Southern Ocean Winds, Diapycnal Diffusion and the Atlantic Meridional Overturning

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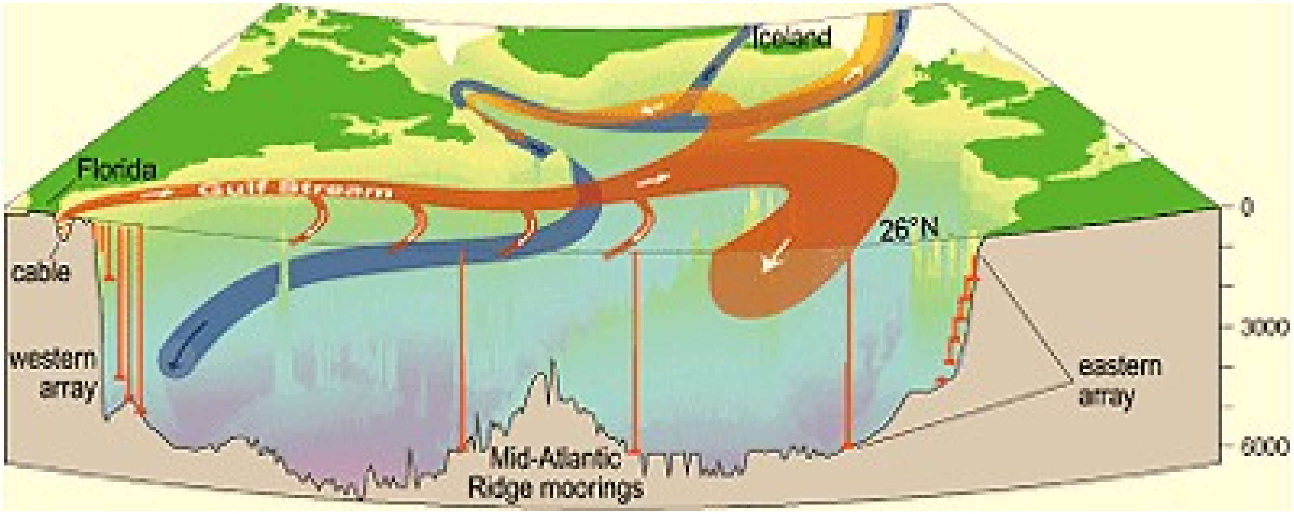


Cunningham et al 2013

Overview

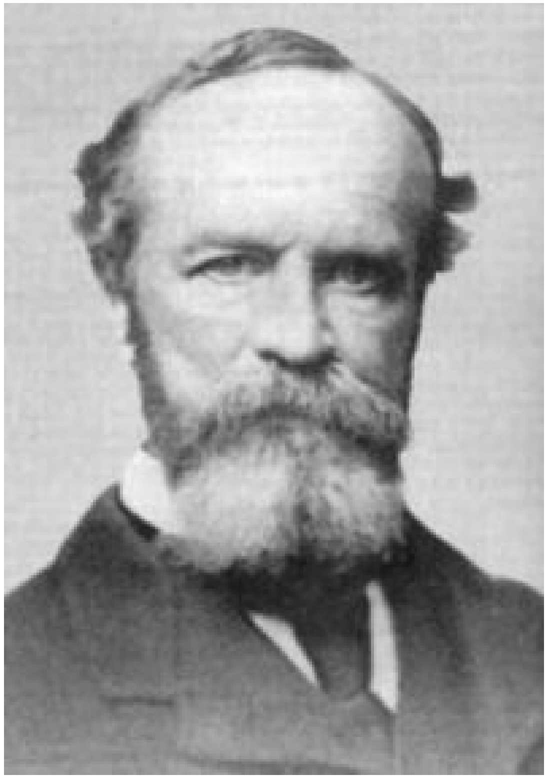
- diapycnal diffusivity
- Southern Ocean winds & eddies
- a theory for everything
- … and GCM against all
- Conclusions

Tropensonne,Nolde

A pragmatic approach

A belief is true, if in the long run it works for all of us, and guides us expeditiously through our semihospitable world.

(William James)



Some Background

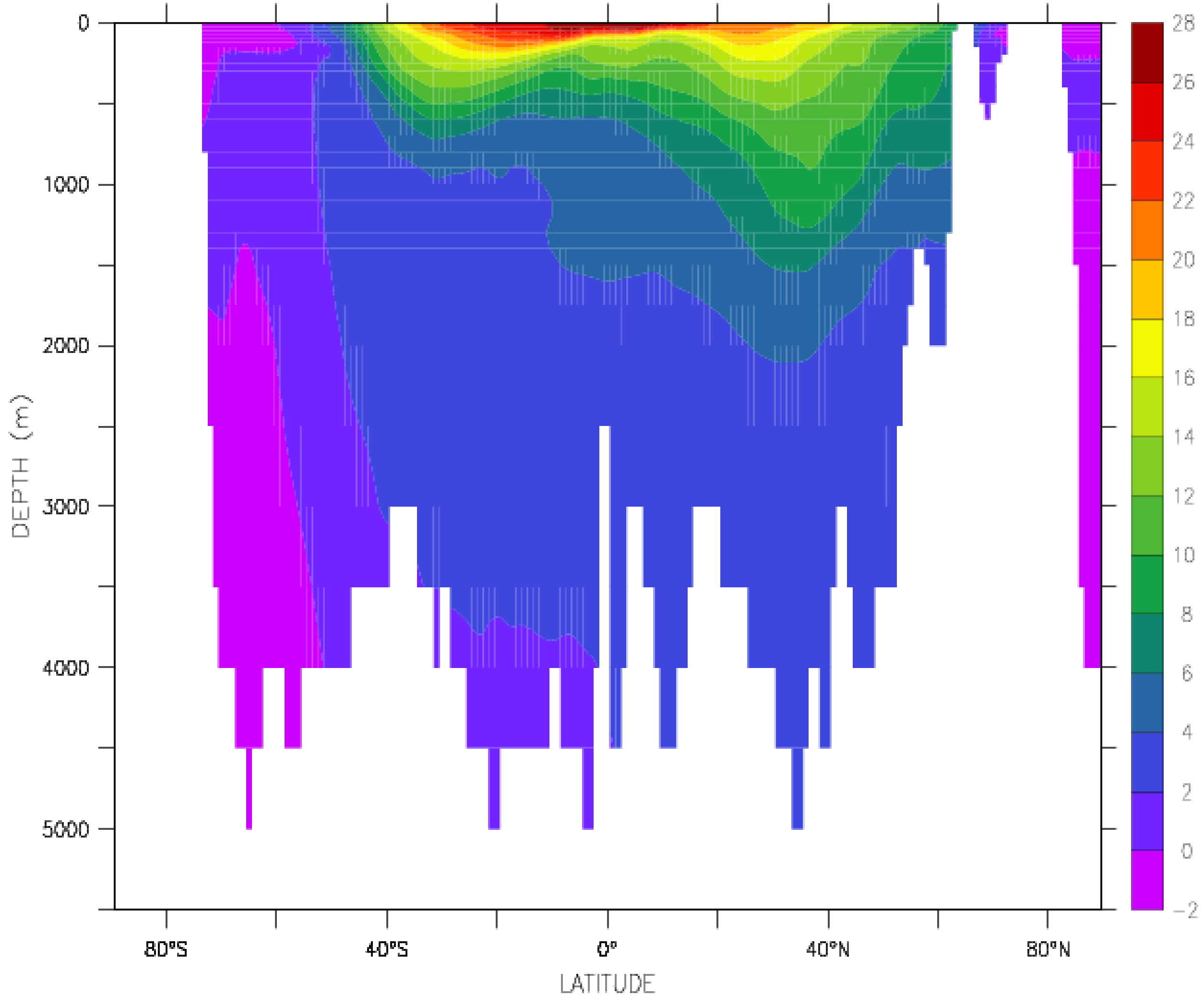
Sandstroem (1908): heating and cooling on same geopotential

Jeffrey (1925): turbulence mixes heat downward

Munk (1966): downward diffusion is balanced by abyssal upwelling

Munk and Wunsch (1998): Where does all the energy come from?

