Quantifying Salt-Advection Feedback in GFDL and CESM Pre-Industrial Control Simulations

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AMOC science meeting, May 23-25, 2017, Santa Fe, NM

Project Goal: to understand the controls and responses of freshwater budget of the Atlantic Ocean, and the role of the AMOC

more specifically, interplay between surface FW flux, storage, and interocean exchanges; identify drivers and response terms, and their operating time scales

Inter-basin exchange or ocean FW transport across a latitude is contributed by:

1) the AMOC;
2) gyre circulation;
3) eddies and mixing.

$F_{ov}(y) = -1/S_o \int_{-H}^{0} \bar{V}^{*} \langle S \rangle \, dz$ **Drijfhout et al. (2011)**

F_{ovs} **– F_{ov} at 33°S or southern boundary of the Atlantic Ocean**

$F_{ov}(y)$ **– F_{ov} as a function of latitude**

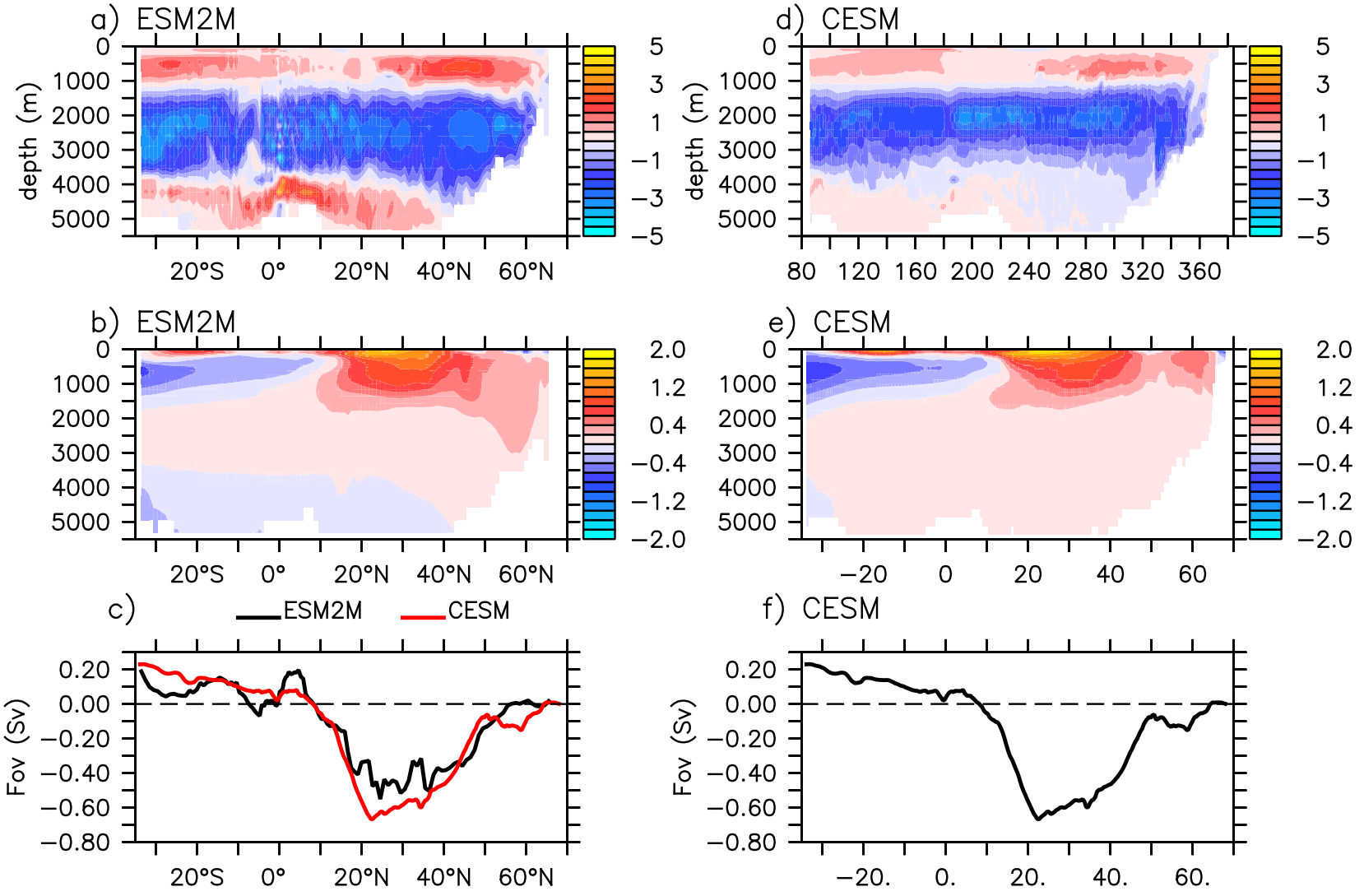
Input : GFDL and CESM, 1° ocean, pre-industrial control simulations in CMIP5 archive, monthly mean fields

