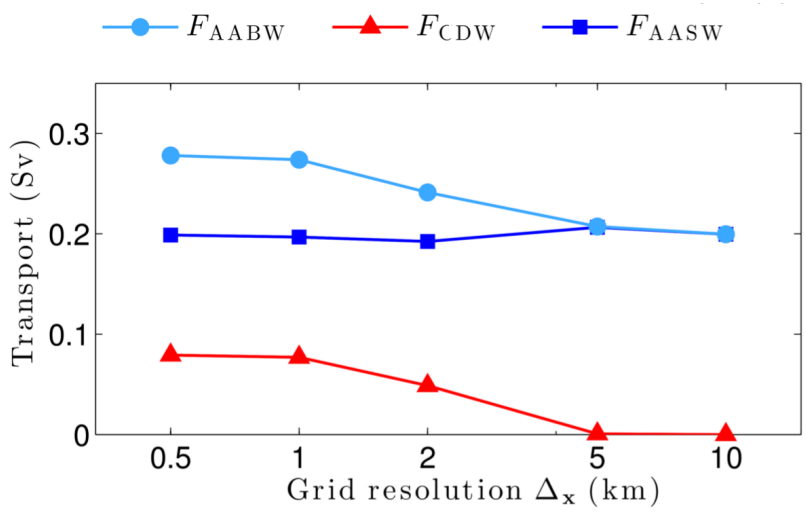
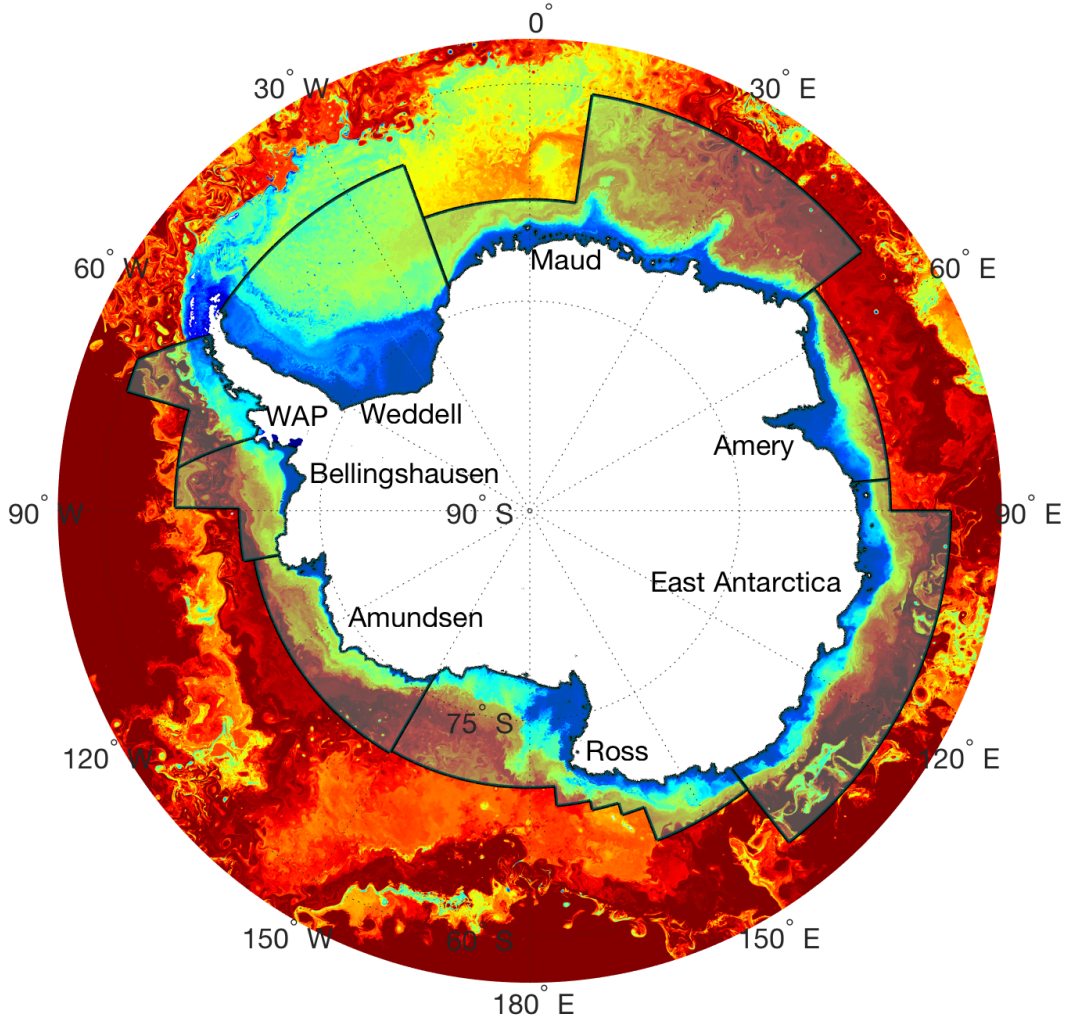