Davies (1994ab): You will never figure it out!



observed temperature at 20W (Levitus)

How do we constrain the diffusivity (k)?

- inverse modelling or water mass budget (Munk, Walin, Gordon)

- microstructure measurements (Gregg, Polzin, Toole, Alford)

- tracer release (Ledwell, Watson & Law)

- adjoint techniques (Wunsch, Stammer)

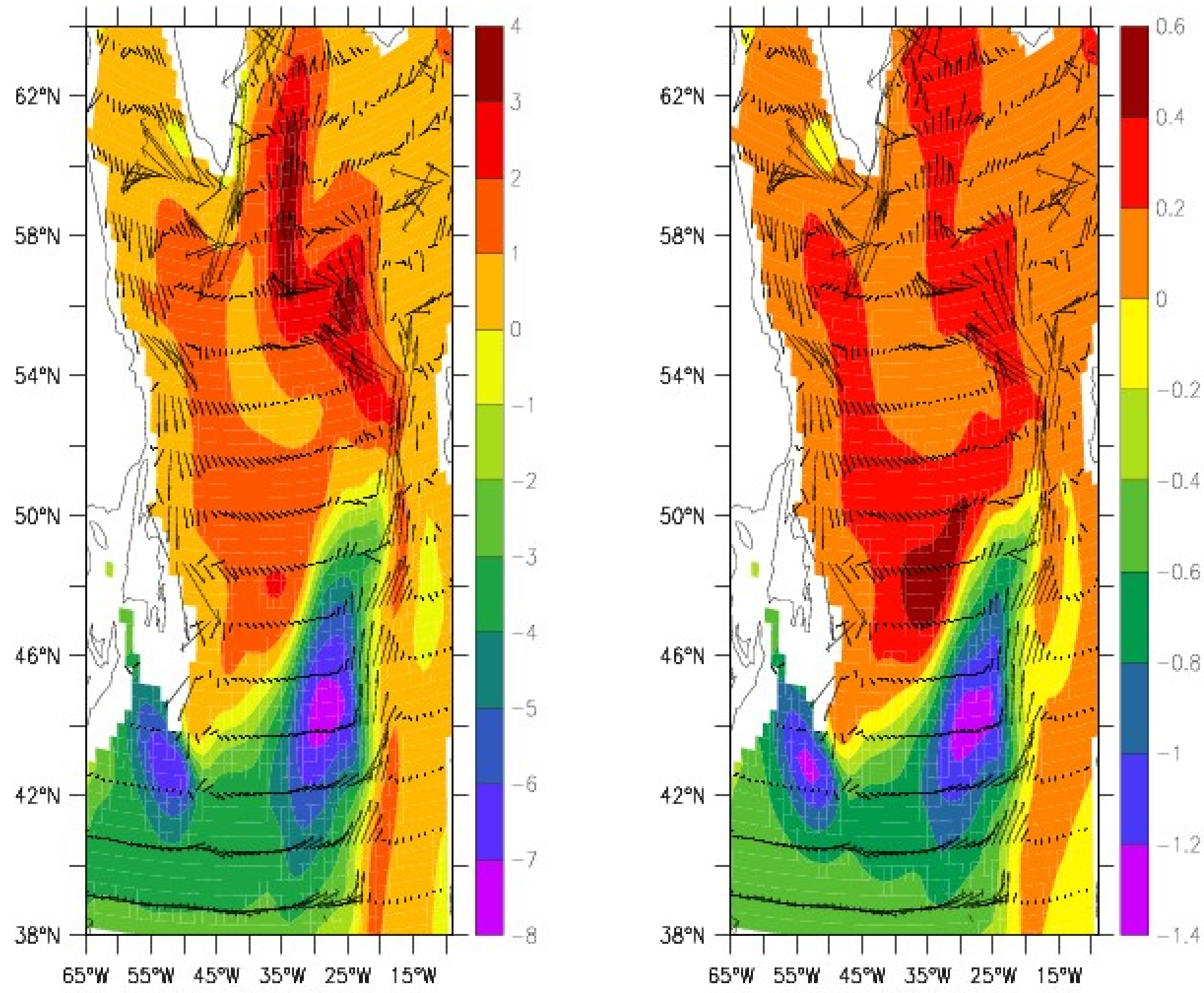
- energy sources/sinks (Munk, Wunsch)

Large scatter, but models show that for MOC or stratification the details don't seem to matter.
(Bryan, McWilliams et al., Marotzke)

