

# 2nd US AMOC Meeting

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## A coupled model-observation comparison of the Atlantic heat transport associated with the AMOC

**GFDL/NOAA/Princeton  
University**

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**RSMAS**

*Bill Johns*



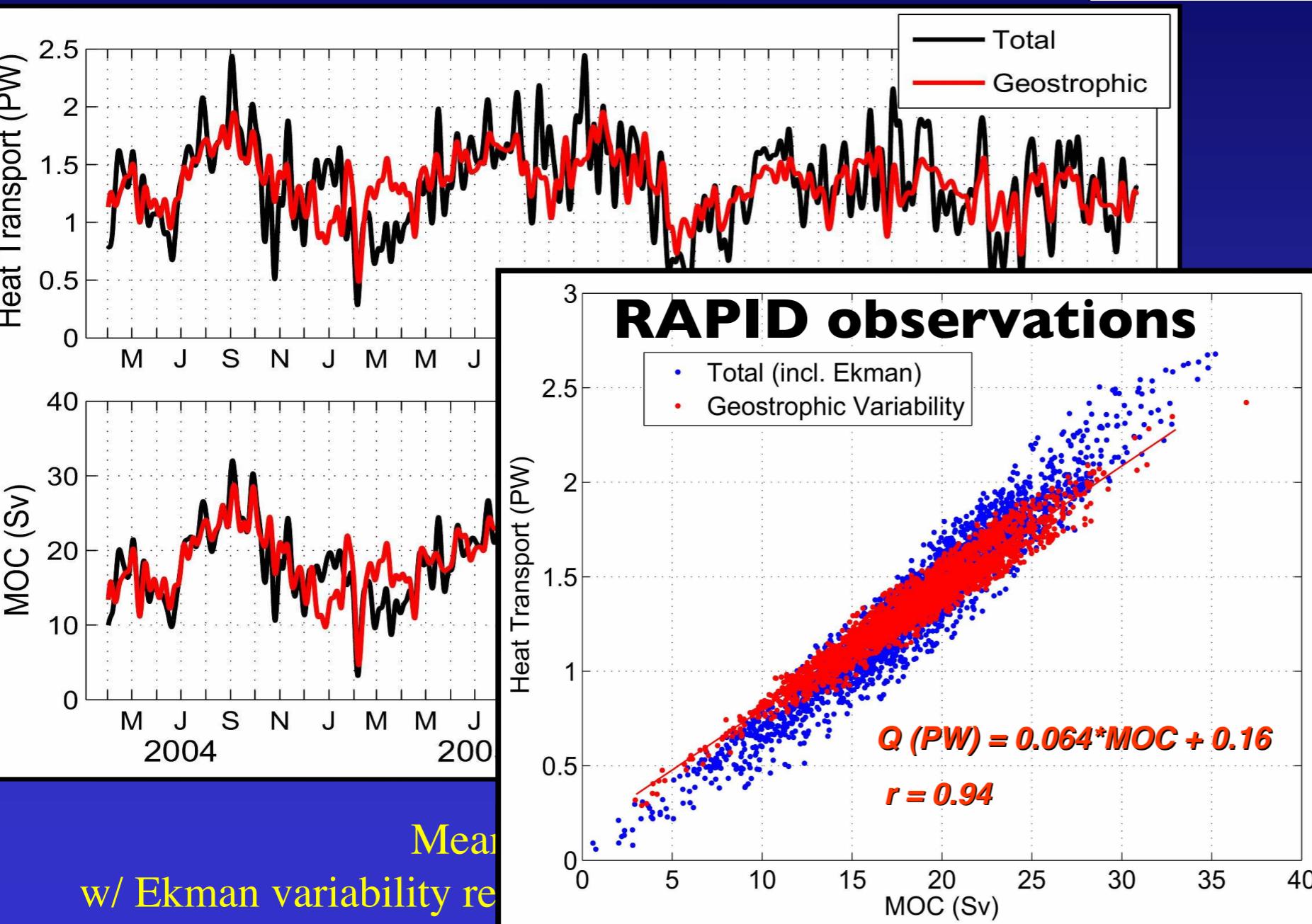
**GFDL**

Geophysical  
Fluid  
Dynamics  
Laboratory

# Motivations: What sets the amplitude of the Meridional Heat Transport (MHT)?

Heat Transport and MOC Variability  
(w and w/out Ekman contribution)

$$Q_{\text{net}} = 1.33 \pm 0.40 \text{ PW}$$



in latest  
observations

but less than IPW  
in most coupled  
models  
(CMIP Jia 2003)

$$Q_{\text{overturning}} = \rho_0 C_p * \text{MOC} * \Delta T$$

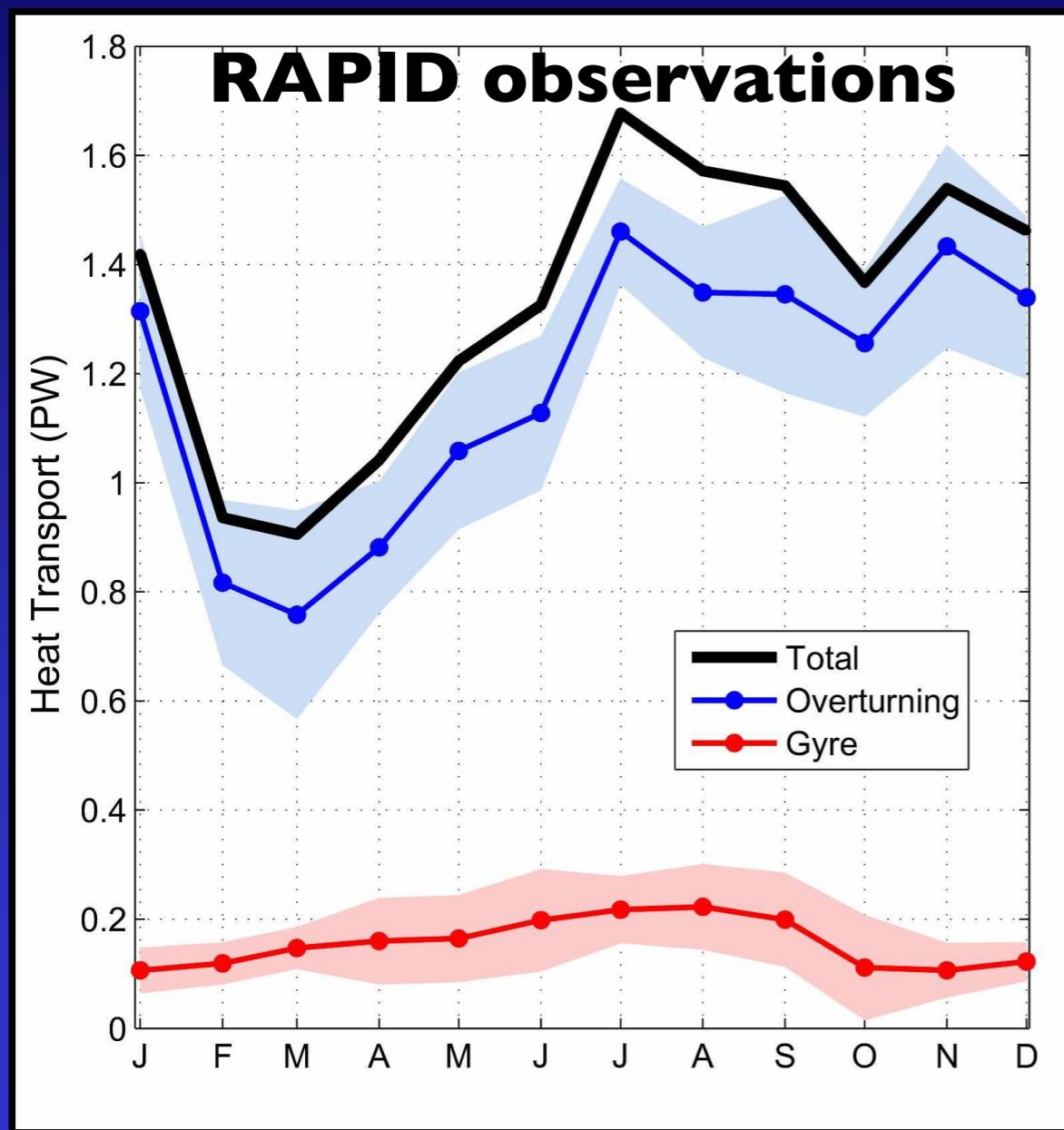
In RAPID:

$$Q_{\text{tot}} = 0.079 * \text{MOC} - 0.123$$

What is the link  
MOC / MHT in  
coupled models?

