Oceanic overturning and heat transport: The role of background diffusivity

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Simulations

- Six simulations run for 2200 years to approximate equilibrium (drift $< 0.02^\circ$C/100 yr)
- Identical except for the background diffusivity κ_0
- How do the overturning cells scale with κ_0?
- How does the meridional heat transport scale with κ_0?

Model

- CM2G: coupled climate model at GFDL
- Atmosphere resolution: $2^\circ \times 2.5^\circ$, 24 levels
- Ocean resolution 1°, 63 levels
- Isopycnic ocean model with GM-parameterisation

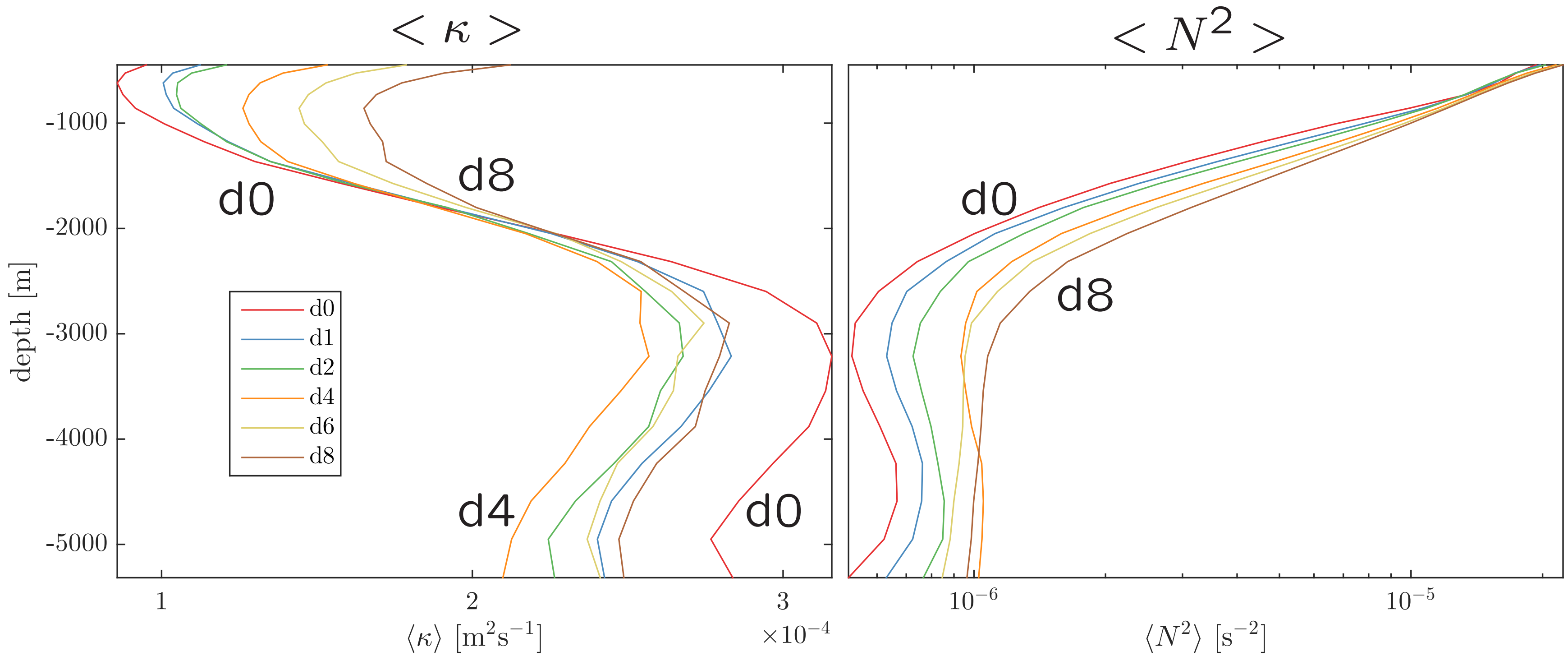
Parameterization of vertical diffusivity

