Atlantic Meridional Overturning Circulation and North Atlantic Freshwater Budget in CFSv2

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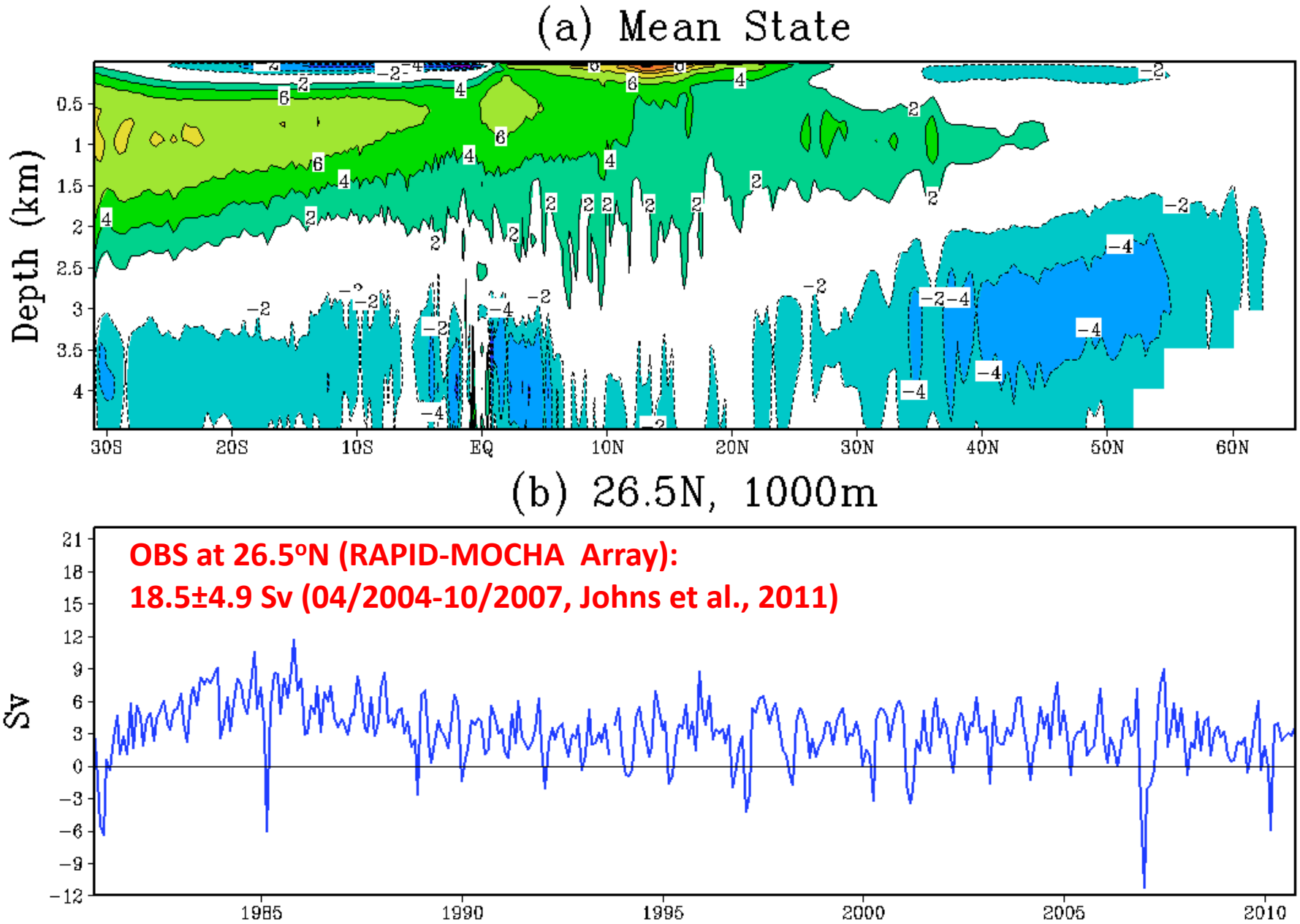
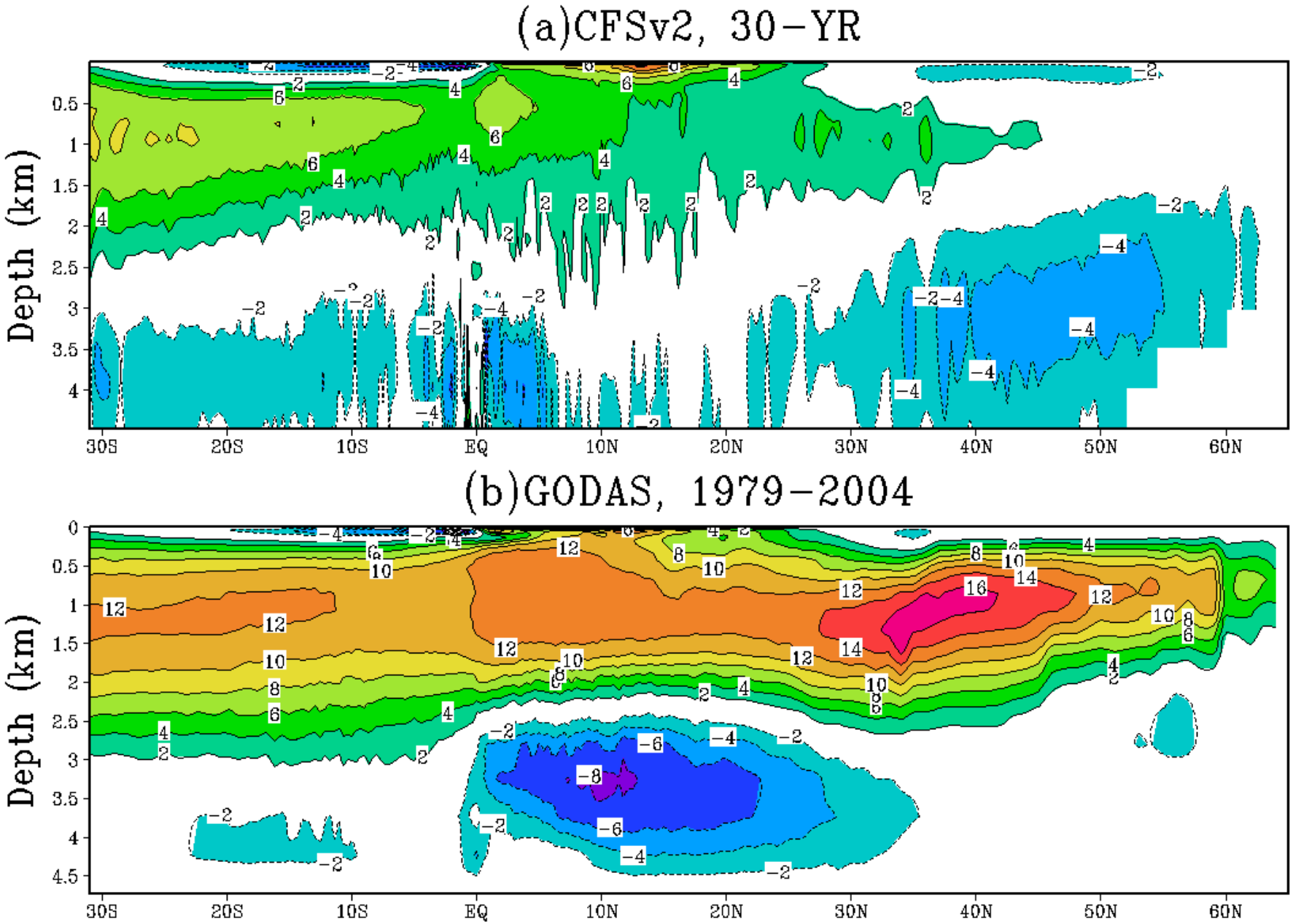
Acknowledgments: Xingren Wu (EMC/NCEP)
Zeng-Zhen Hu (CPC/NCEP)