Strong seasonal cycle in the observed MHT due to the overturning

## Seasonal Cycle of Overturning and Gyre Heat Transports



**Summer maximum (July), late winter minimum (March)**

**peak to peak variation 0.6 PW**

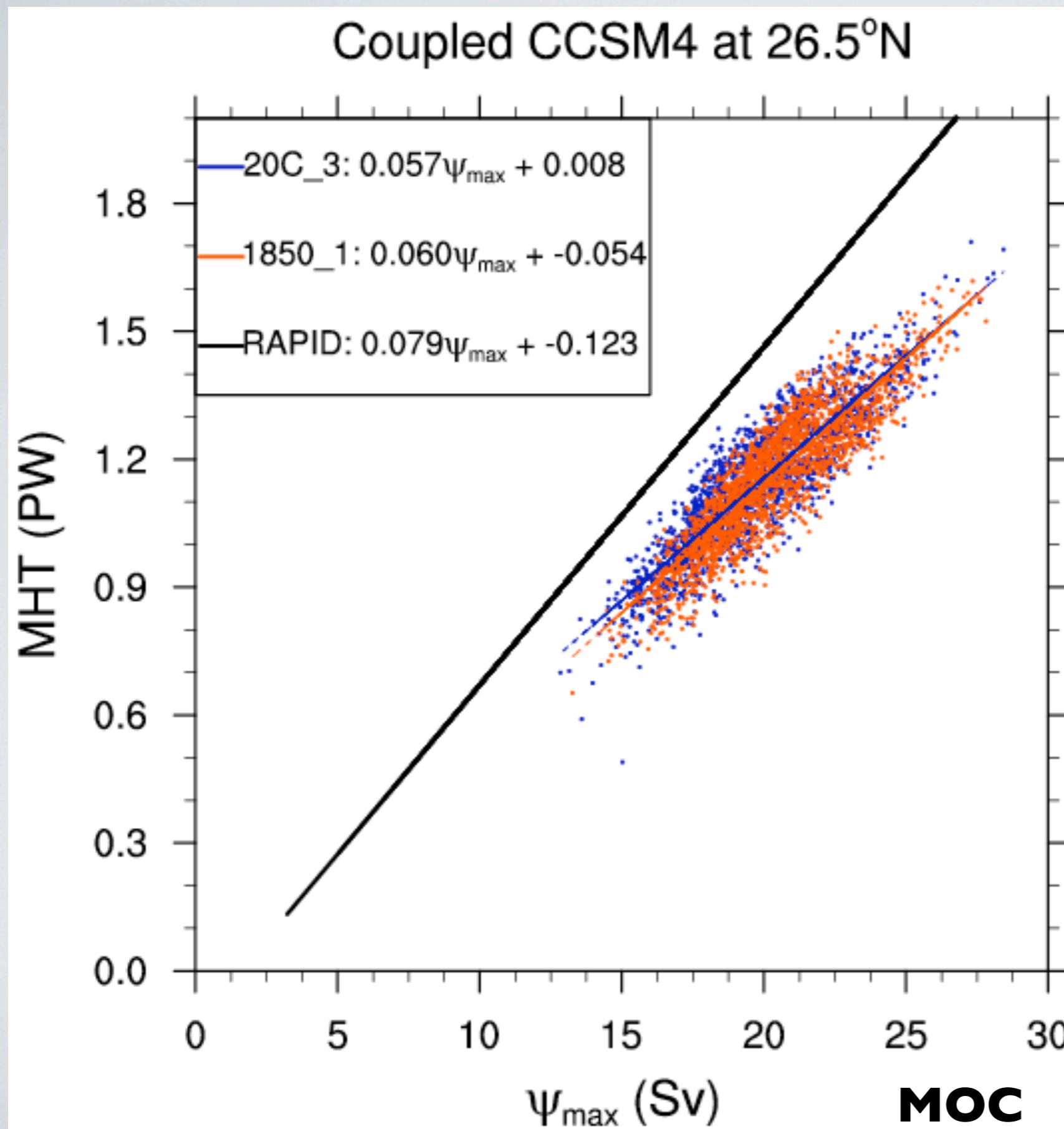
**seasonal cycle set by overturning**

**what is the annual cycle in coupled models?**



**NCAR and GFDL models**

# Link MHT/MOC in the NCAR model



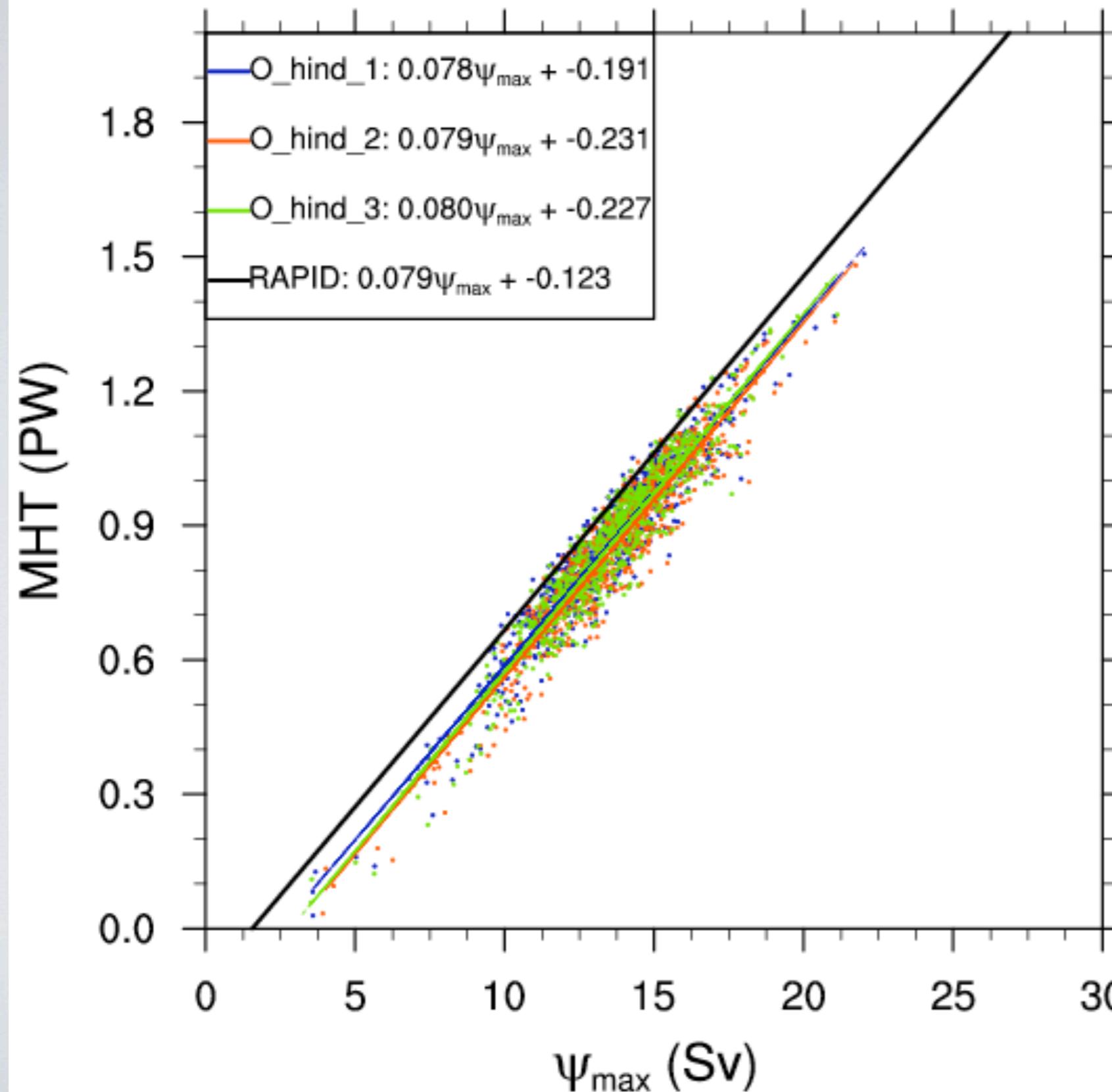
**NCAR CCSM4  
coupled model**

**preindustrial and  
present day simulations  
(156yr mean 1850-2005)  
compared to RAPID  
observations**

**same slope  
smaller than RAPID**

# Link MHT/MOC in the NCAR model

CCSM4 ocean-only hindcasts at 26.5°N



**NCAR CCSM4  
ocean-only model**

**60yr hindcasts  
(1948-2007)**

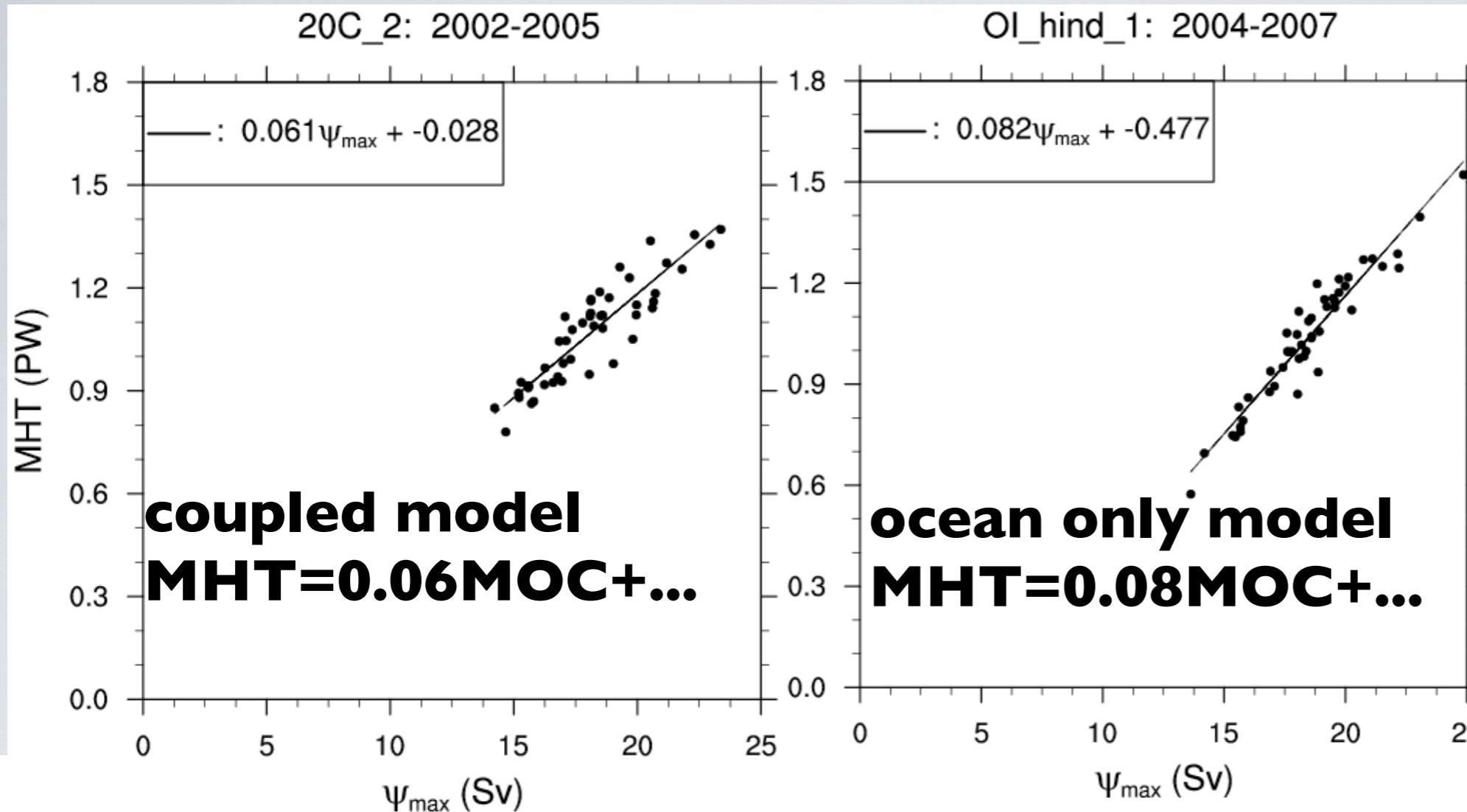
**with different surface  
salinity restoring**