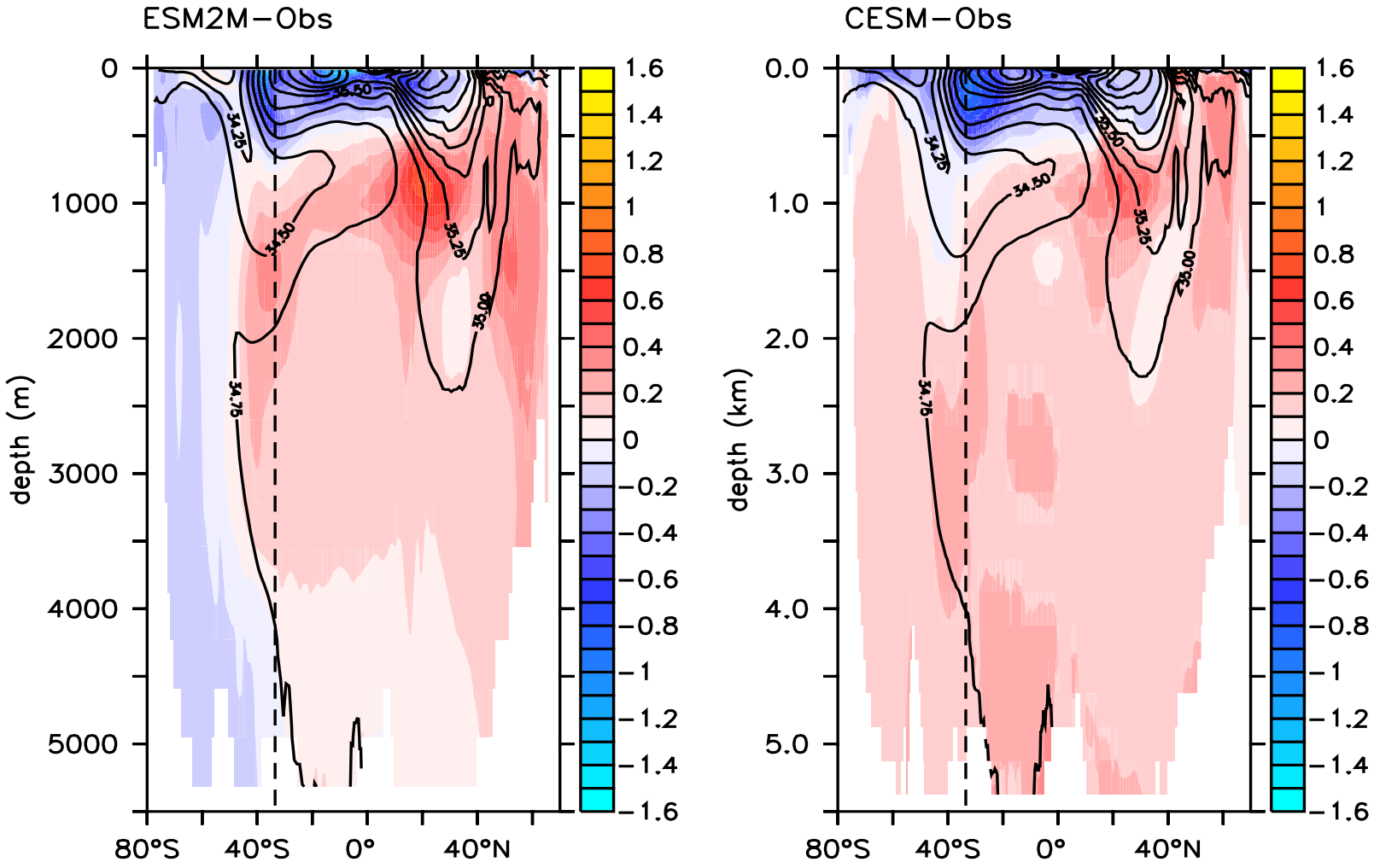
mean state structure

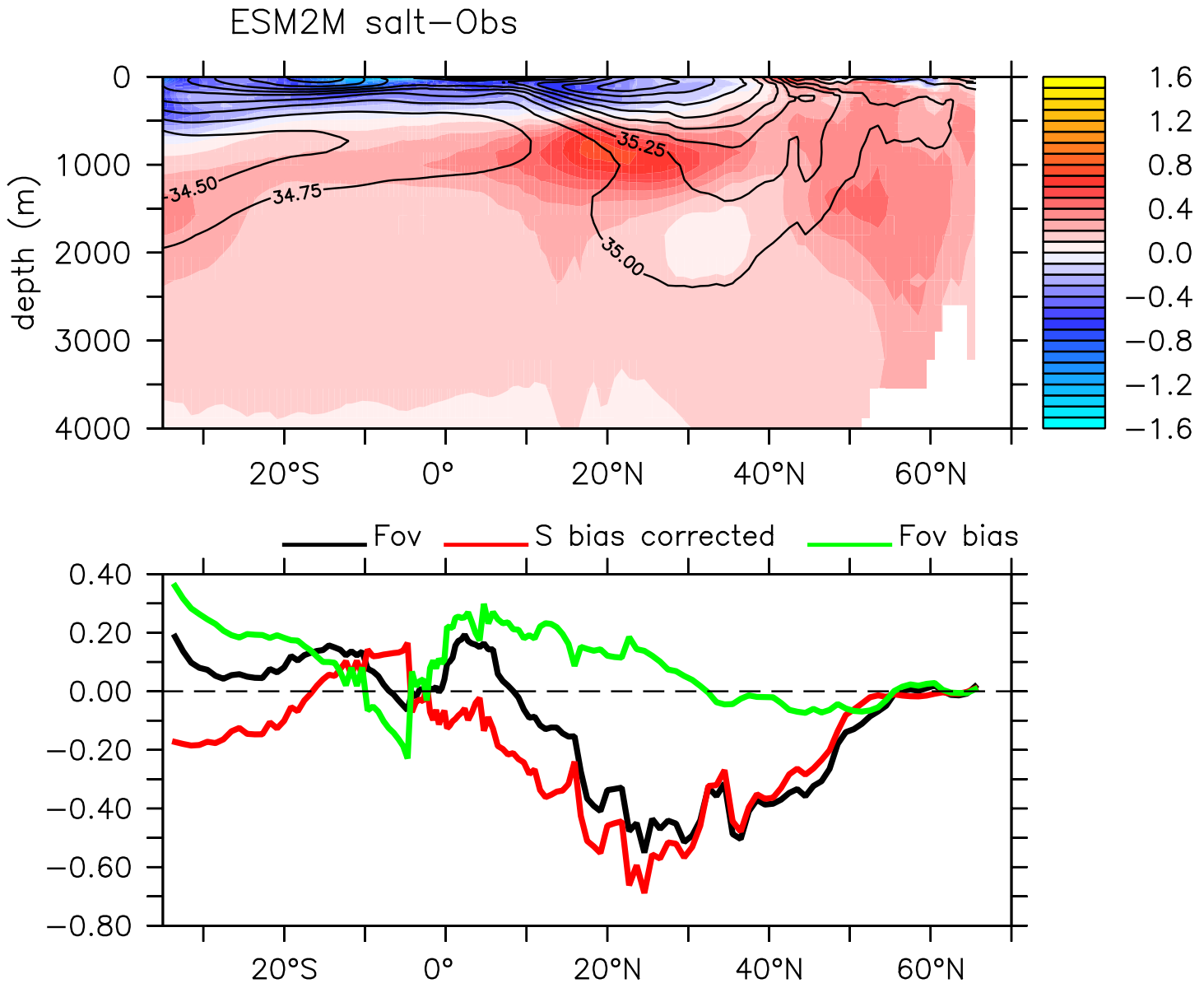
$\overline{T}^*$

$\overline{(S)}-35$

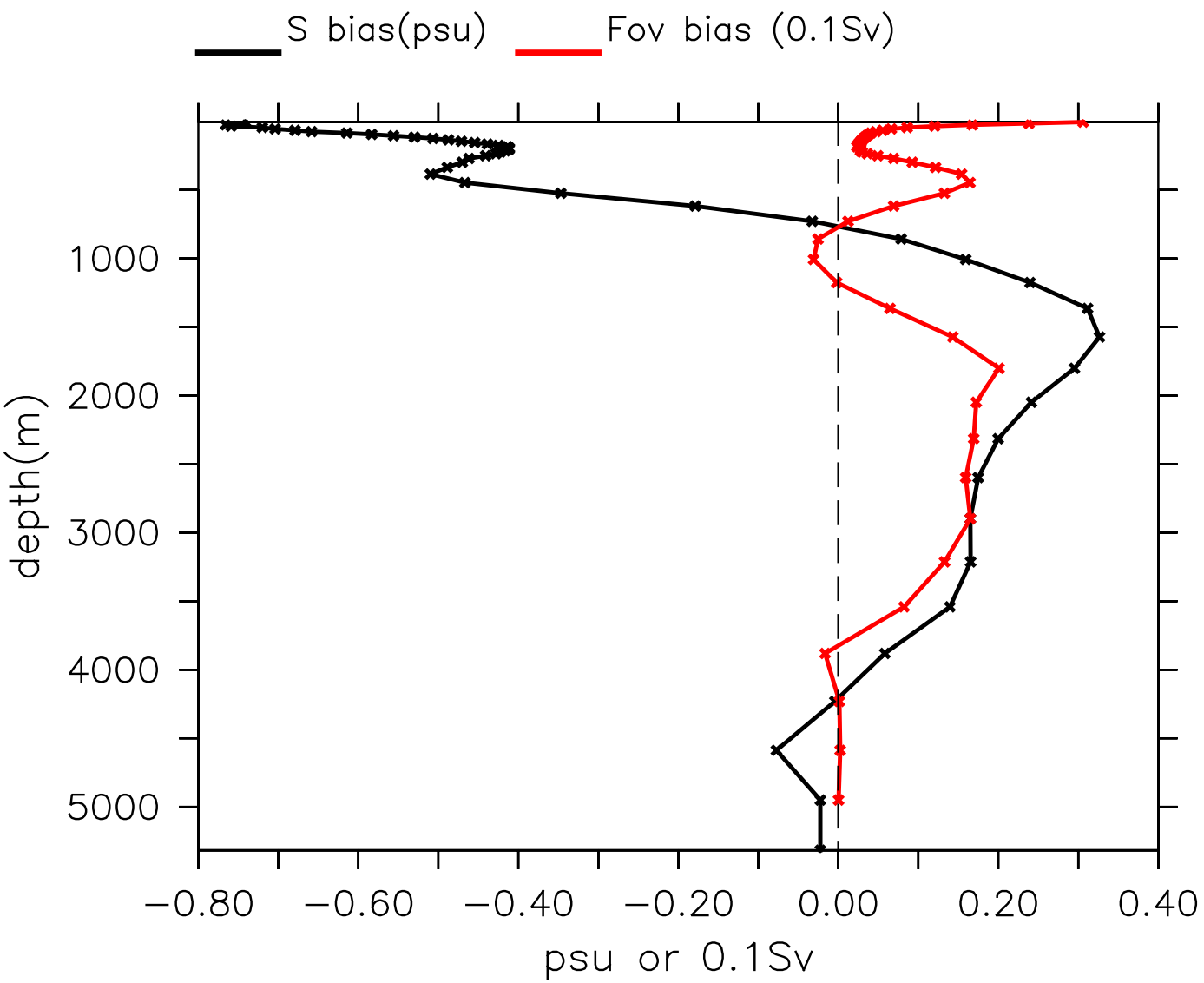
F_{ov}



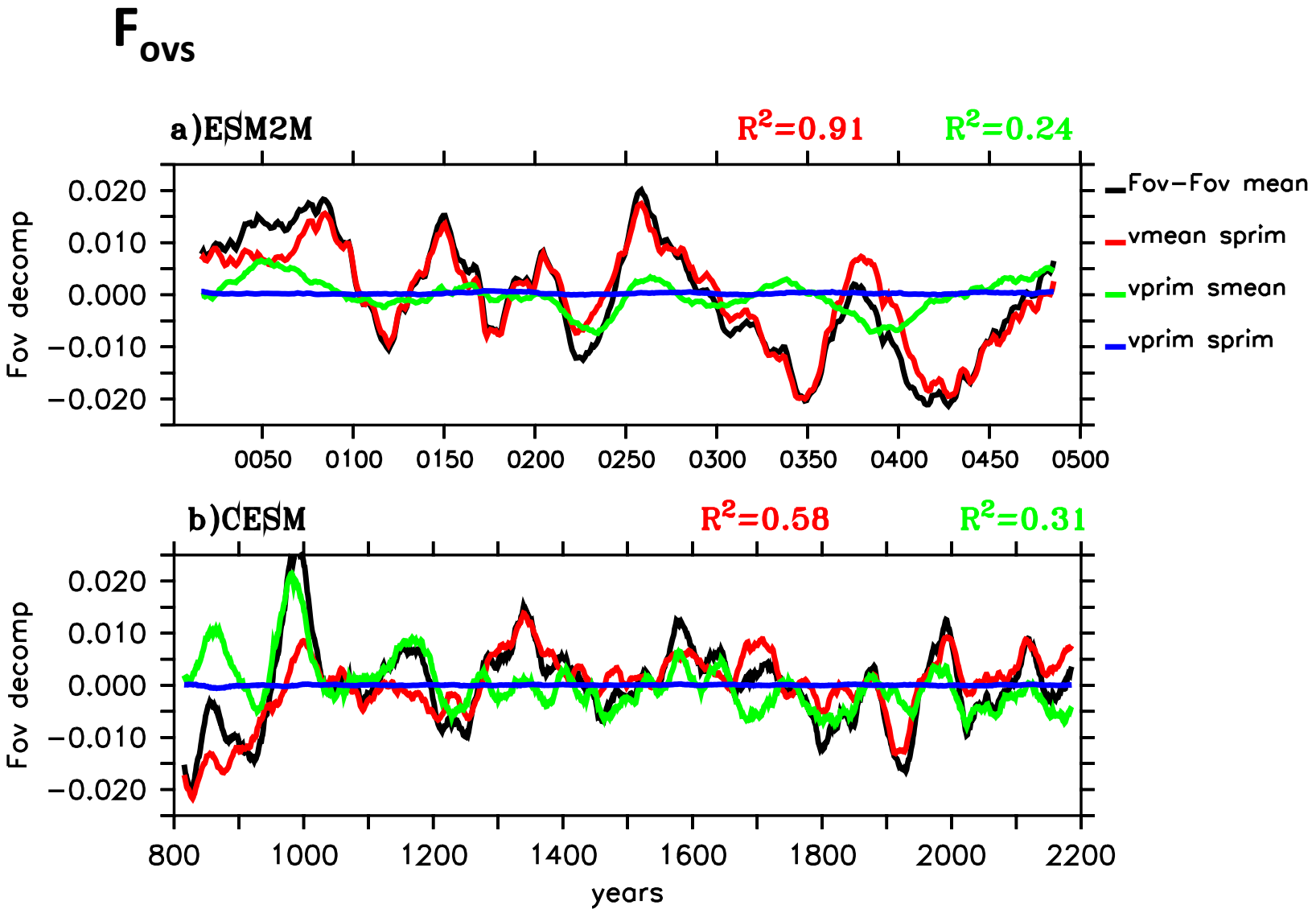

ESM2M−Obs
CESM−Obs
depth (m)
depth (km)
0
1000
2000
3000
4000
5000
0.0
1.0
2.0
3.0
4.0
5.0
80°S
40°S
0°
40°N
34.25
34.50
34.75
35.00
35.25
35.50
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−1.2
−1.4
−1.6


ESM2M salt−Obs
depth (m)
0
1000
2000
3000
4000
34.50
34.75
35.25
35.00
1.6
1.2
0.8
0.4
0.0
−0.4
−0.8
−1.2
−1.6
20°S
0°
20°N
40°N
60°N
Fov
S bias corrected
Fov bias
0.40
0.20
0.00
−0.20
−0.40
−0.60
−0.80
20°S
0°
20°N
40°N
60°N