The North Atlantic Response

difference in temperature on the 1.028 isopycnal

vectors: velocity in control on the same surface

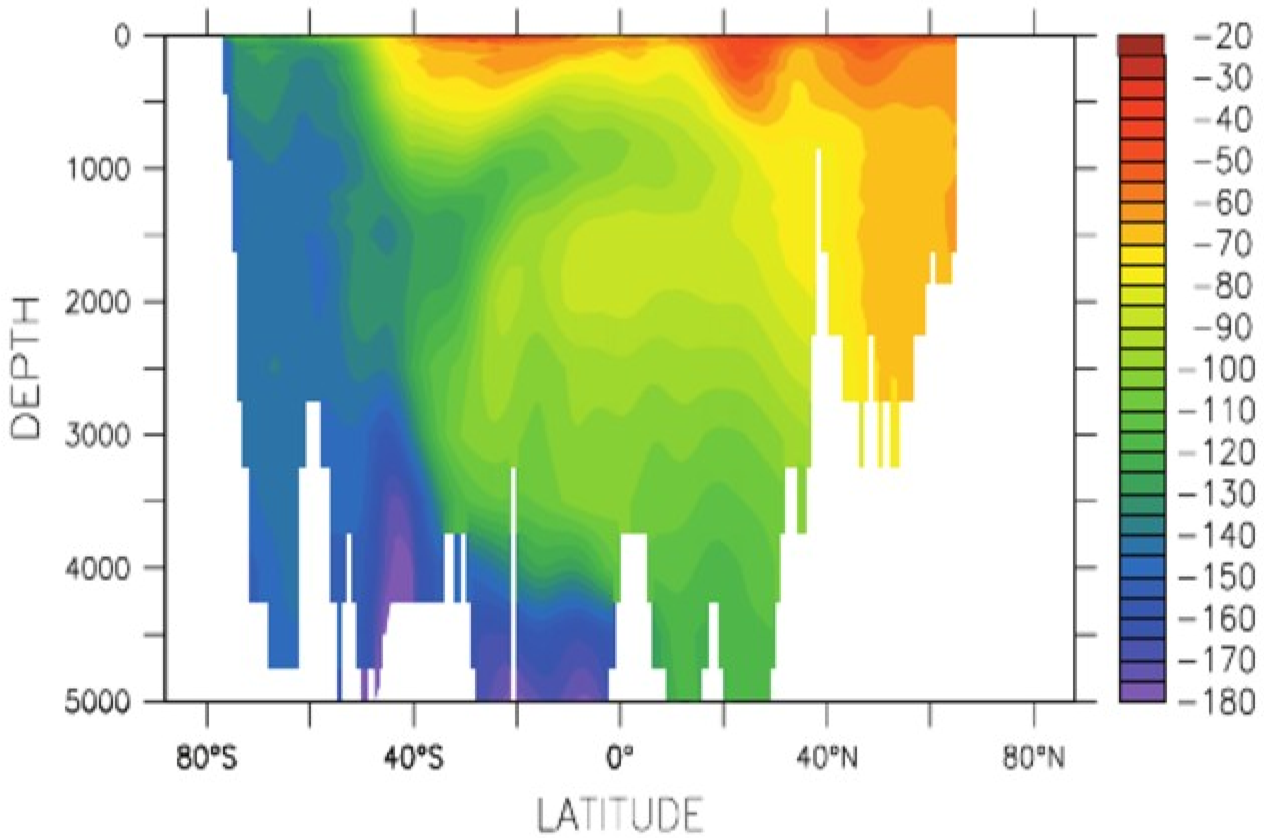


difference in salinity on the 1.028 isopycnal

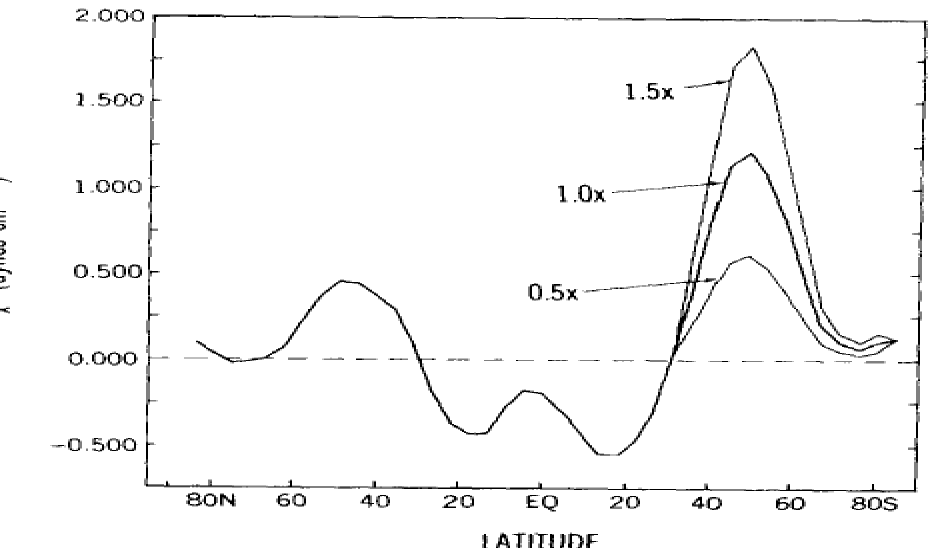
Jochum 2009

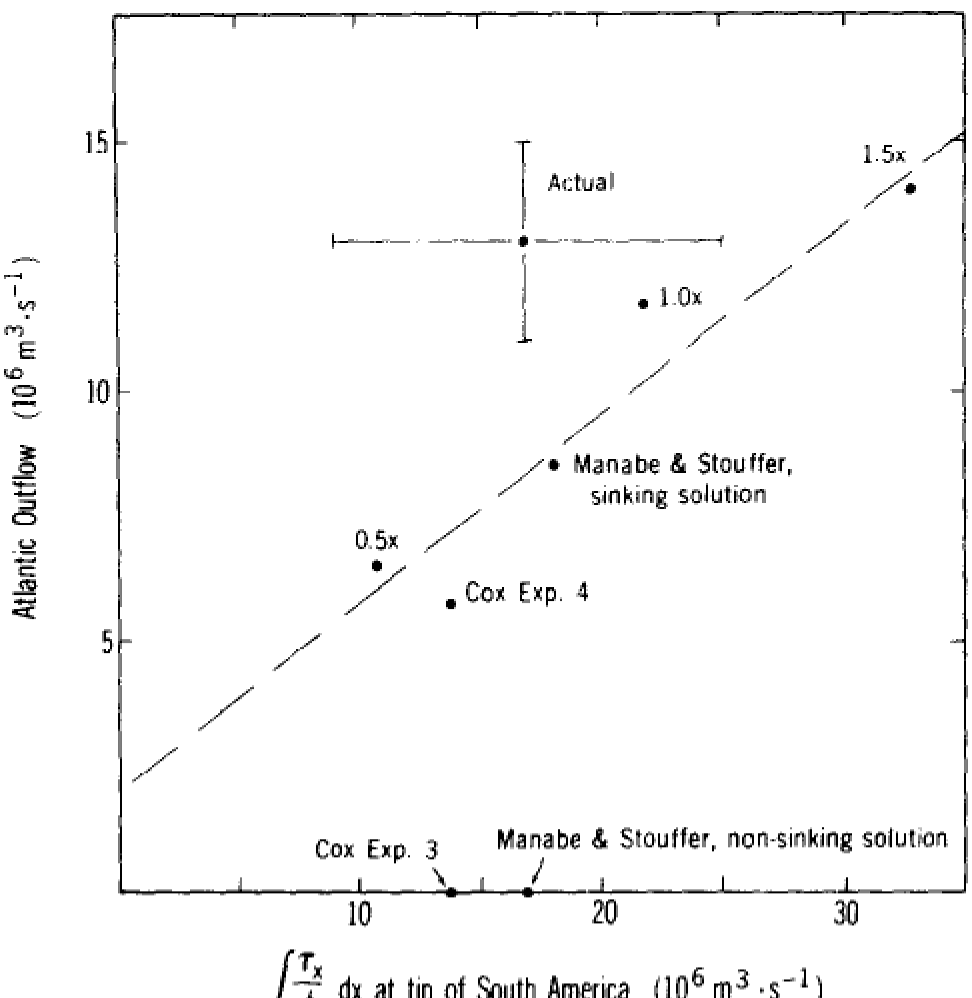
Ledwell & PSI - control

Toggweiler and Samuels, 1995: a fresh start



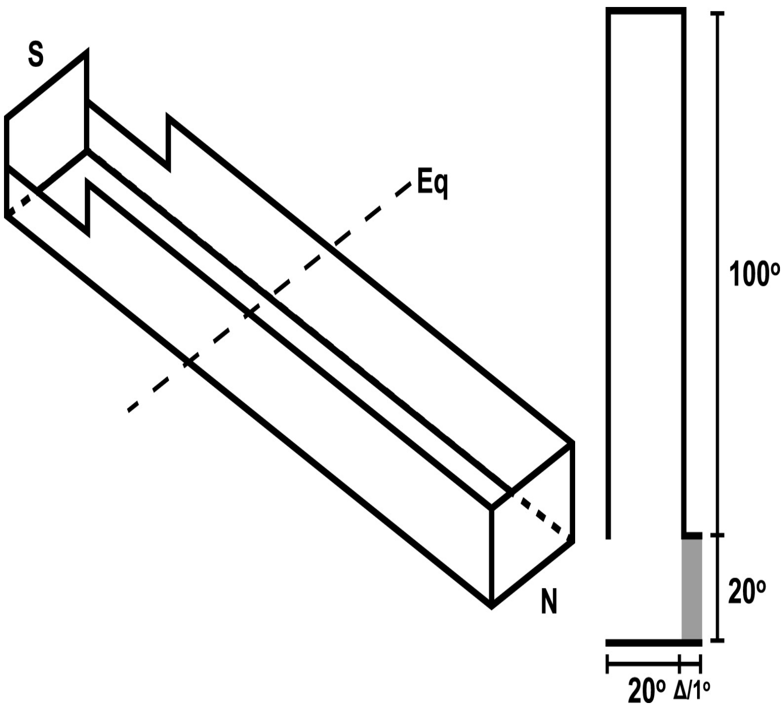
Radiocarbon along 28W (Key et al. 2004, based on WOCE)

