How well do the CMIP5 models represent the water properties of the Atlantic Meridional Overturning Circulation?

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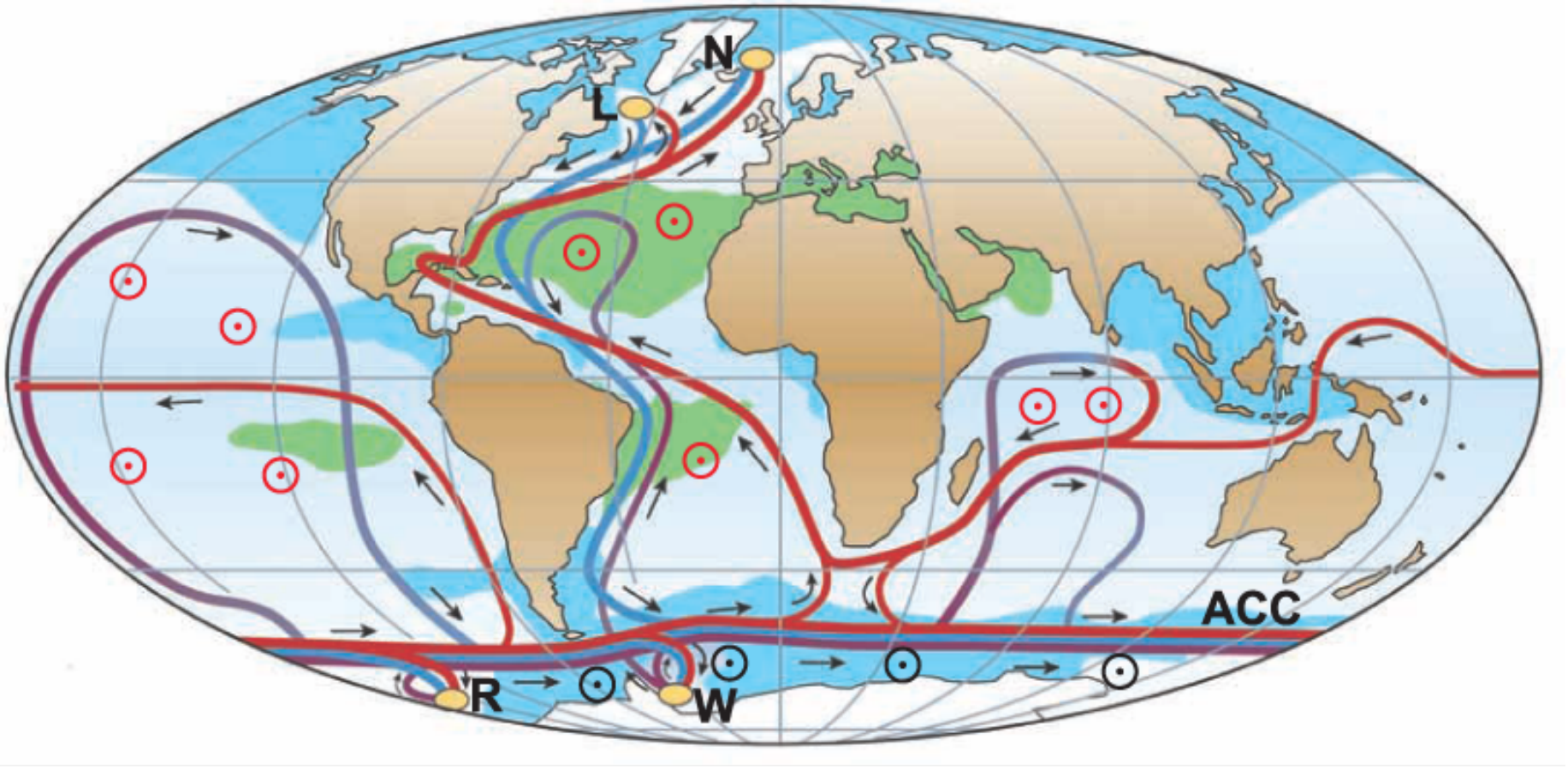
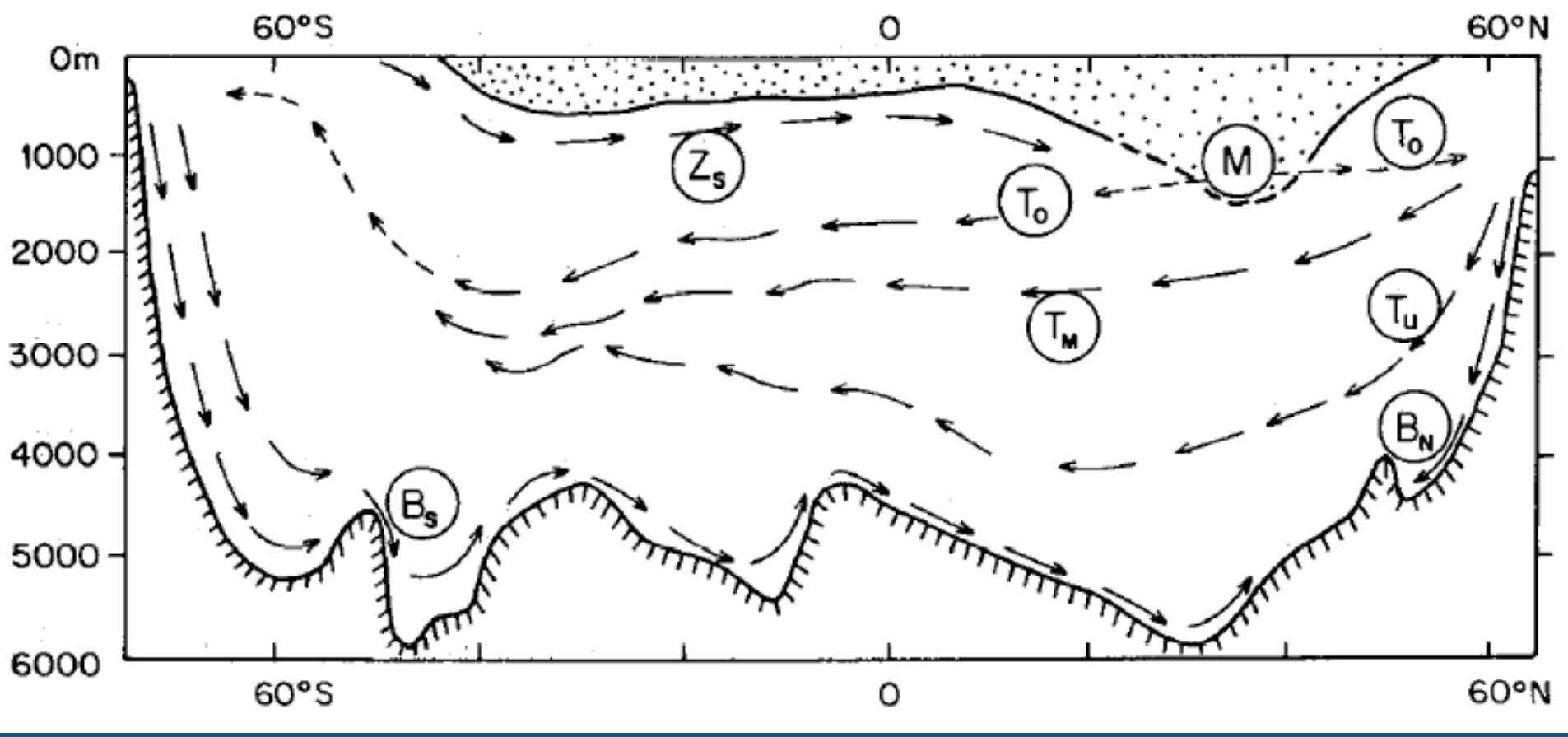
supported by NOAA-CPO-MAPP

Atlantic MOC in global ocean

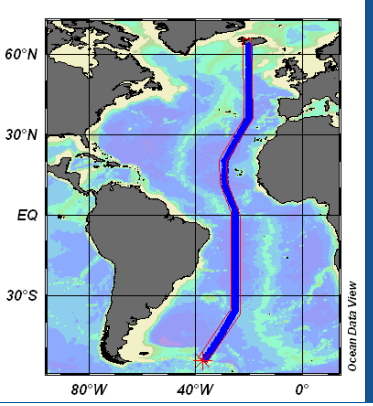


Schematic of the global overturning circulation (*Kuhlbrodt et al., 2007*)