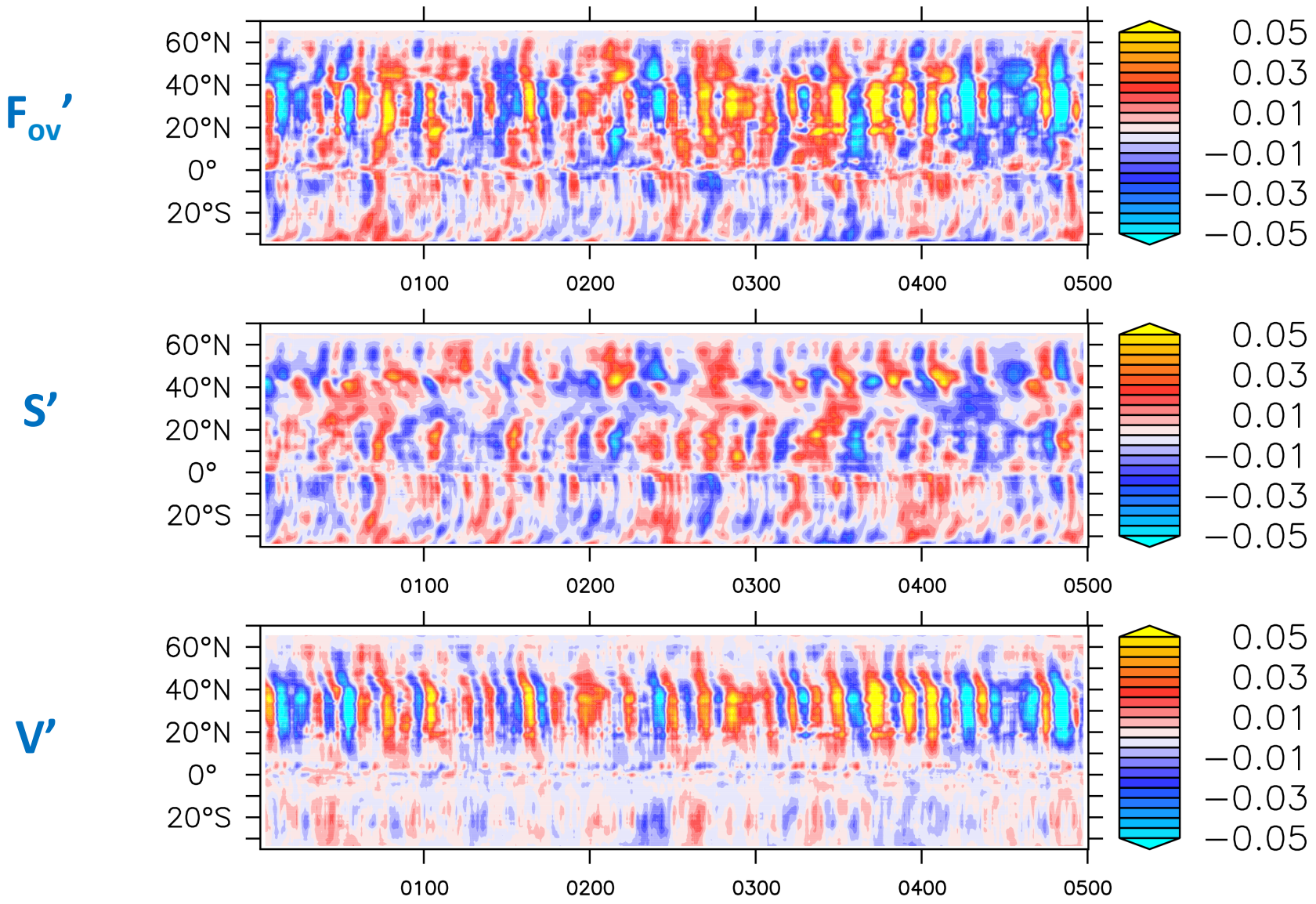
bias vertical distribution, at 33°S



S' dominates Fov', over most of the Atlantic Ocean

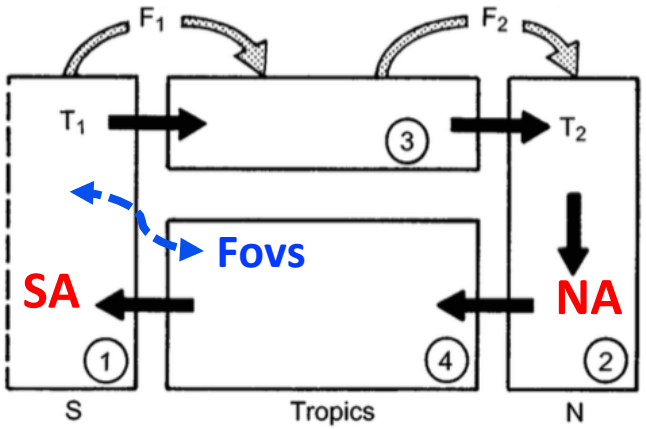


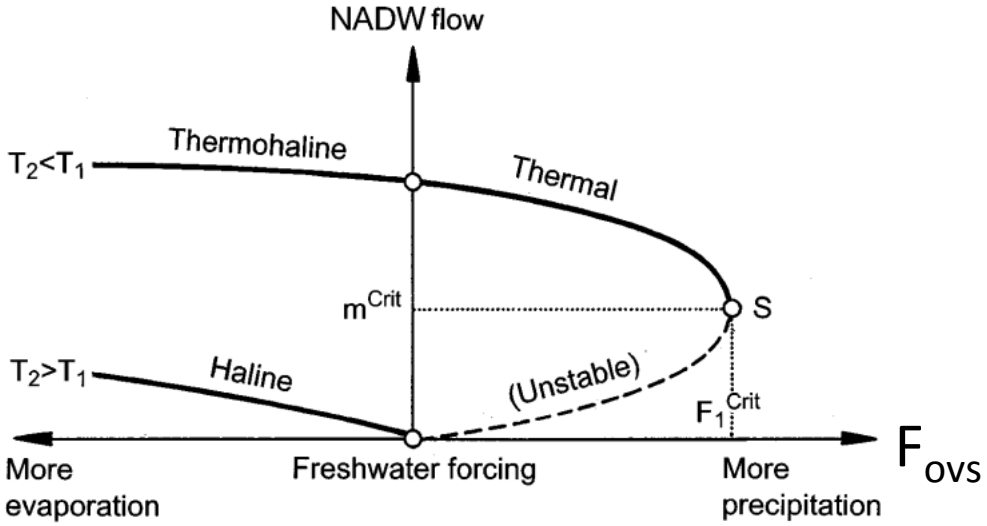
GFDL-ESM2M


F_{ov}'
S'
V'
60°N
40°N
20°N
0°
20°S
0100
0200
0300
0400
0500
0.05
0.03
0.01
−0.01
−0.03
−0.05

Sign of F_{ovs} as an AMOC stability indicator

Rahmstorf (1996)





used by CGCM studies – e.g., Hawkins et al. (2011), Liu et al. (2017), etc.

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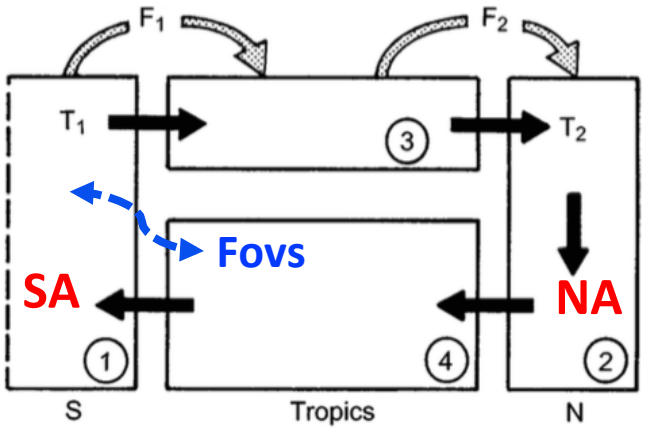
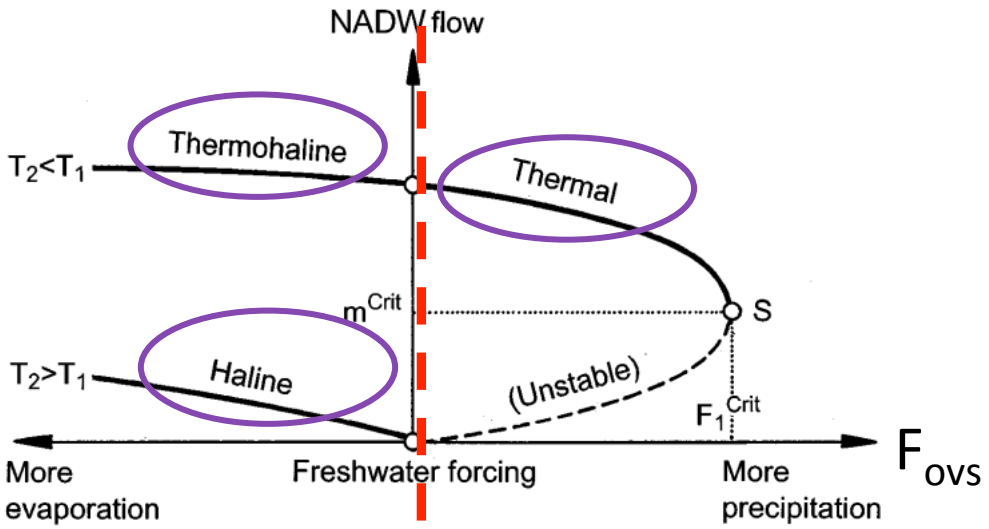
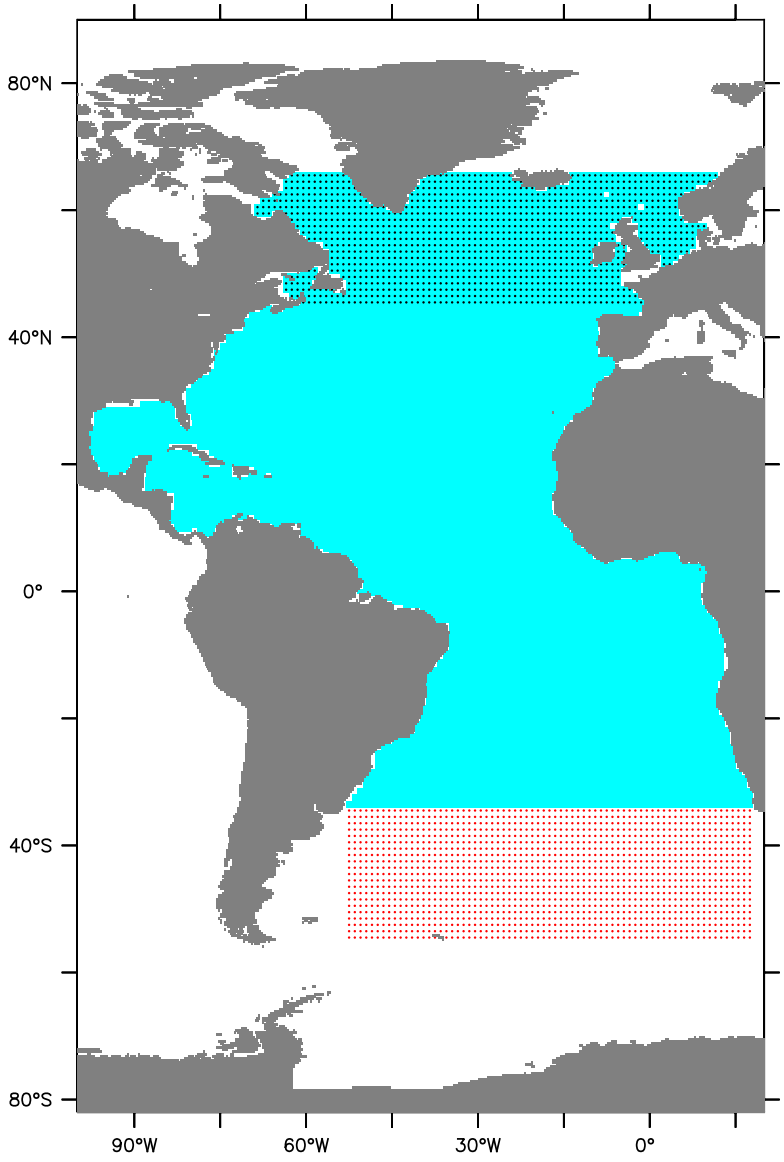




F_{ovs}>0, saltier NA

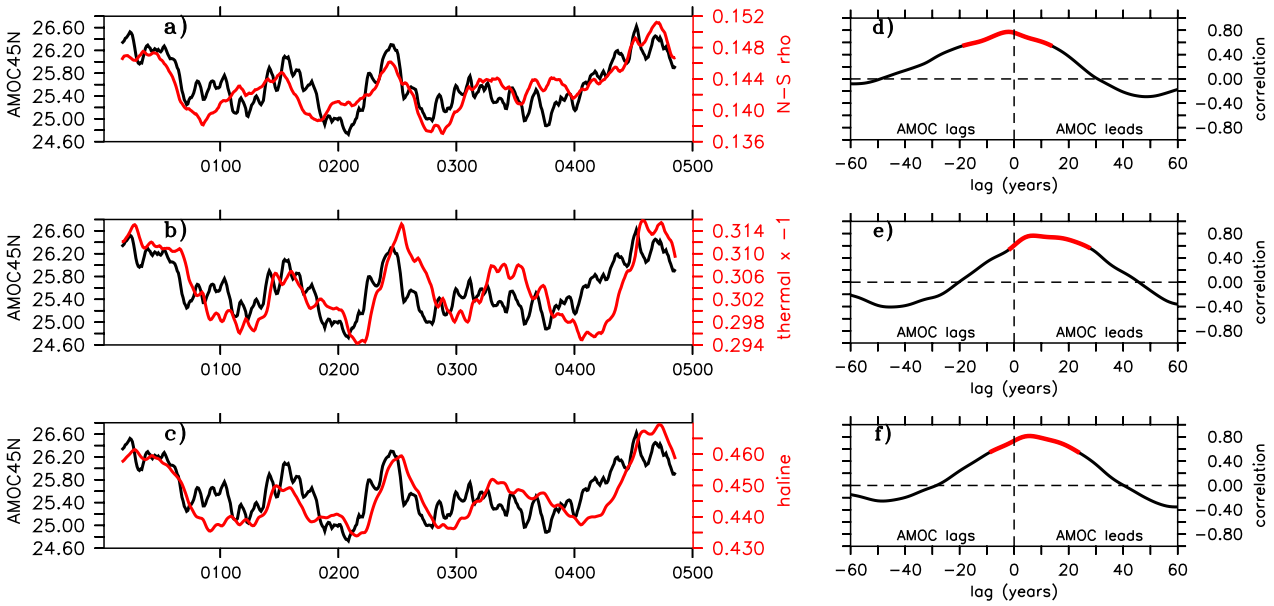
F_{ovs}<0, fresher colder NA

used by CGCM studies – e.g., Hawkins et al. (2011), Liu et al. (2017), etc.



