Comparing the meridional heat transport at 26.5 N and its relationship with the MOC in two CMIP5 coupled models and in RAPID-array observations

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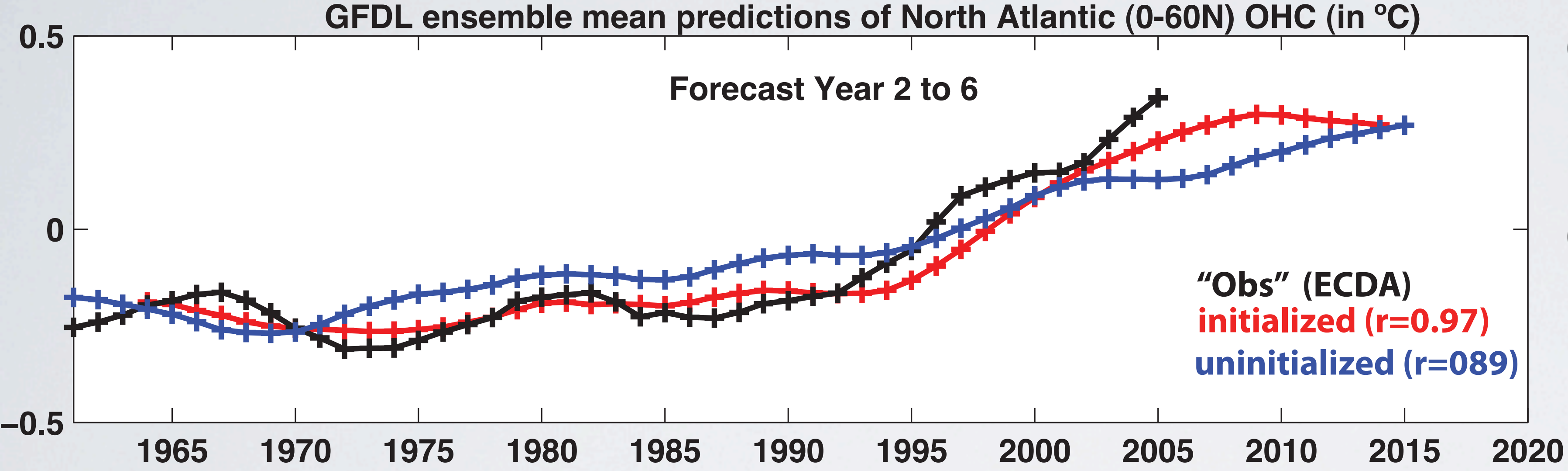
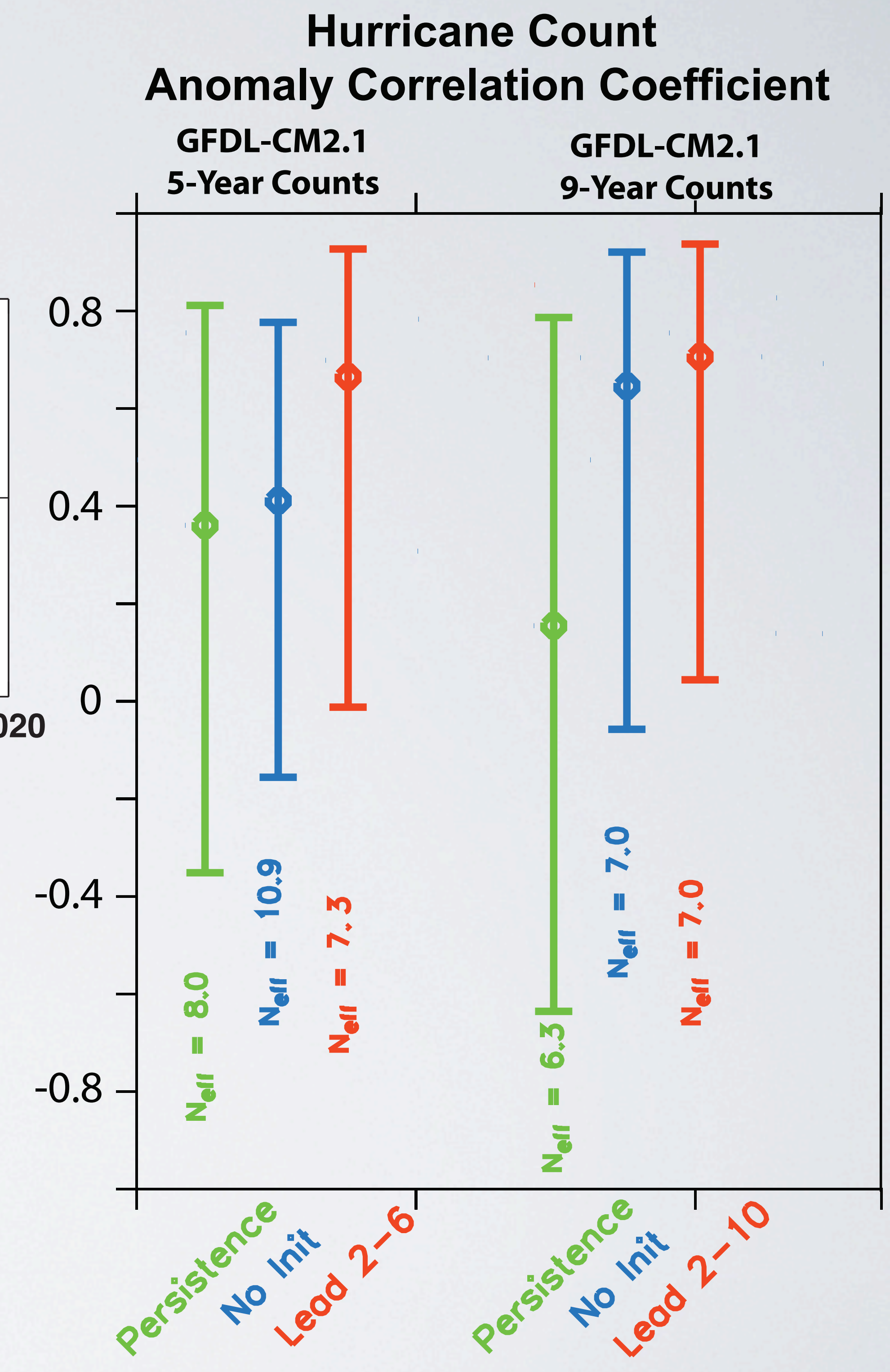
Acknowledgements: Bill Johns (Univ Miami), Steve Yeager (NCAR), Gokhan Danabasoglu (NCAR), Tom Delworth (GFDL), Tony Rosati (GFDL)

WCRP Open Science Conference, Denver, CO
October 24-28, 2011

Motivation: Can we trust CMIP5 decadal predictions?

The largest skill in the initialized decadal predictions appears in the North Atlantic

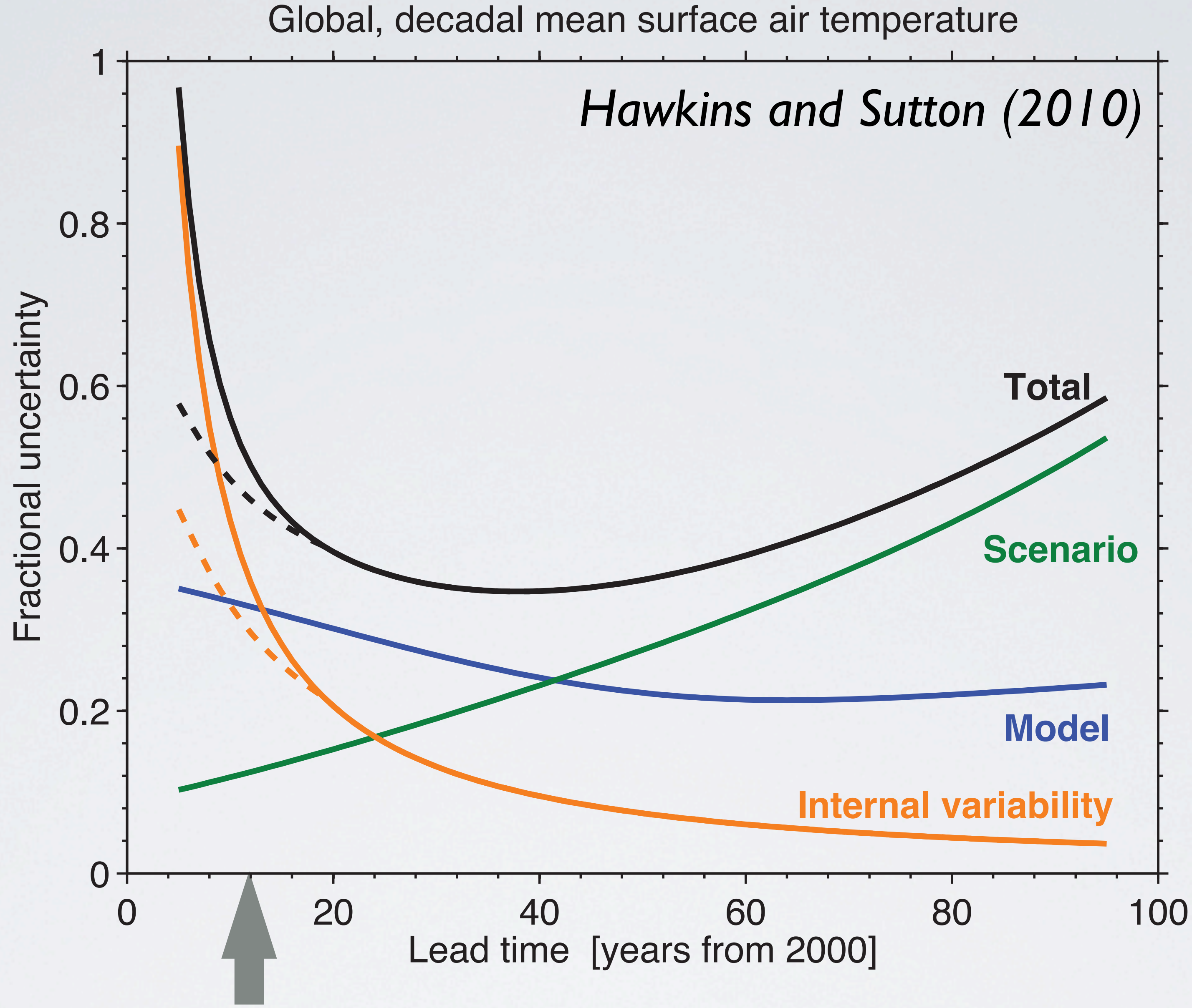




Poster #08B "*Verification of decadal forecasts*" C25

Can we trust these predictions?
How good are the models in the North Atlantic?