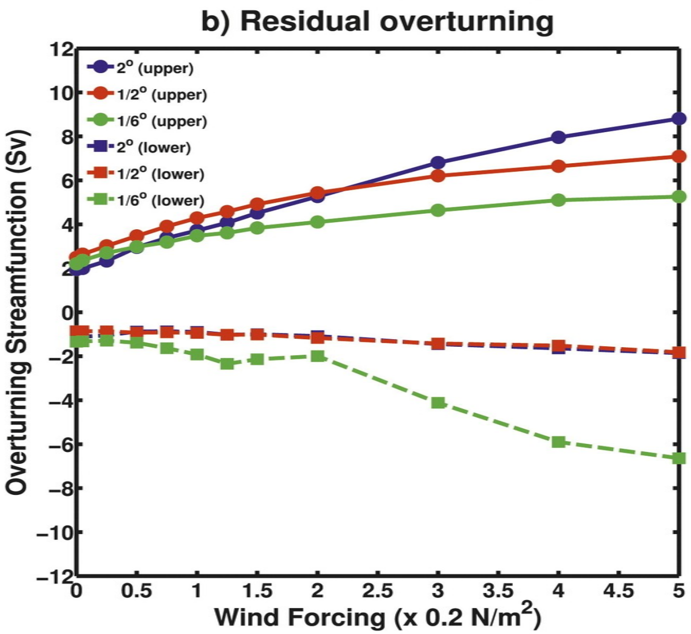


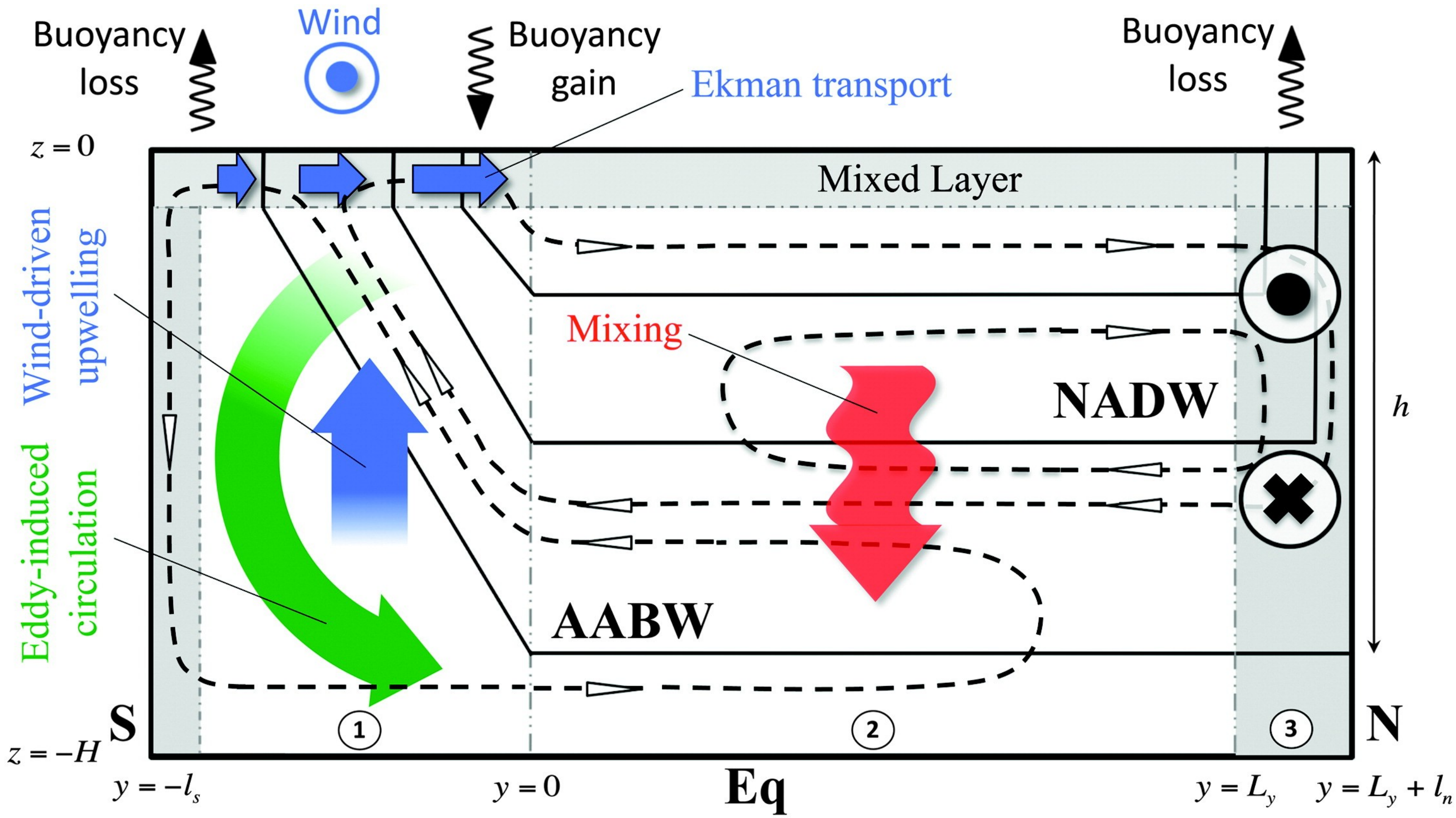


AMOC ~ SO winds

Real Oceanographers, Real Eddies: Munday, Johnson and Marshall, 2013



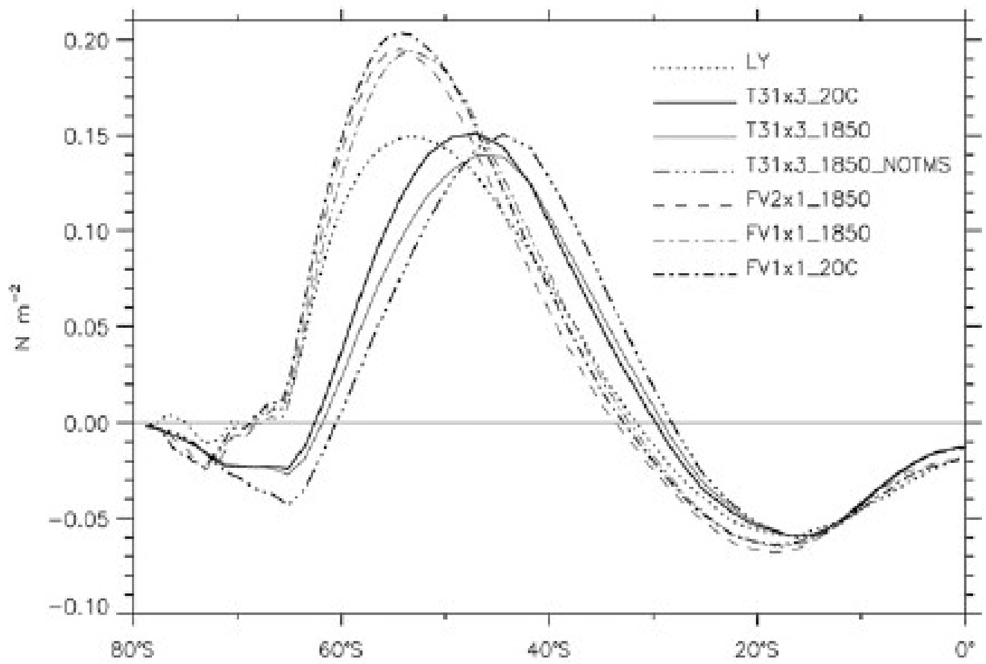




$$\frac{\Delta b h^2}{f_3} - \left(\frac{\tau_0}{\rho_0 f_1} - K_e \frac{h}{l_s}\right) L_x = \frac{\kappa_v}{h} L_x L_y. \qquad (4.4)$$

NADW production – SO upwelling = mixing driven upwelling