A classical qualitative view

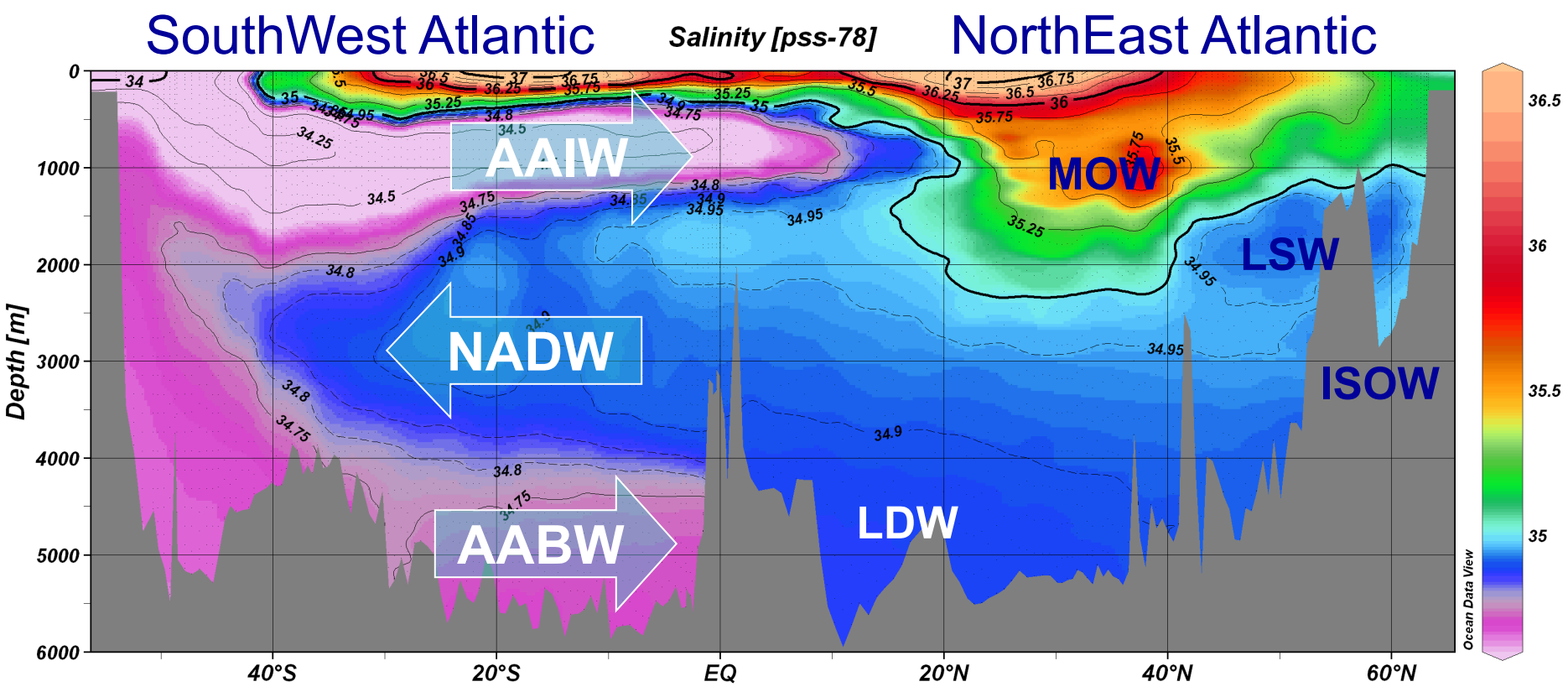


Meridional spreading of water masses in the Atlantic (*Wüst ,1935)*.
Z_S: Subantarctic Intermediate Water; $B_{S(N)}$:bottom water from south (north); T_O: Upper NADW; T_M: Middle NADW; T_U: Lower NADW; M is the Mediterranean influence. The stippled area is Wüst's warm water sphere.



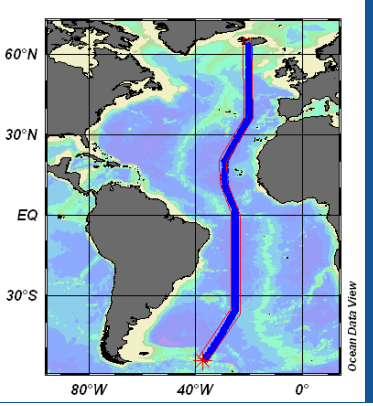
Hydrographic section

Tsuchiya et al. (1992)



South Georgia Island

Iceland

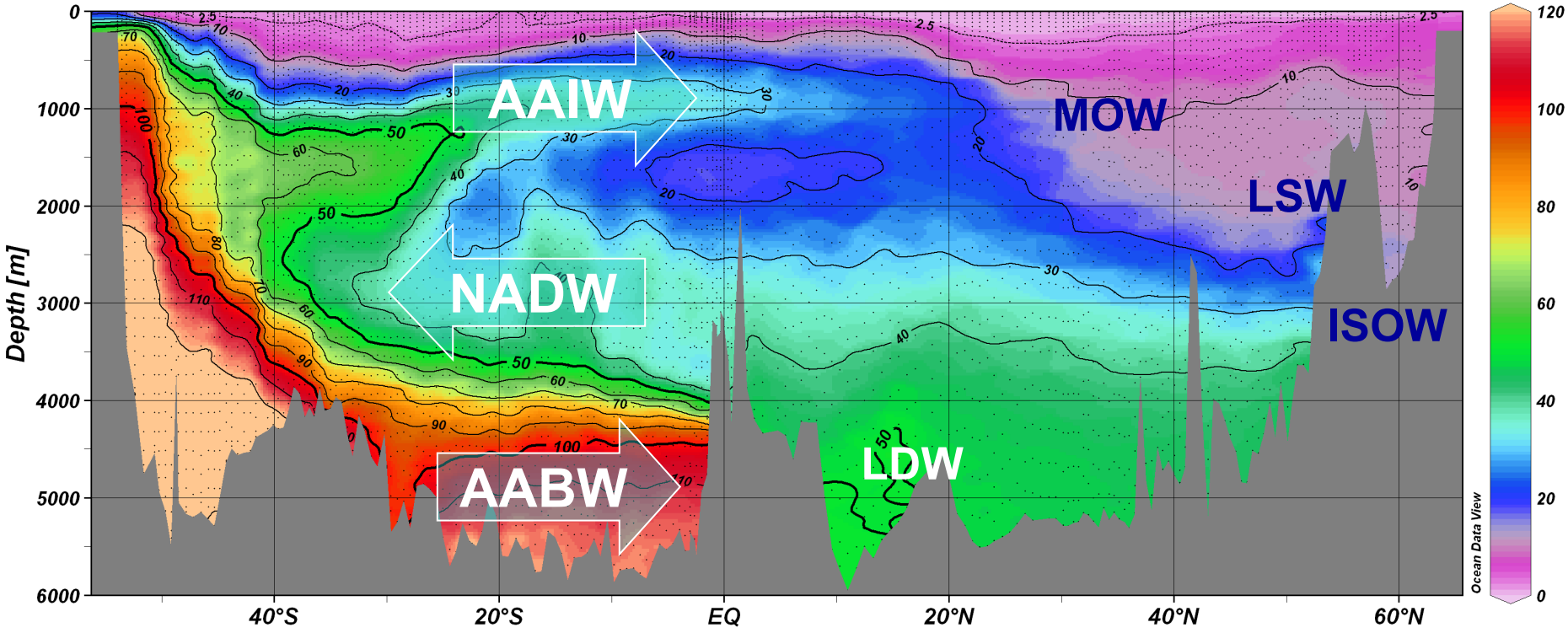


Hydrographic section

SouthWest Atlantic

Silicate [µmol/kg]

NorthEast Atlantic



South Georgia Island

Iceland

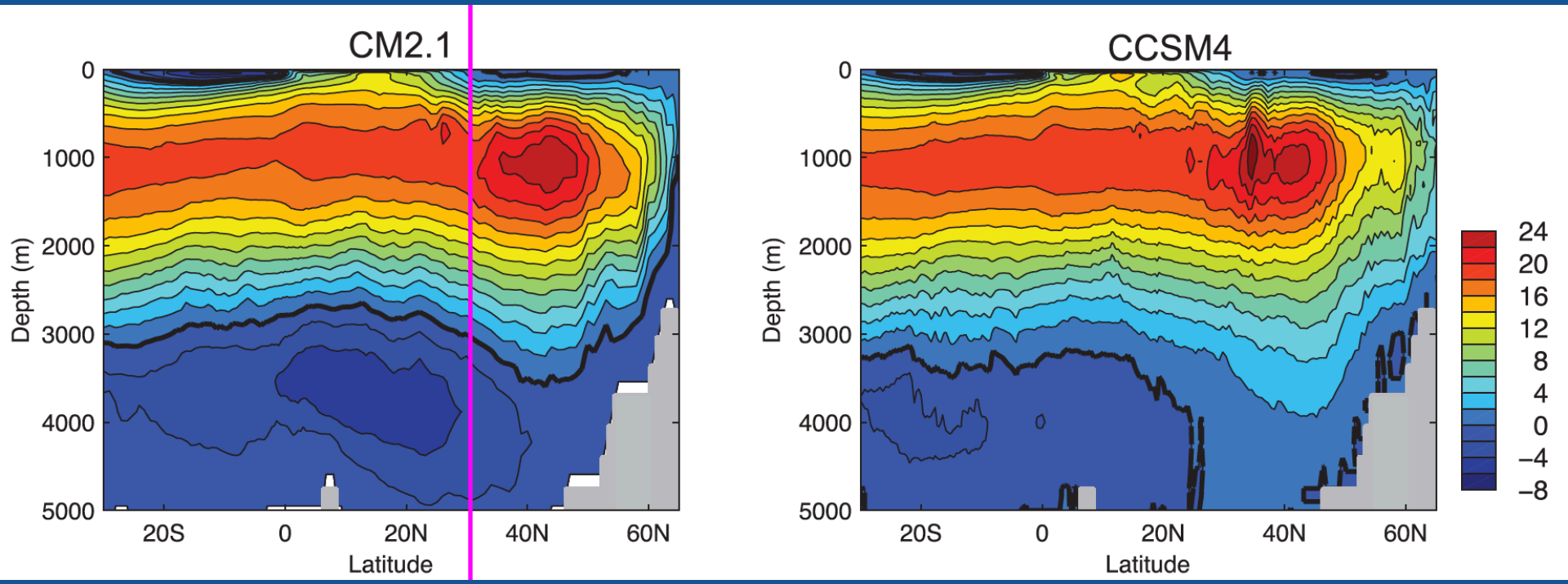
- The AMOC is a fundamental element in the earth climate system, transporting heat, freshwater (salinity anomaly), and other tracers (e.g., CO_2) over basin scale.

- There are two factors that determine the heat/freshwater transports: the AMOC strength, and the water properties in the northward and southward limbs of the AMOC.