Motivation: Reduce the source of uncertainty in decadal predictions

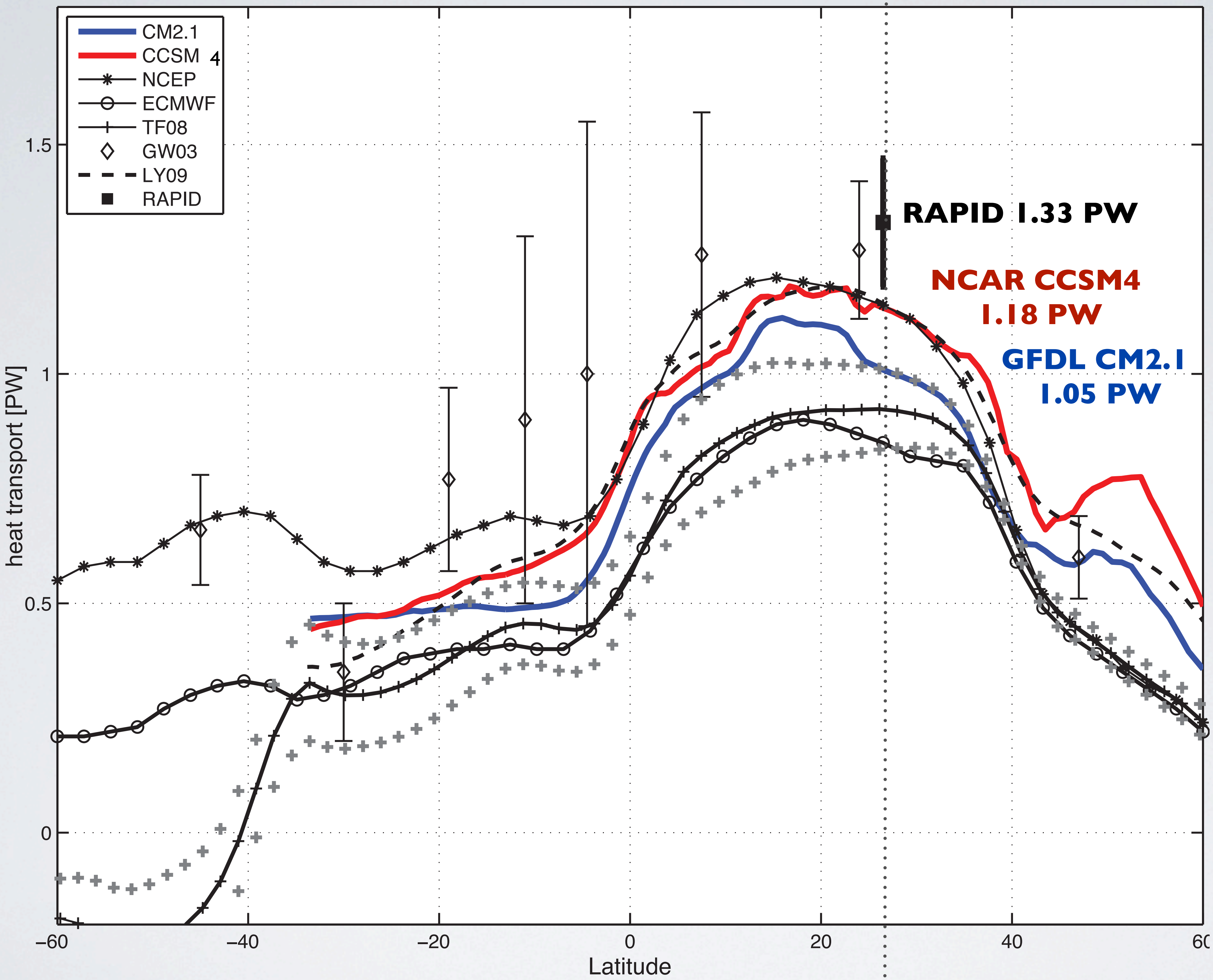


10-20 yr predictions: model errors and internal variability are the largest source of uncertainty.
Challenge for initialized predictions: models go toward their own mean state, which is often far from observations

Need to improve models and understand the mechanisms of variability.

We look here at two CMIP5 coupled models: GFDL CM2.1 and NCAR CCSM4

Objective: understand the large uncertainty in the simulated ocean heat transport (MHT)



CM2.1 and CCSM4 like many coupled models underestimate the MHT at 26N

Msadek R., W. Johns, S. Yeager, G. Danabasoglu, T. Rosati, T. Delworth, in prep

Models and data

- **Two coupled models with comparable resolution ~ 1° ocean X 2° atmosphere**

  GFDL CM2.1 *(Delworth et al. 2006, Gnanadesikan et al. 2006)*
  model used for CMIP5 decadal prediction experiments

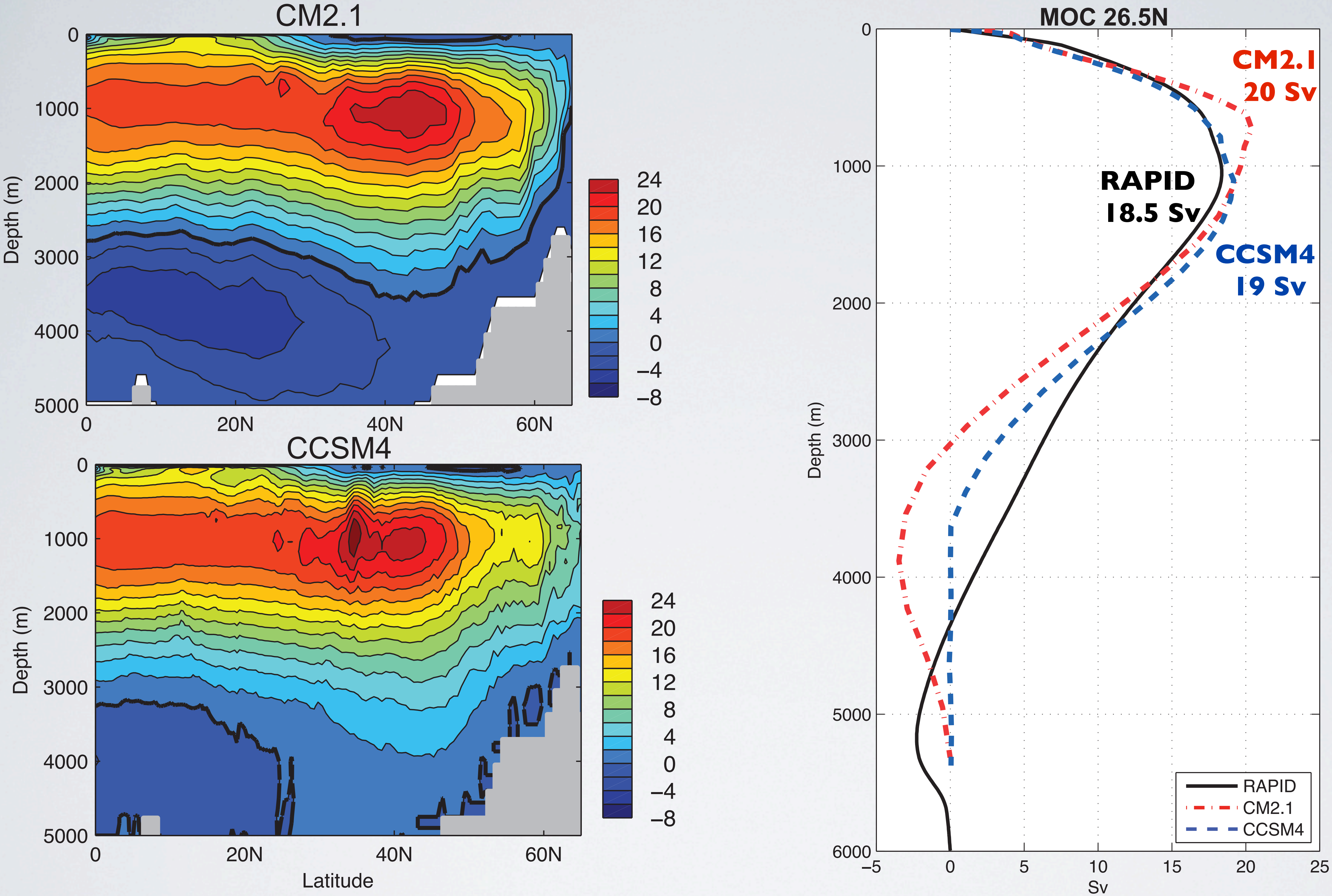
  NCAR CCSM4: *(Gent et al. 2010, Danabasoglu et al. 2011)*
  IPCC AR5 model
  The ocean model includes a new parameterization of Nordic Seas overflows *(Danabasoglu et al. 2010)*