[Stewart and Thompson, GRL 2015]

Circum-Antarctic cross-slope heat fluxes



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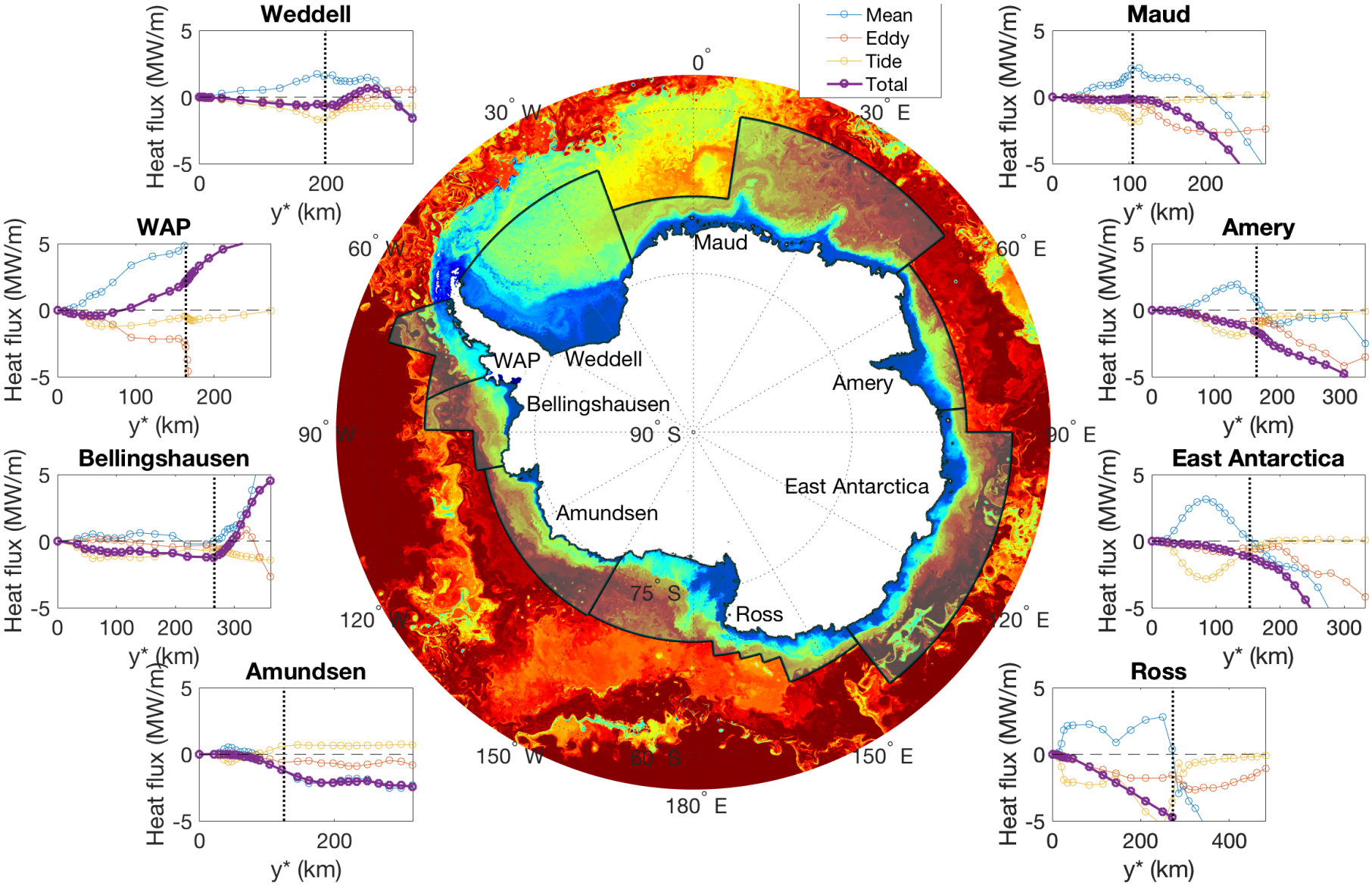