AMOC strength in CMIP5

- **The strength of the circulation is defined as the maximum overturning streamfunction.**

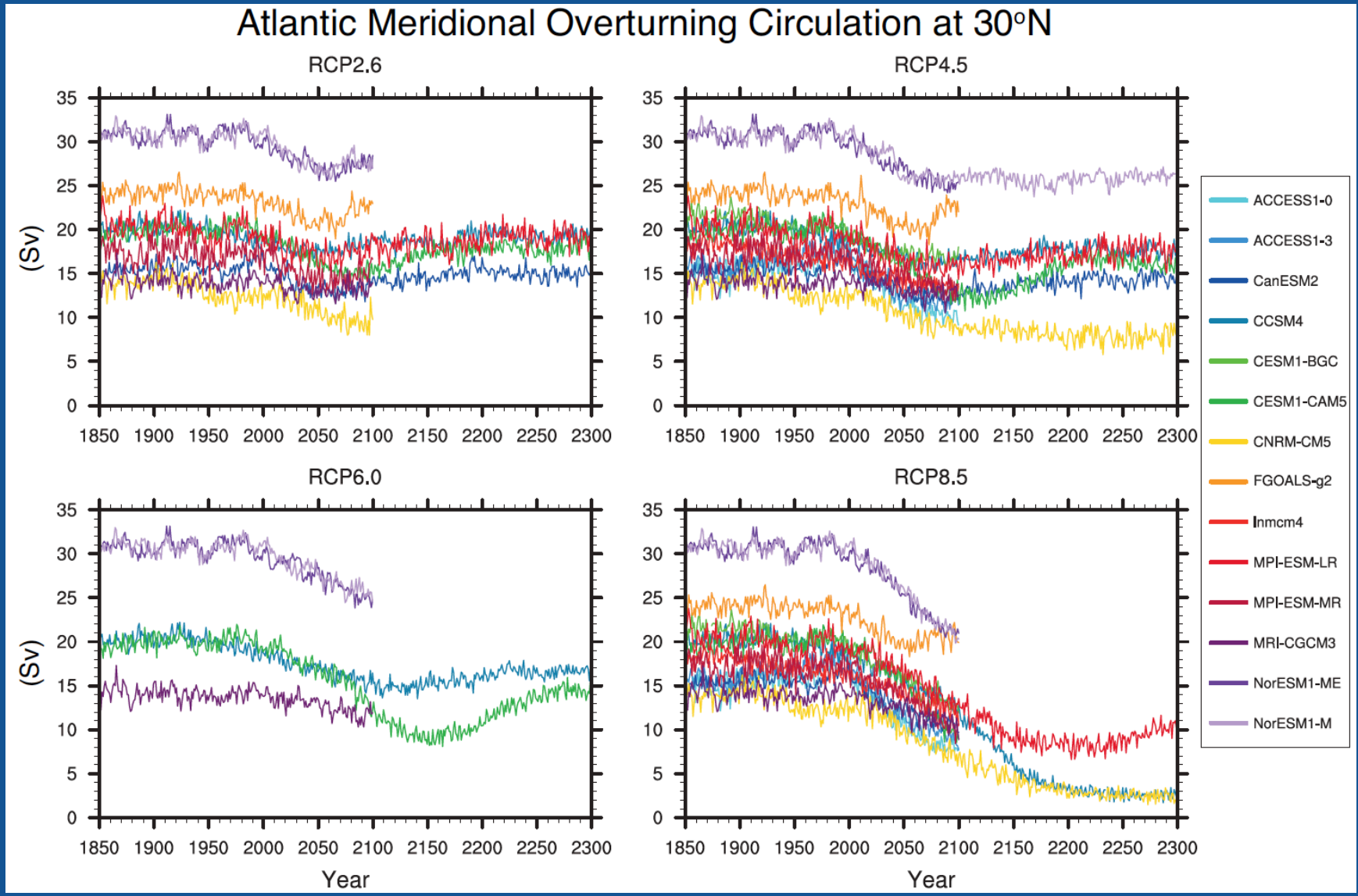
Msadek et al. (2013) J. Climate



Time mean meridional overturning streamfunction in two CMIP5 models

AMOC strength in CMIP5

Collins et al., 2013-IPCC5

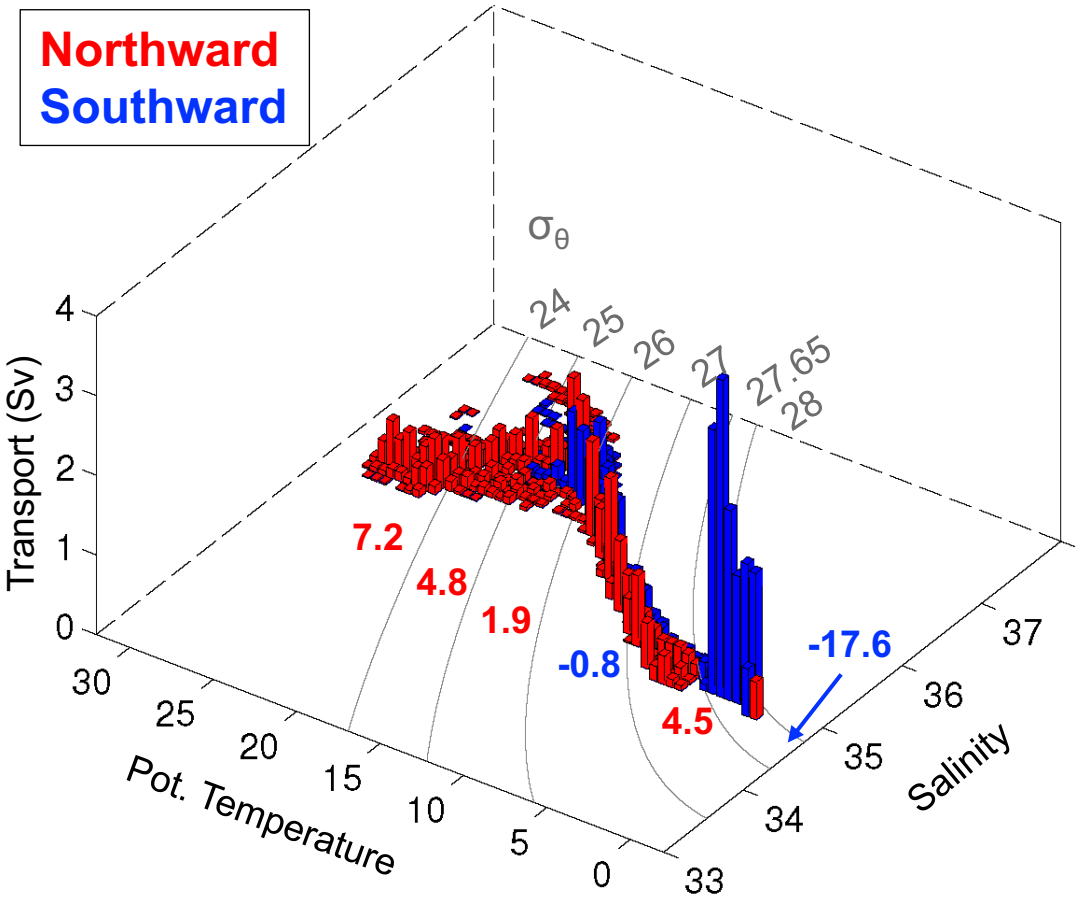


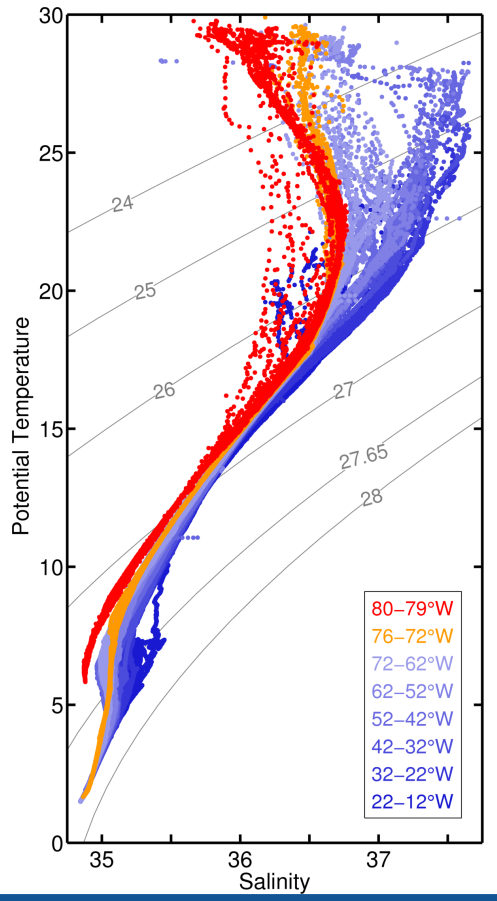
How about the water properties?