- Close to mixed layer: mainly shear-driven (Jackson et al, 2008)

- Lower thermocline: κ_0 is important. Default: $\kappa_0 < 2{\times}10^{-5} m^2/s$

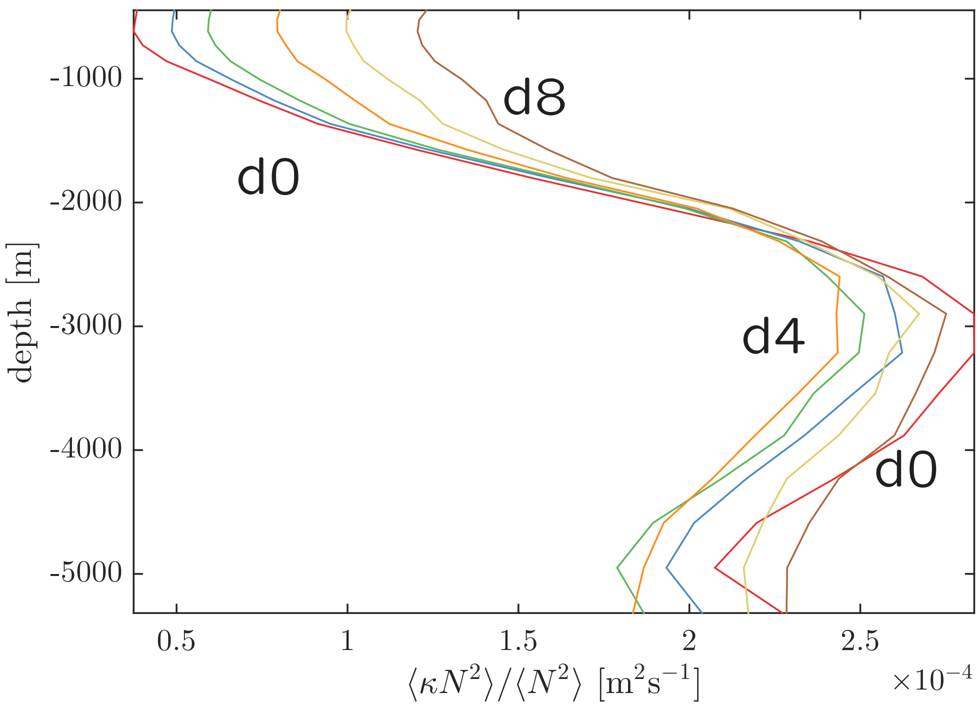
- Below 2000 m: mainly tidal mixing (St. Laurent et al, 2002)