- **RAPID-MOCHA observations** *(Cunningham et al. 2007, Kanzow et al. 2007)*

  First 3.5 years of MHT and MOC data *(Johns et al. 2011)*

→ **Understand the link between MOC and MHT at 26N**

Do models underestimate the MHT because of a too small MOC? No

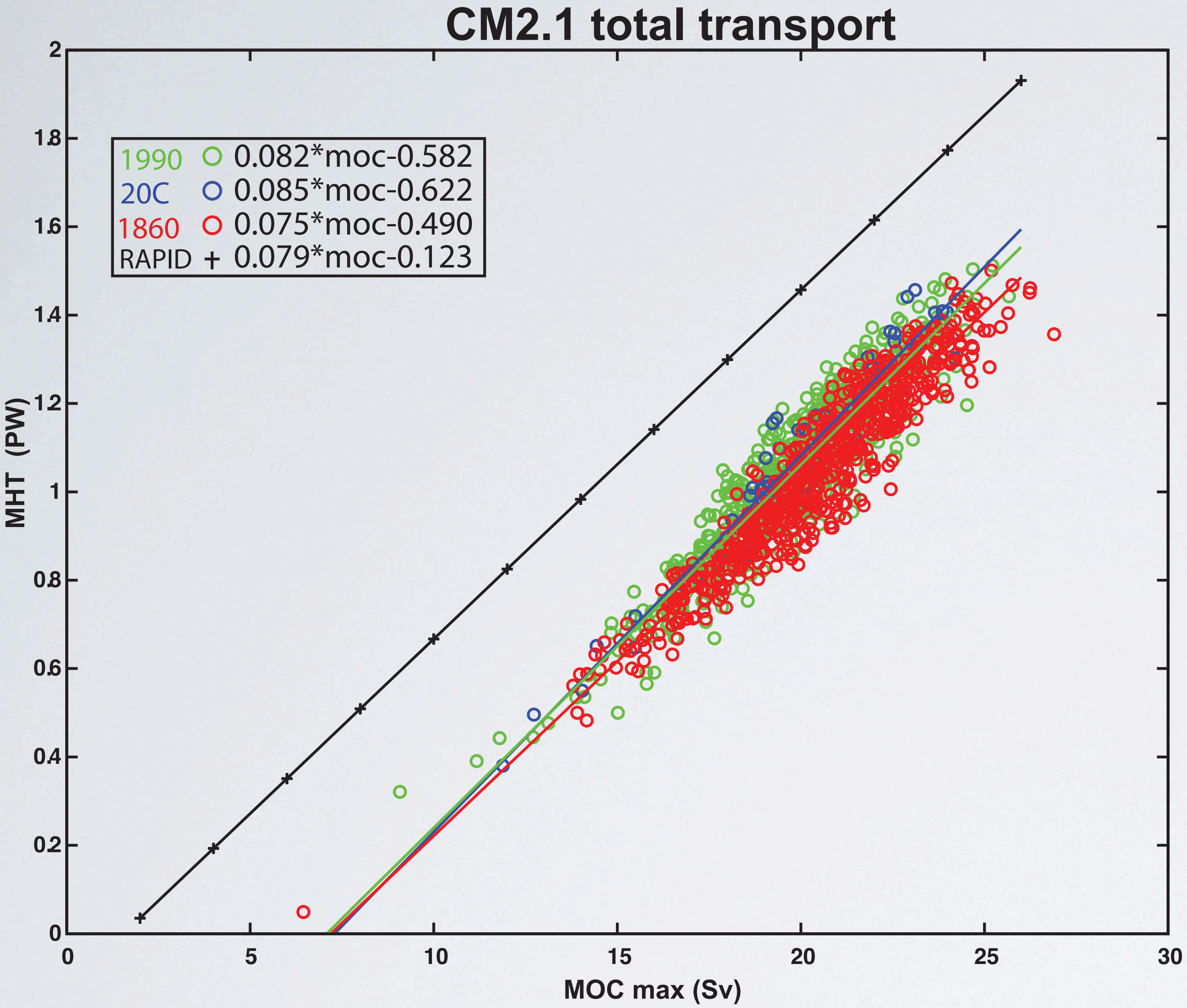


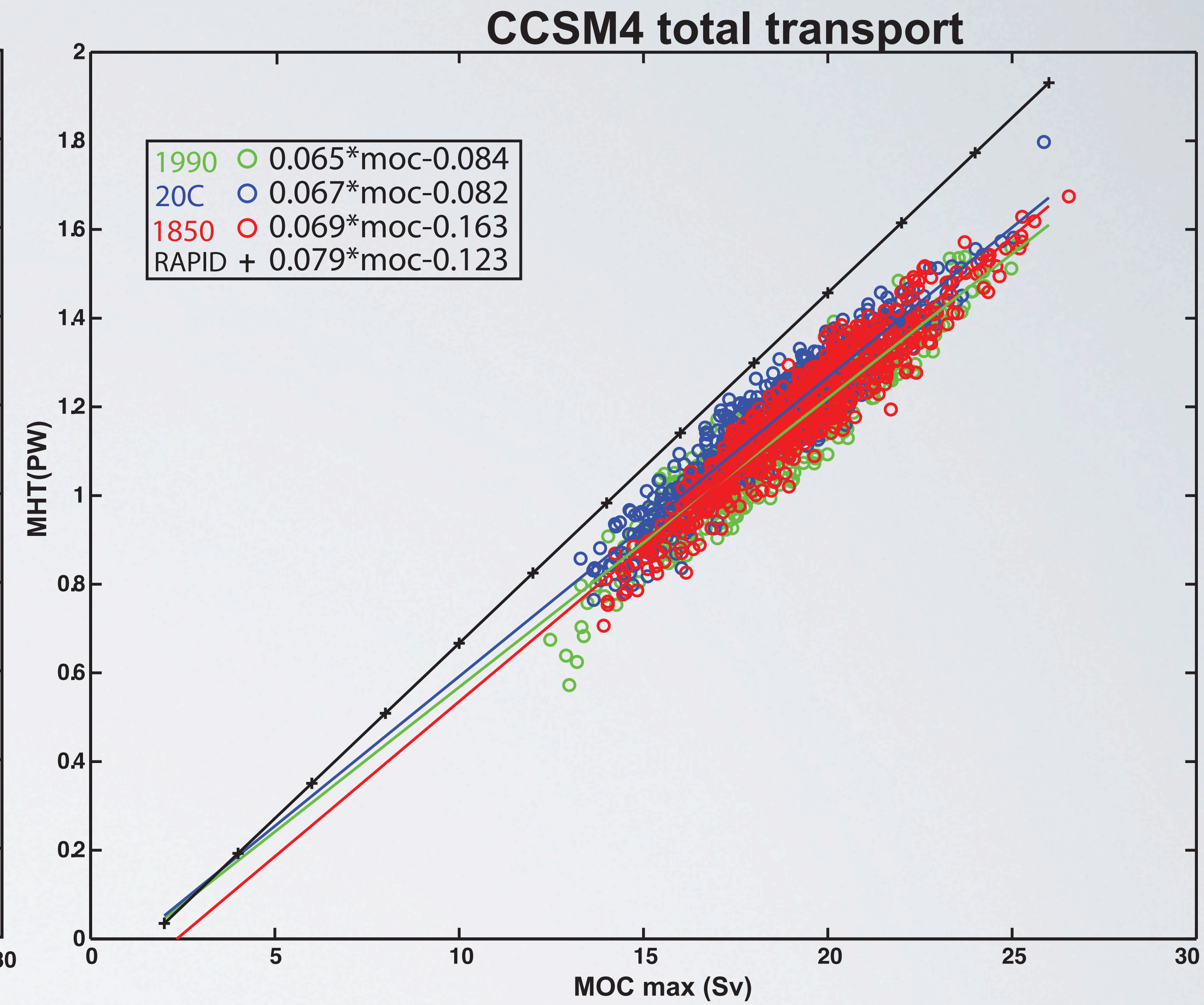
Better representation of the NADW cell in CCSM4, because of more realistic overflows