- At 26N
- As a function of latitude

Transport on T/S at 26N

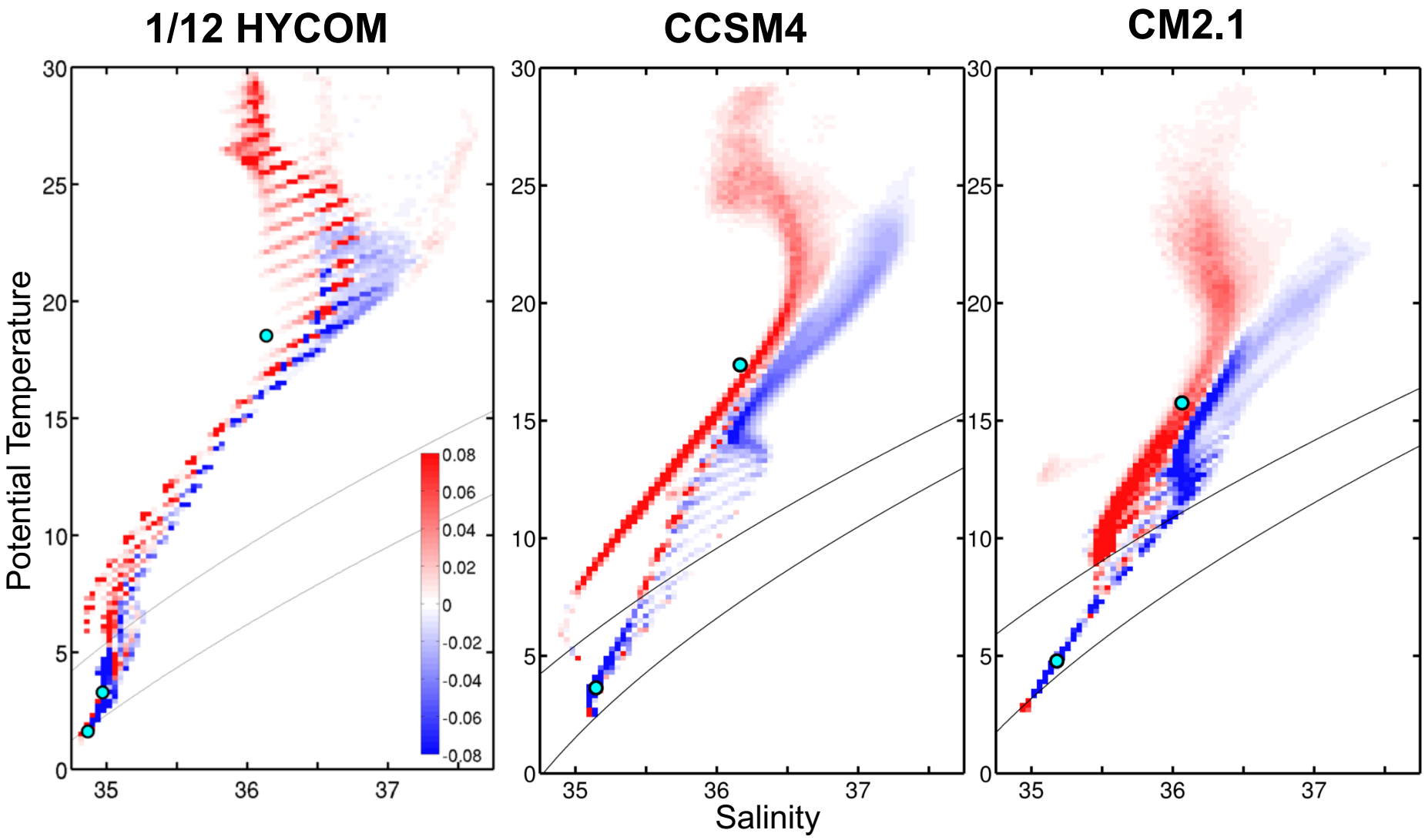
(Xu et al., 2016-J.Climate)



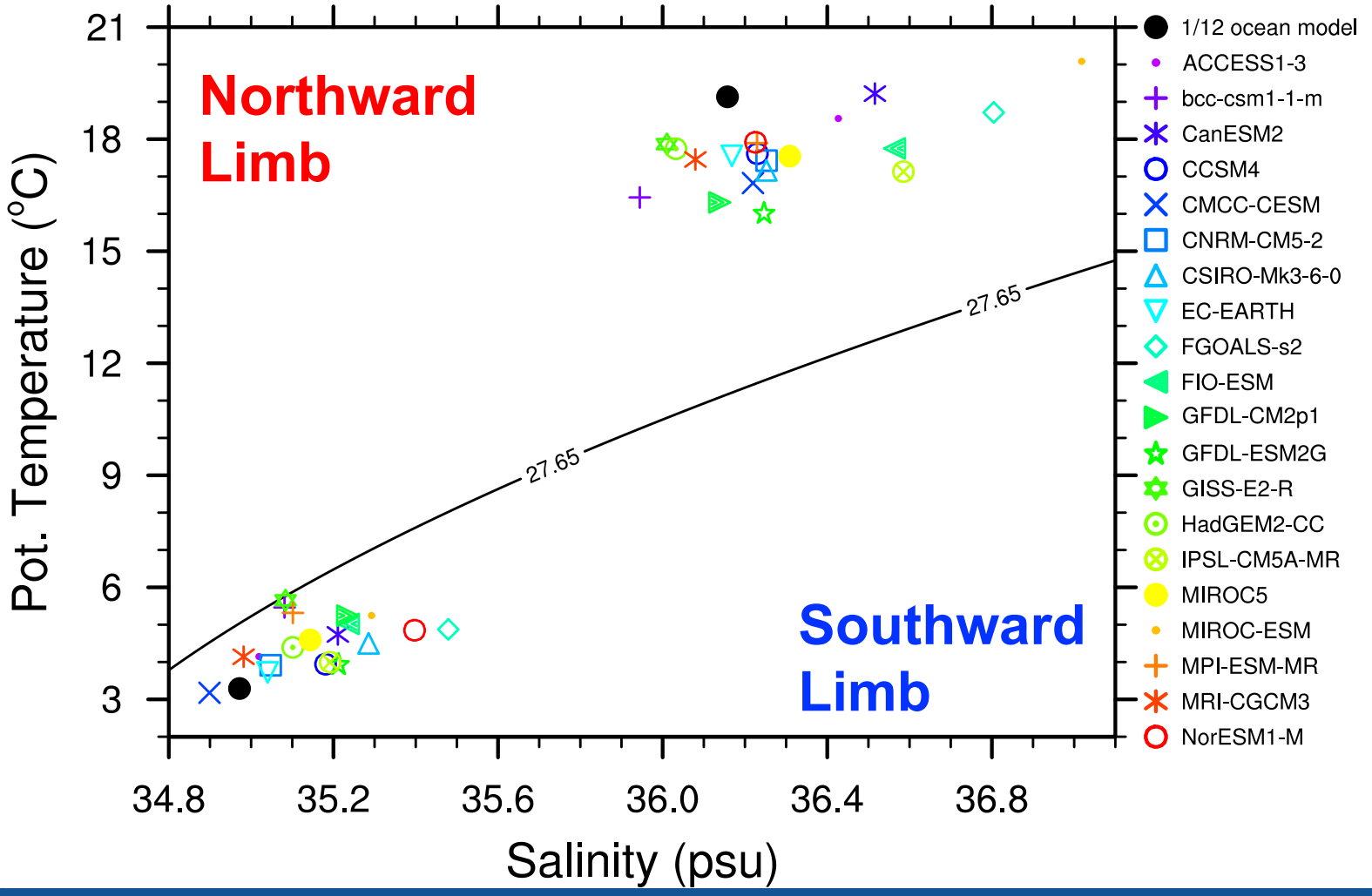


Left: Meridional transports on T-S plane, Q(T,S), at 26ºN from a high-resolution ocean simulation. Right: T-S diagram from observations.