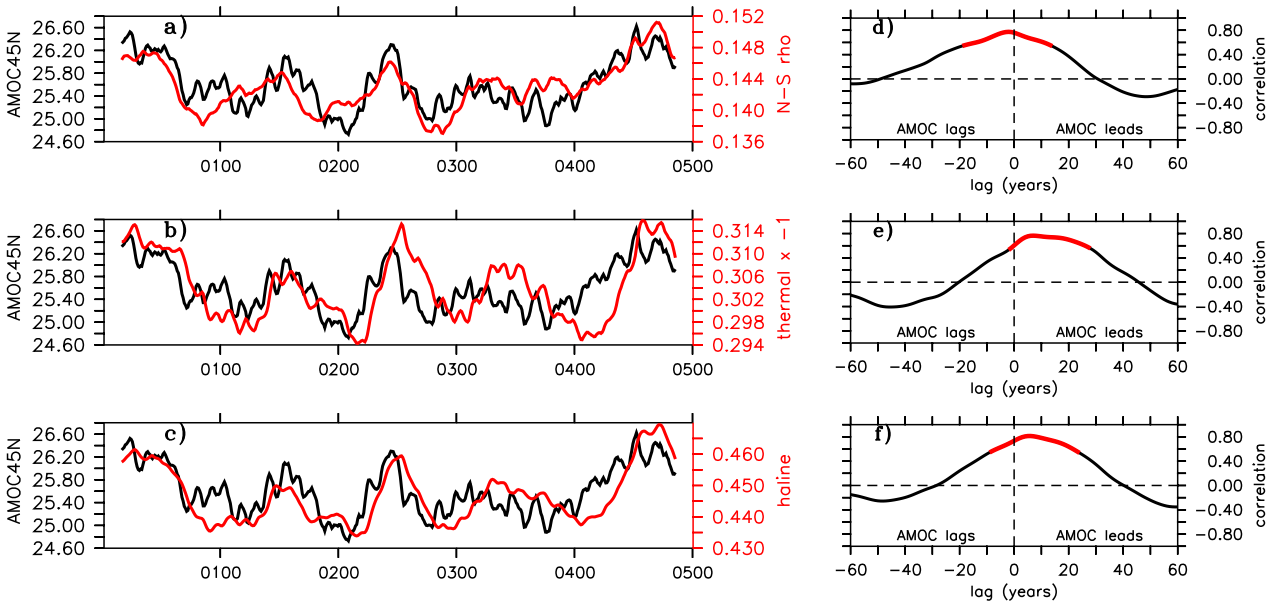
0-4000 m

AMOC variability correlated with N-S density difference – as in box model

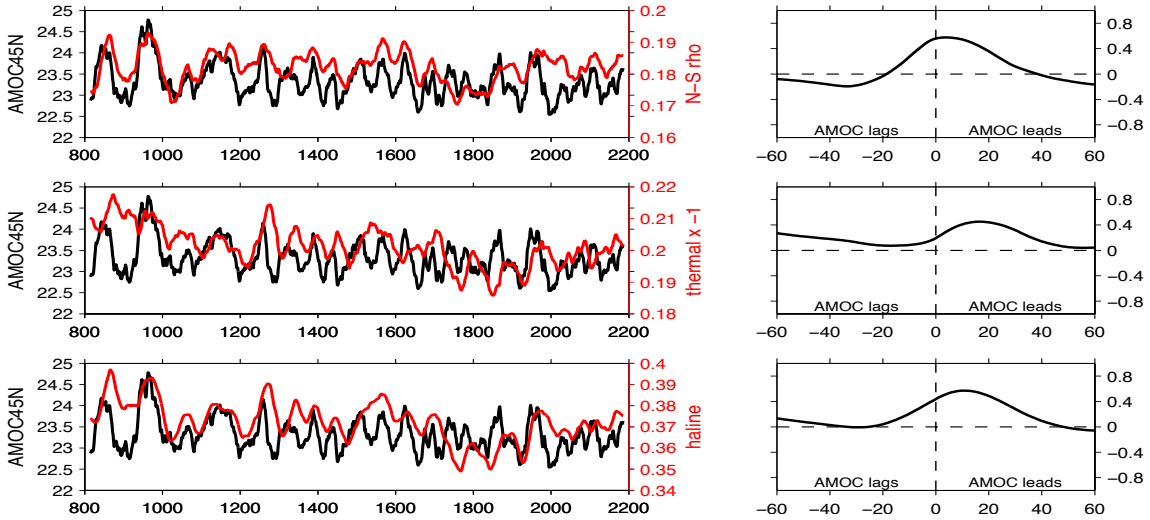


ESM2M

AMOC variability correlated with N-S density difference – as in box model

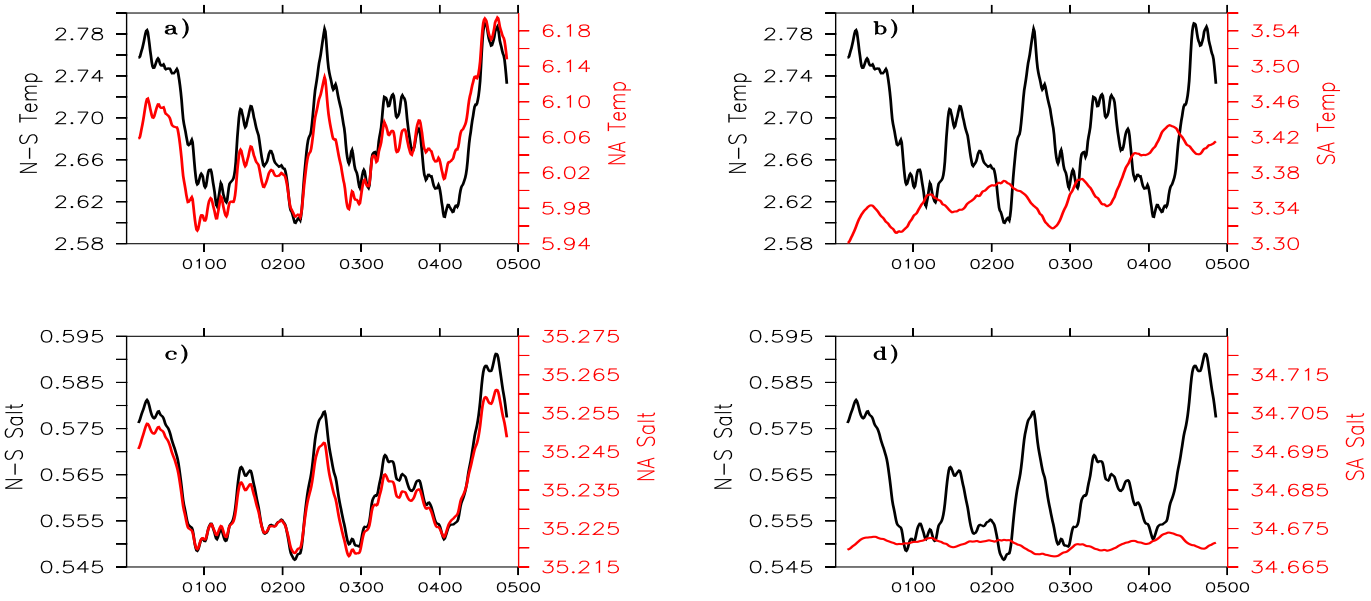


ESM2M



CESM

But, what contributes to the N-S density dif - is it south or north or both?