**weak medium strong**

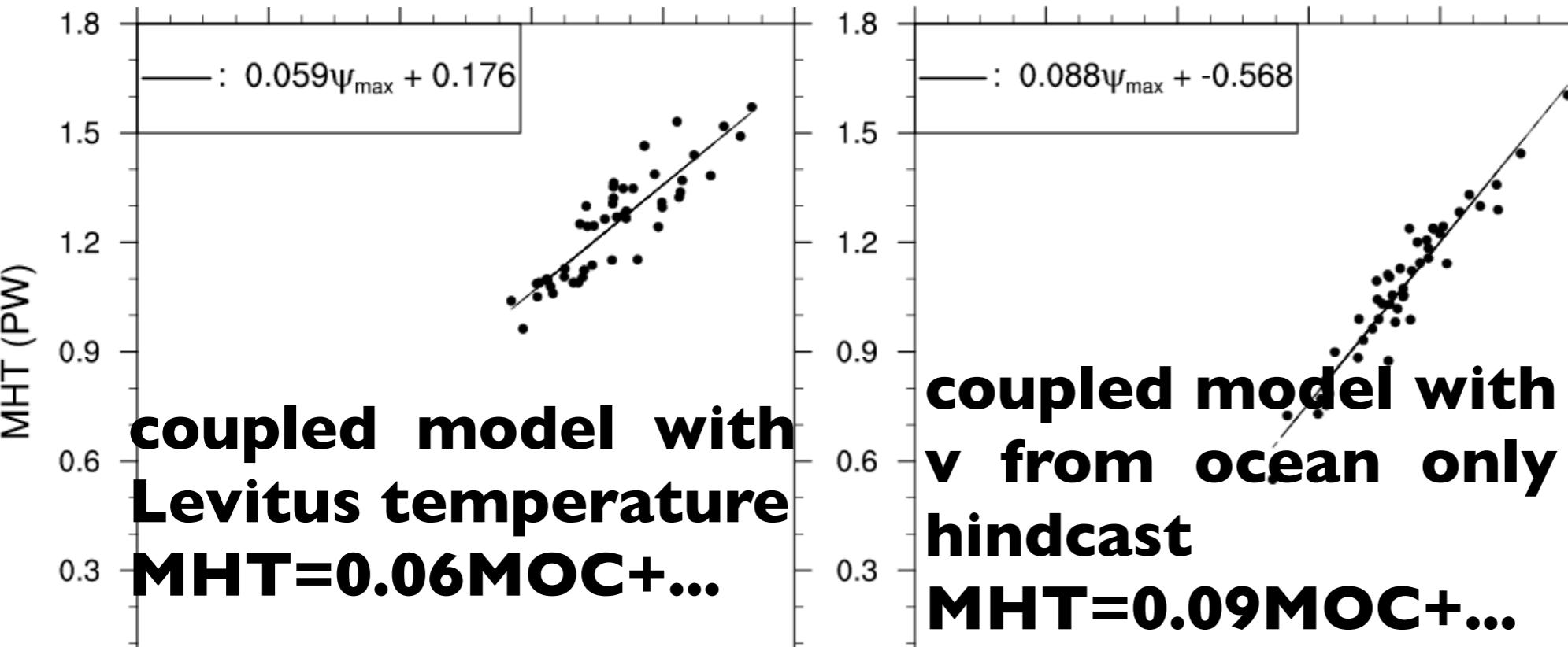
**slope comparable to  
RAPID**

**more negative  
y-intercepts**

# Link MHT/MOC in the NCAR model

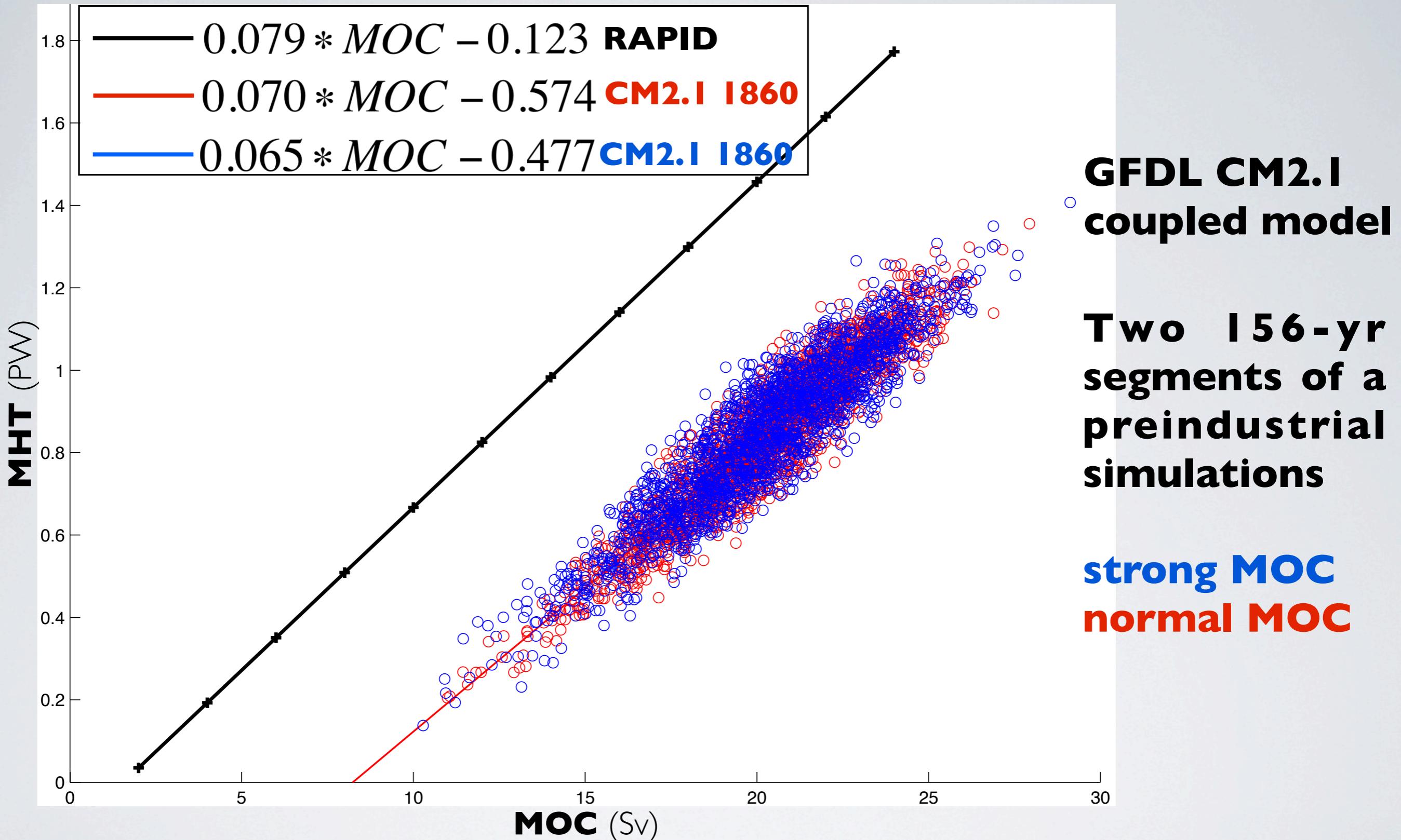


**smaller slope than RAPID: why? error in v? error in T?**



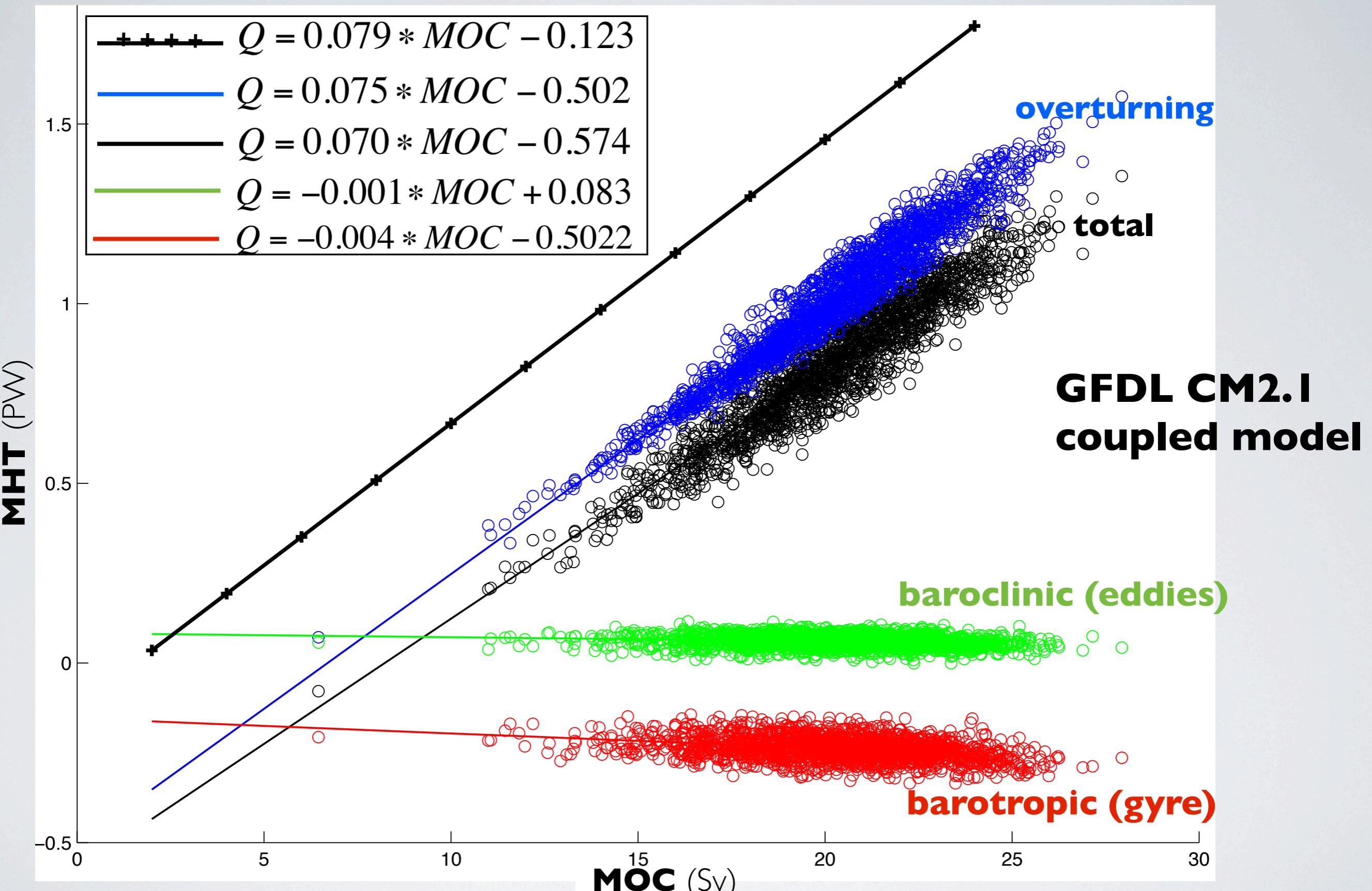
**The error in the MHT/MOC slope in the NCAR model might result from velocity biases**

# Link MHT/MOC in the GFDL model



Slope MHT/MOC larger than in NCAR but still smaller than RAPID. If we take MOC in density coordinates  $Q = 0.075 * MOC - 0.450$ . Large y-intercept: error in the horizontal circulation transport?

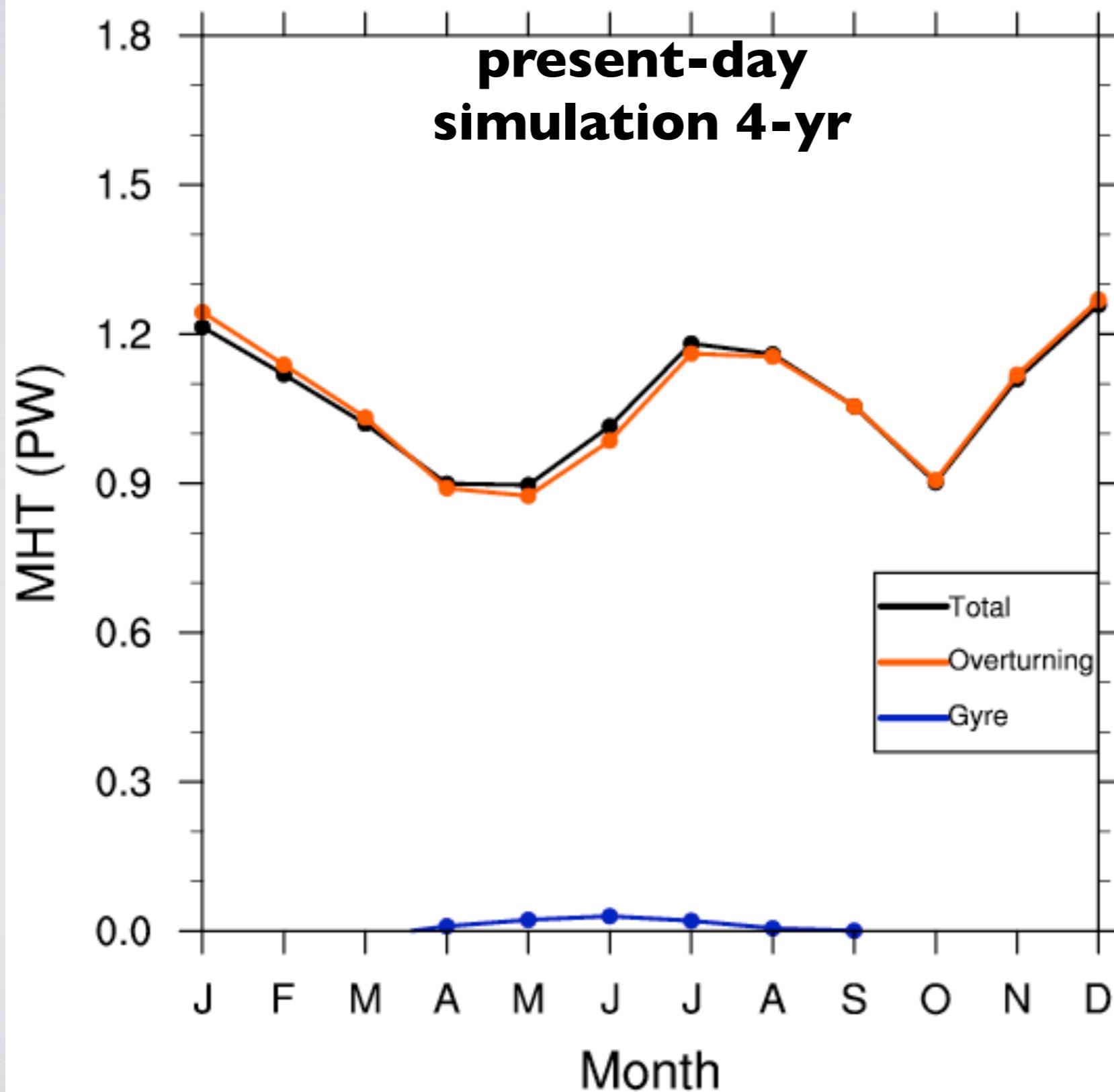
# Link MHT/MOC in the GFDL model



**OVERTURNING component of the MHT closer to observations**

# Seasonal cycle of the MHT in the NCAR model

20C\_2: 2002-2005 mean



**mean MHT  
1.1 PW  
mean MOC  
18.1 Sv**

**good phasing summer  
maximum (August),  
late winter-spring  
minimum**

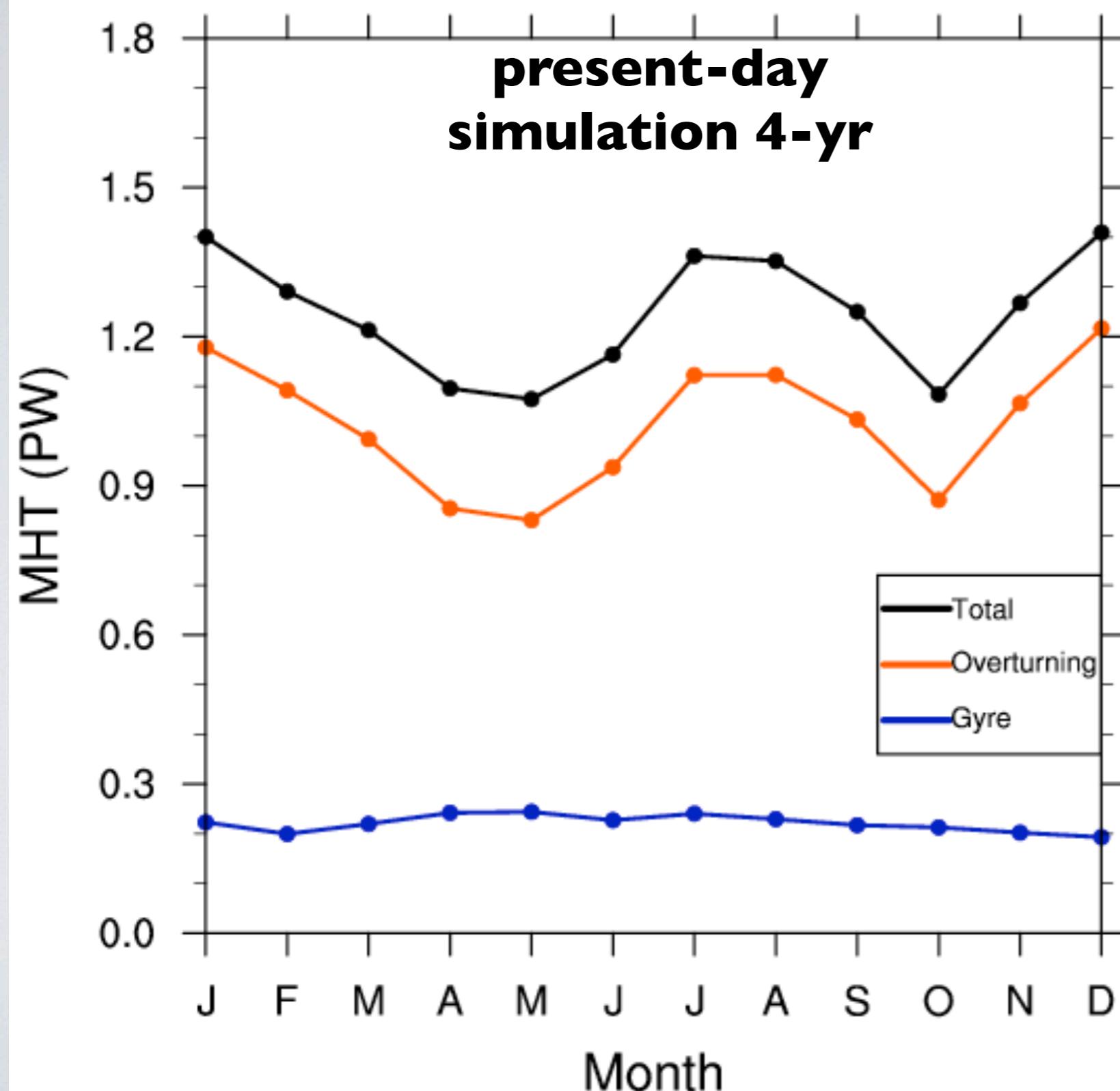
**peak-to-peak  
0.3 PW**

**seasonal cycle set  
by overturning  
no gyre component**

# Seasonal cycle of the MHT in the NCAR model

20C\_2: 2002-2005 mean (Levitus TEMP)