Both models have a stronger than observed MOC maximum

If the MOC dominates the MHT, it should be stronger than observed, not weaker

Sensitivity of the MHT to a change in the MOC at 26N





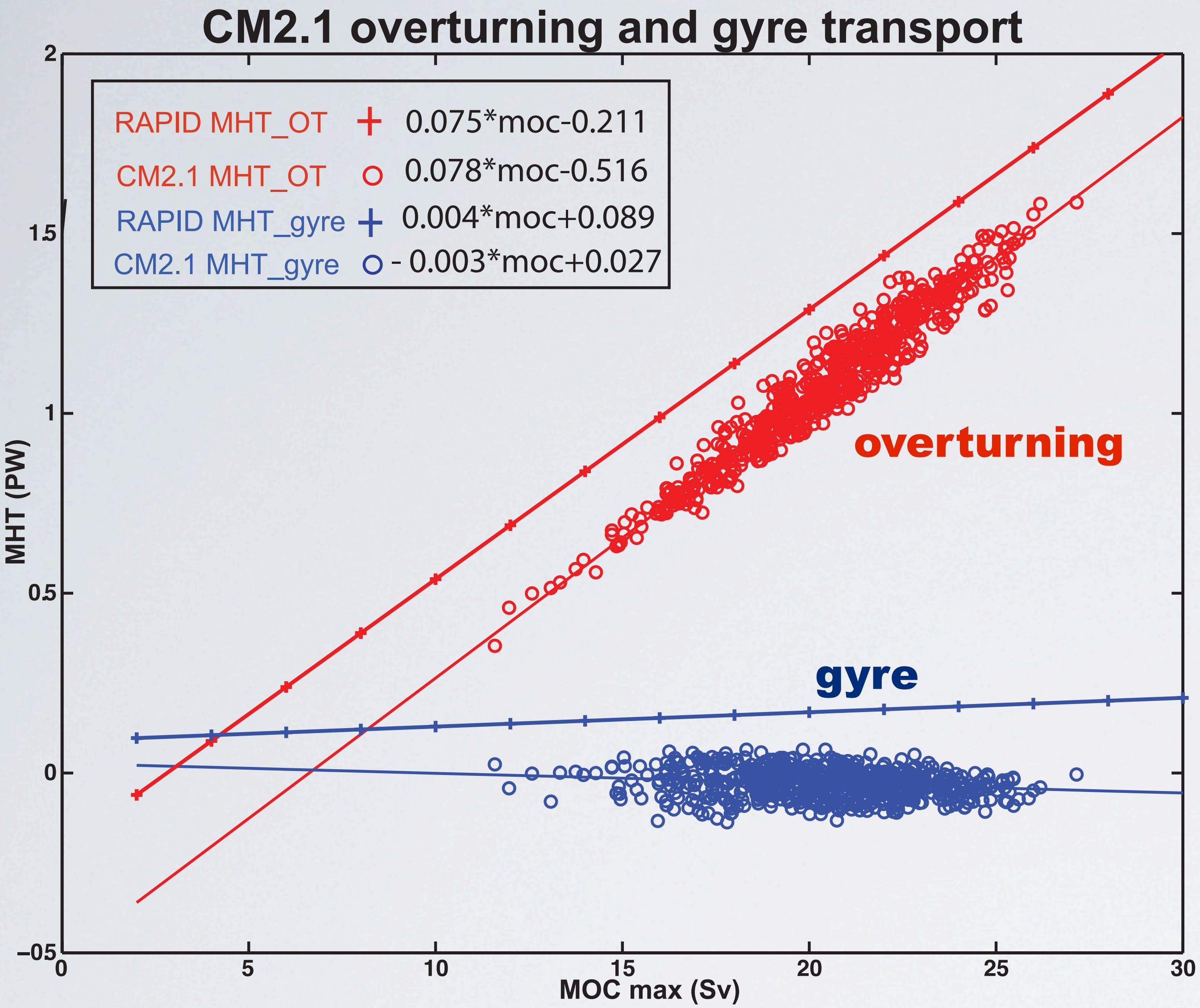
Slope comparable to RAPID in CM2.1

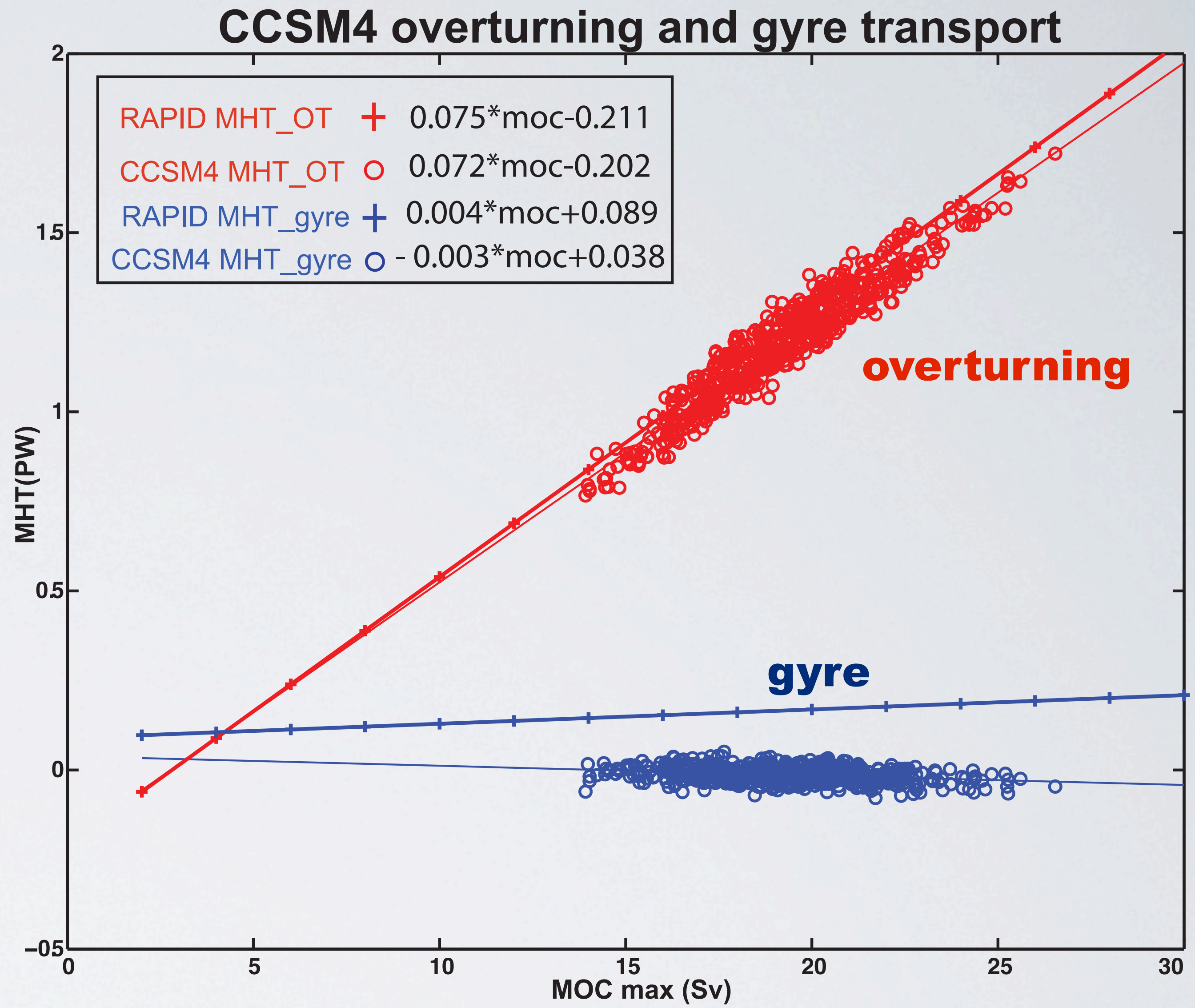
Slope smaller than RAPID in CCSM4

Linear relationship between MHT and MOC at 26N reproduced in both models

Some variability according to forcing (preindustrial, present-day, historical)