Gnanadesikan 1999, Shakespeare and Hogg 2012, Nikurashin and Vallis, 2012



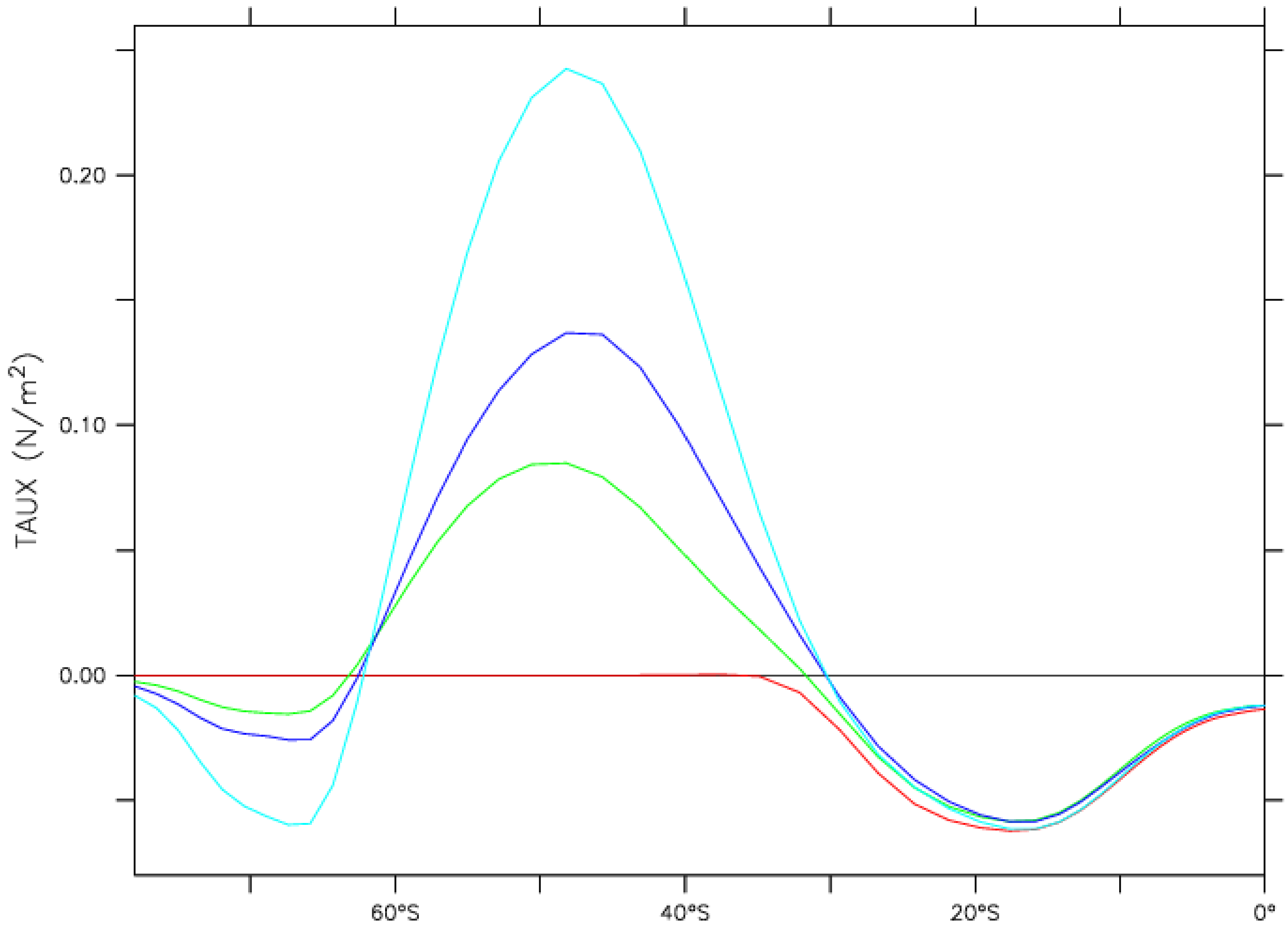
Shields et al. 2012

The GCM: CCSM4 in its T31x3 configuration:

3.75 x 3.75 degree, 26 levels in the atmosphere
0.6 - 3 degree, 60 levels in the ocean

Danabasoglu & Marshall the Elder (2007) version of stratification dependent isopycnal and thickness diffusion