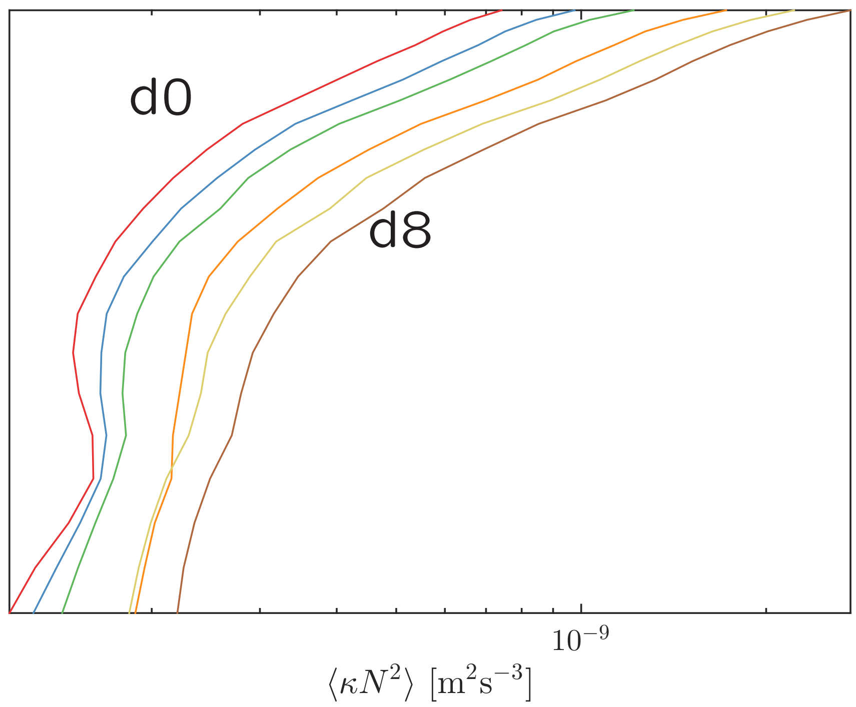
Resulting diffusivity profiles



simulation	d0	d1	d2	d4	d6	d8
added to κ_0 [10^{-5}m^2/s]	0	1	2	4	6	8
500-1000 m average κ	9	10	11	13	15	17