Sensitivity of the MHT to a change in the MOC at 26N



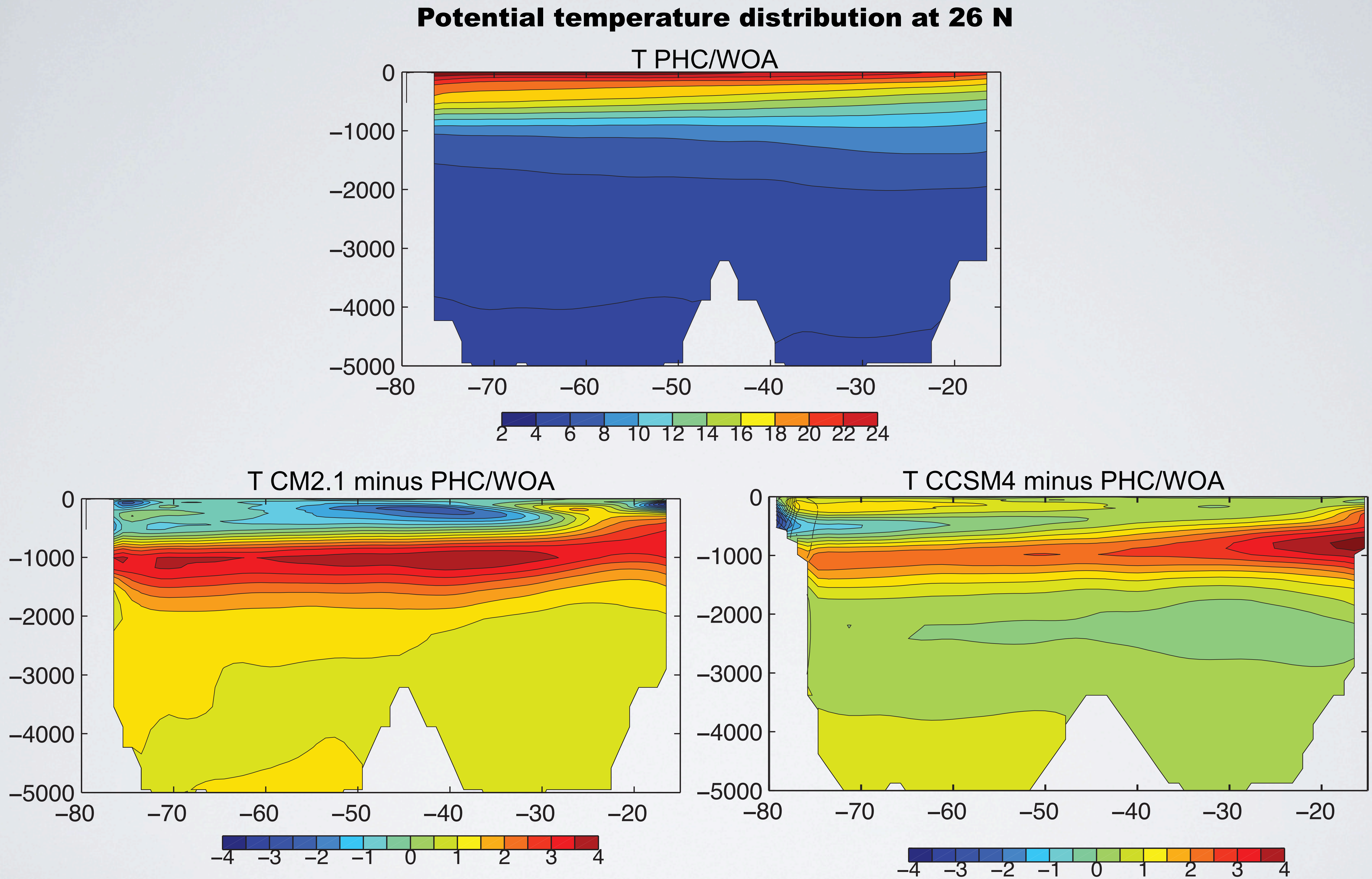


The overturning component dominates the link between MOC/MHT in the models as in RAPID

Slope for the overturning component comparable to observations in CCSM4, slightly overestimated in CM2.1

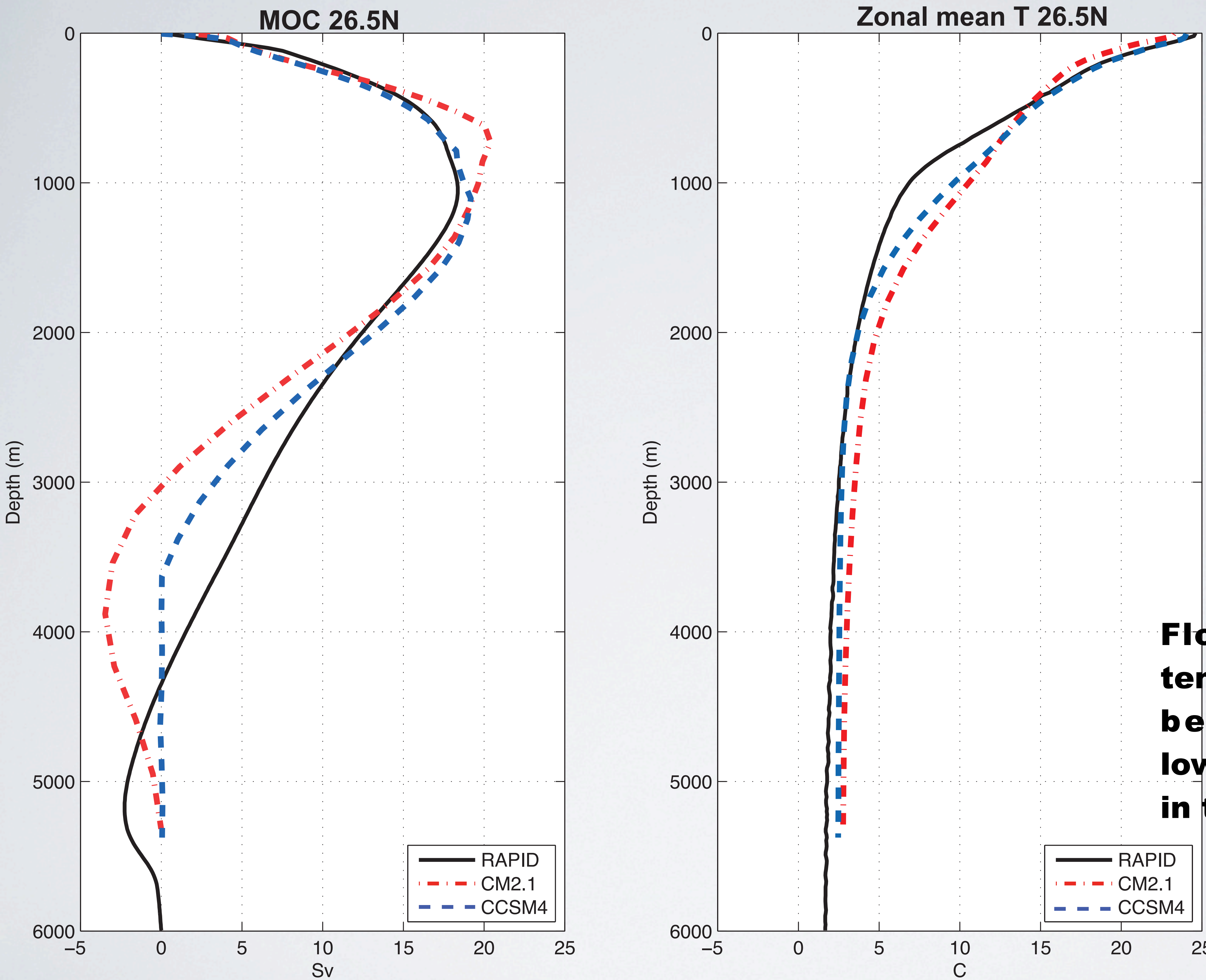
Small contribution of the gyre component but wrong sign in both models, decreasing the slope of the total transport

Are we getting the right overturning heat transport for the right reasons?



Thermocline too flat in the models => upper ocean too cold, lower ocean too warm. Delta T too small tends to reduce to overturning heat transport

Are we getting the right overturning heat transport for the right reasons?



RAPID
UPPER T=20.6 C
LOWER T=2.9 C
DeltaT=17.7 C

CM2.1
UPPER T=16.8 C
LOWER T=4.8 C
DeltaT=12 C

CCSM4
UPPER T=17.7 C
LOWER T=3.7 C
DeltaT=14 C

Flow weighted mean temperature difference between upper and lower NADW too small in the models

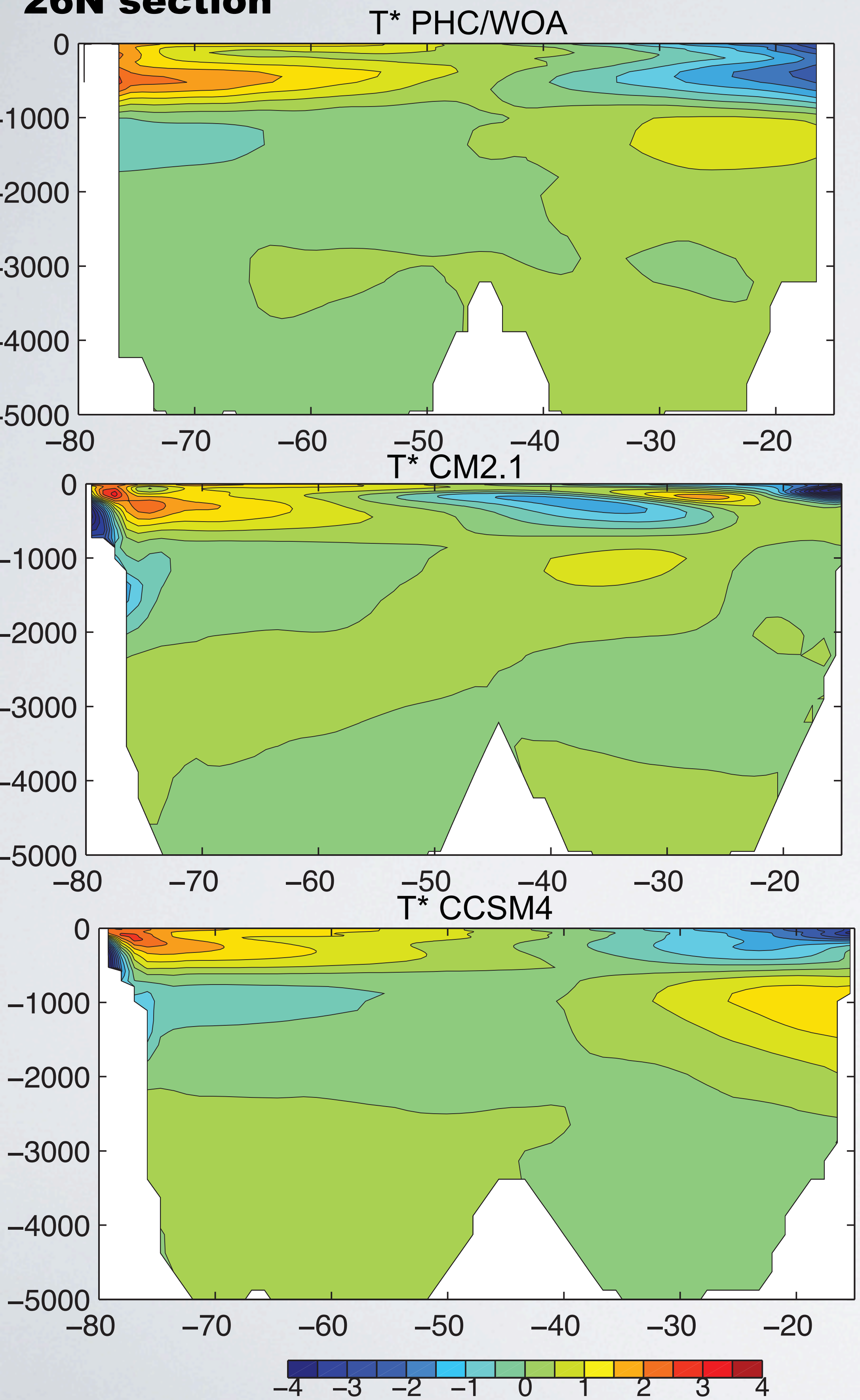
MOC bias => stronger overturning MHT **T bias => weaker overturning MHT**