**present-day  
simulation 4-yr**



**The model temperature  
is replaced by WOA  
climatology**

**mean MHT  
1.25PW**

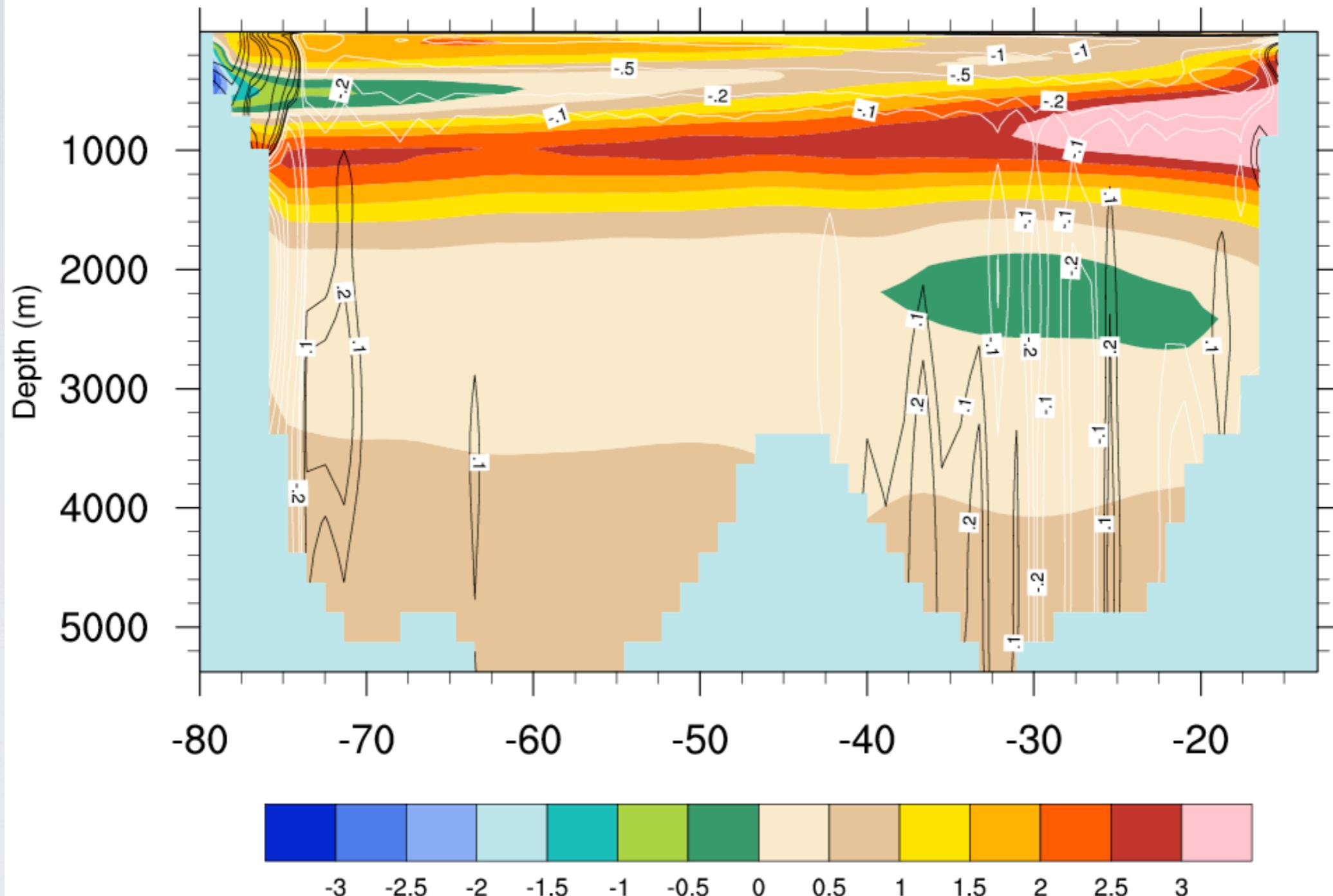
**no change in the  
o overturning transport**

**positive gyre transport**

**positive also in ocean-  
only hindcast**

# Temperature bias in the NCAR model

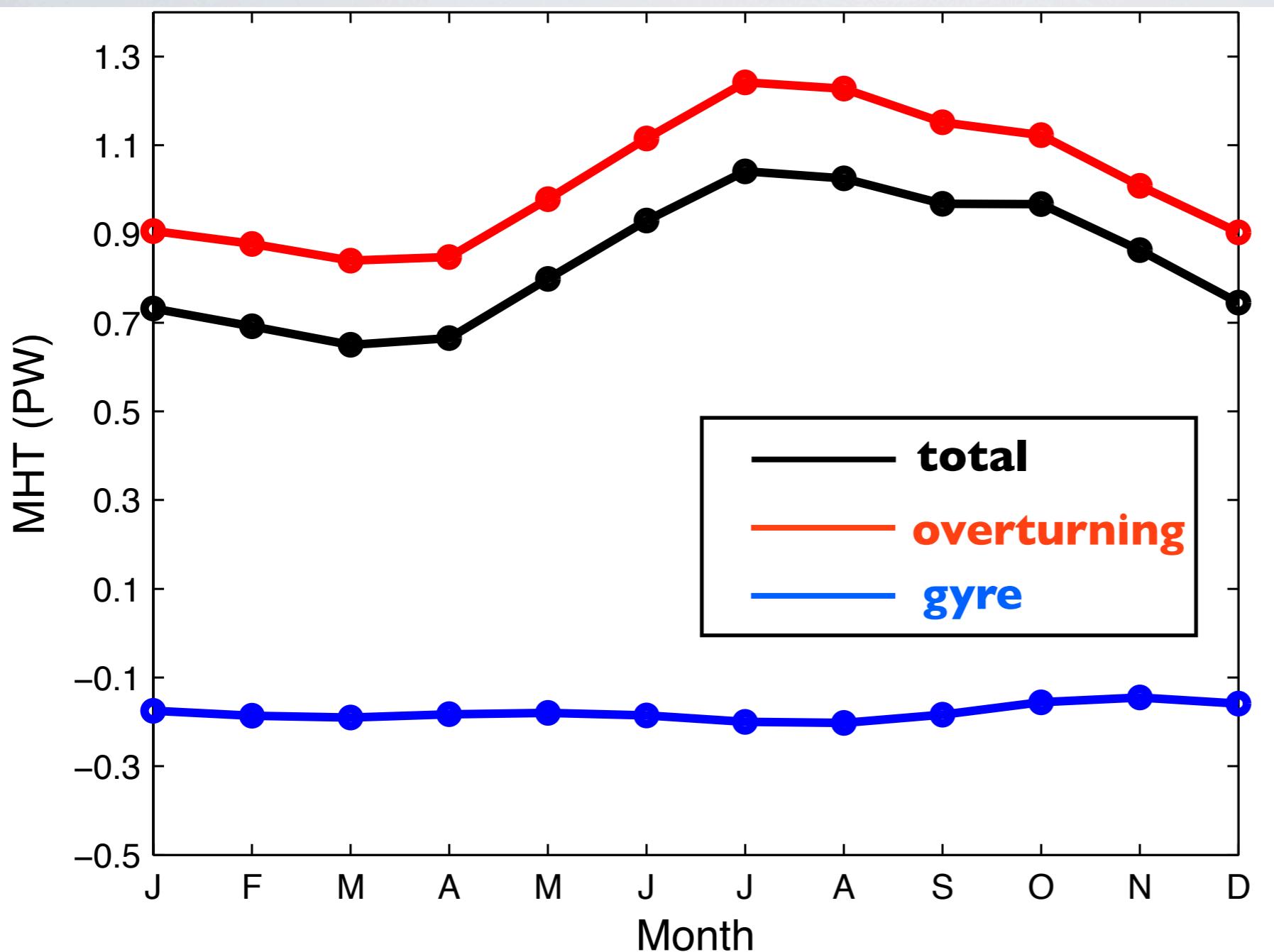
20C\_2: 2002-2005 mean, TEMP anomaly at 26.5N



**Small zonal mean bias: compensated between 400-800m: no influence on the overturning**  
**Too cold western boundary current flow, too warm DWBC**  
**underestimation of the gyre heat transport**

# Seasonal cycle of the MHT in the GFDL model

## Preindustrial simulation



mean MHT  
0.84 PW

(1 PW ovHT)