High-resolution vs. CMIP5 models

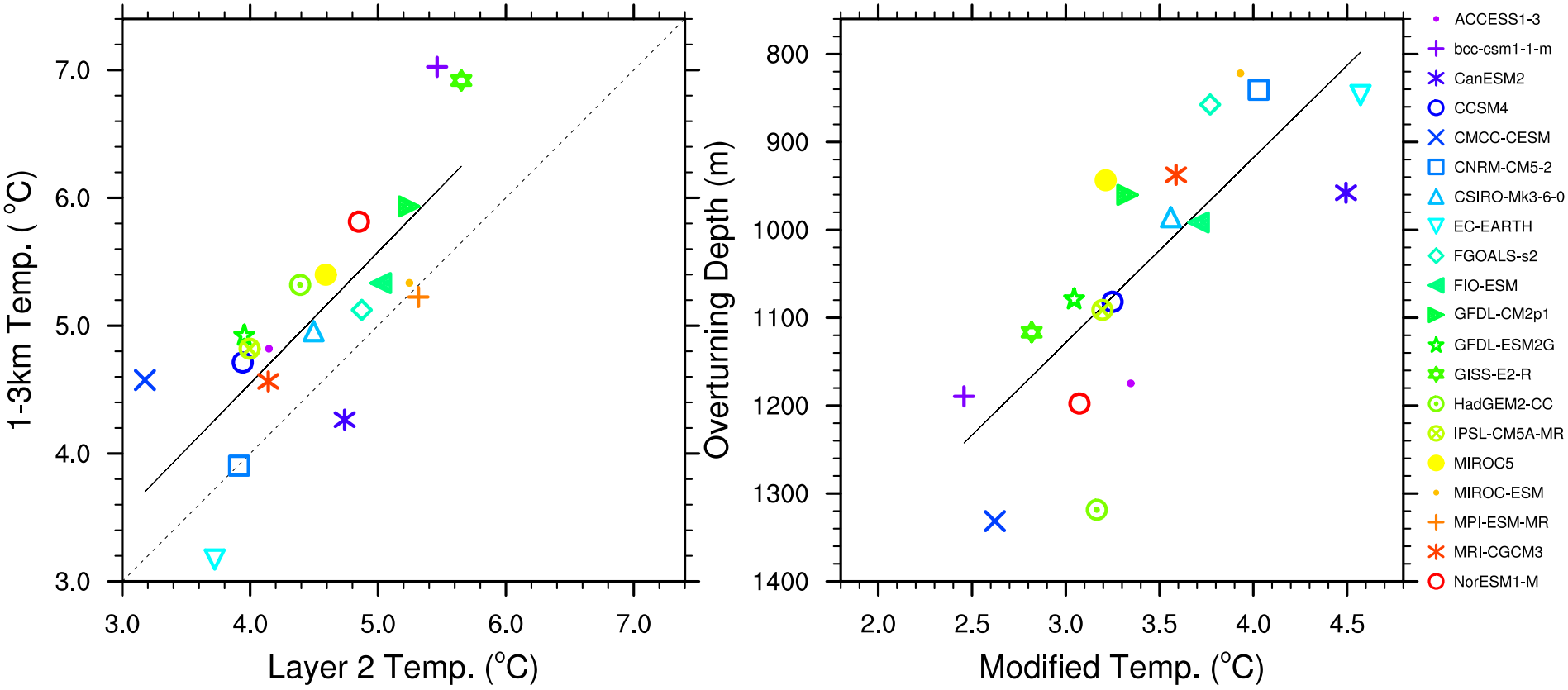


Transport weighted T/S



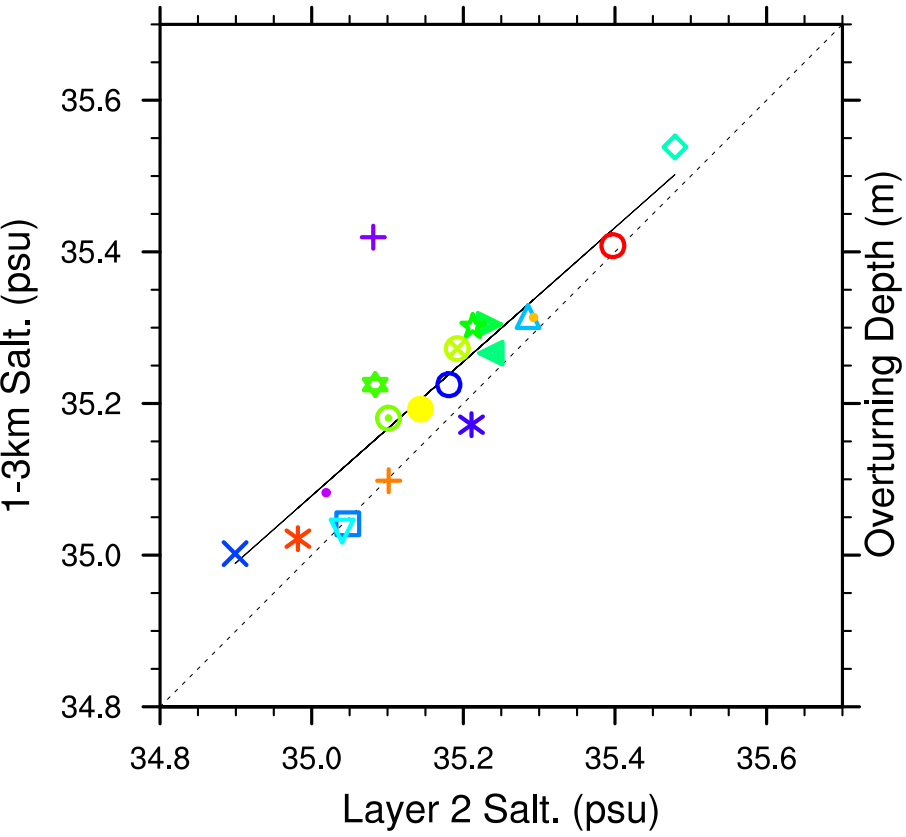
The 20 CMIP5 models exhibit, in general, a colder northward limb and a warmer southward limb, thus a smaller temperature contrast

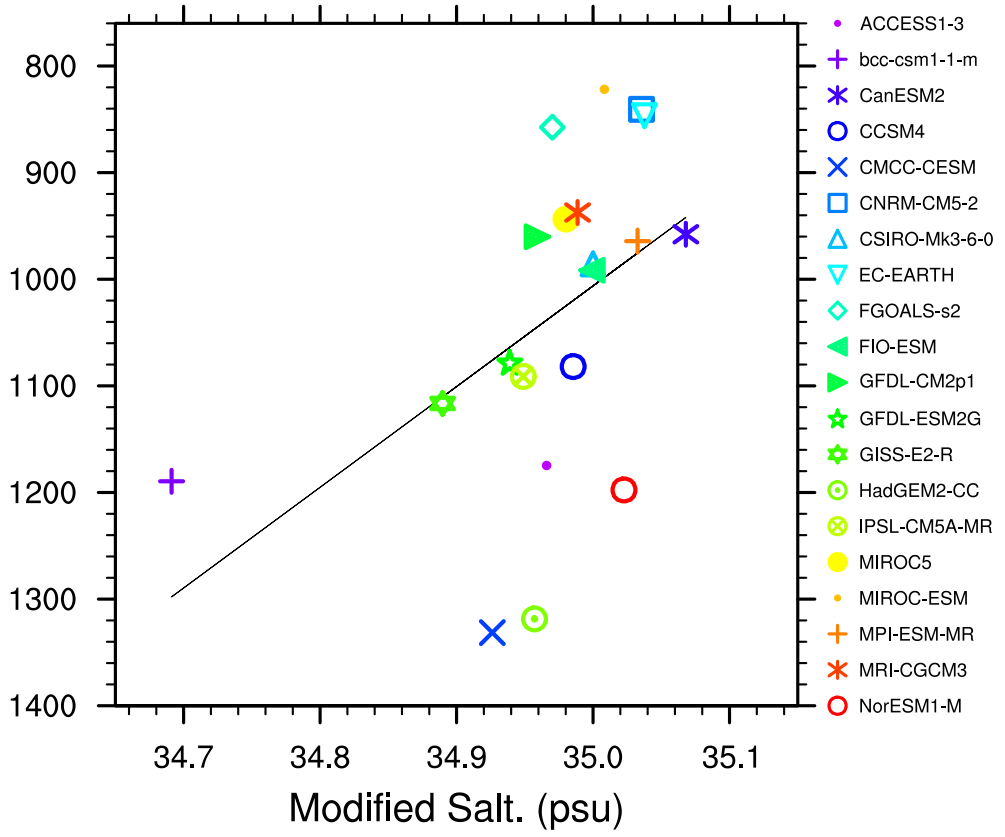
Warmer NADW in CMIP5



The layer 2 (NADW) temperature is correlated to, a) model bias in between 1000 and 3000 m and b) AMOC structure (overturning depth)