Buoyancy flux





$< \kappa N^2 > / < N^2 >$ $< \kappa N^2 >$

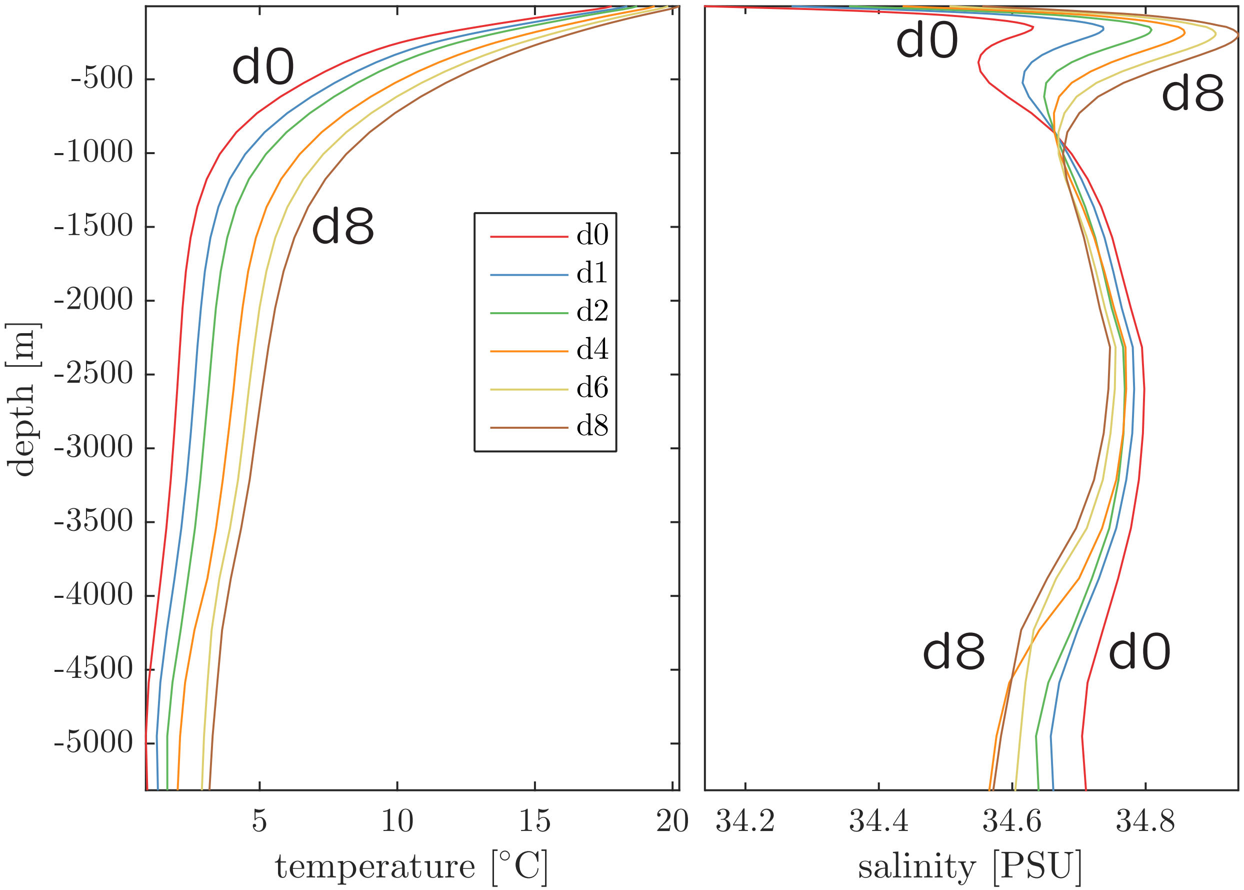
Explanation

- Higer temperature in thermocline increases deep stratification N

- Tidal mixing decreases: $\kappa_{StL} \sim N_b N^{-2} \sim N^{-1}$

- Buoyancy flux increases: $\kappa_{StL} N^2 \sim N$

T and S profiles