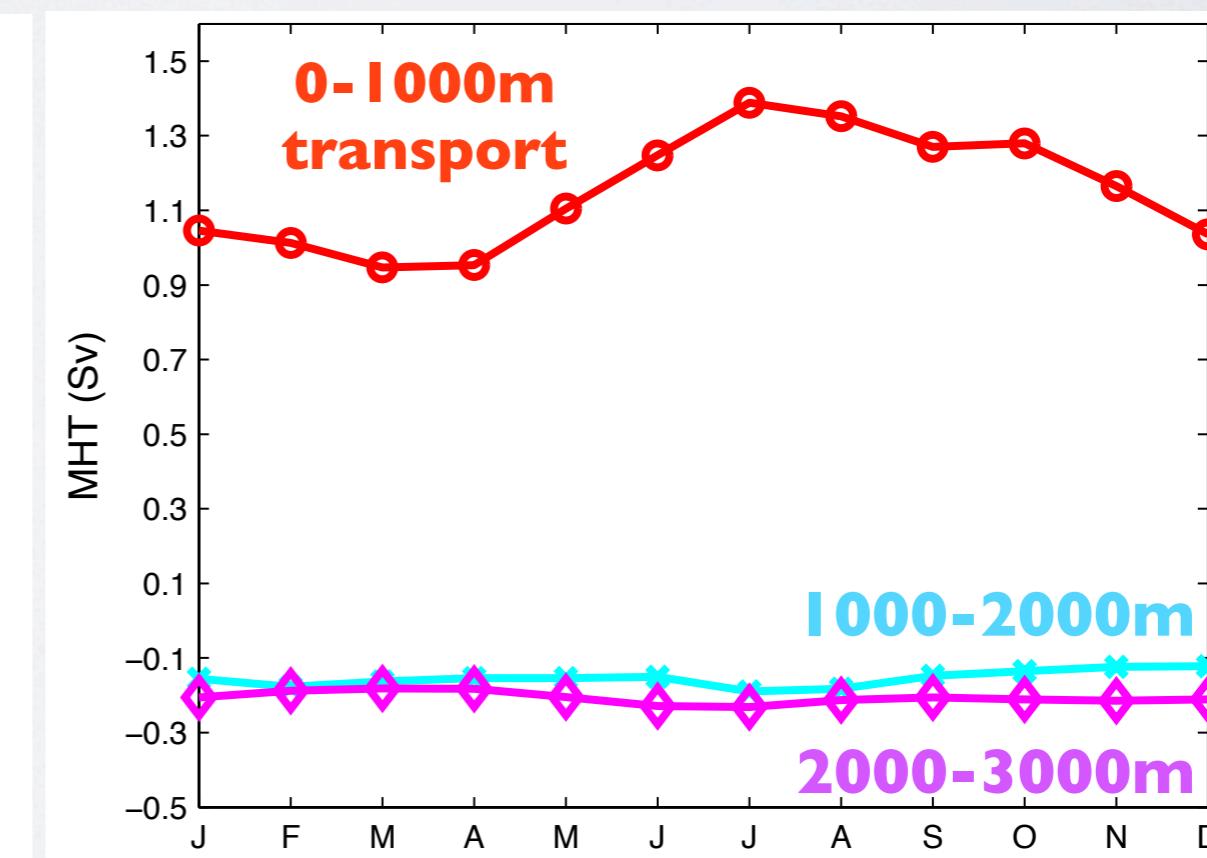
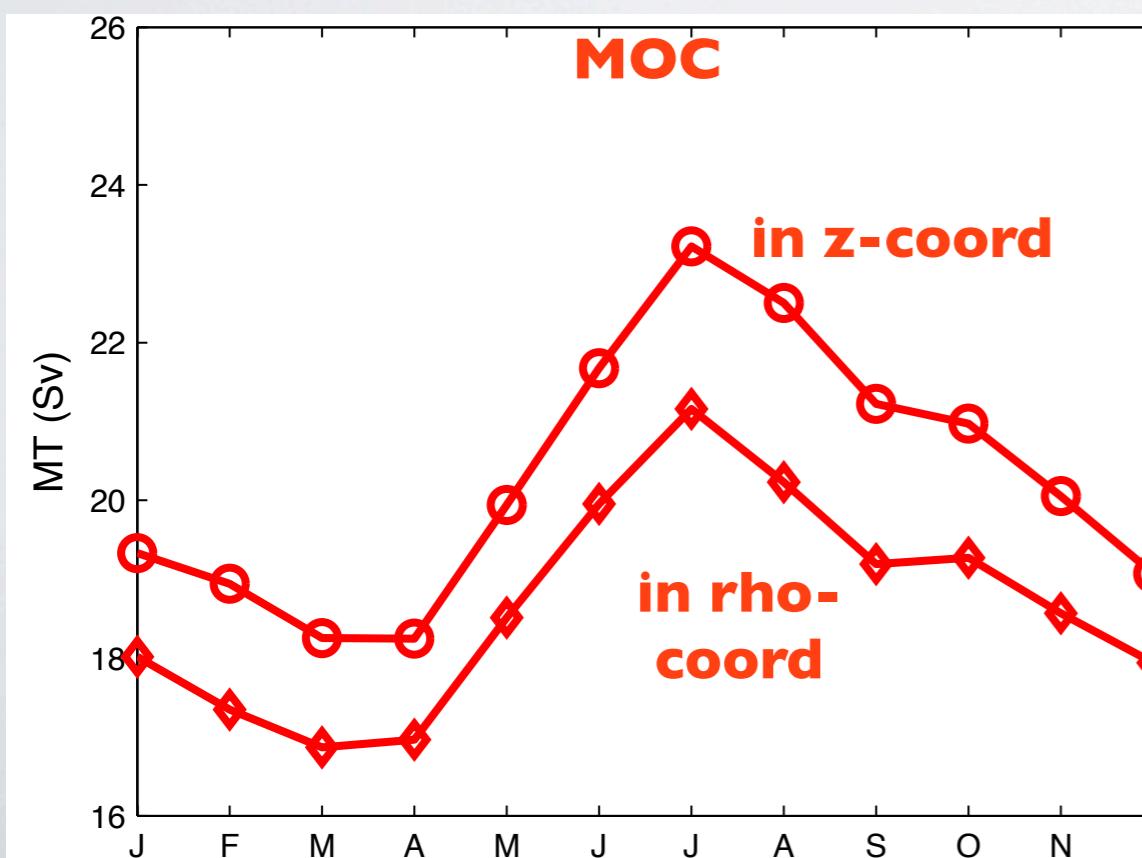
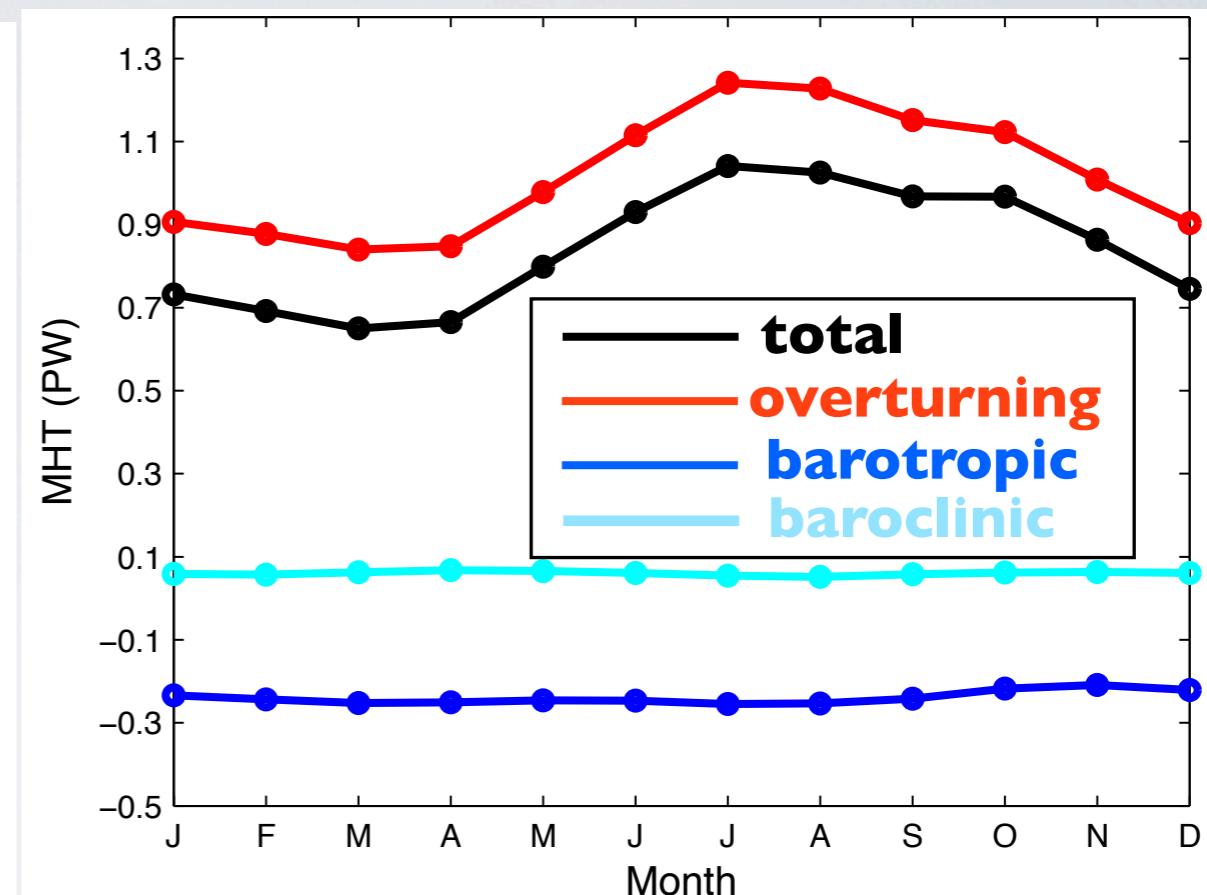
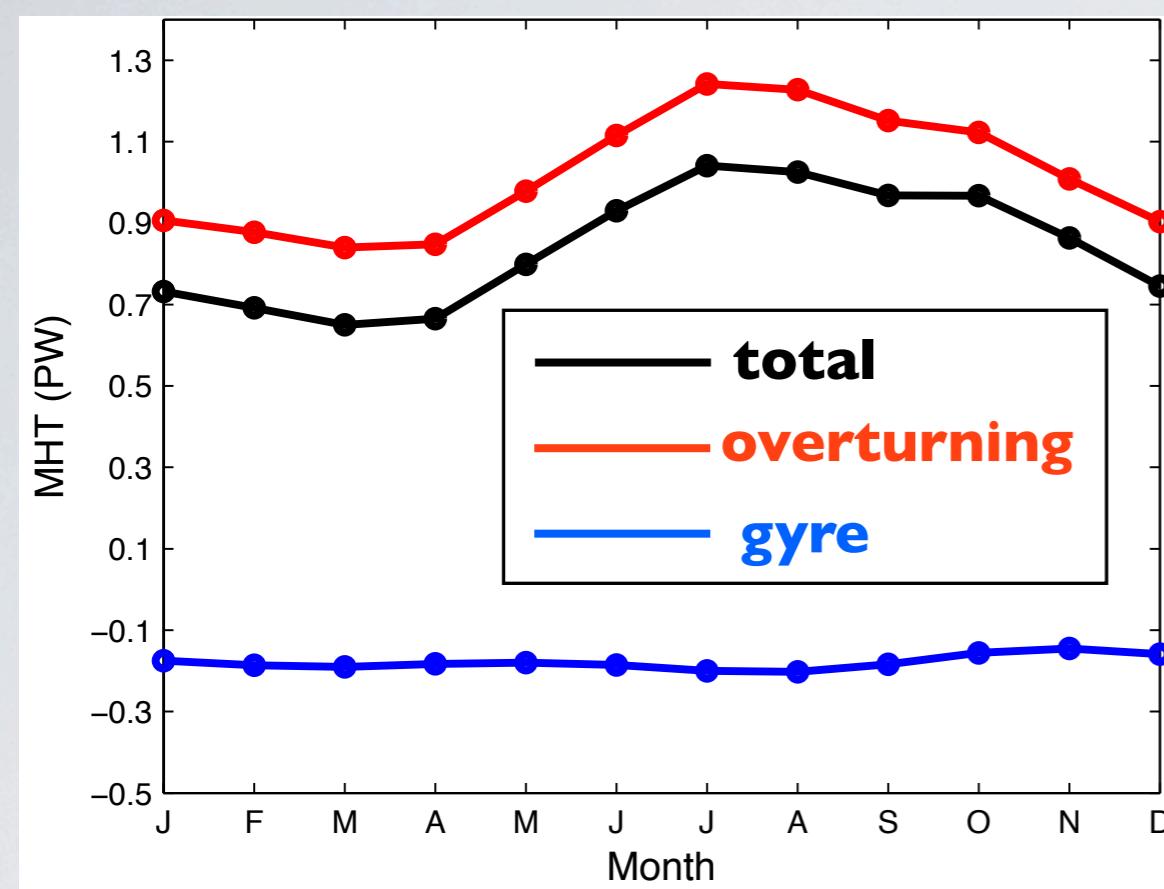
mean MOC  
20Sv

good phasing  
maximum in July,  
secondary peak late  
fall, minimum in  
March

peak-to-peak  
0.4 PW

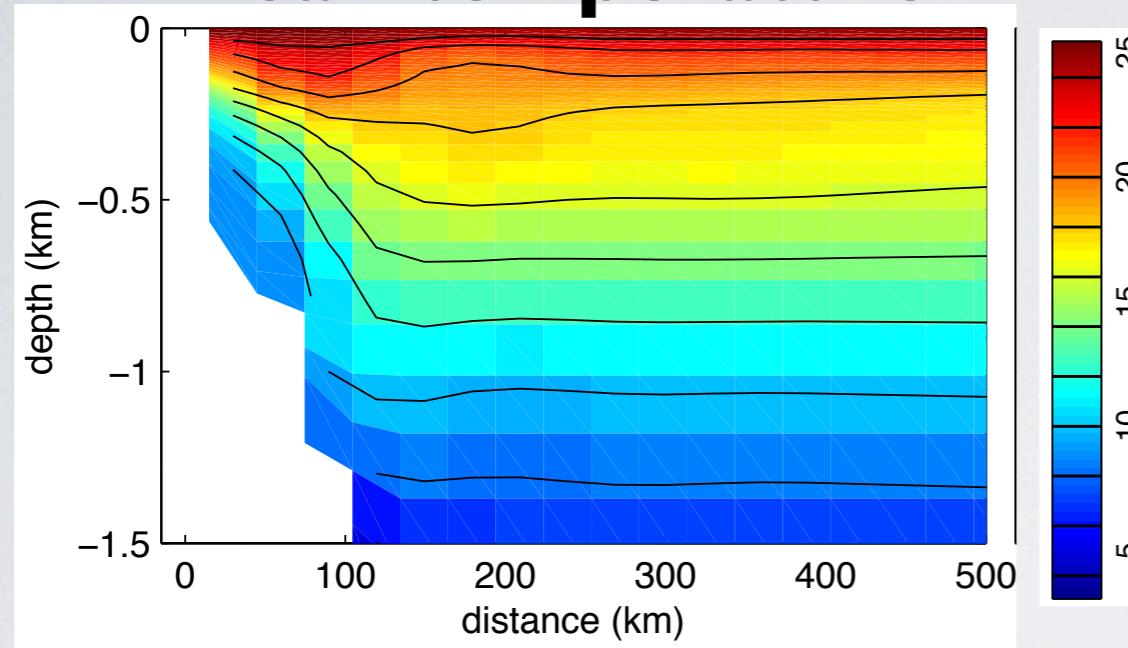
seasonal cycle set  
by overturning  
southward gyre  
transport