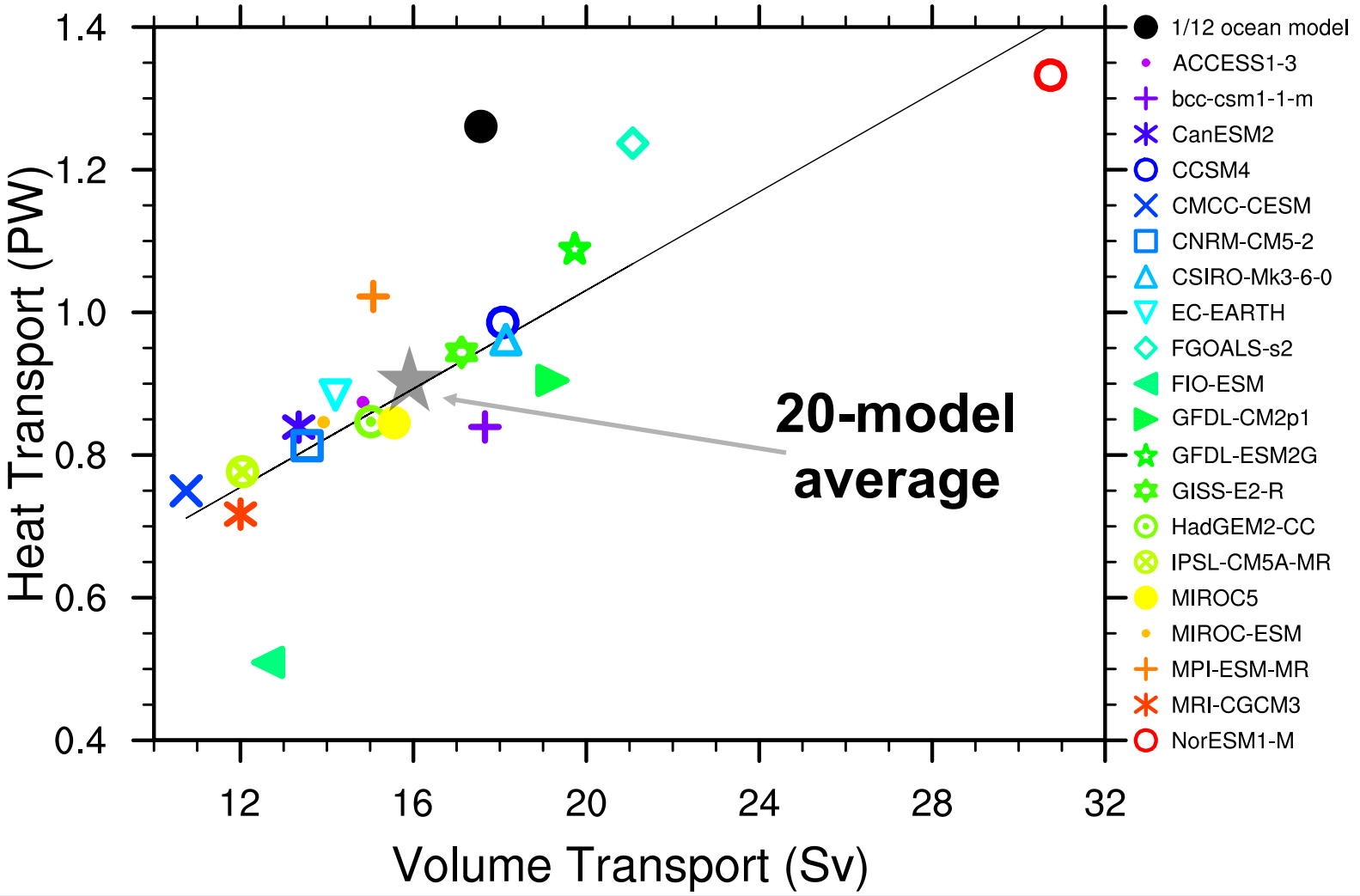
Saltier NADW in CMIP5





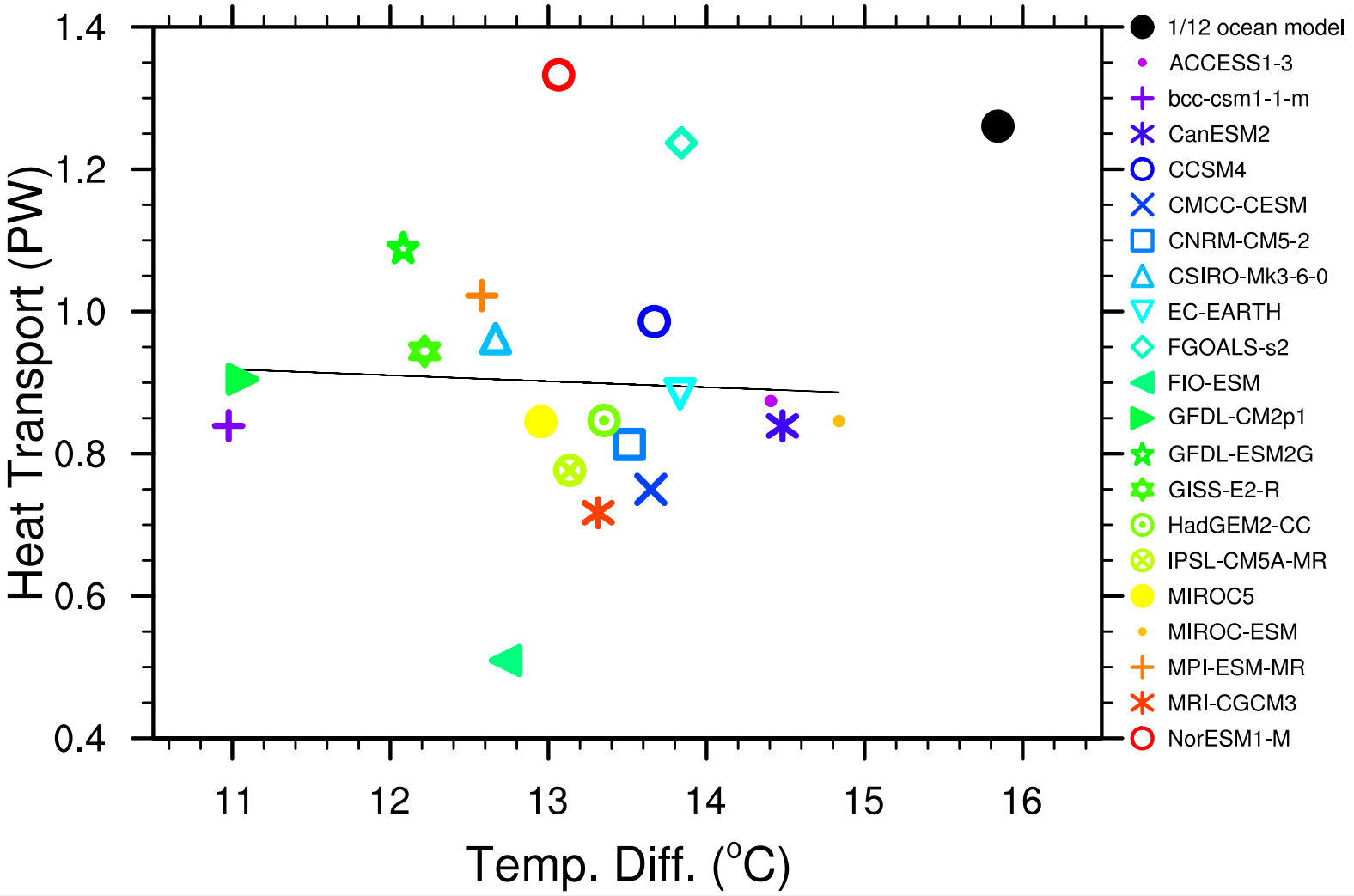
The layer 2 (NADW) salinity is mostly correlated to model bias between 1000 and 3000 m, no clear relation with the AMOC structure.

MHT vs AMOC strength at 26N



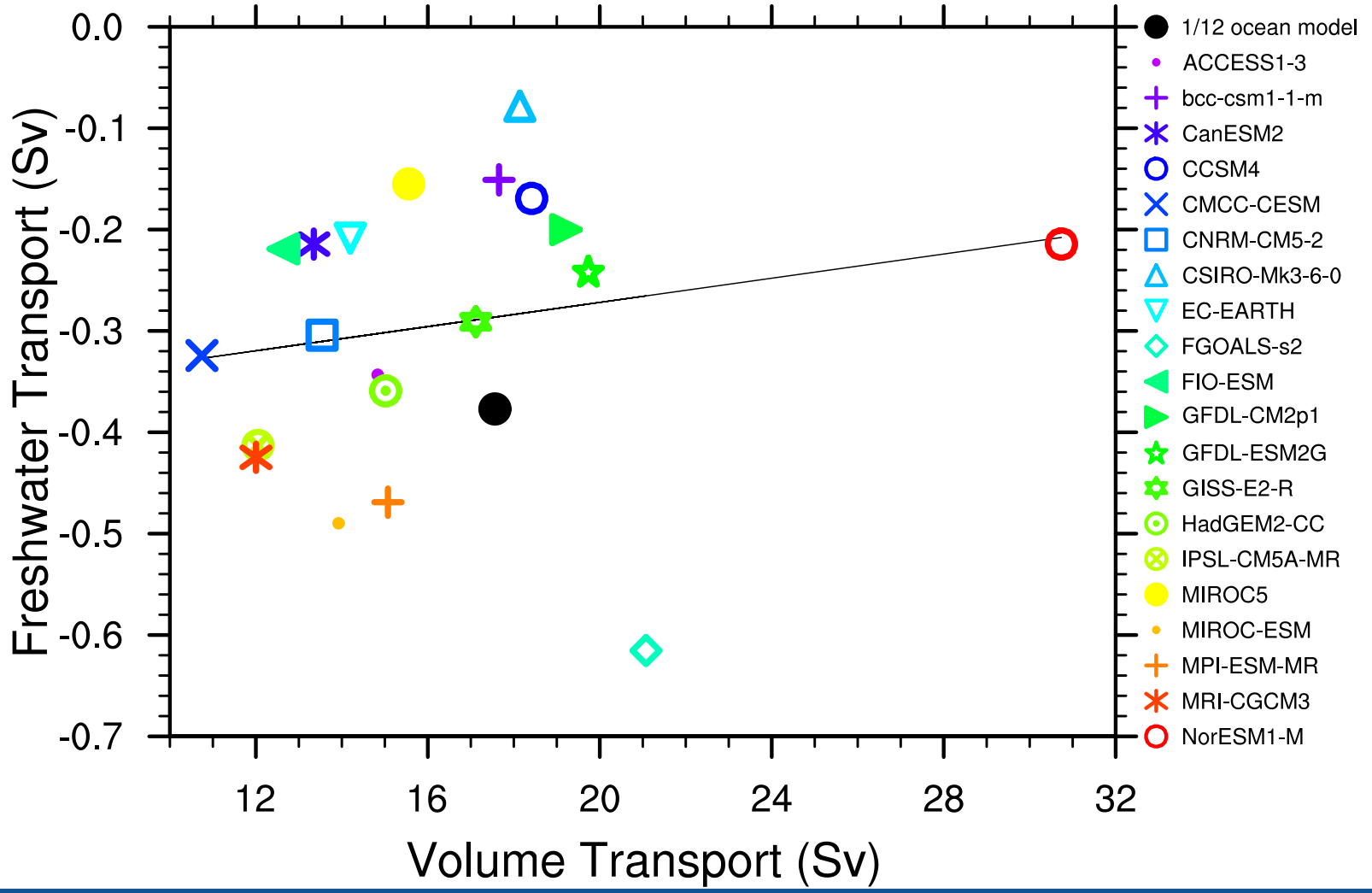
The model spread of MHT correlates with the AMOC strength; the average MHT is lower more due to smaller temperature contrast