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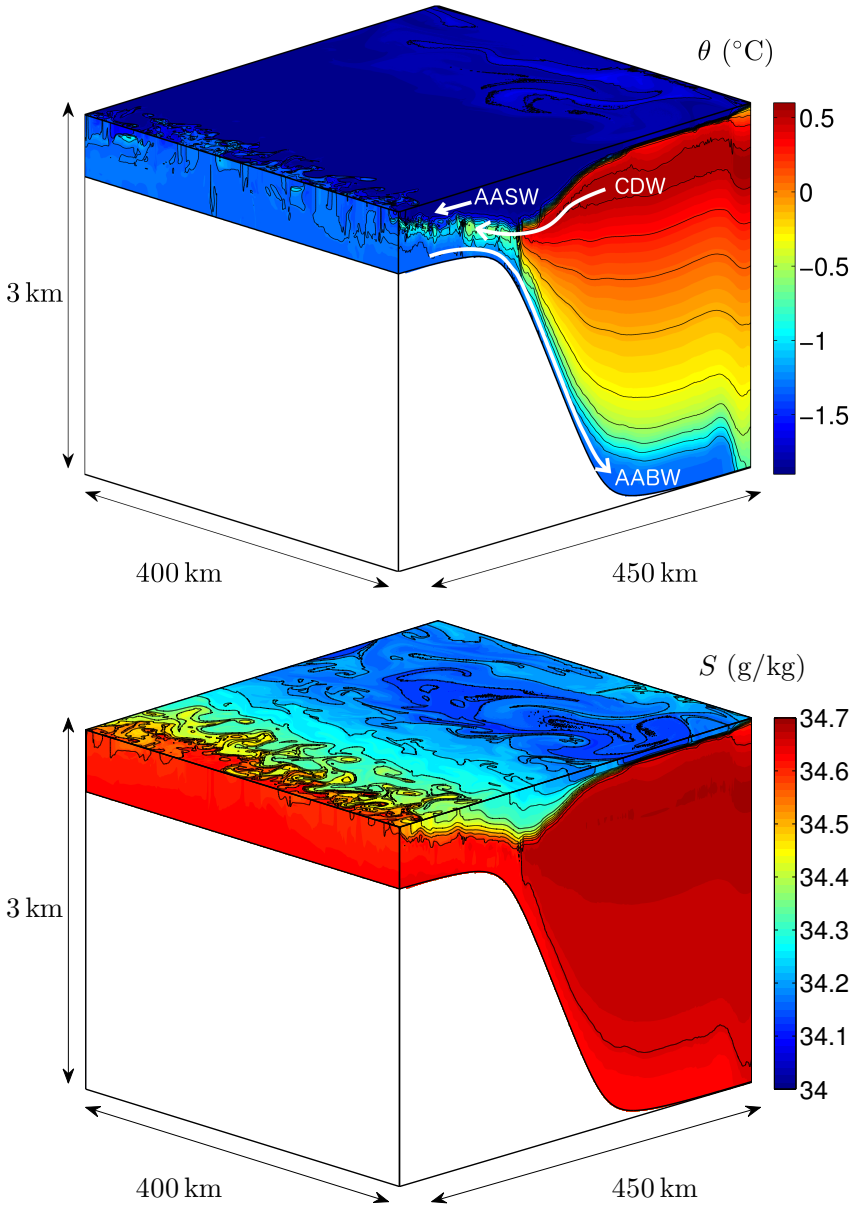