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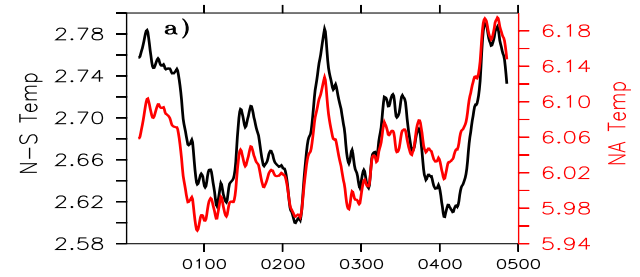
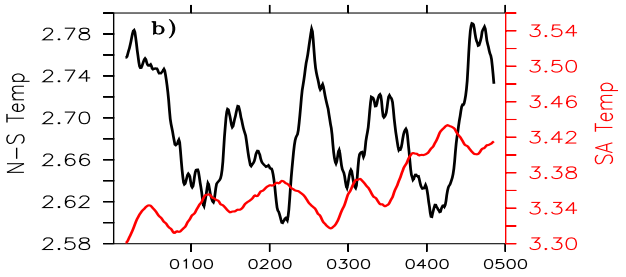
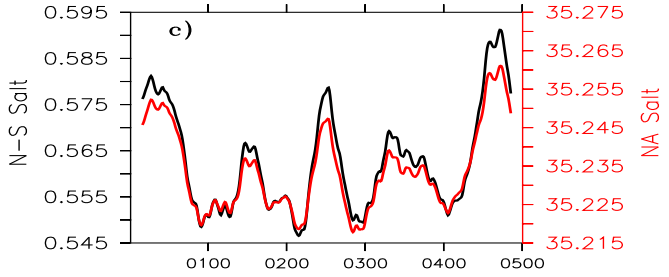
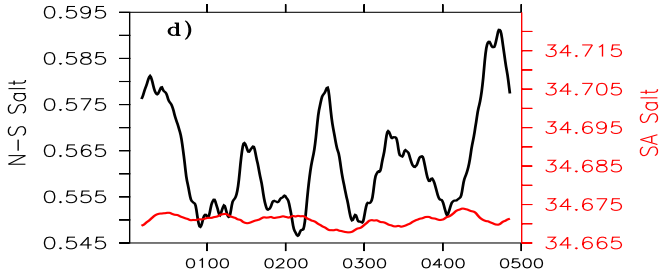
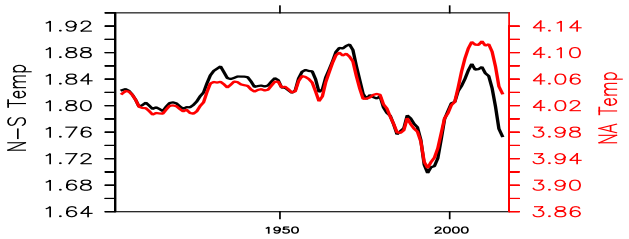


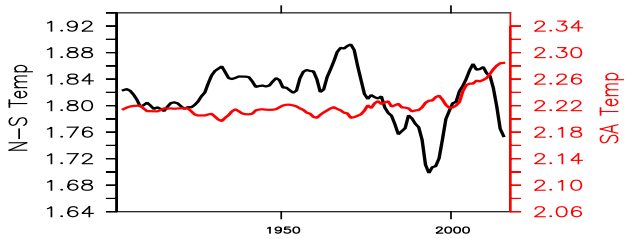


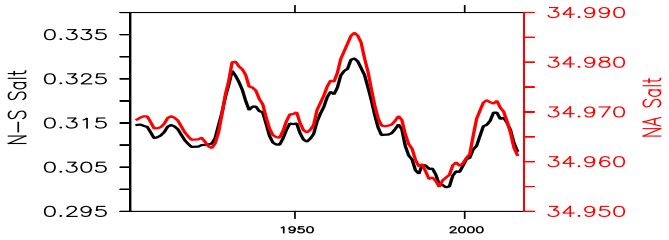


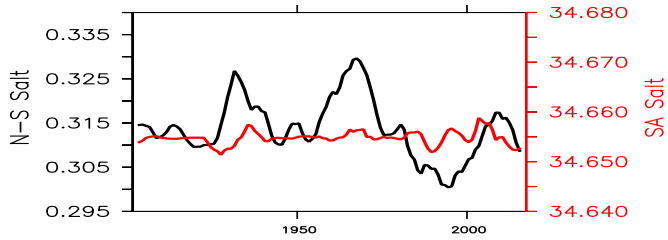


ESM2M



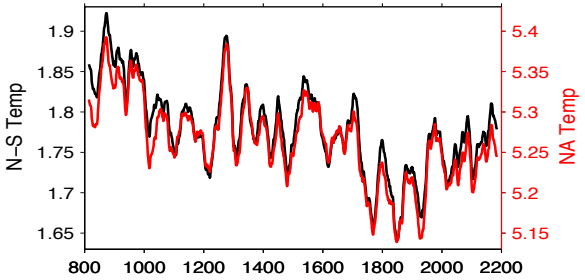


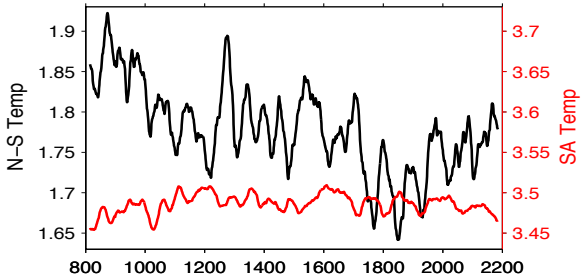


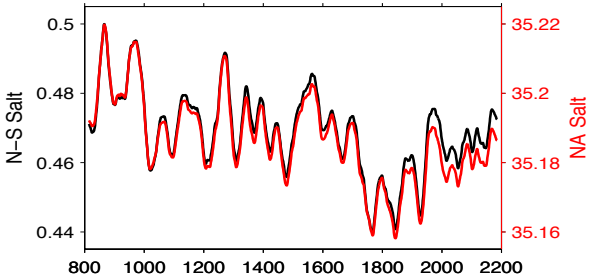


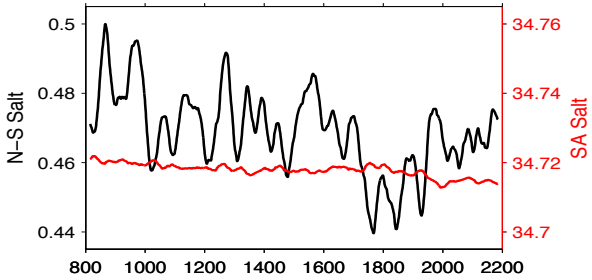
EN4

But, what contributes to the N-S density dif - is it south or north Atlantic or both?