Compensation of errors contribute to the right overturning MHT in both models

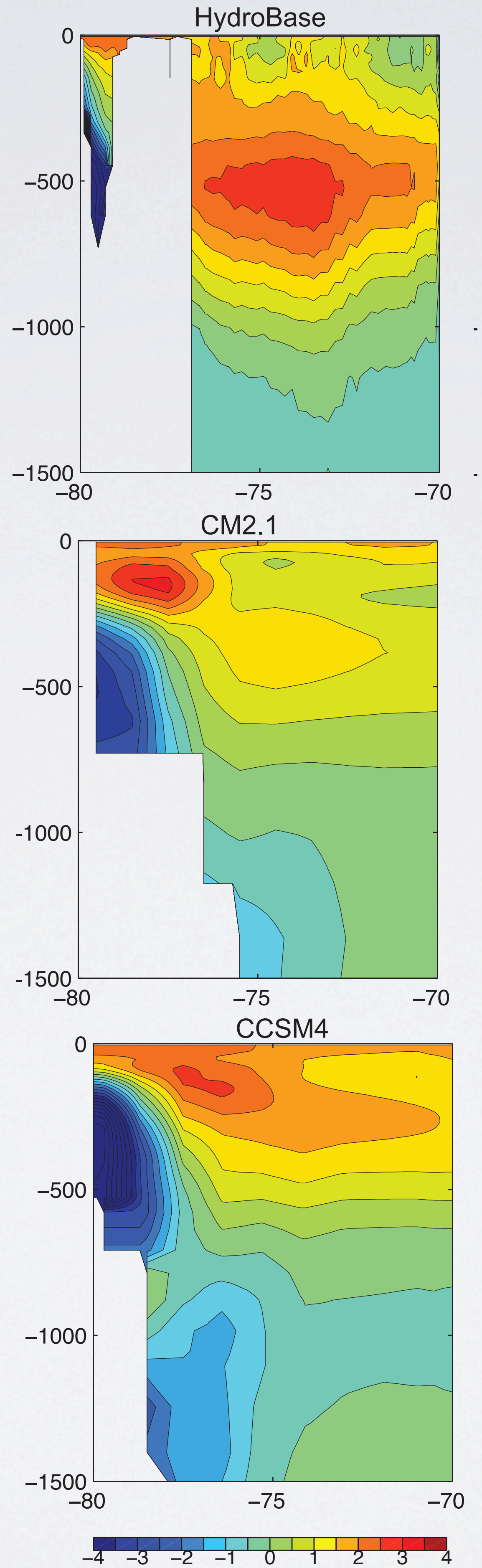
Why is the gyre MHT negative?

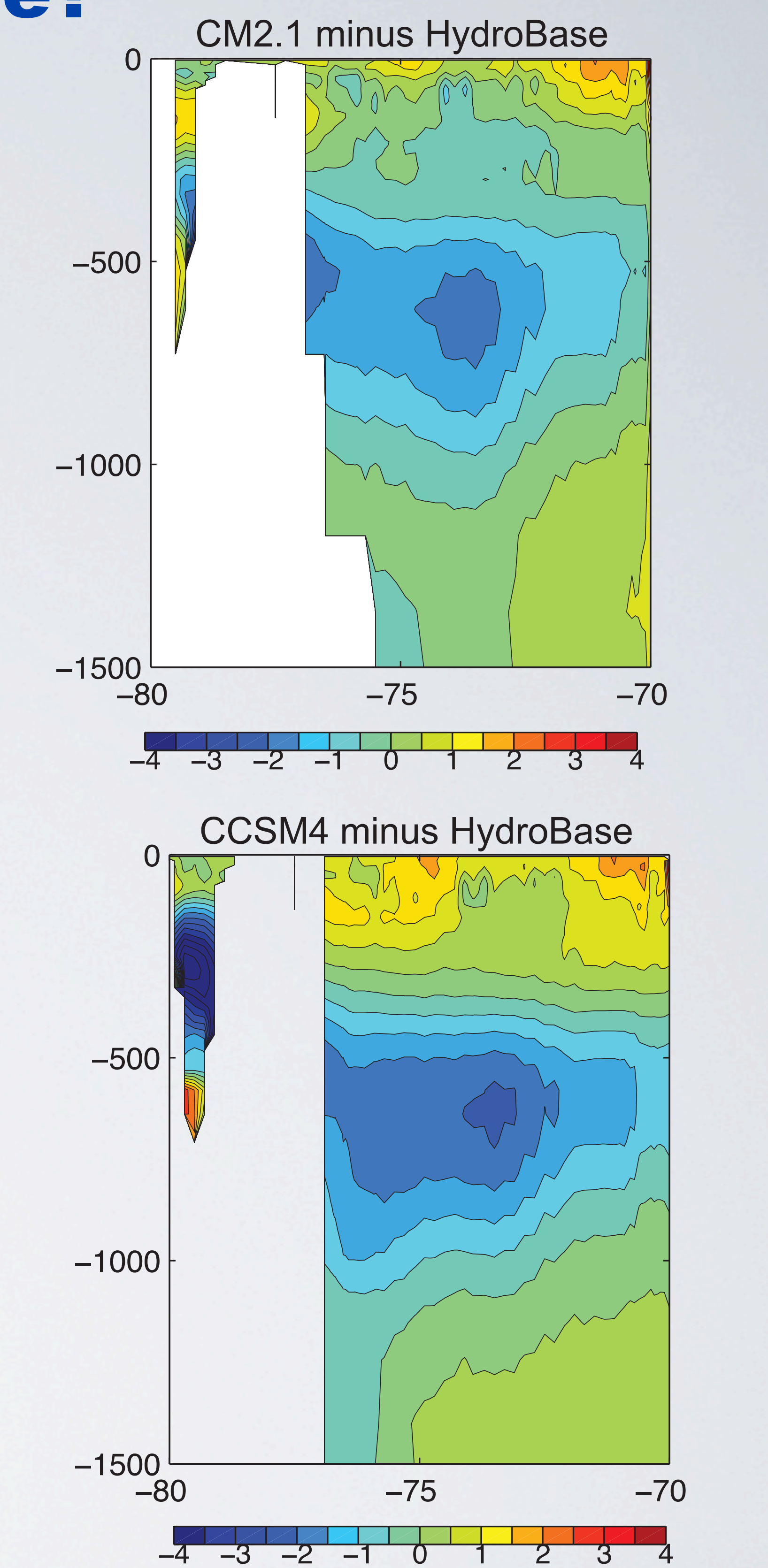
Temperature anomalies relative to the zonal mean