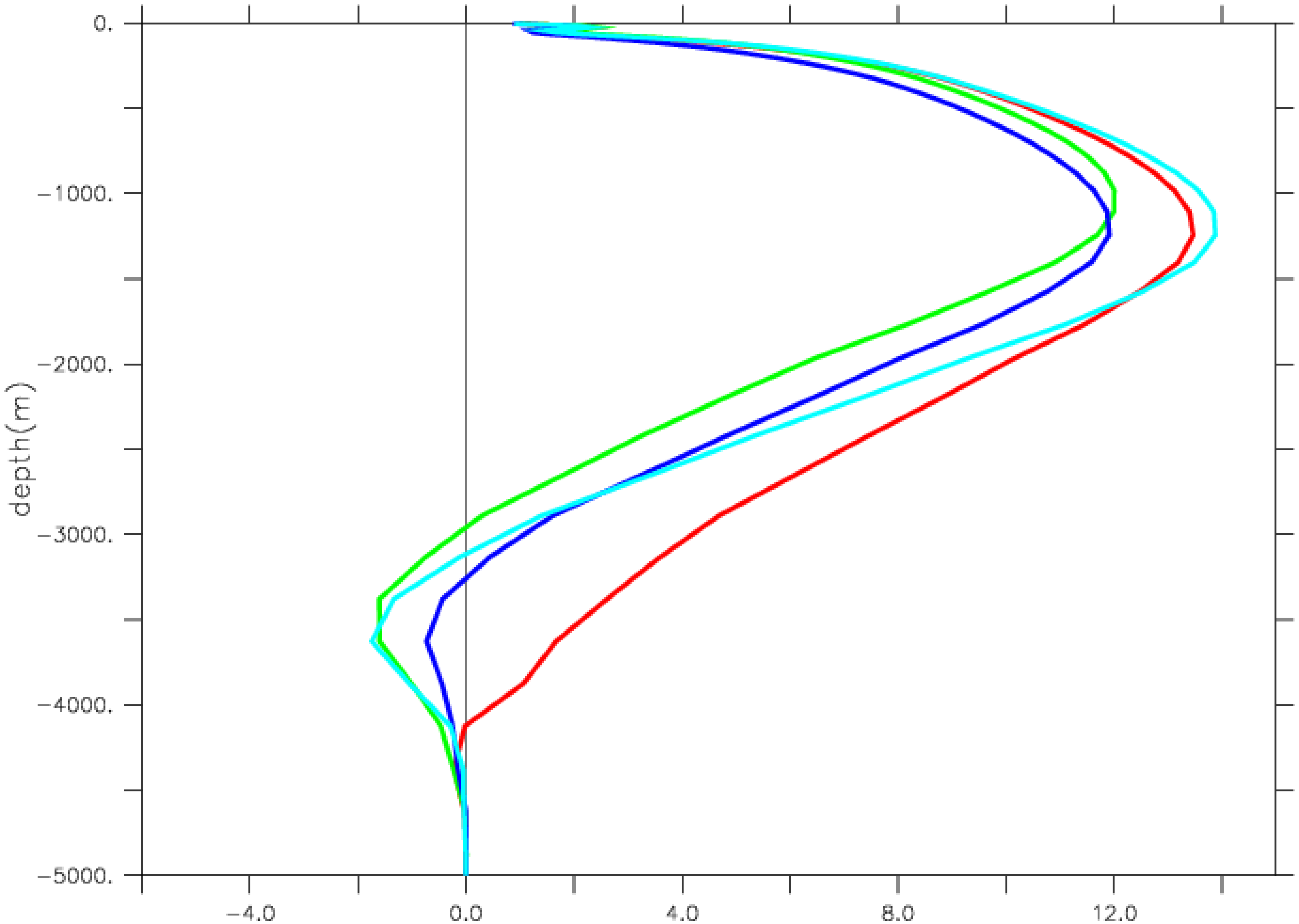
zonally averaged wind stress



NULL, HALF, CONT, TWO

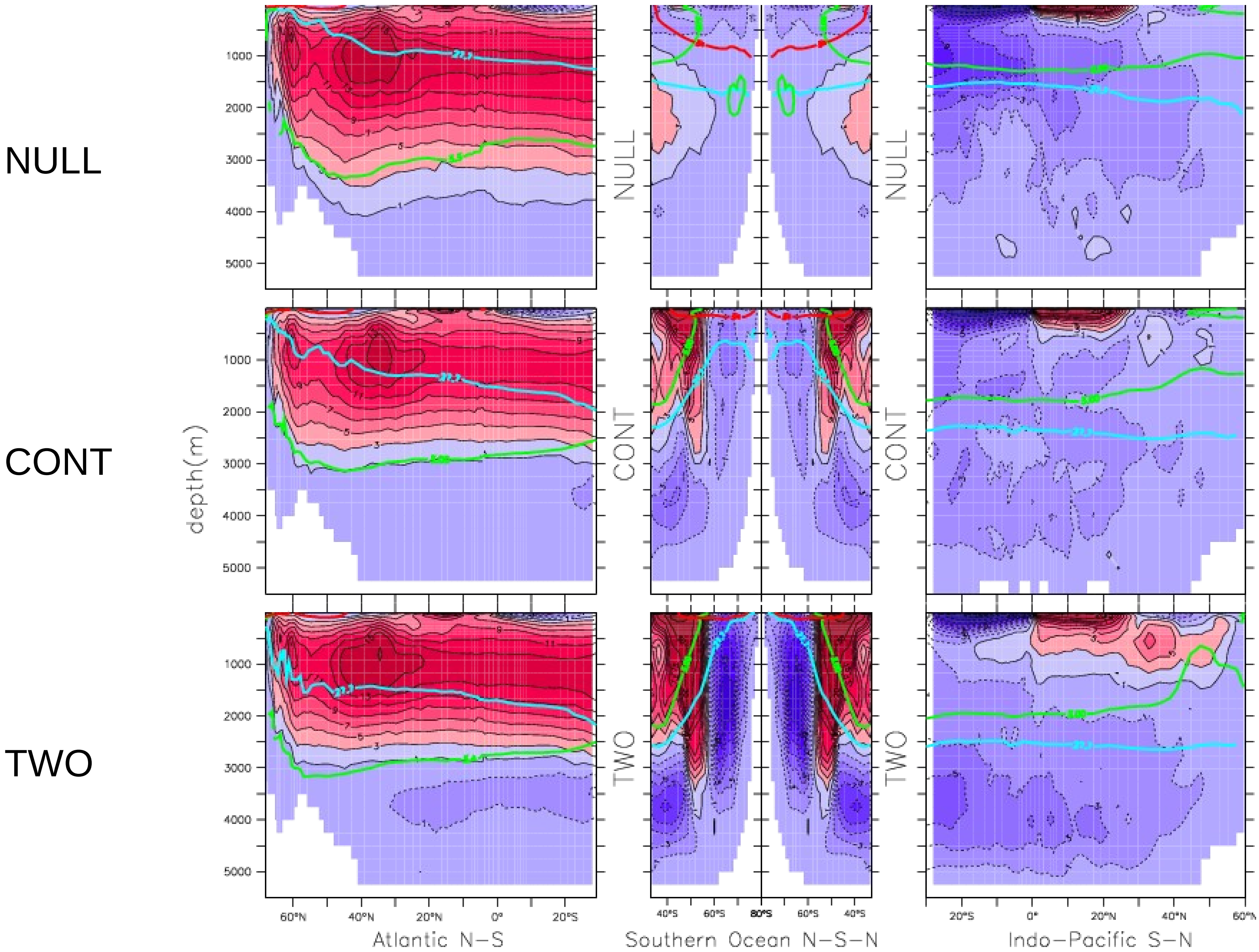
AMOC at equator

NULL, HALF, CONT, TWO

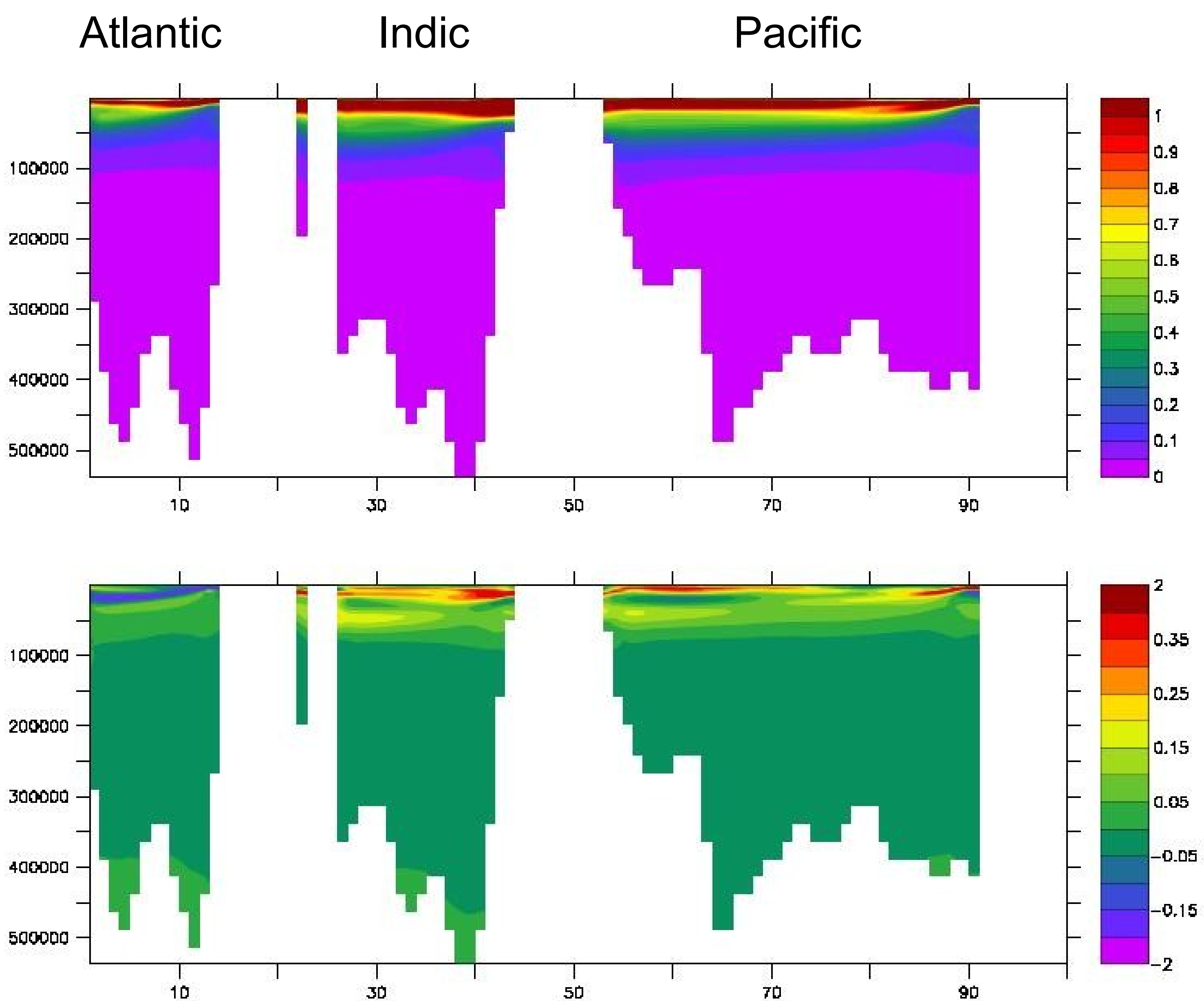


Exp.	$taux_{max}$	$AMOC_{eq}$	$Up_{Pacific}$	SO_{Euler}	SO_{eddy}	$SO_{resid.}$	κ_{GM}
NULL	0.00	13	9	5	-7	4	500
HALF	0.09	12	7	20	-11	15	570
CONT	0.14	12	3	35	-15	26	610
TWO	0.25	14	1	60	-22	42	700

Residual Overturning in the various basins



Blue: sigma27; Red: 34.3 psu; Green: 3 C



Stratification along 30S (x1e5), top: NULL, bottom: NULL−TWO

$$\frac{\Delta b h^2}{f_3} - \left(\frac{\tau_0}{\rho_0 f_1} - K_e \frac{h}{l_s}\right) L_x = \frac{\kappa_v}{h} L_x L_y . \qquad (4.4)$$