# Seasonal cycle of the MHT in the GFDL model

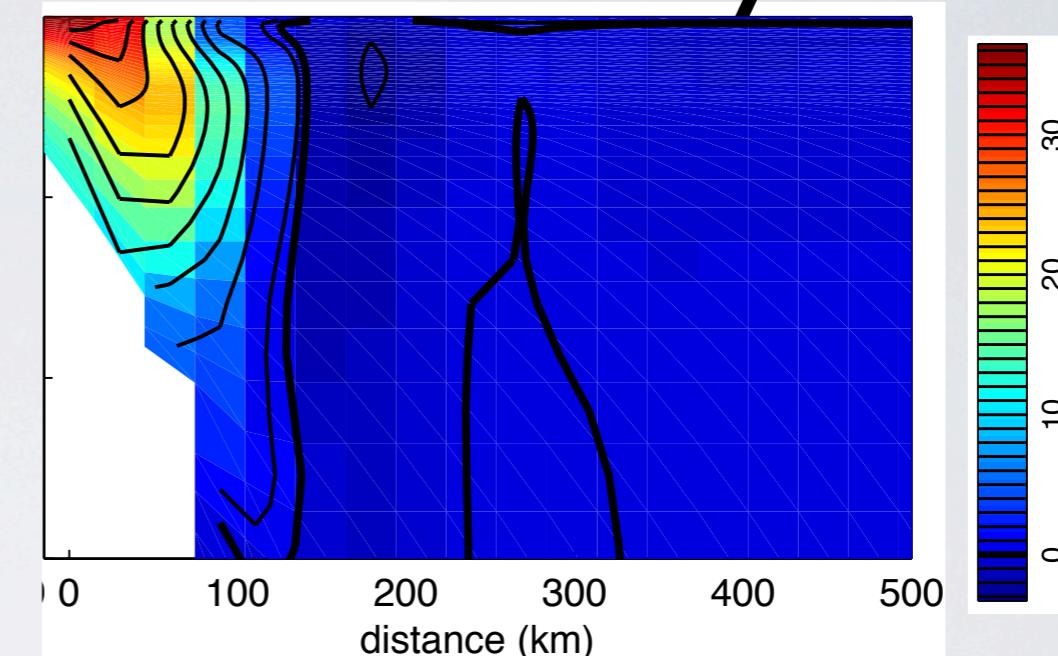


Why do we have a southward transport by the gyre circulation in the GFDL model?