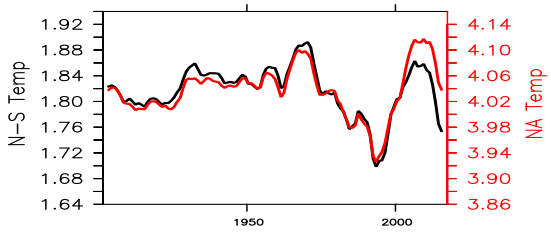


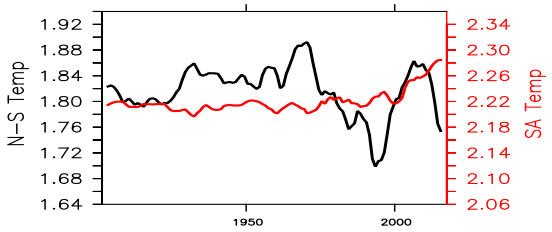


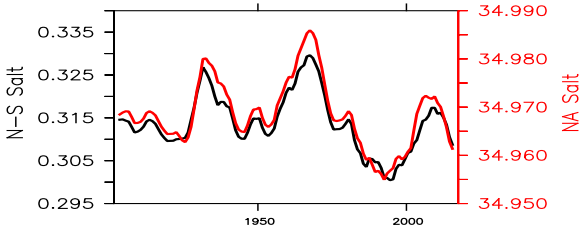


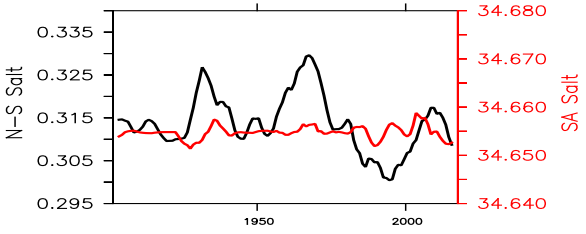


CESM



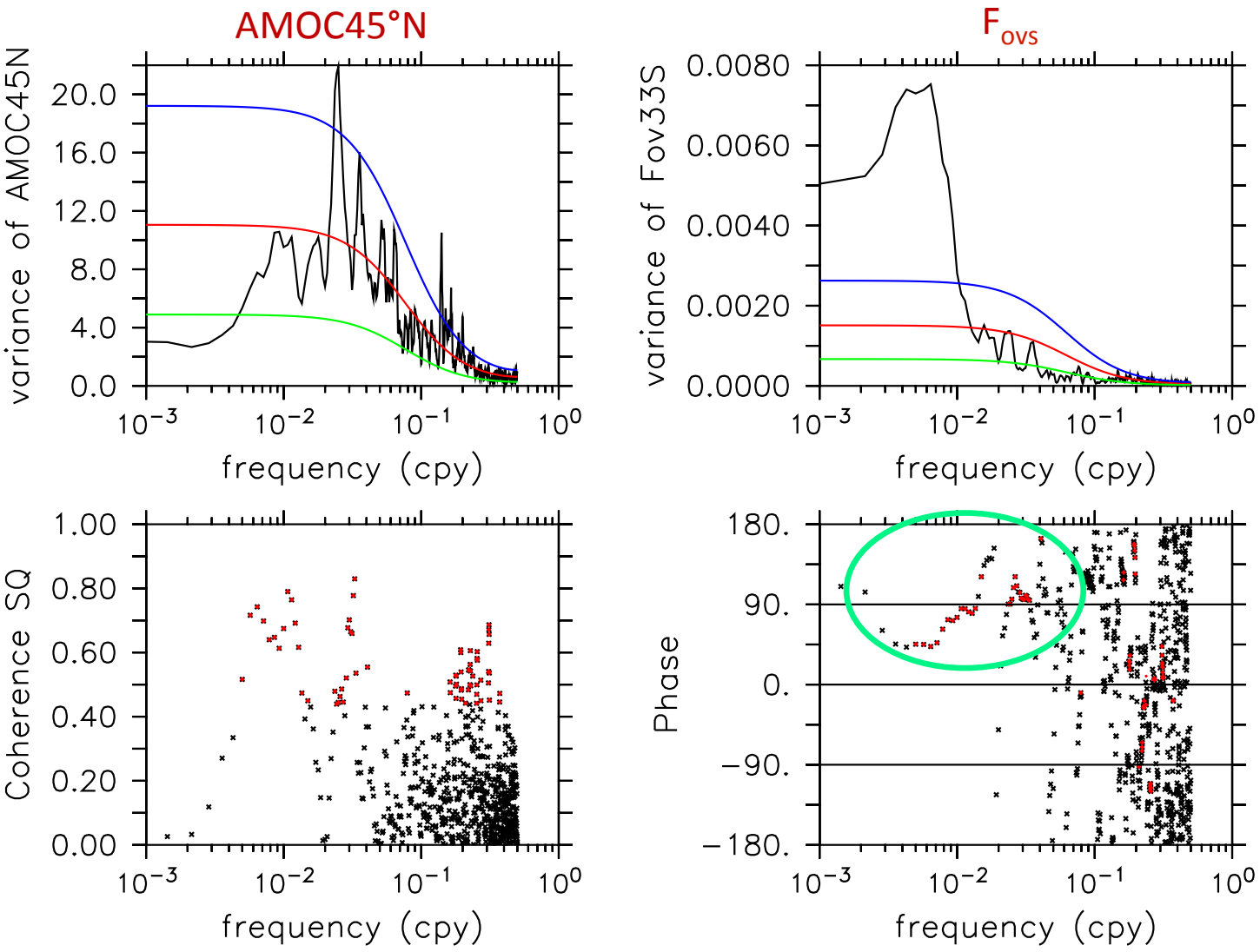




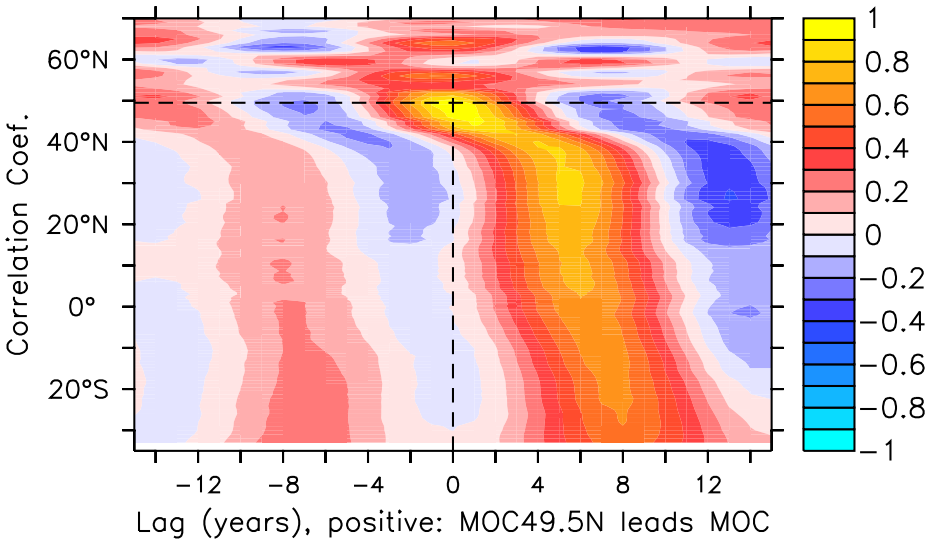


EN4

How does F_{ovs} interact with far-field AMOC?

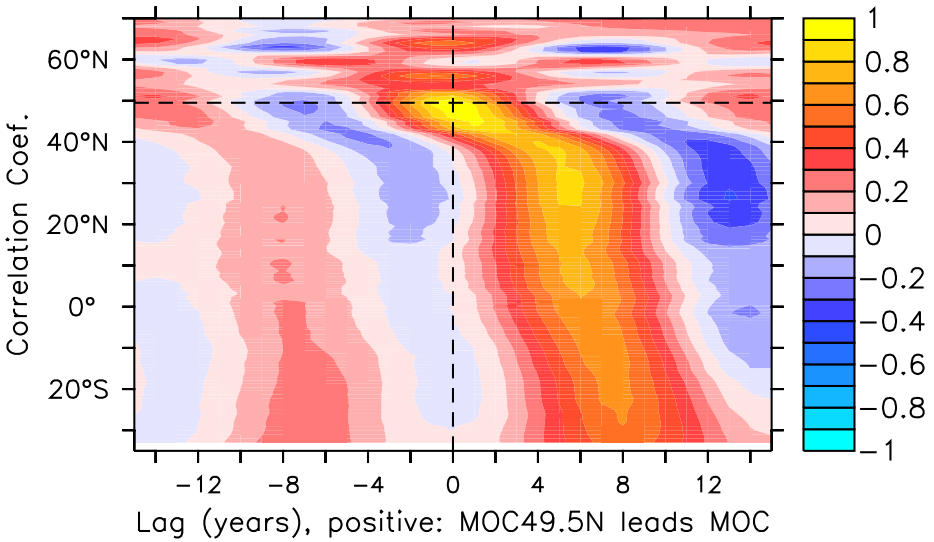


Lagged correlation between MOC49°N and MOC(y)



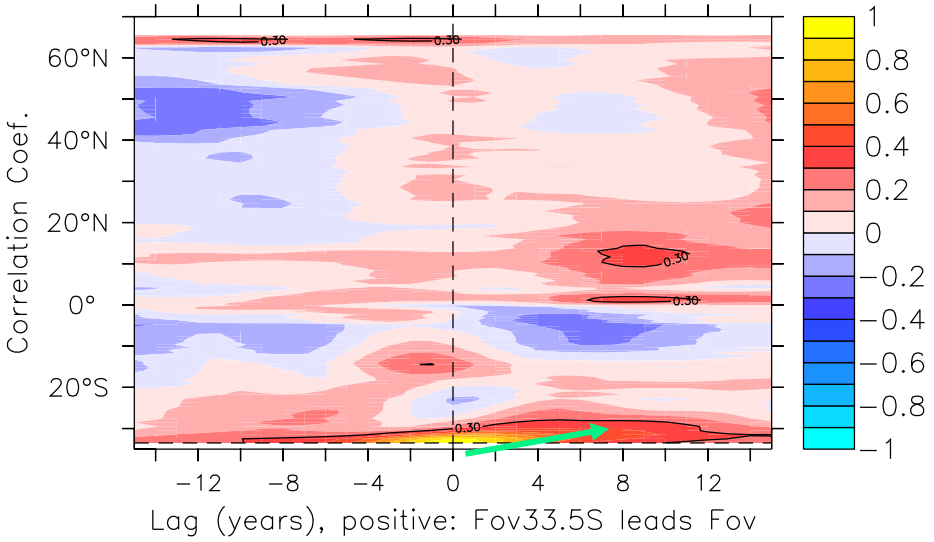
Southward propagation as in Zhang (2010)

Lagged correlation between MOC49°N and MOC(y)