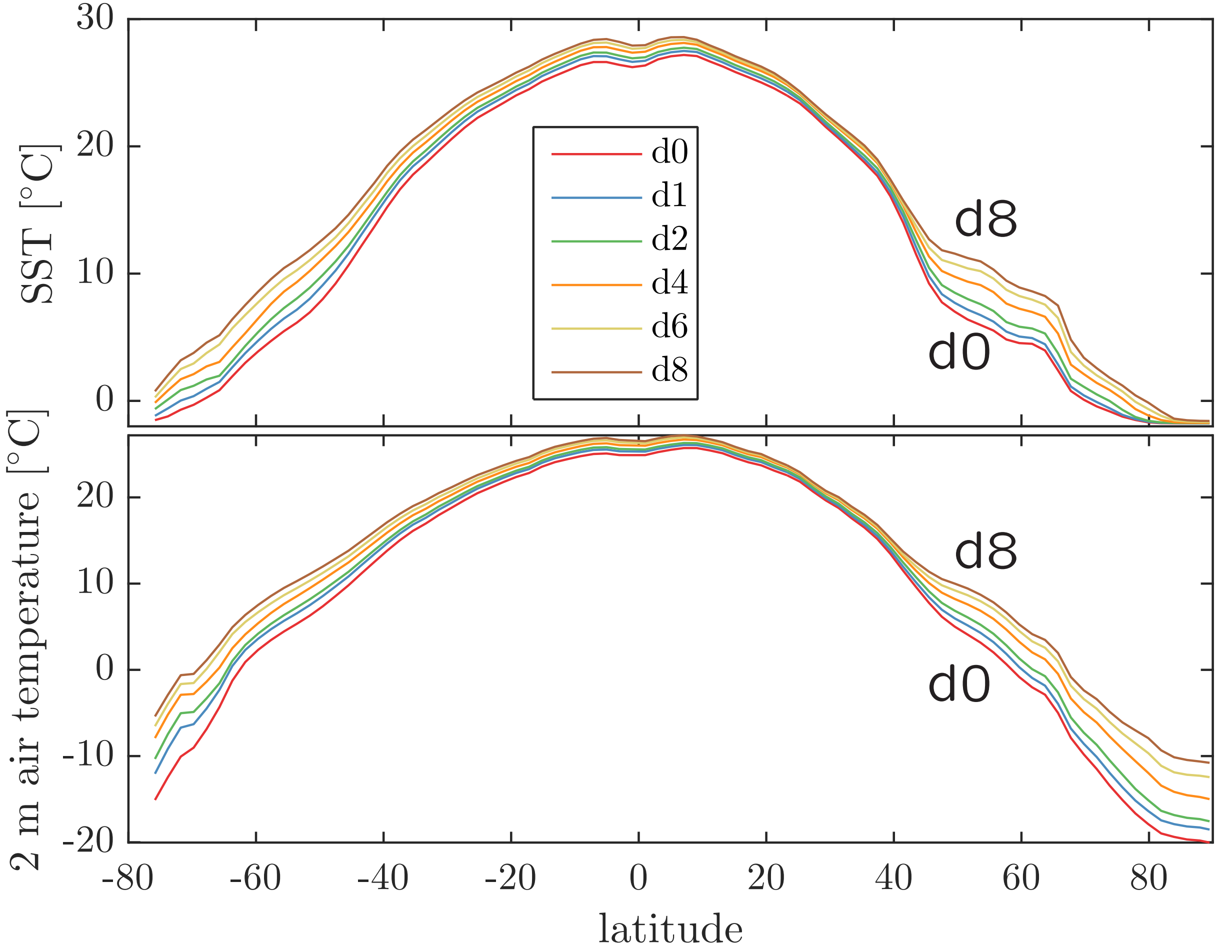


T S

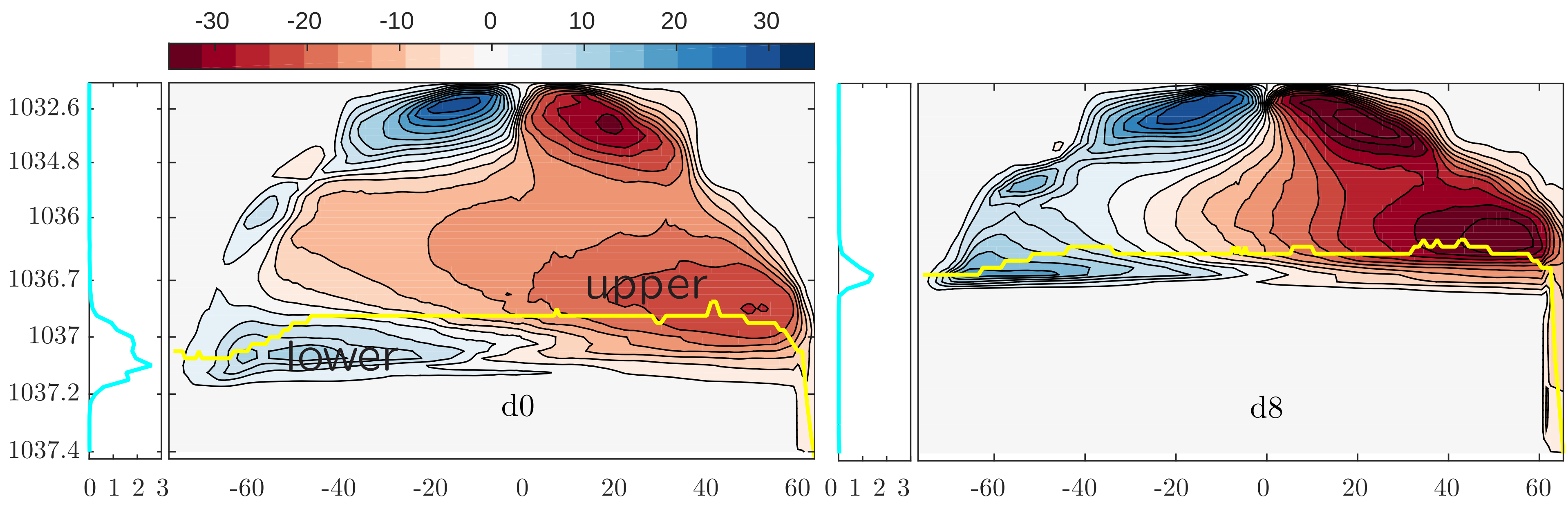
Changes from d0 to d8

- 2 m air temp: increase by 3°C
- SST: increase by 2.4°C
- Mean ocean T: increase by 3.6°C
- Much less sea ice, particularly in the Southern Hemisphere
- Weaker Hadley cell, weaker winds
- Decreasing albedo (less sea ice plays small role)