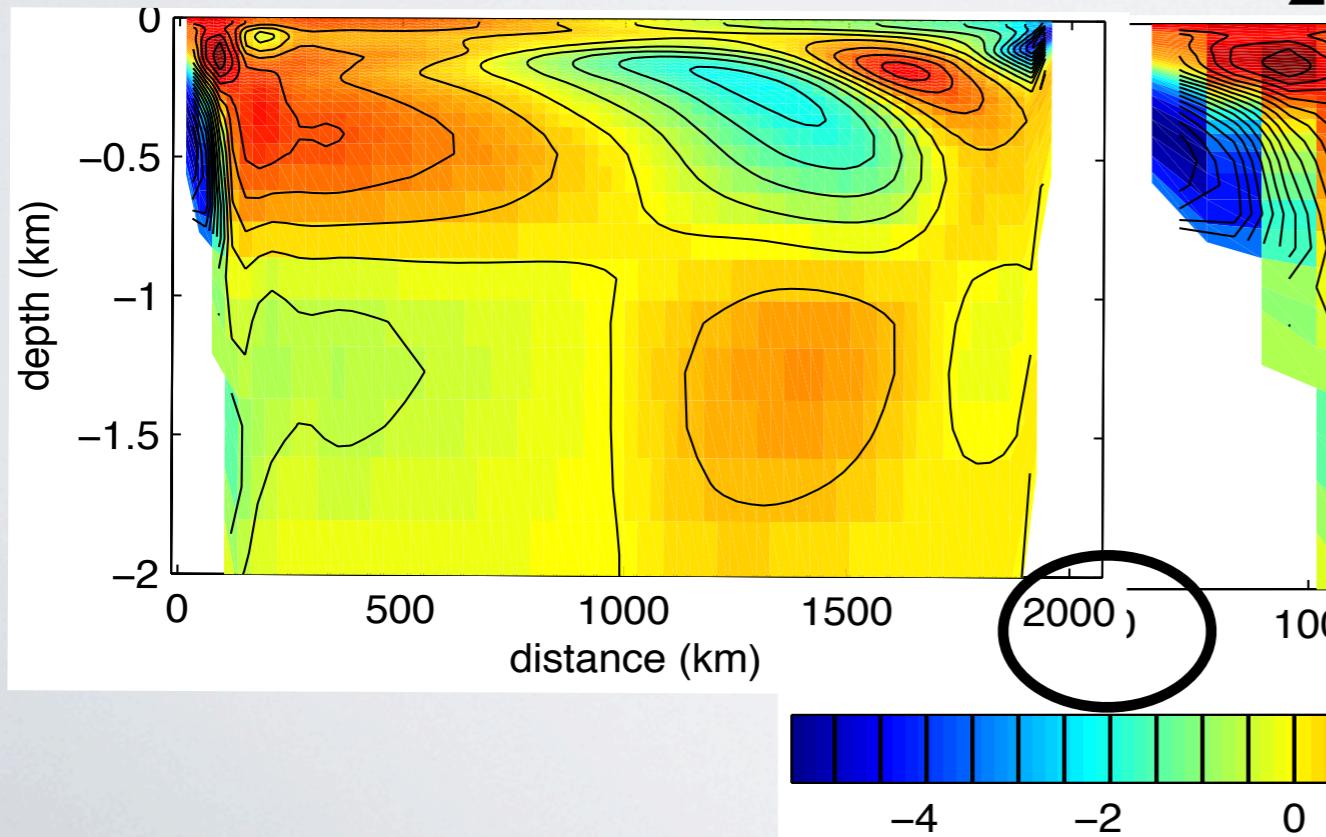
**mean temperature**



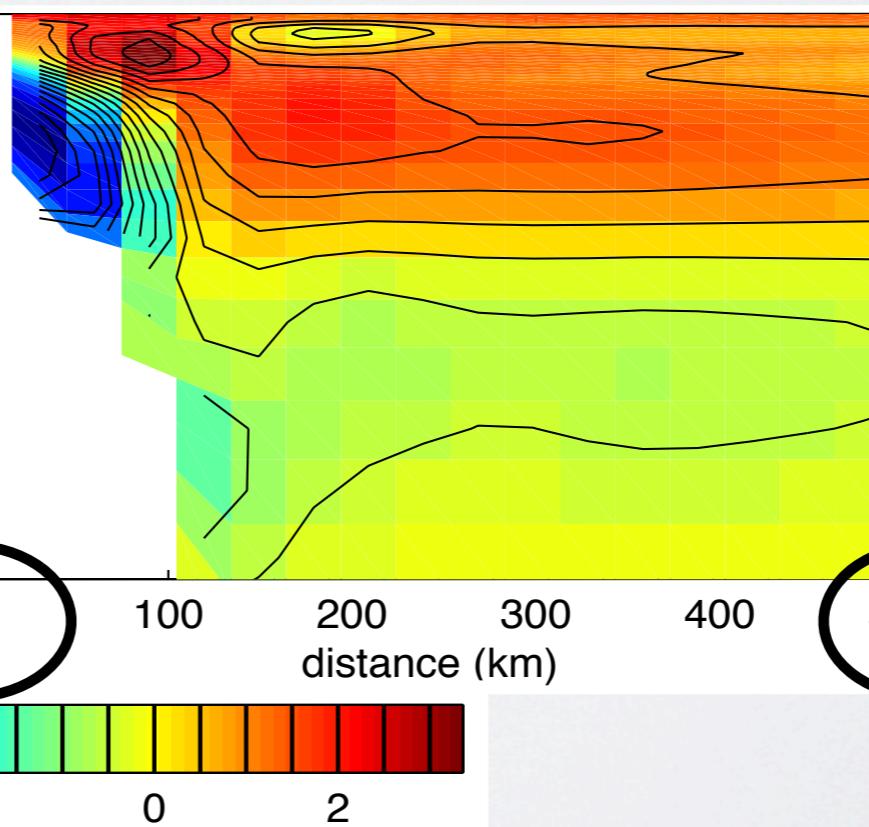
**mean velocity**



**temperature relative to zonal mean 26N  
whole basin**



**zoom on the WBC**

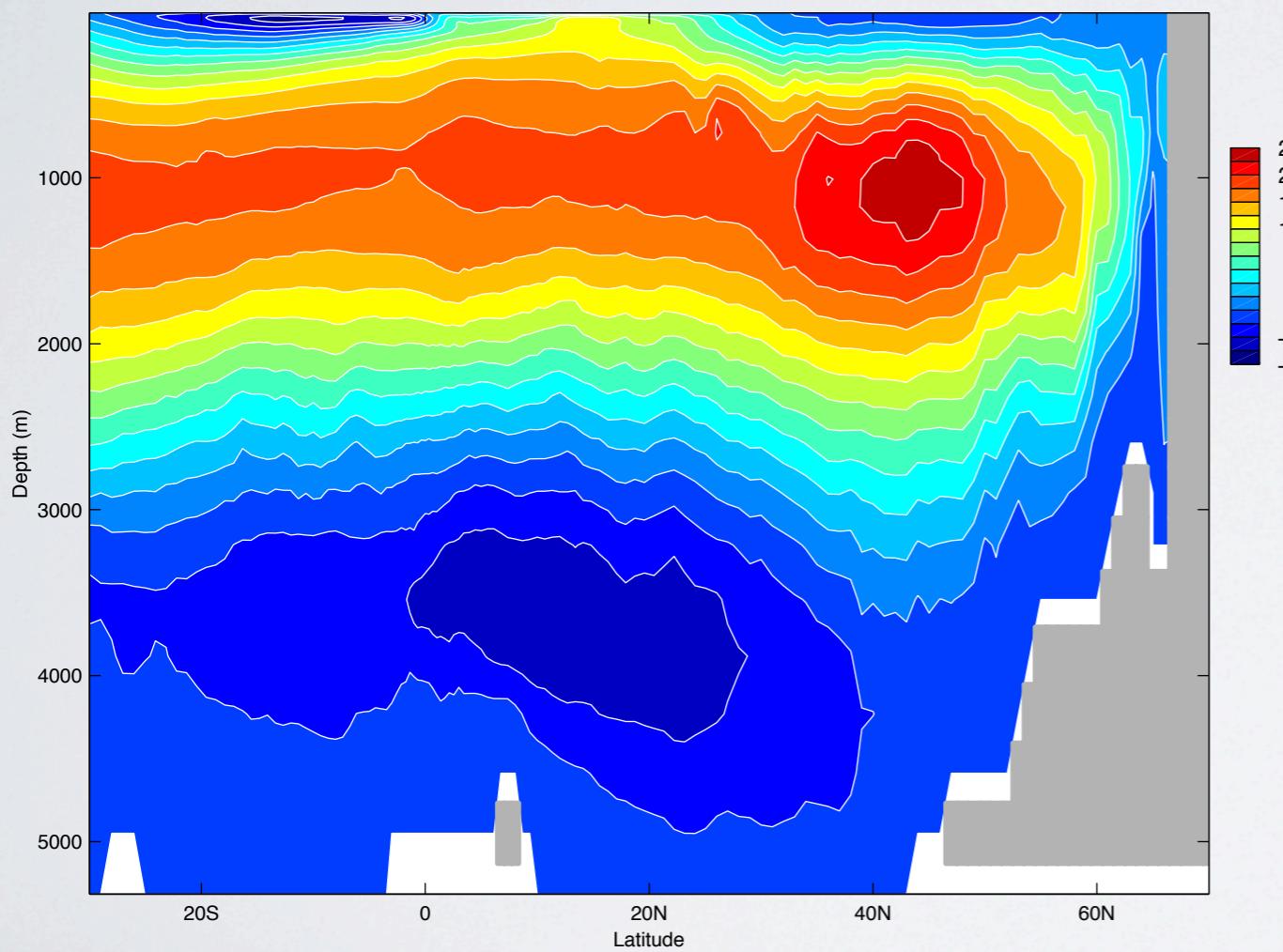


**A too cold WBC  
relative to the  
zonal mean  
leads to a  
southward  
transport**

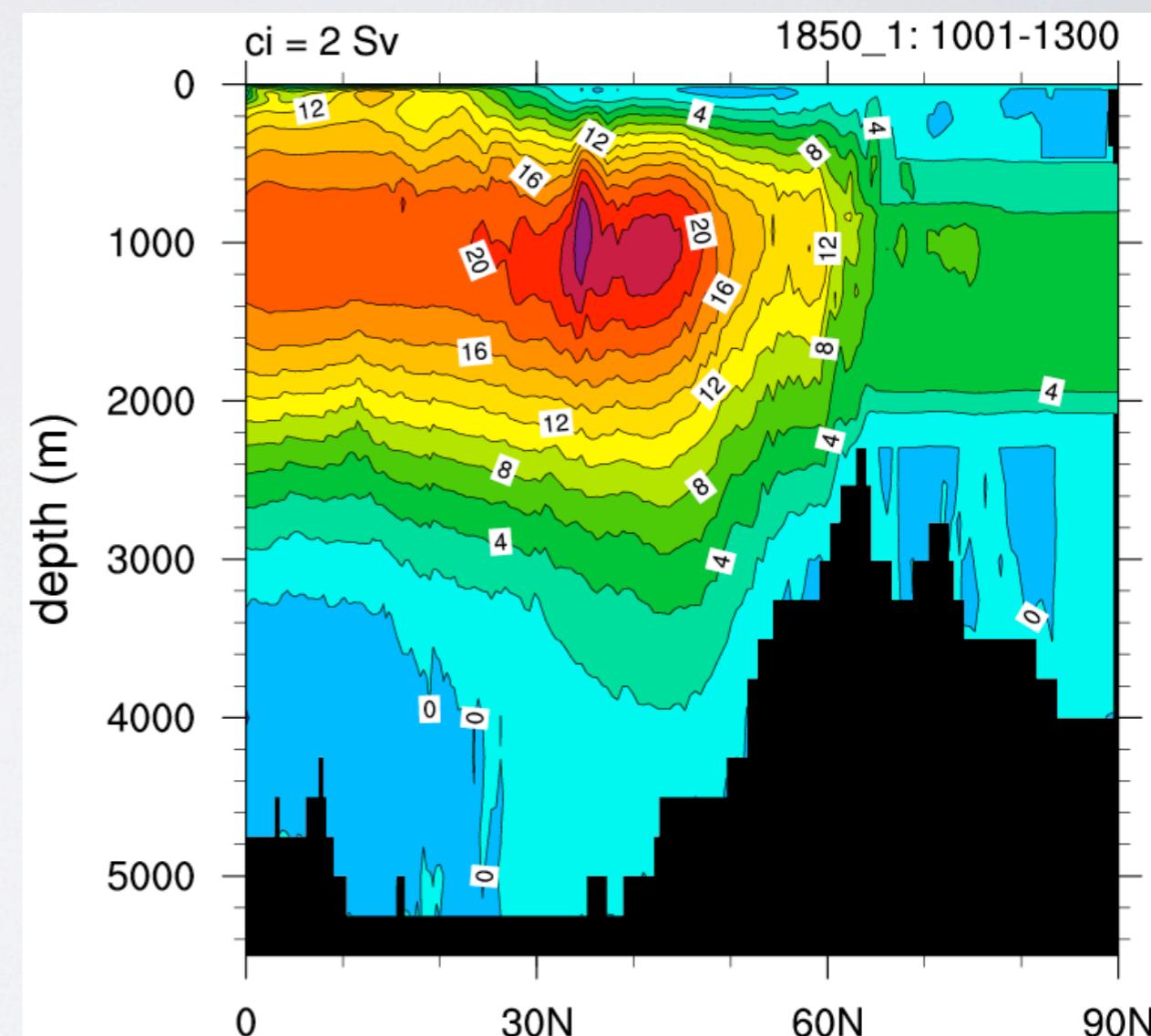
Is 26N representative of the  
whole North Atlantic?

## Mean MOC

### GFDL model

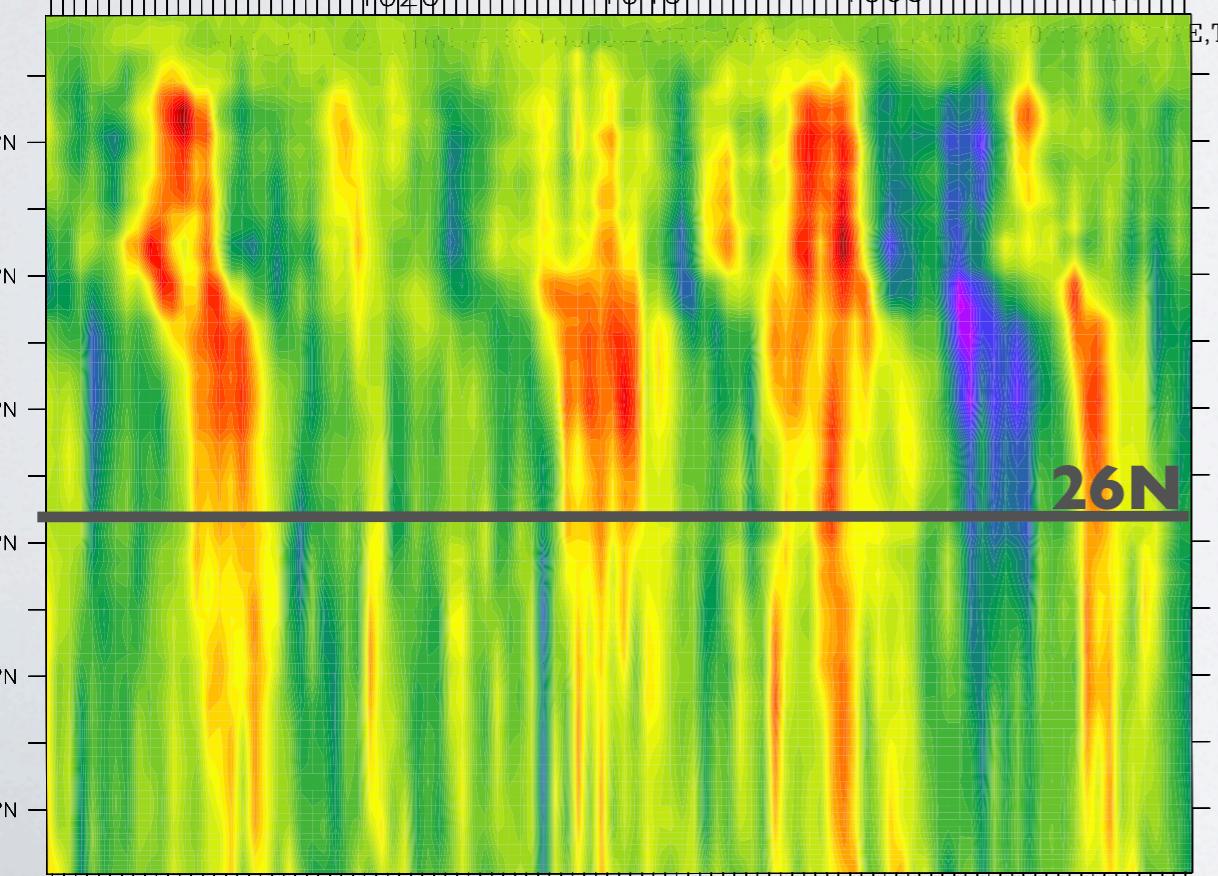
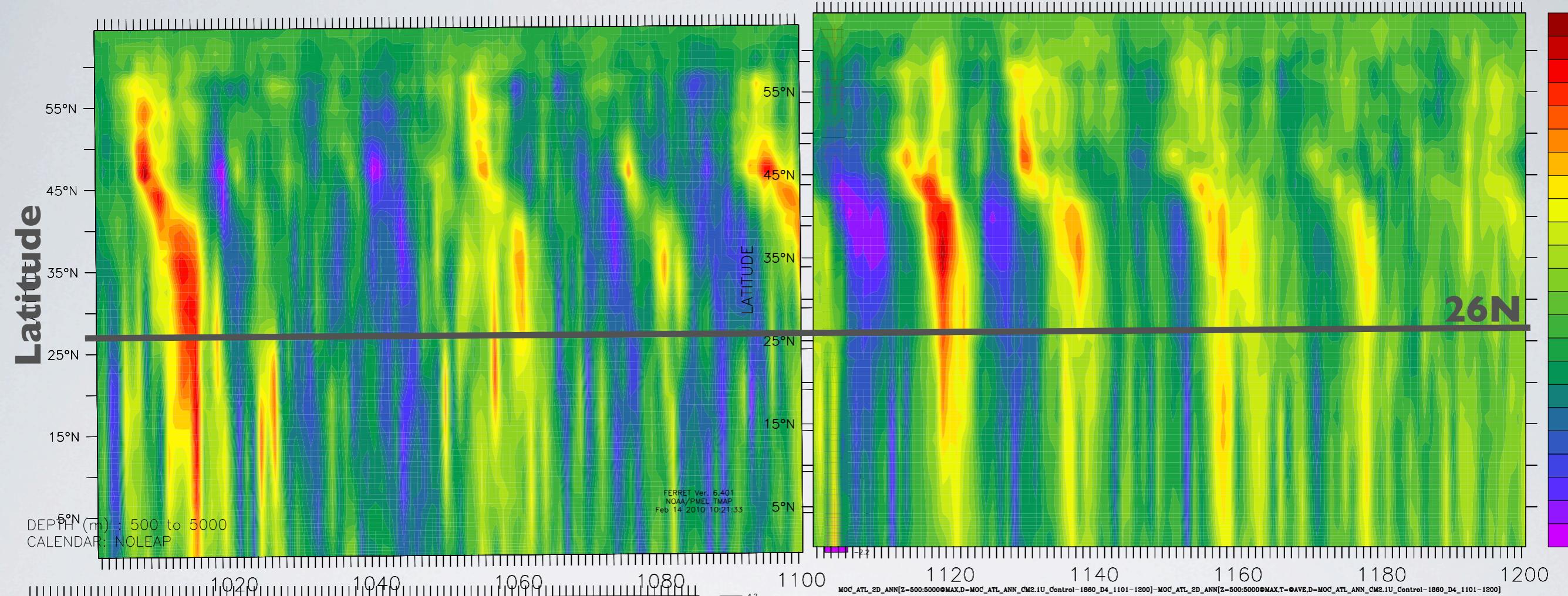