26N section



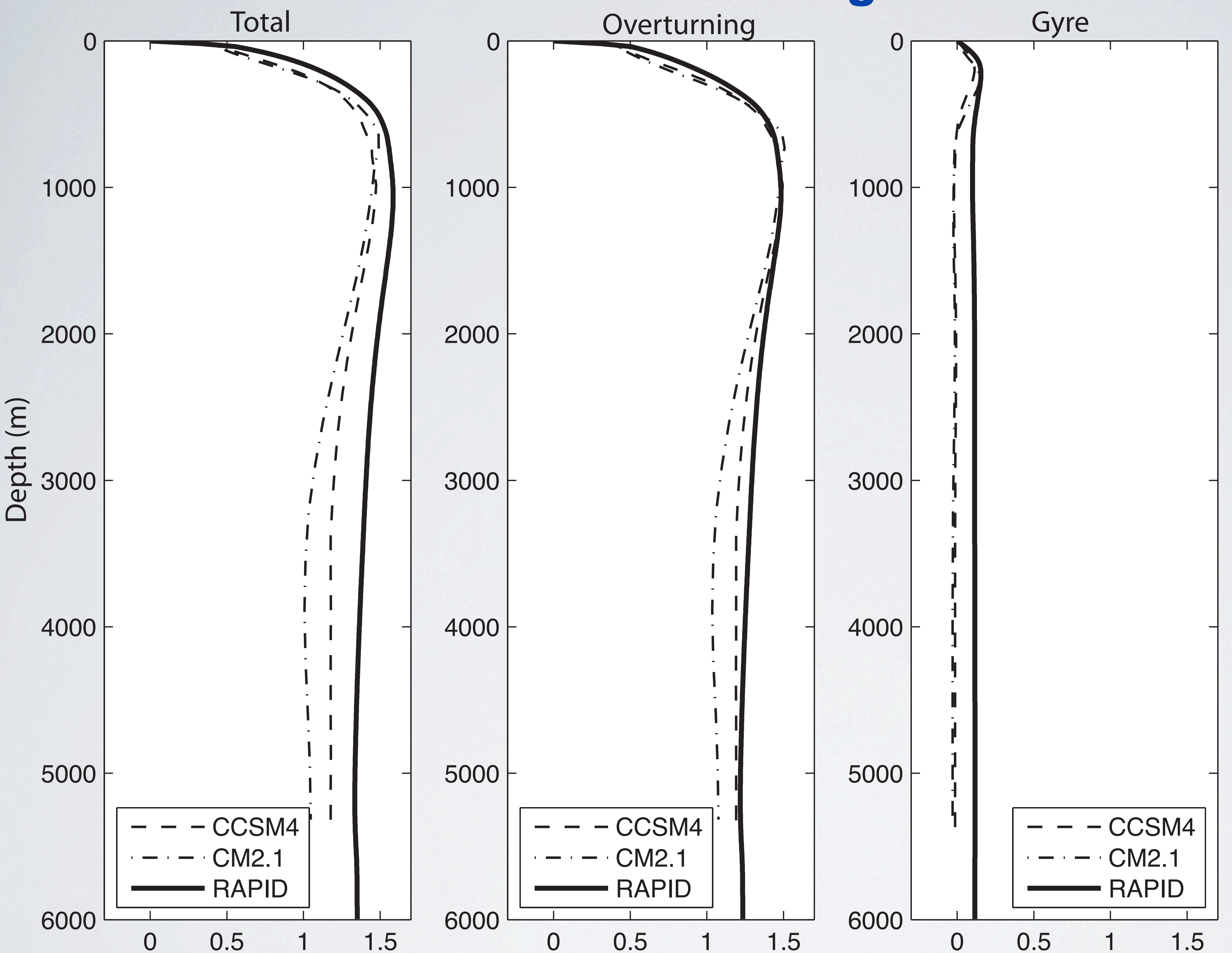
western boundary





Cold bias at the western boundary collocated with positive velocity anomalies reduces the northward MHT by gyre circulation

Cumulative vertical integral of VT



Equals net heat transport (in PW) at the bottom when the mass budget is closed

RAPID
total=1.33 PW
overturning=1.20 PW
gyre=+0.13 PW

CM2.1
total=1.05 PW
overturning=1.08 PW
gyre=-0.03PW

CCSM4
total=1.18 PW
overturning=1.19PW
gyre=-0.01PW

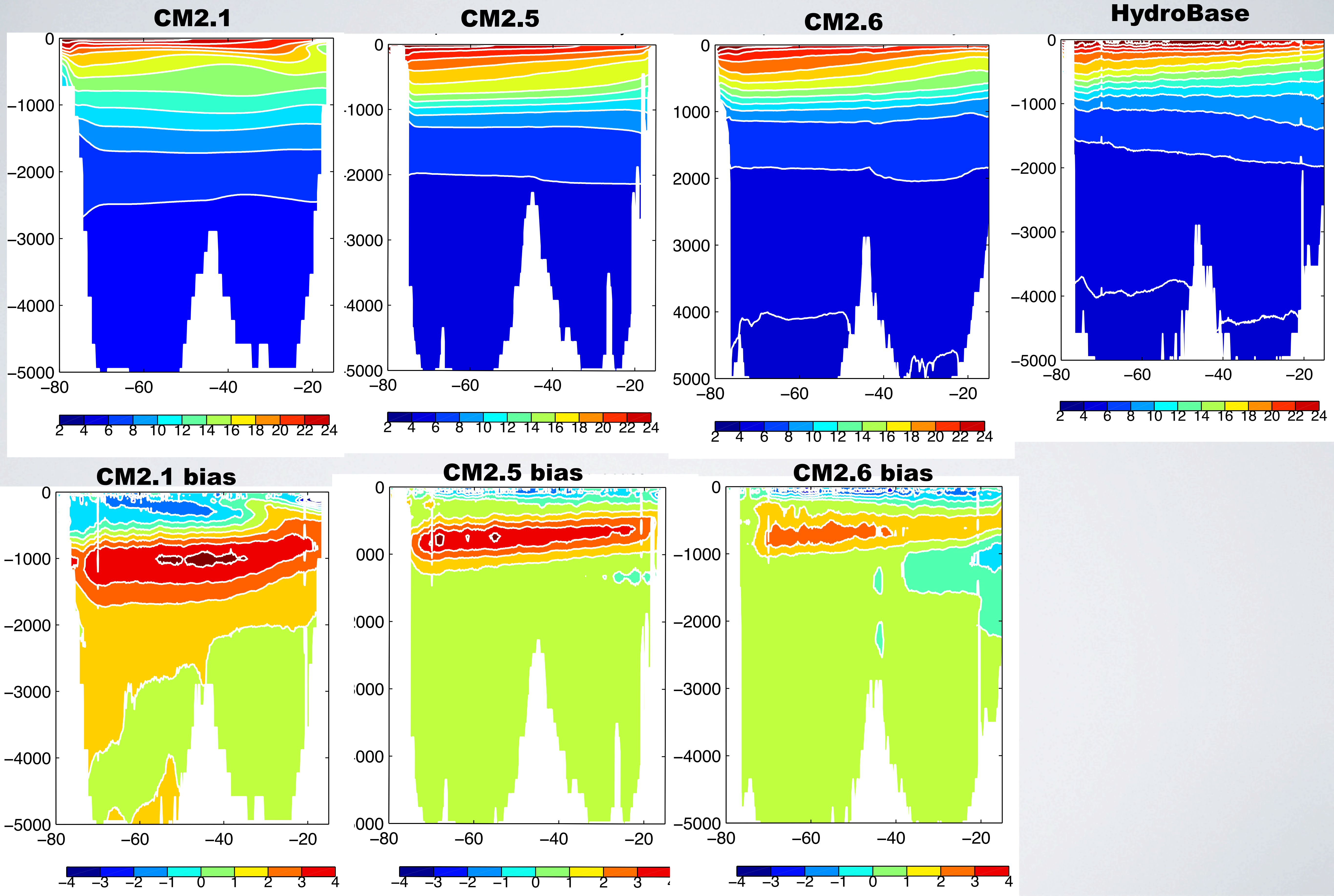
Errors in total MHT come from both overturning and gyre components

The overturning heat transport is underestimated mainly below 2000m with a larger bias in CM2.1

The amplitude of the gyre heat transport is negatively biased with errors developing at 500-800m

Some hope that MHT at 26N will get better with resolution

Mean potential temperature at 26N in different GFDL coupled models



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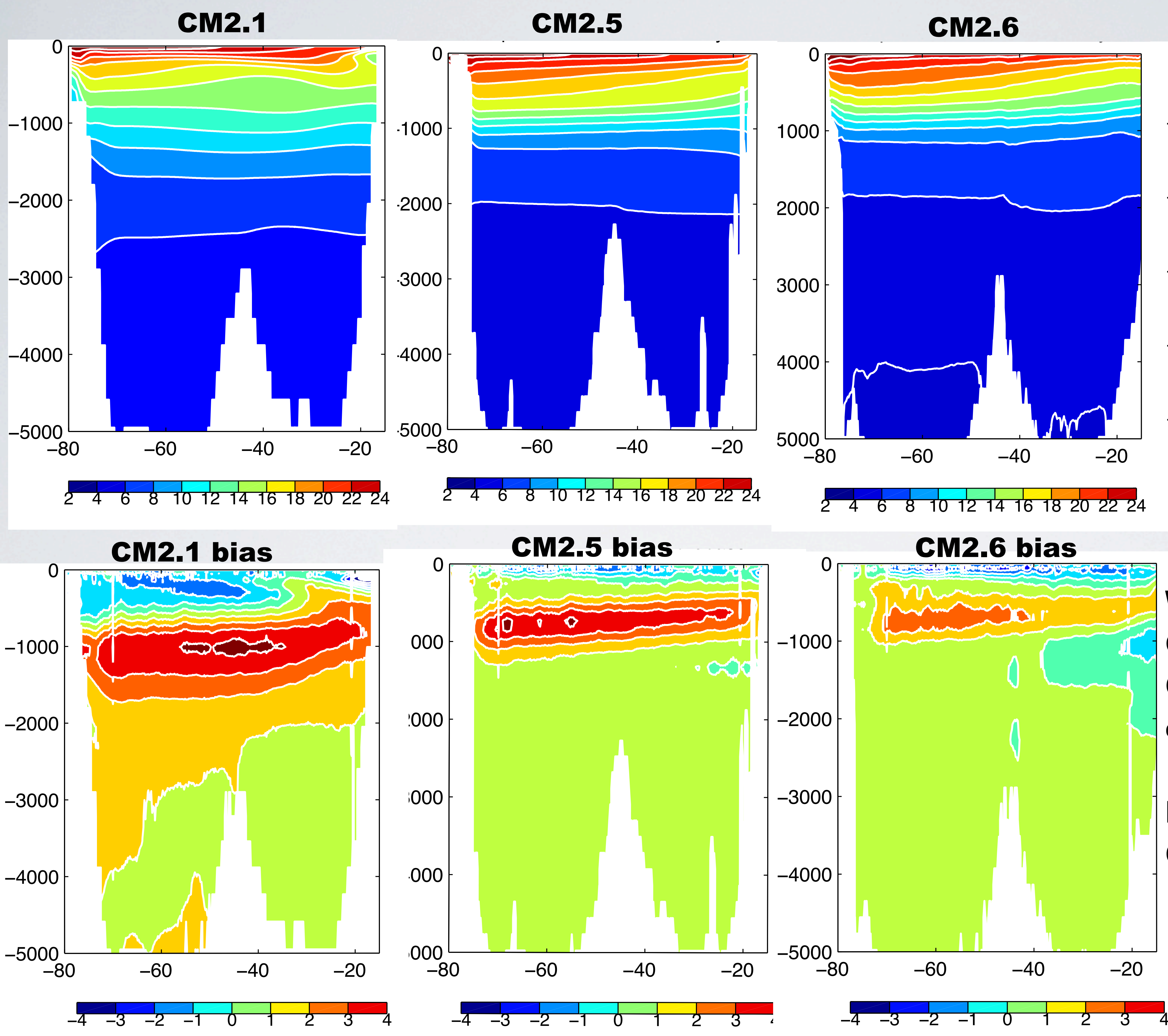
Mean potential temperature at 26N



Want to see more on GFDL CM2.5 and CM2.6 high resolution coupled models?