SST and 2m air temp



Overturning $\psi(lat, \sigma_2)$

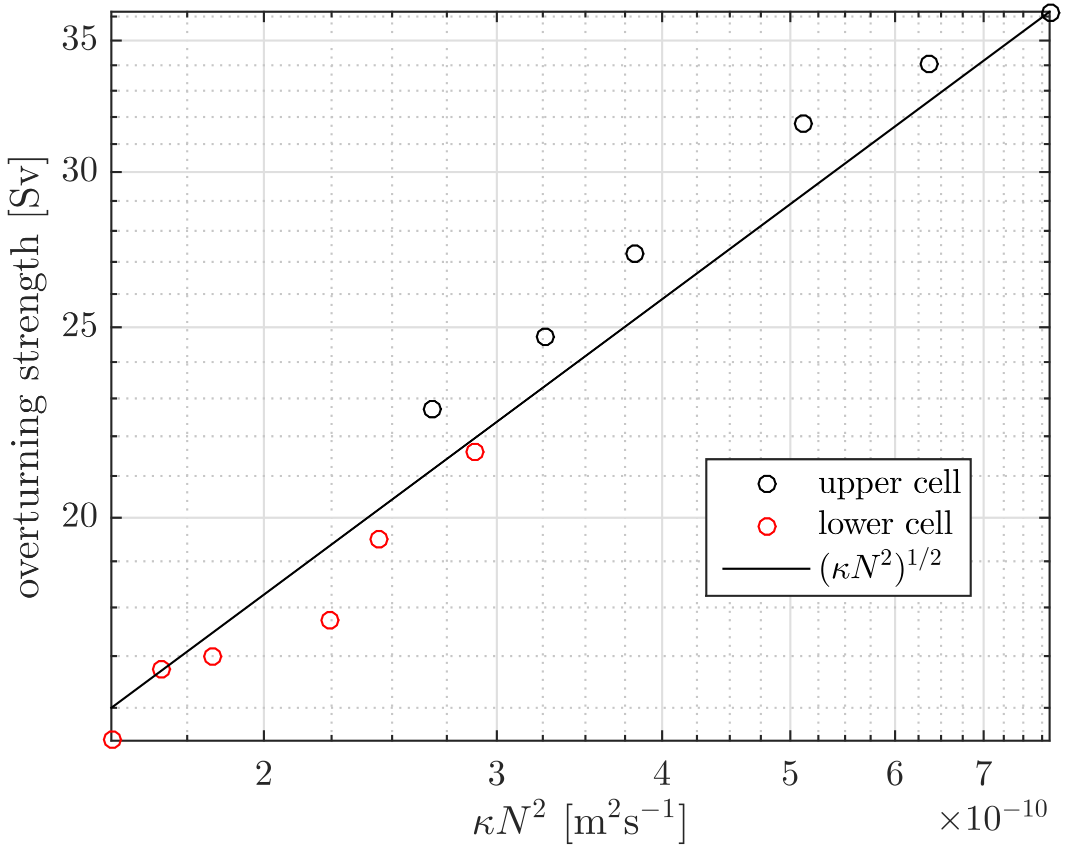


d0 d8

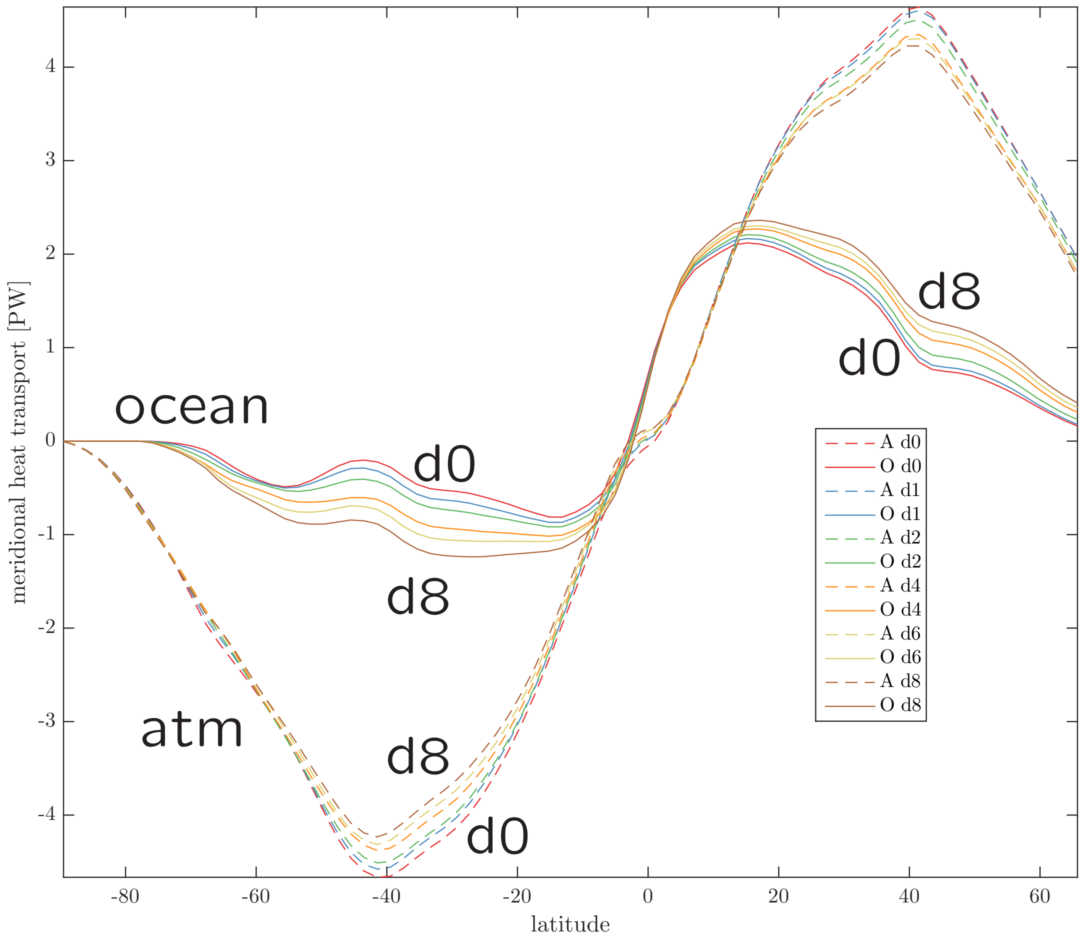
Blue curve: incrop area

Yellow curve: 2000 m depth

Scaling with mixing energy κN^2



Meridional heat transport



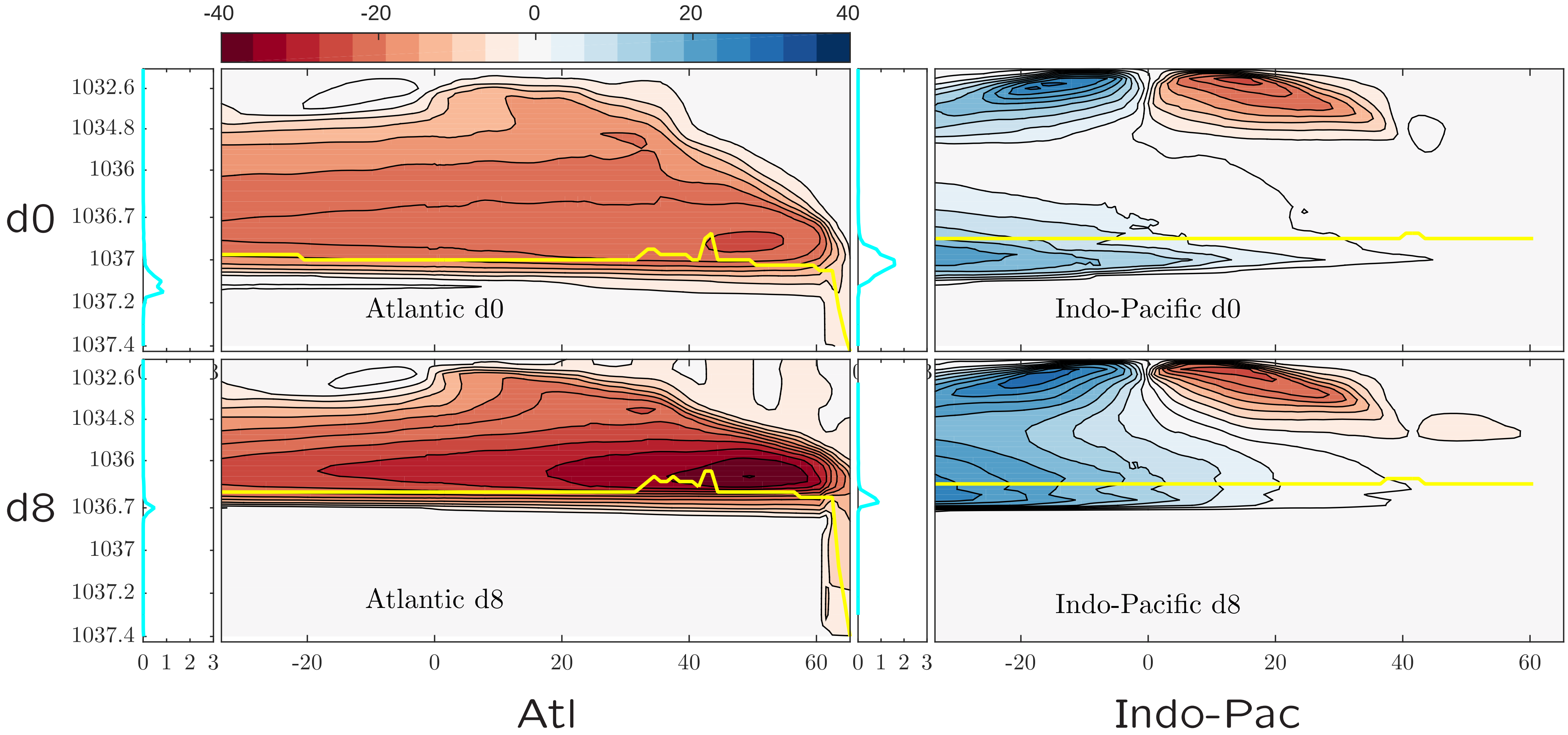
Meridional heat transport

- Ocean heat transport increases with increasing κ_0

- Atmospheric heat transport decreases

- Almost no inrease of total heat transport

Basin overturning $\psi(lat, \sigma_2)$



Changes from d0 to d8

Atlantic