### NCAR model



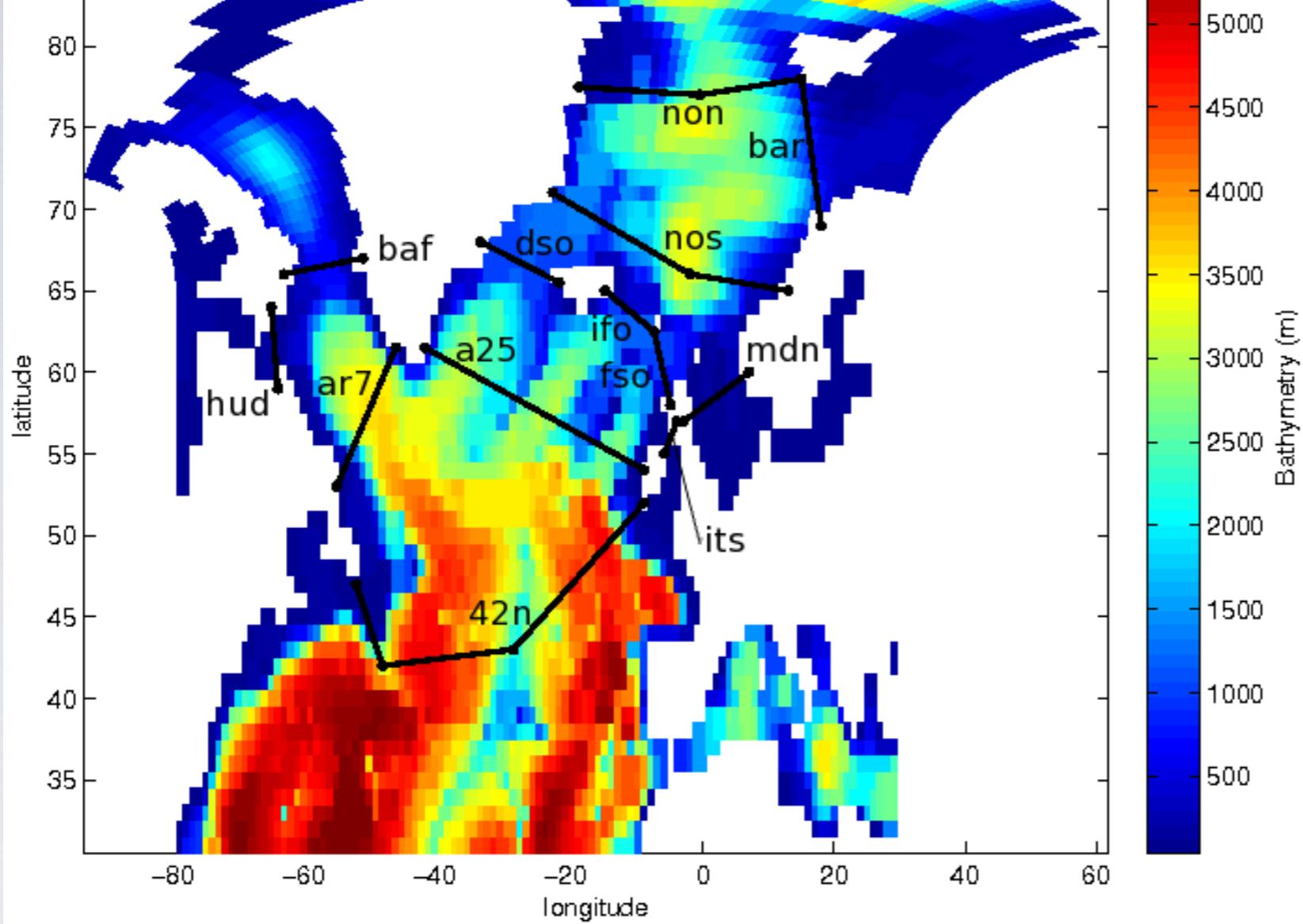
Meridional dependence of the MOC

# Meridional coherence of the MOC: GFDL

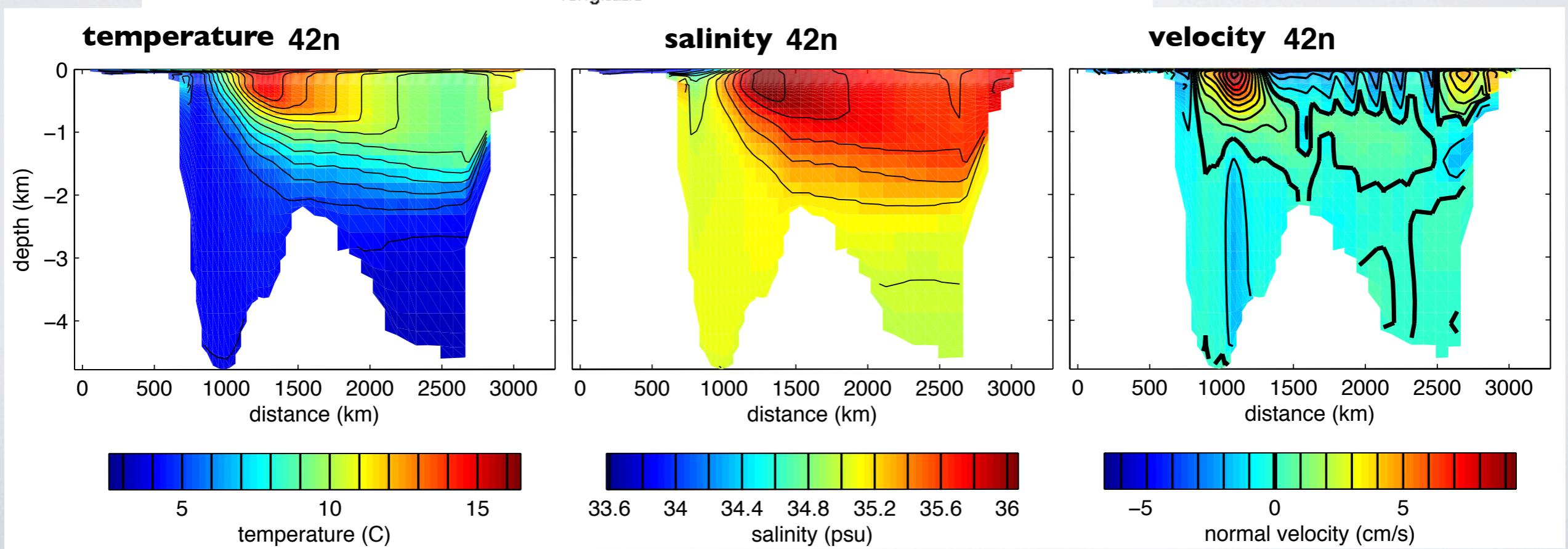


**The maximum of the MOC varies with latitude and time**

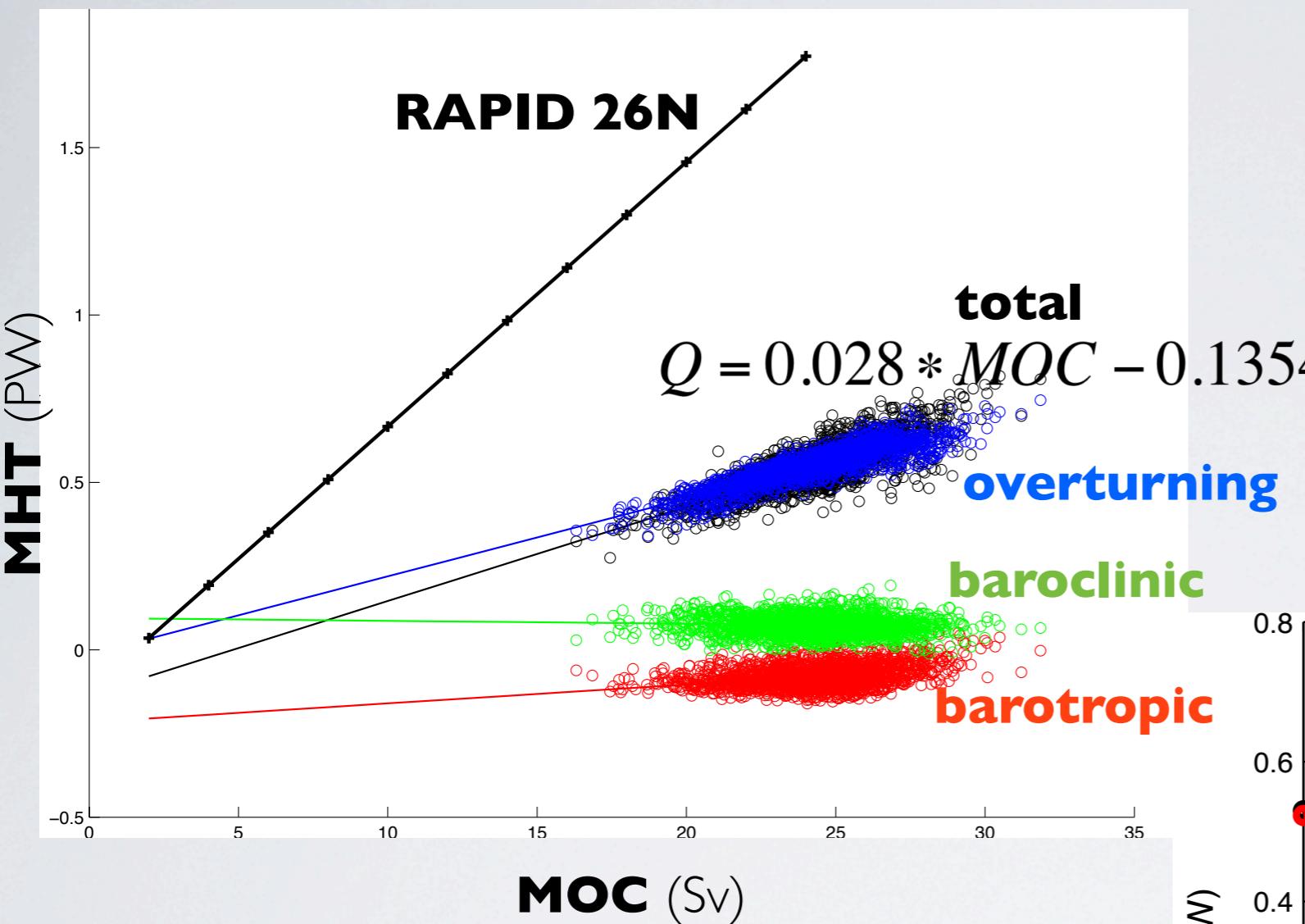
***model dependent...  
Bingham et al. (2007)***



**FCVAR project 2010**  
**Deshayes and Curry**  
**(whoi)**



# Link MHT/MOC at 42N in the GFDL model

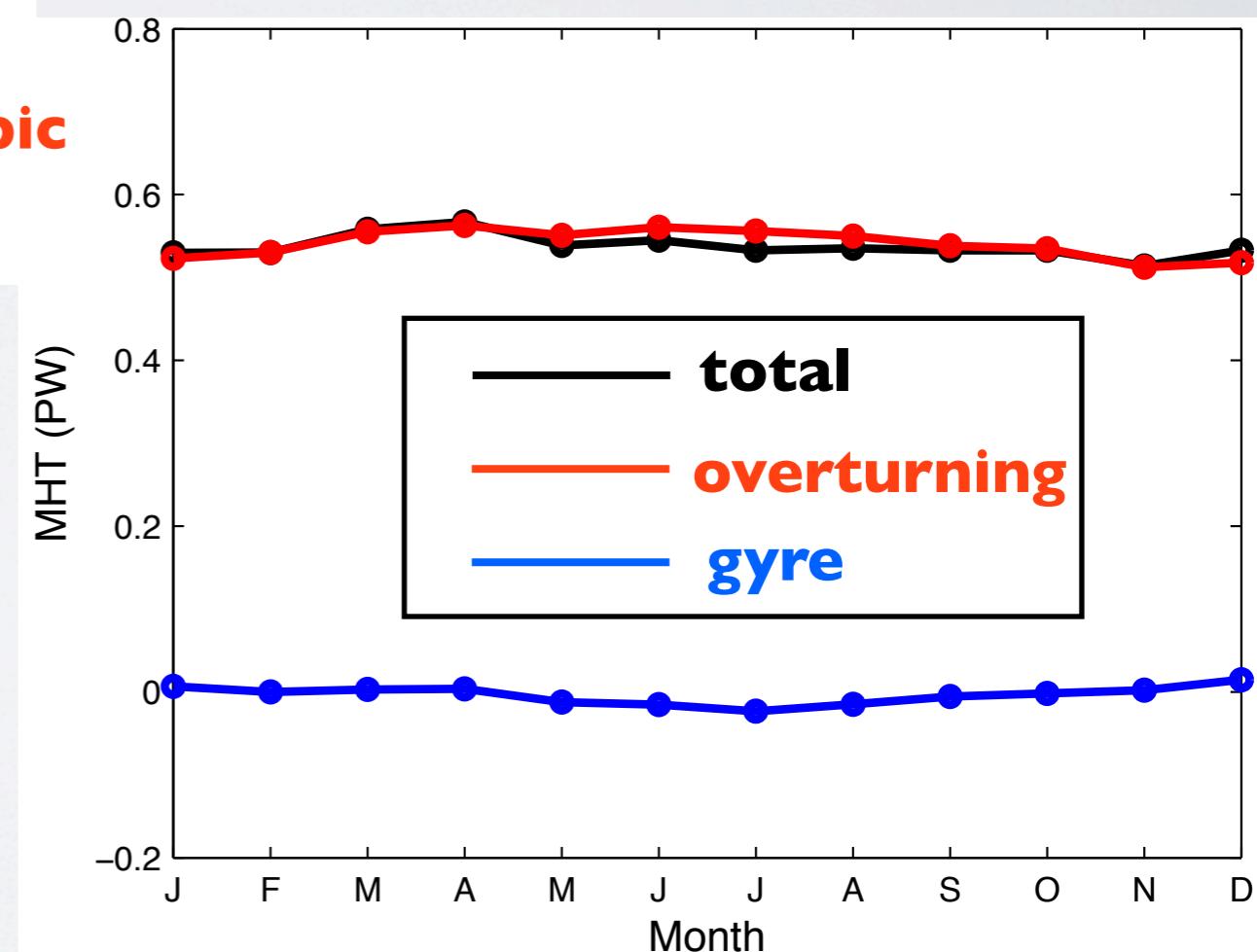


**At 42N, the total heat transport is only due to the overturning  
No seasonal cycle**

**What is the observed  
→ MOC at 42N?**

**mean MHT  
0.5 PW  
mean MOC  
24Sv**

**Stronger MOC but less relevant in terms of heat transport**



# Conclusions

-NCAR and GFDL coupled models reproduce the strong correlation between the MHT and the MOC

- The MOC strength is realistic but a smaller temperature difference between upper and lower layer can reduce the overturning and thus the total transport

-The total transport is weaker than observations primarily because of a bias in the horizontal circulation

Likely due to the poor representation of the western boundary current

-The seasonal cycle of the MHT is well reproduced in both models: right wind stress curl (Kanzow et al. 2010)

-The seasonal variations are largely due to the overturning

-The MHT is maximum at 26N but the MOC in models is stronger in the north. Where is the maximum of the MOC in the observations? Uniform...(SAMOC, ARI9,...)

# Future work

-Same decomposition than rapid: Ekman transport, geostrophic, eddies ...

-The Florida strait current is not resolved: higher resolution models

-Compare models with similar diagnostics at other latitudes/observed sections