Poster by Keith Dixon C37 #TH85B

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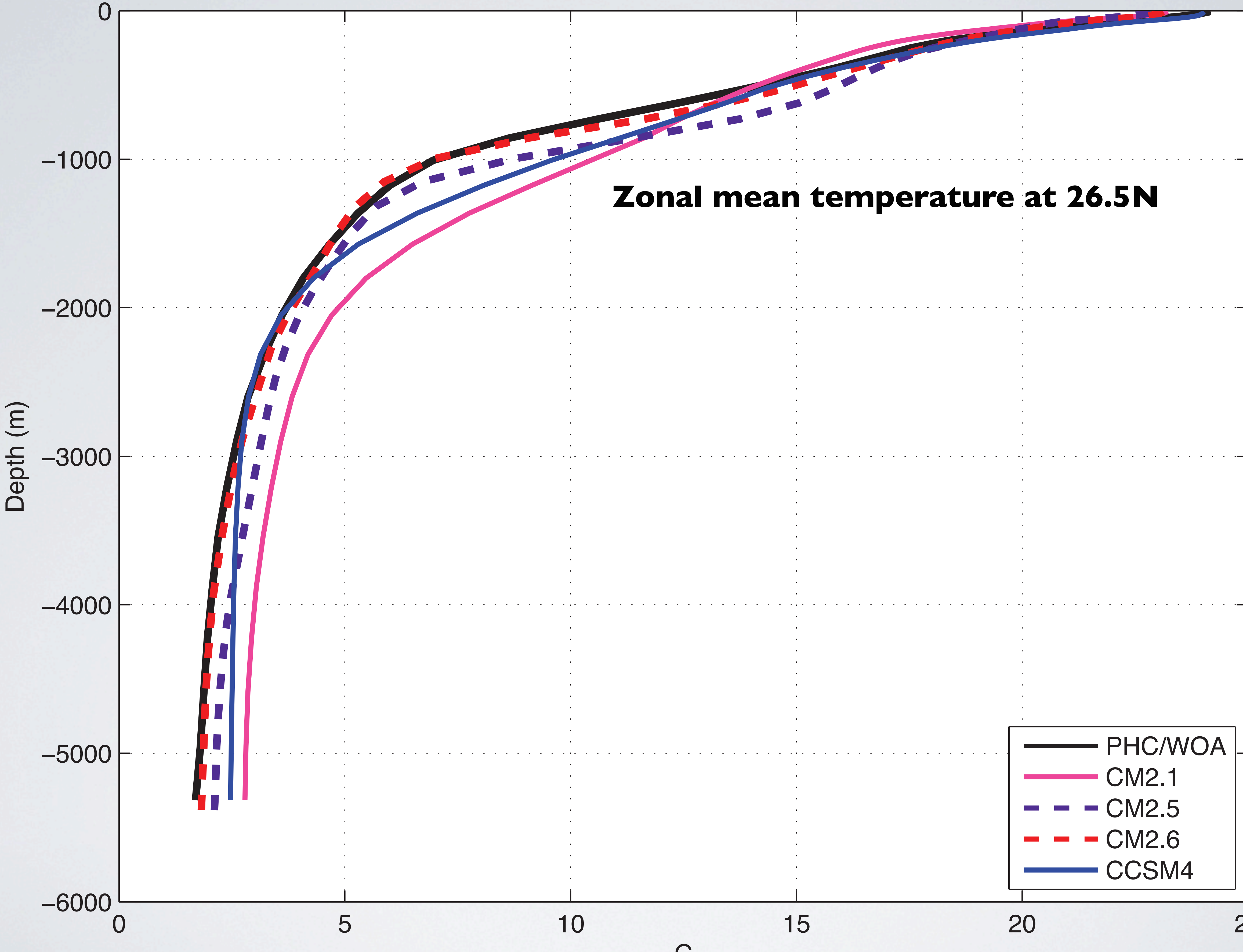

The bias is largely reduced when increasing resolution

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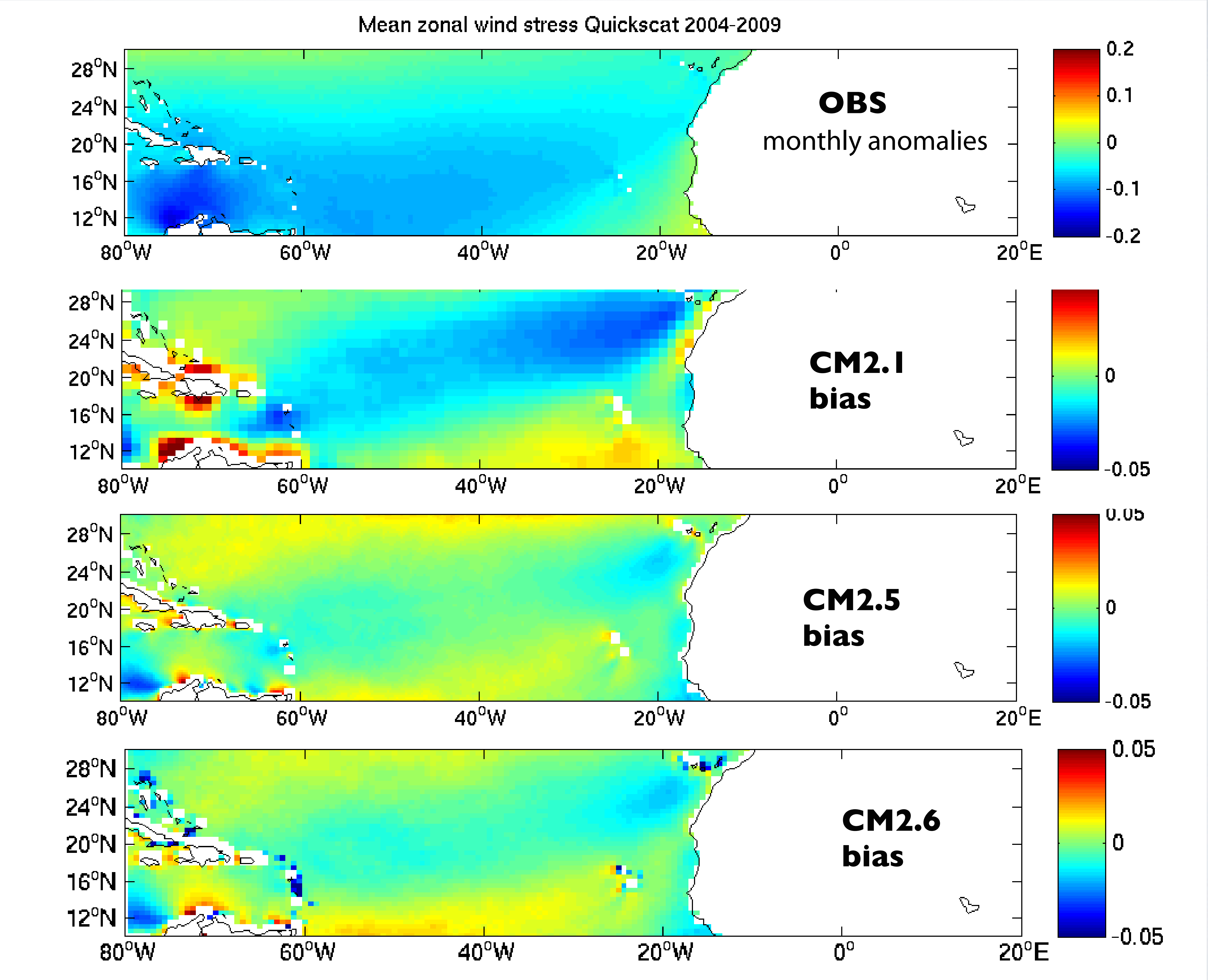

Wind stress bias decreases with resolution

Conclusion

-GFDL CM2.1 and NCAR CCSM4 underestimate the total MHT at 26N compared with RAPID observations

-Both models reproduce the MOC/MHT linear relationship but with a smaller slope than observed in CCSM4 and a right slope for the wrong reasons in CM2.1

-The overturning component dominates the MHT in the models consistent with observations. The realistic overturning MHT in the models is partly due to compensation of errors.

-The contribution of the gyre circulation to the total MHT is small but positive in observations. It is negatively biased in both models reducing the total MHT

-Biases at the western boundary (Florida current) are the main source of errors.

-CCSM4 has a better representation of the NADW and thus of MOC and associated MHT because of the overflow parameterization (parameterization added in future GFDL model)

-Model biases are largely reduced when increasing resolution, suggesting that the problem could be addressed with more hope of success in the future

-RAPID is very useful to improve models and better understand the MOC. Need to maintain the array beyond 2014 to assess not only the mean state but the variability beyond the seasonal cycle

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