MHT vs (T_1-T_2) at 26N



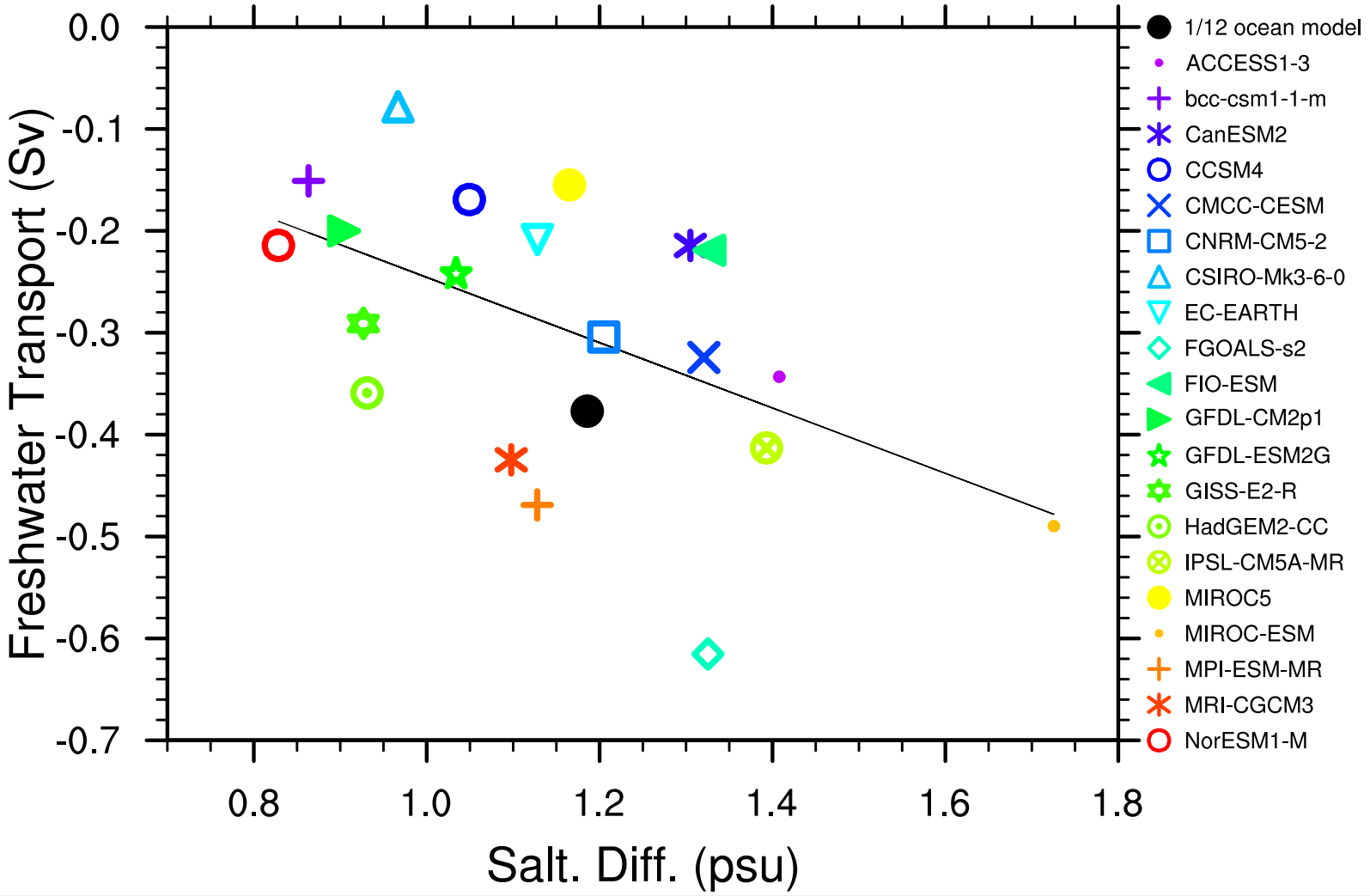
The model spread of MHT does not correlate with the (T_1-T_2); But the lower average MHT is in a large part because of smaller (T_1-T_2)

MFWT vs AMOC strength at 26N



The model spread of the MFWT does not correlate with the AMOC strength.

MFWT vs (S_1-S_2) at 26N

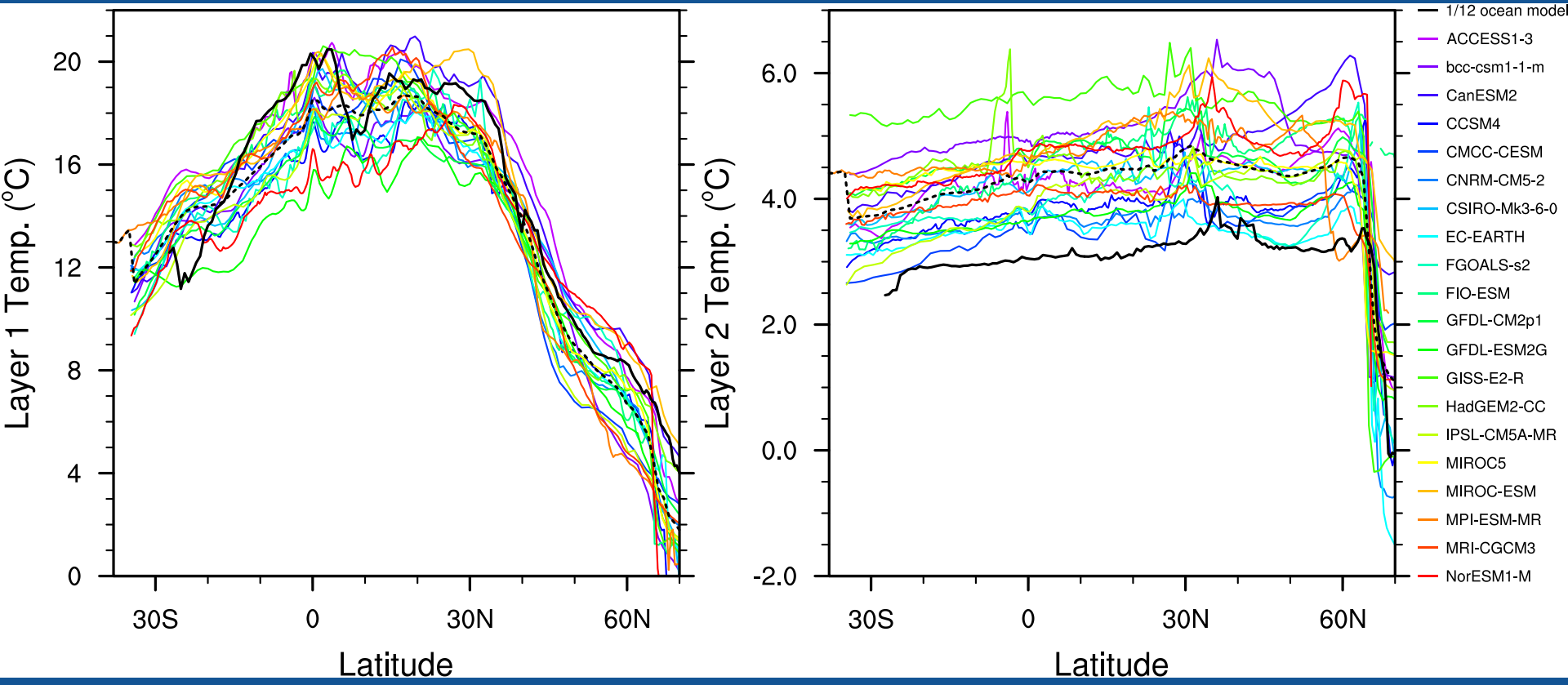


The model spread of the MFWT correlates with the salinity contrast (S_1-S_2)

Temp. as a function of latitude

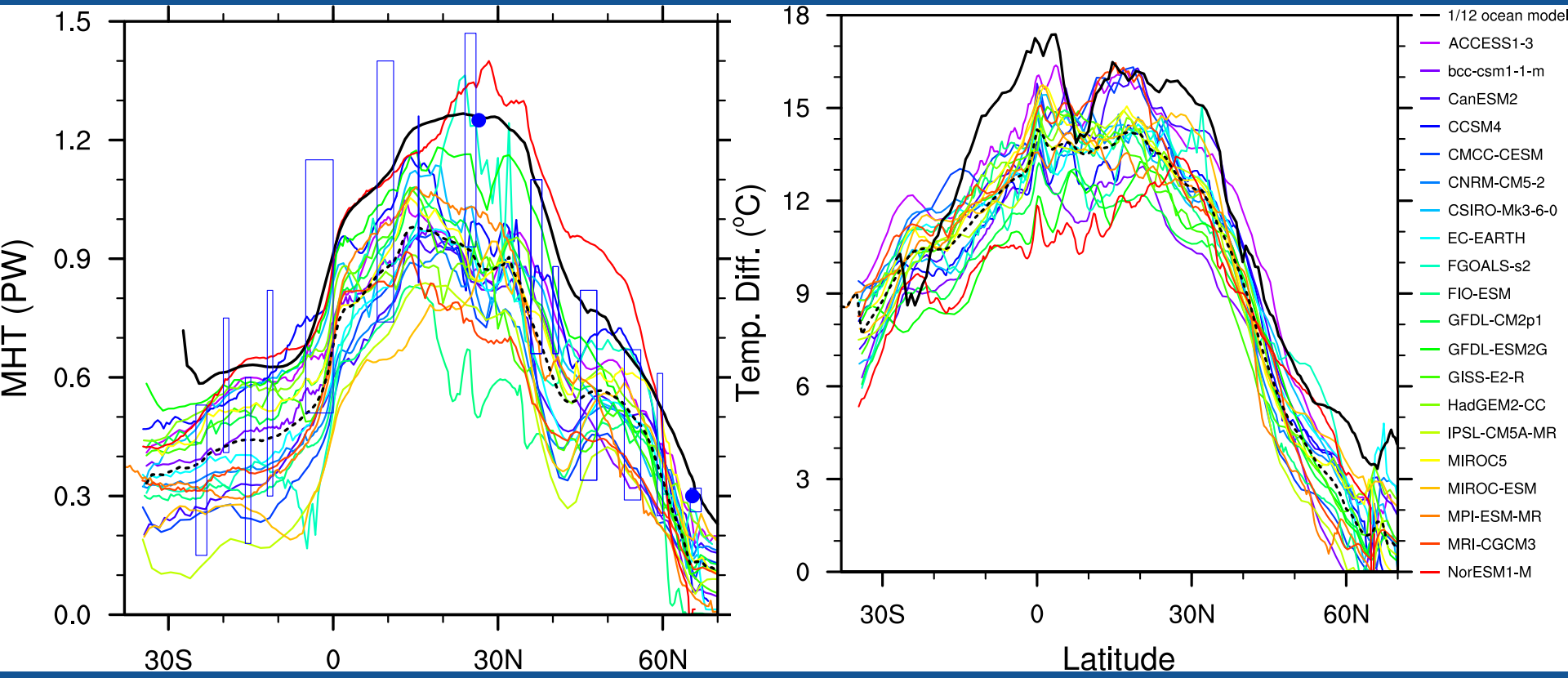
Layer 1

Layer 2



The water in southward limb is warmer in CMIP5 models than in high-resolution model; the water in the northward limb is often warmer.