	overturning (ψ_{max})	heat transport ($\psi_{max}\Delta T$)
20°N	+40%	+25% (+0.3 PW)
20°S	+25%	+10% (+0.1 PW)

Larger heat transport because of stronger overturning, though temperature contrast is smaller

Changes from d0 to d8

Indo-Pacific

	overturning (ψ_{max})	heat transport ($\psi_{max}\Delta T$)
20°N	$+$ 5%	$-$15% ($-$0.1 PW)
20°S	$+$15%	$+$40% ($+$0.4 PW)

- 20°N: smaller heat transport because of smaller temperature contrast

- 20°S: much larger temperature contrast, because upper and lower parts get more connected

Conclusions

Larger κ_0, mainly affecting lower thermocline, gives:

- larger N and smaller κ in the deep ocean
- buoyancy flux $< \kappa N^2 >$ increases almost uniformly
- warmer climate (in both hemispheres) and smaller albedo

Conclusions (cont.)

- both deep global overturning cells scale with mixing energy as $\psi \sim (\kappa N^2)^{1/2}$

- ocean heat transport increases with increasing κ_0, compensated by decreasing atmospheric transport

- increasing Atlantic heat transport is mainly caused by stronger overturning

- increasing South Indo-Pacific heat transport is mainly caused by larger ΔT from stronger upwelling through thermocline