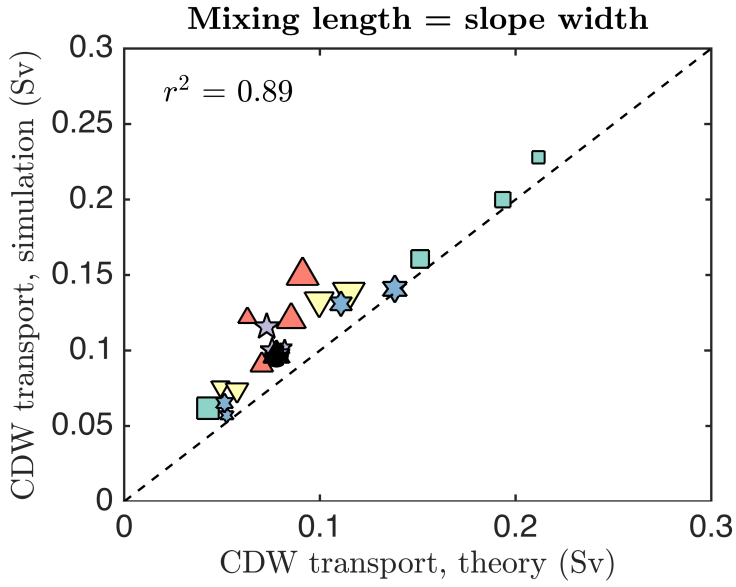

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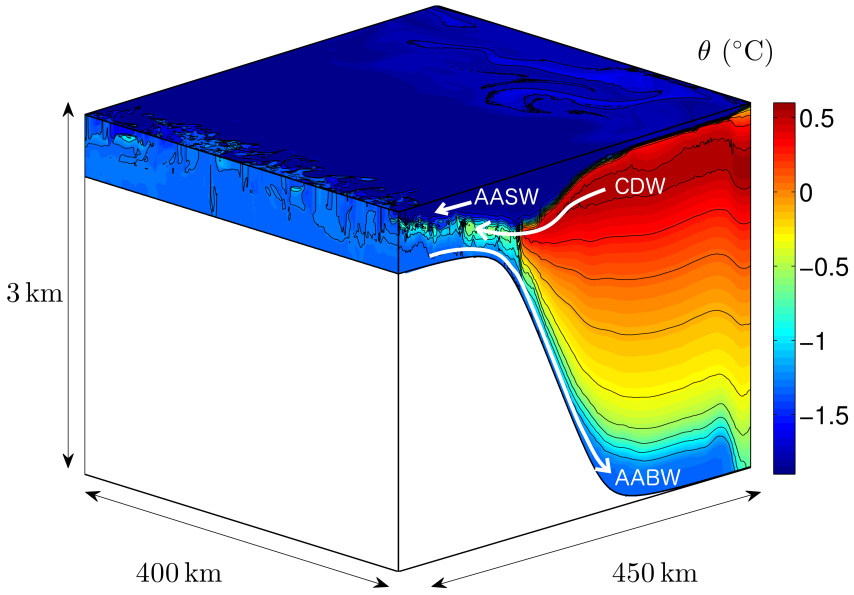