MHT versus T_1-T_2

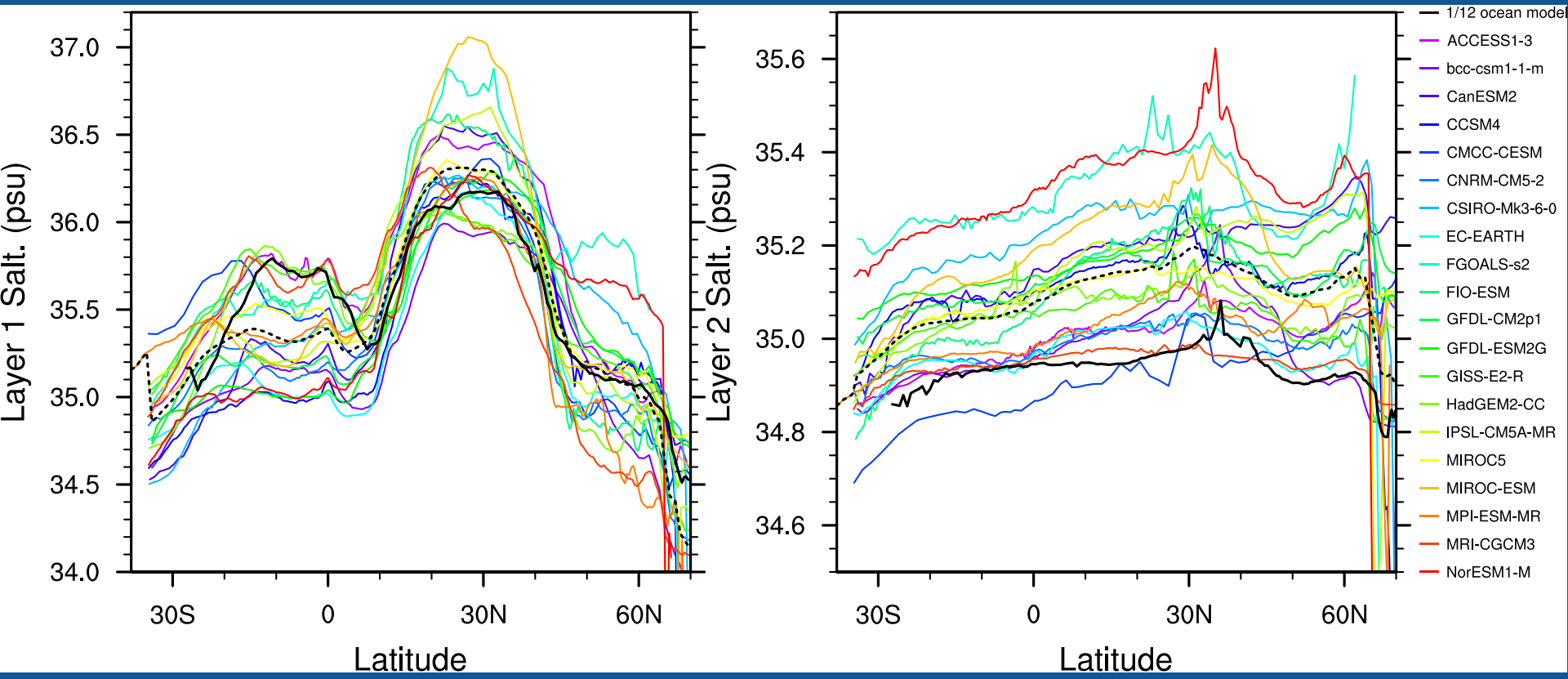


CMIP5 models exhibit MHT pattern that is in reasonable agreement with the observations, but lower in magnitude.

Saln. as a function of latitude

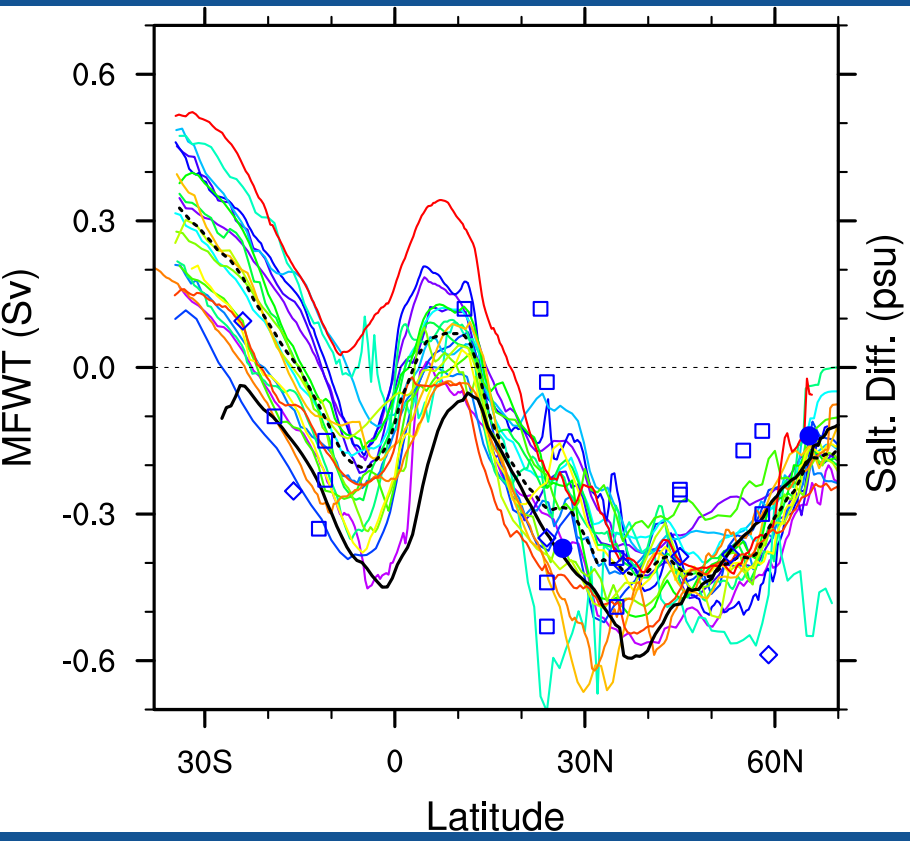
Layer 1

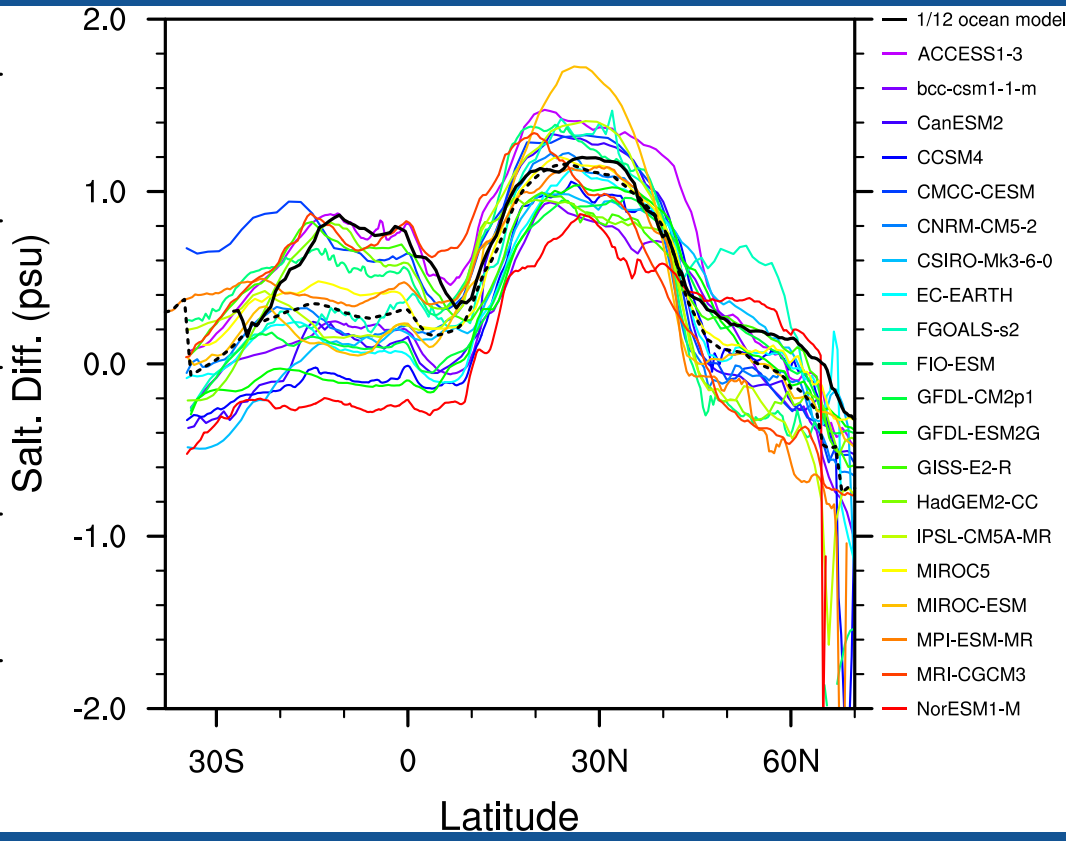
Layer 2



The water in southward limb is saltier in CMIP5 models than in high-resolution model.

MFWT and S_1-S_2





CMIP5 models exhibit MFWT pattern that is in reasonable agreement with the observations & high-res. Ocean simulation, large discrepancy in south Atlantic.

Summary

- The CMIP5 models, on average, represent the strength and the water properties of the AMOC reasonably well.

- Quantitatively, the CMIP5 models exhibit a warmer southward limb and colder northward limb of the AMOC. This smaller temperature contrast contributes to the lower MHT in 20 CMIP5 models, although the model spread is still controlled by AMOC strength. The warmer lower limb is related to a) temperature bias in the deep ocean (1000-3000m), and b) the AMOC structure, in particularly the depth of upper interface of the AMOC.

- The CMIP5 models also exhibit a saltier southward limb, which is related to the salinity bias in the deep ocean. The model spread of FWMT is correlated with the salinity contrast between northward and southward limbs.