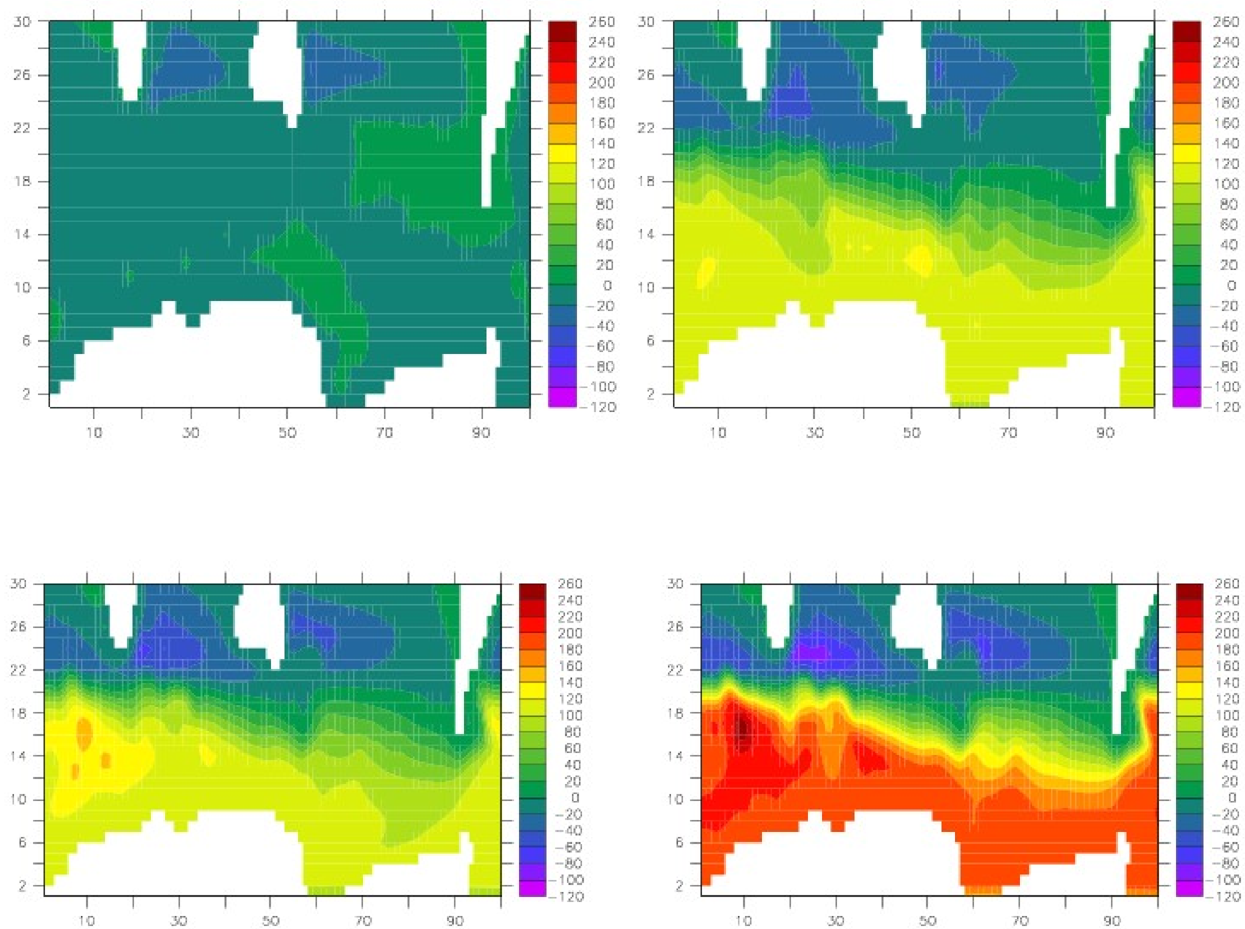
ACC Transport

NULL

HALF

CONT

TWO



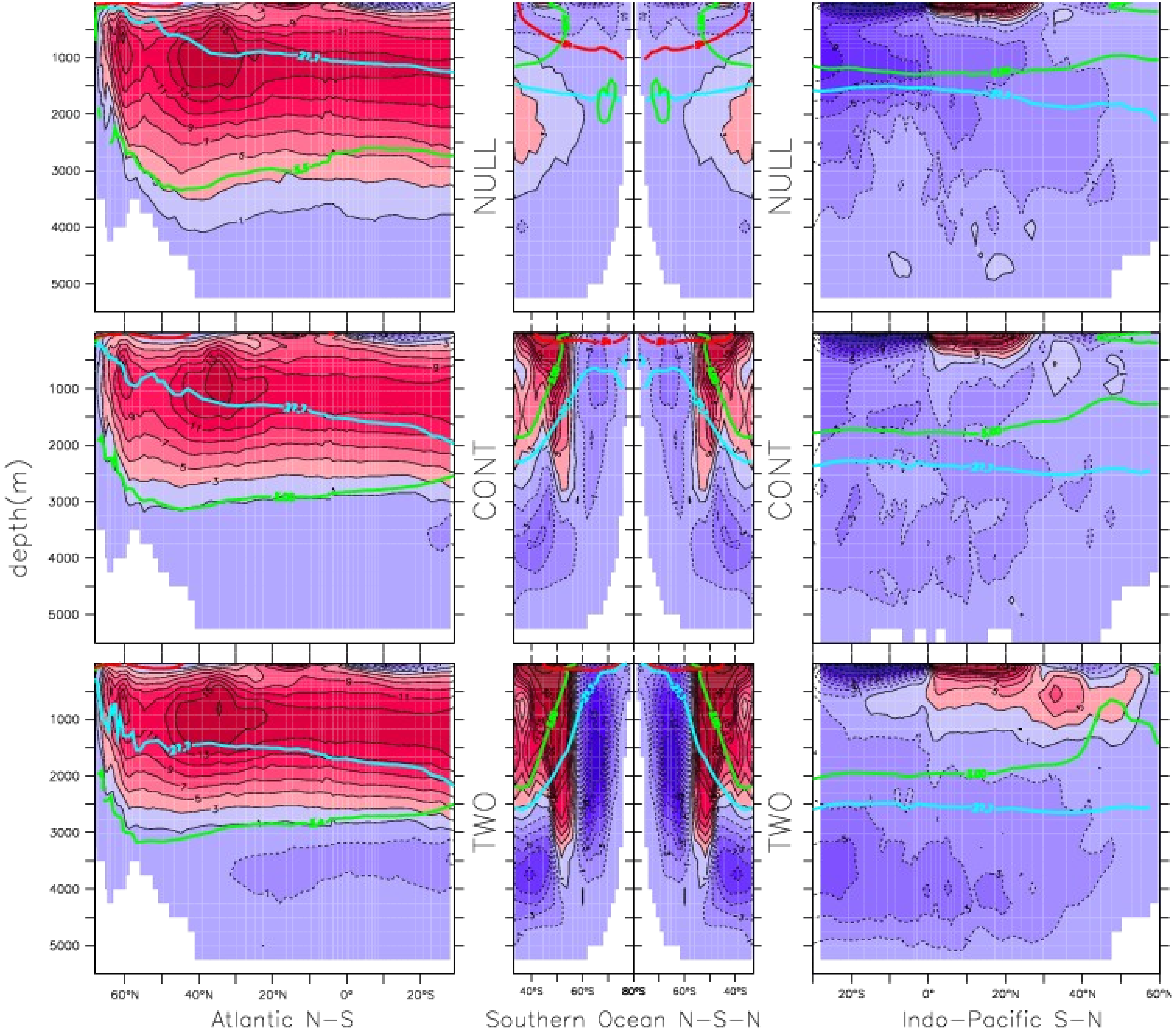
Exp.	$taux_{max}$	$taux_{dp}$	$taux_{ave}$	ACC_{Drake}	κ_{GM}
NULL	0.00	0.00	0.00	0	500
HALF	0.09	0.06	0.02	110	570
CONT	0.14	0.06	0.03	100	610
TWO	0.25	0.14	0.05	180	700

Total Energy used for diabatic mixing:

NULL: 0.31 TW

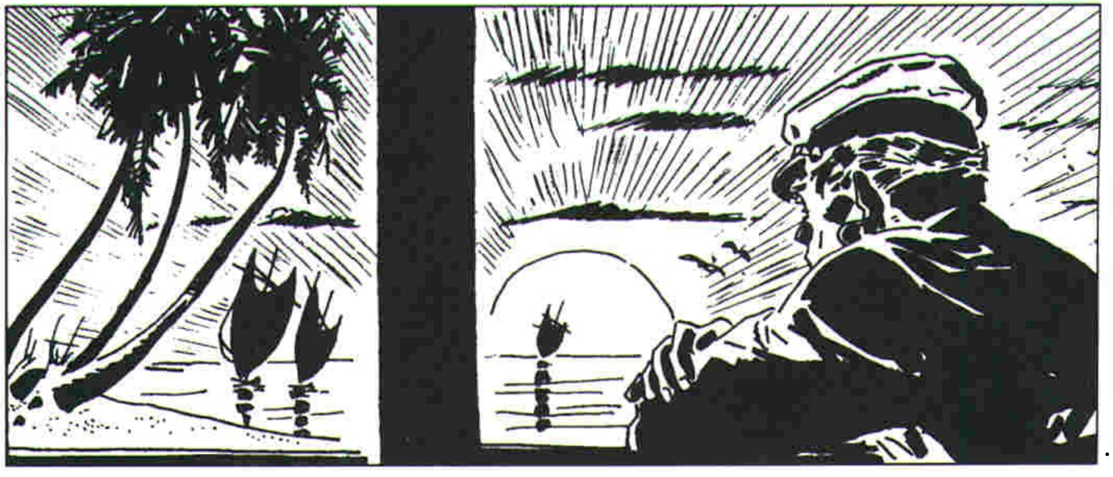
CONT: 0.26 TW

TWO: 0.29 TW



Conclusions

- Within realistic parameter ranges the AMOC is mostly independent from ocean turbulence or Southern Ocean winds
- This result has to be corroborated with an eddy resolving GCM, and with a more physical parameterization of diapycnal mixing, or maybe just repeating Munday et al. with a Pacific basin
- … and, of course, we still have to figure out what the AMOC depends on



(H. Pratt)