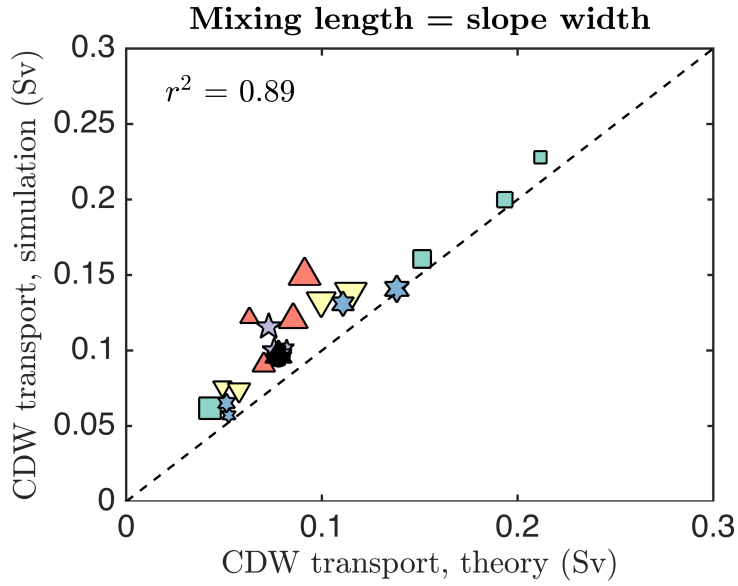
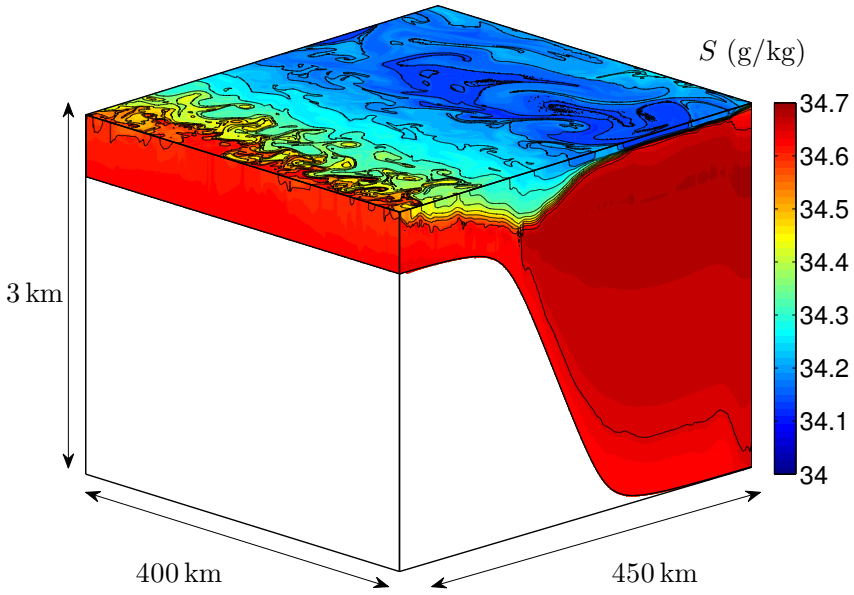
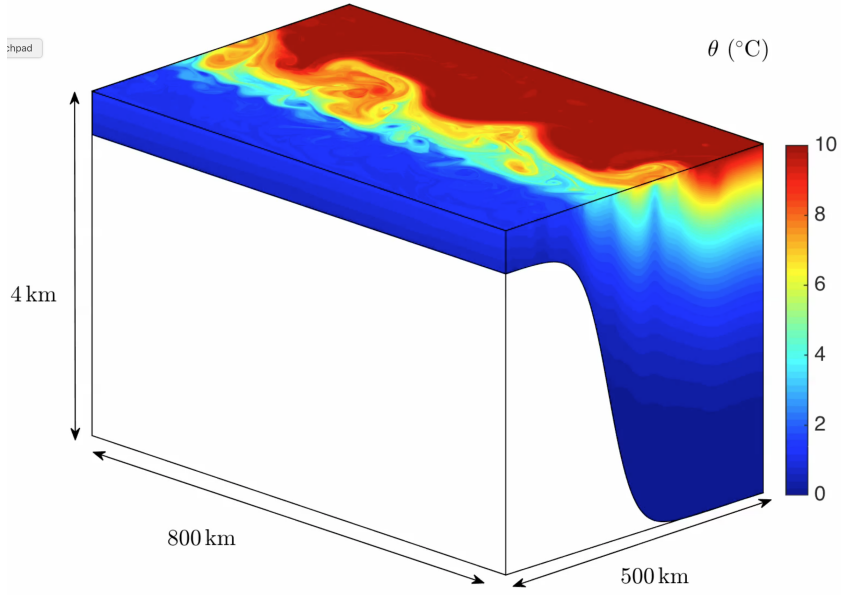