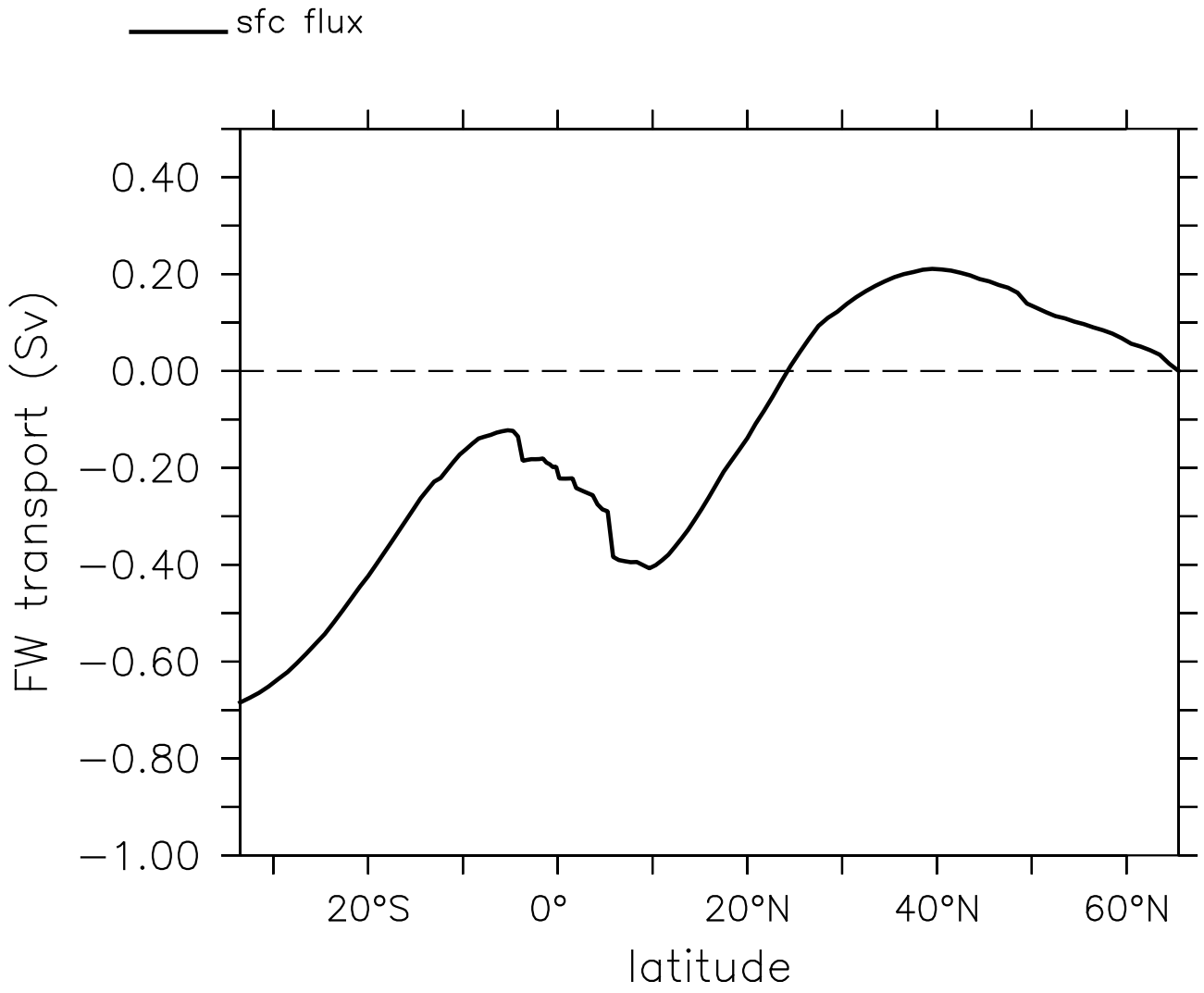
Southward propagation as in Zhang (2010)

Lagged correlation between F_{ovs} and F_{ov}(y)



limited northward penetration

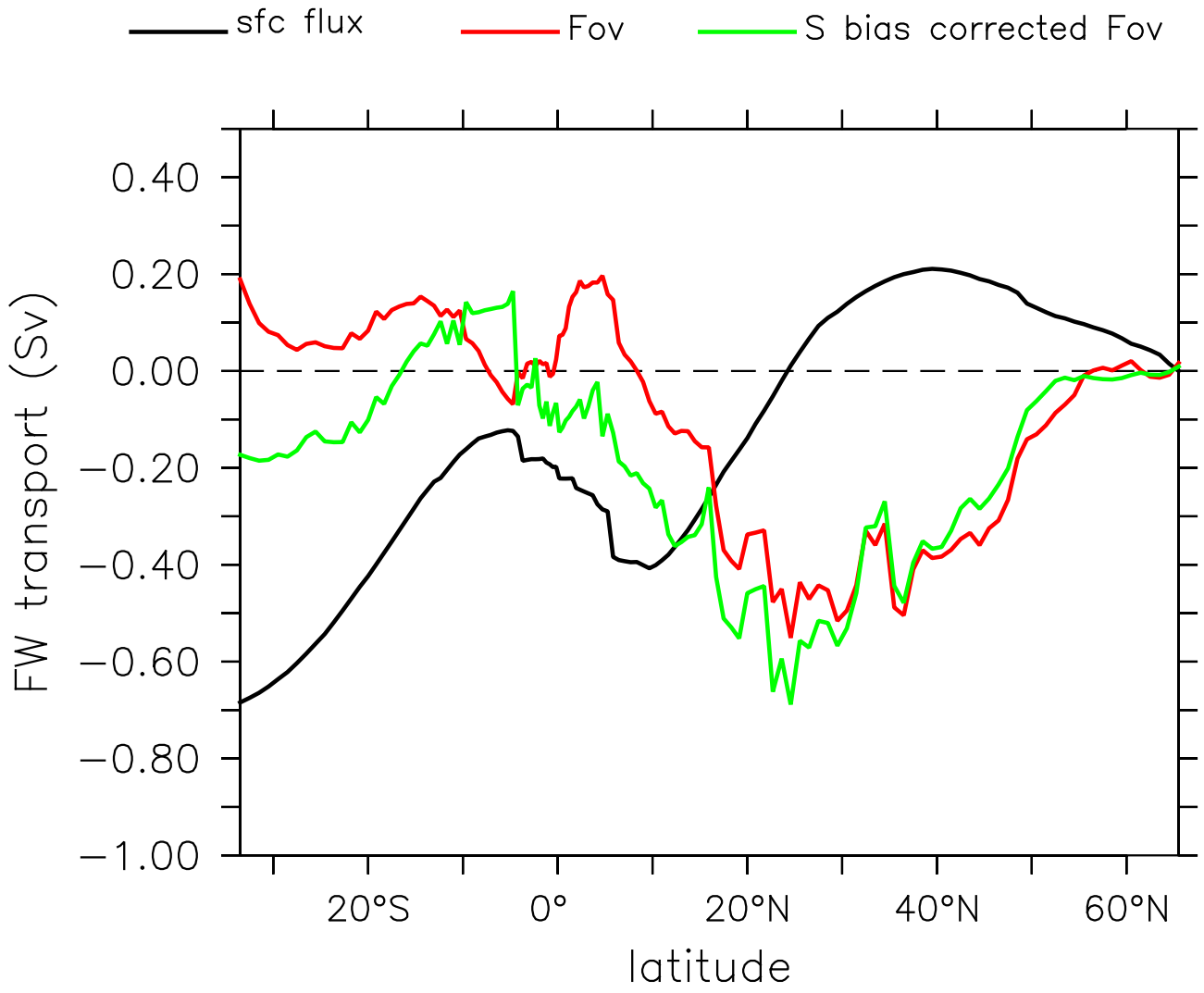
F_{ov} in the context of basin-scale FW budget…



Positive
= into the ocean

meridional
integral starting
from NA

F_{ov} in the context of basin-scale FW budget…



Positive
= into the ocean

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Summary

- A large part of the F_{ov} mean state (including its sign) and variability is controlled by salinity distribution.

- North Atlantic on average is warmer and saltier than the south Atlantic and dominates AMOC variability on multi-decadal time scales. **This is true in both observation and CGCM simulations!** Solution with a saltier NA and negative F_{ovs} does not exist in the Rahmstorf box model, but is the state of observation or CGCMs minus the salt bias .

- North Atlantic AMOC and F_{ovs} have significant coherence on multi-decadal time scales when AMOC variability leads F_{ovs} variability, consistent with southward propagation of the AMOC signal. So far no lead of F_{ovs} on NA AMOC is found, regardless of time scales.

- Modeled air—sea flux imposes FW deficit in the Atlantic Ocean southward of 25°N. How is this balanced by the AMOC and gyre associated FW transport, on what time scales, and what does it mean for AMOC stability? We need full budget calculation!