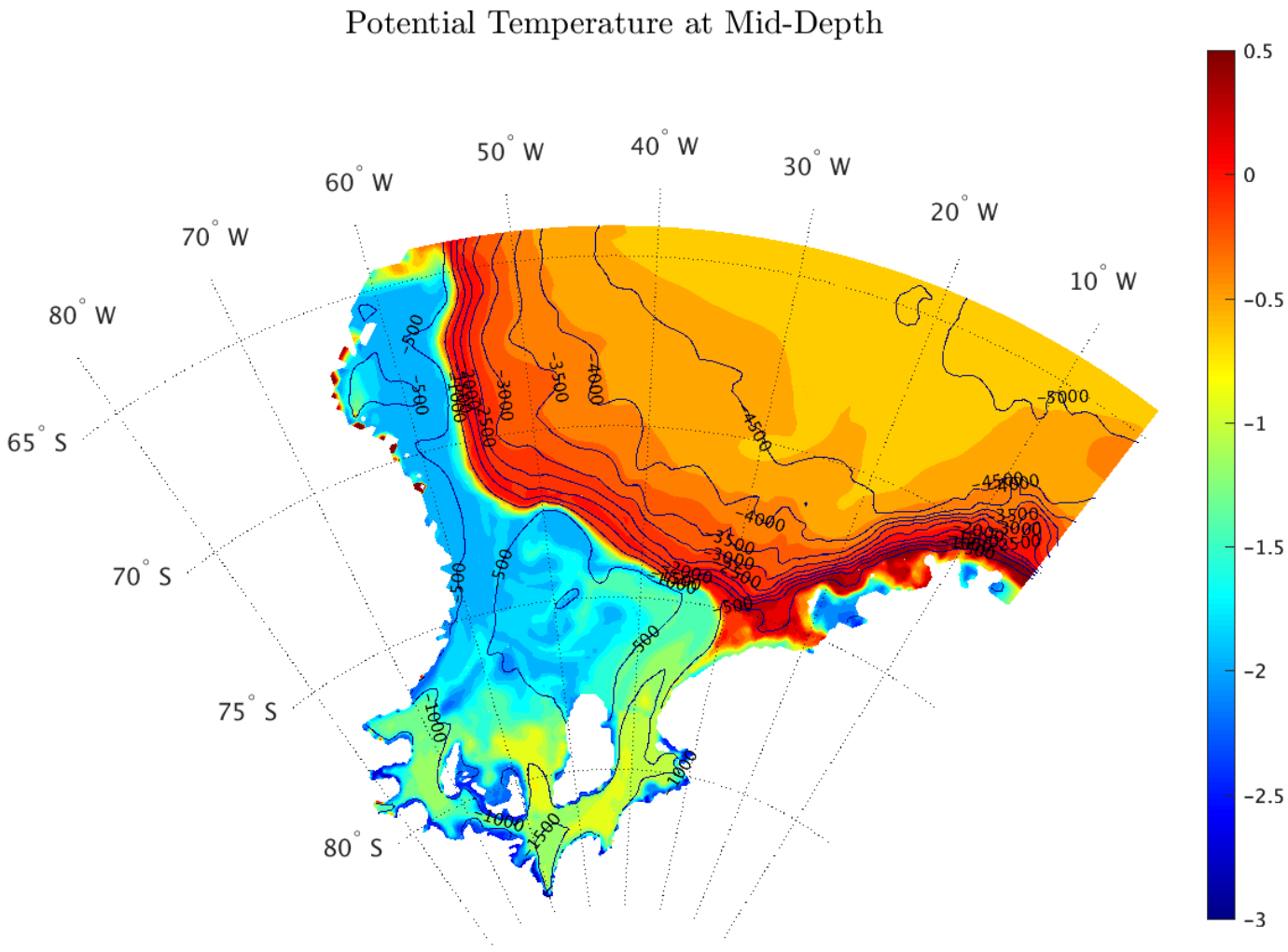




[Stewart and Thompson, JPO 2016]

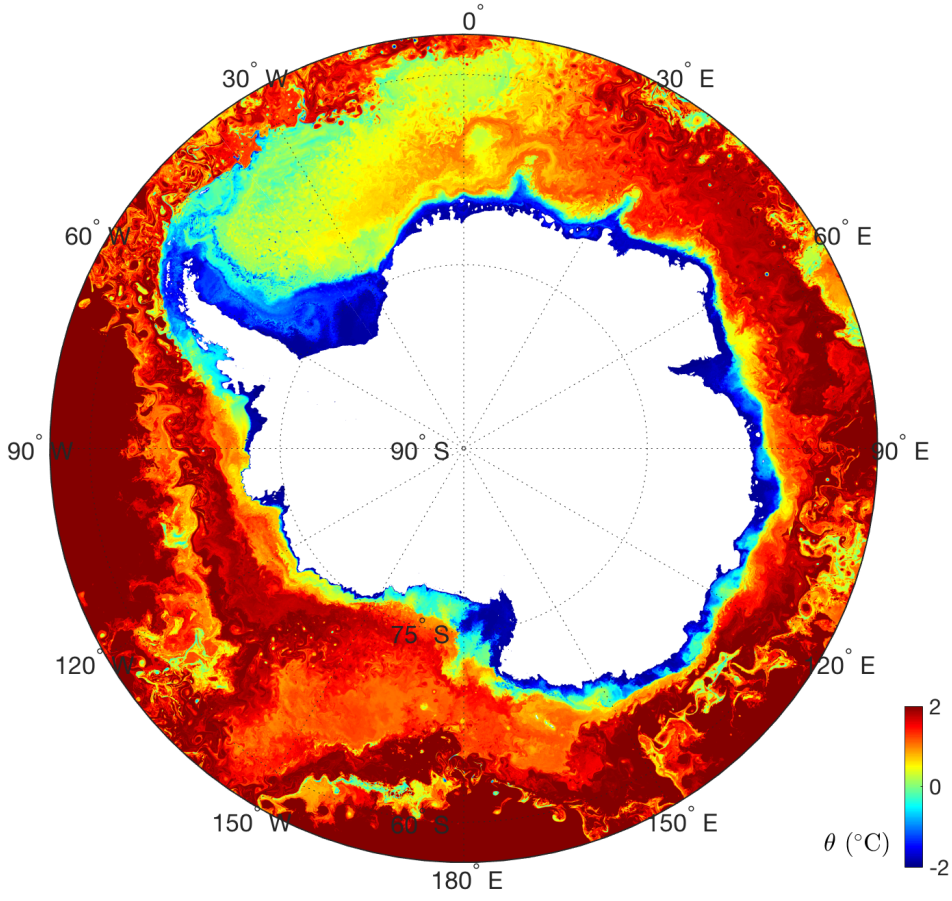
[Wang and Stewart, Ocean Modell. 2018]

Weddell Sea ice melt and dense water production



[Julia Hazel, UCLA]

Continental-scale heat transfer to Antarctica's ice shelves



- Circum-Antarctic regional simulations at eddy- and tide-permitting resolution (in collaboration with D. Menemenlis and M. Schodlok, JPL).
- Process-oriented modeling of eddy/tidal/mean flow interaction (Y. Si).
- Supported by an NSF CAREER award, 2018–2023.

Suggested ingredients for a new Earth System Model

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- Invest in sustained observations in the abyss, on the Antarctic shelf, and within the ice shelf cavities.
  $\rightarrow$ Sea ice-capable Argo floats, tagged seals, AUVs, near-Antarctic SSH measurements are a good start, but not nearly enough.

A final reminder of what we're missing...