AMOC (Sv), CFS_v2, IC: CFSR, 30-yr



Mean Atlantic Meridional Overturning Streamfunction (Sv)



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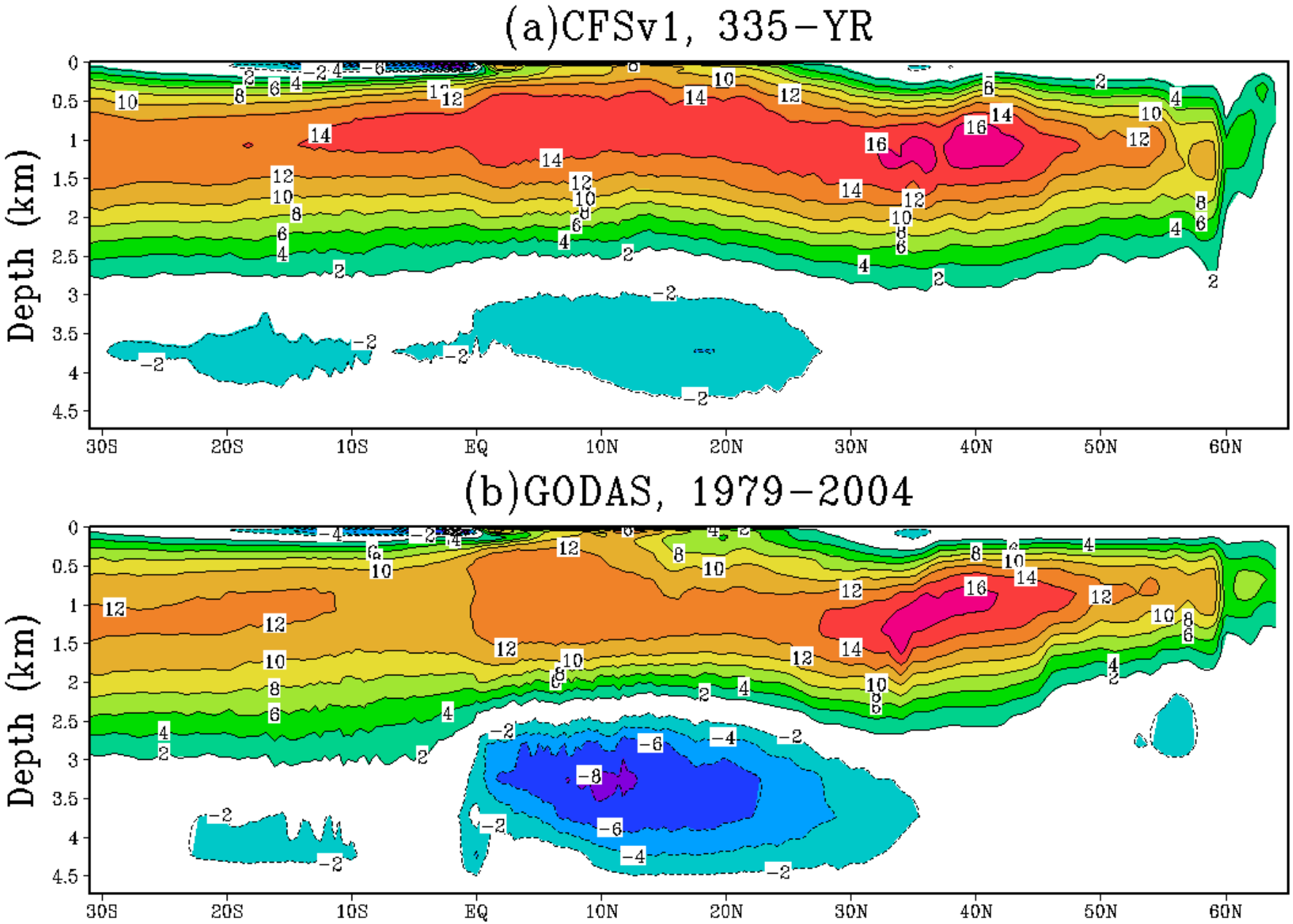
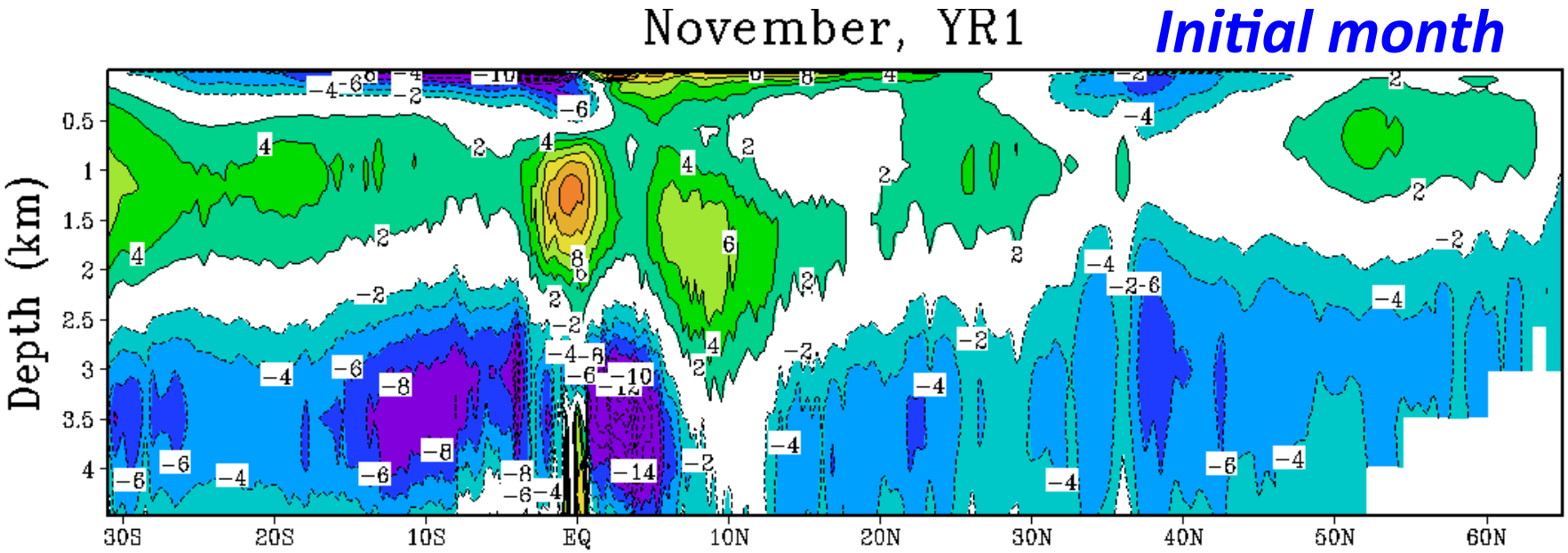
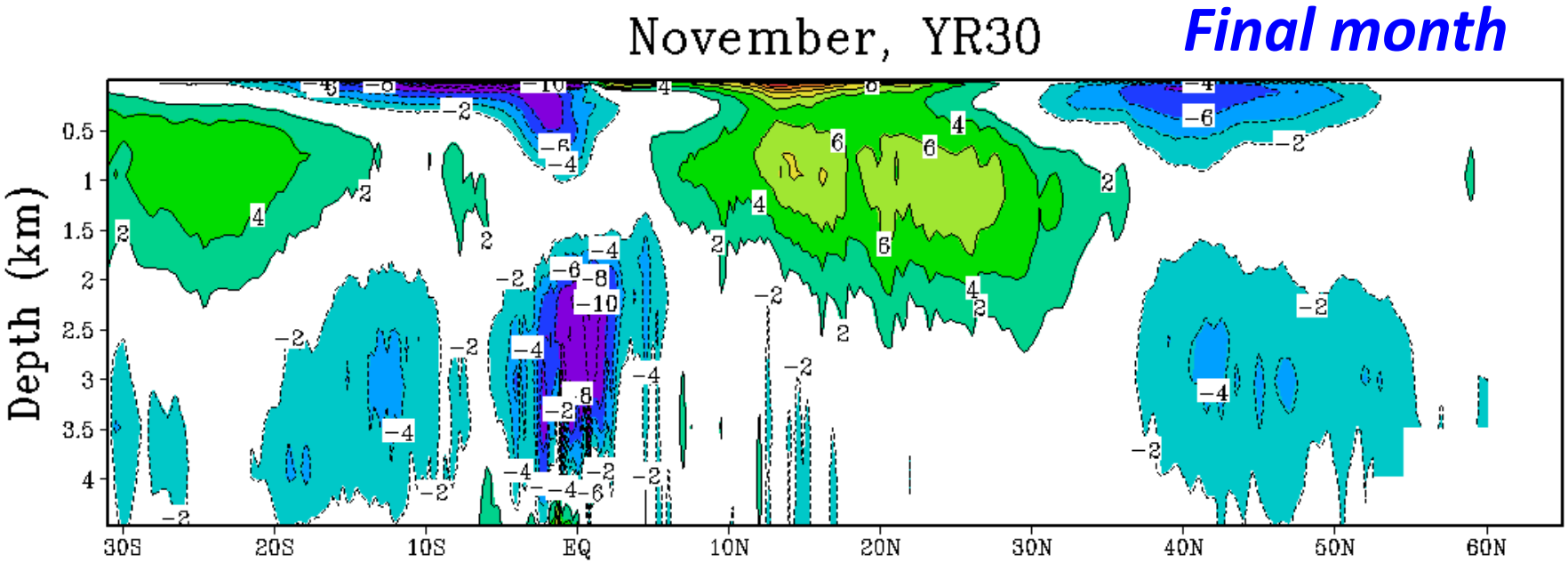
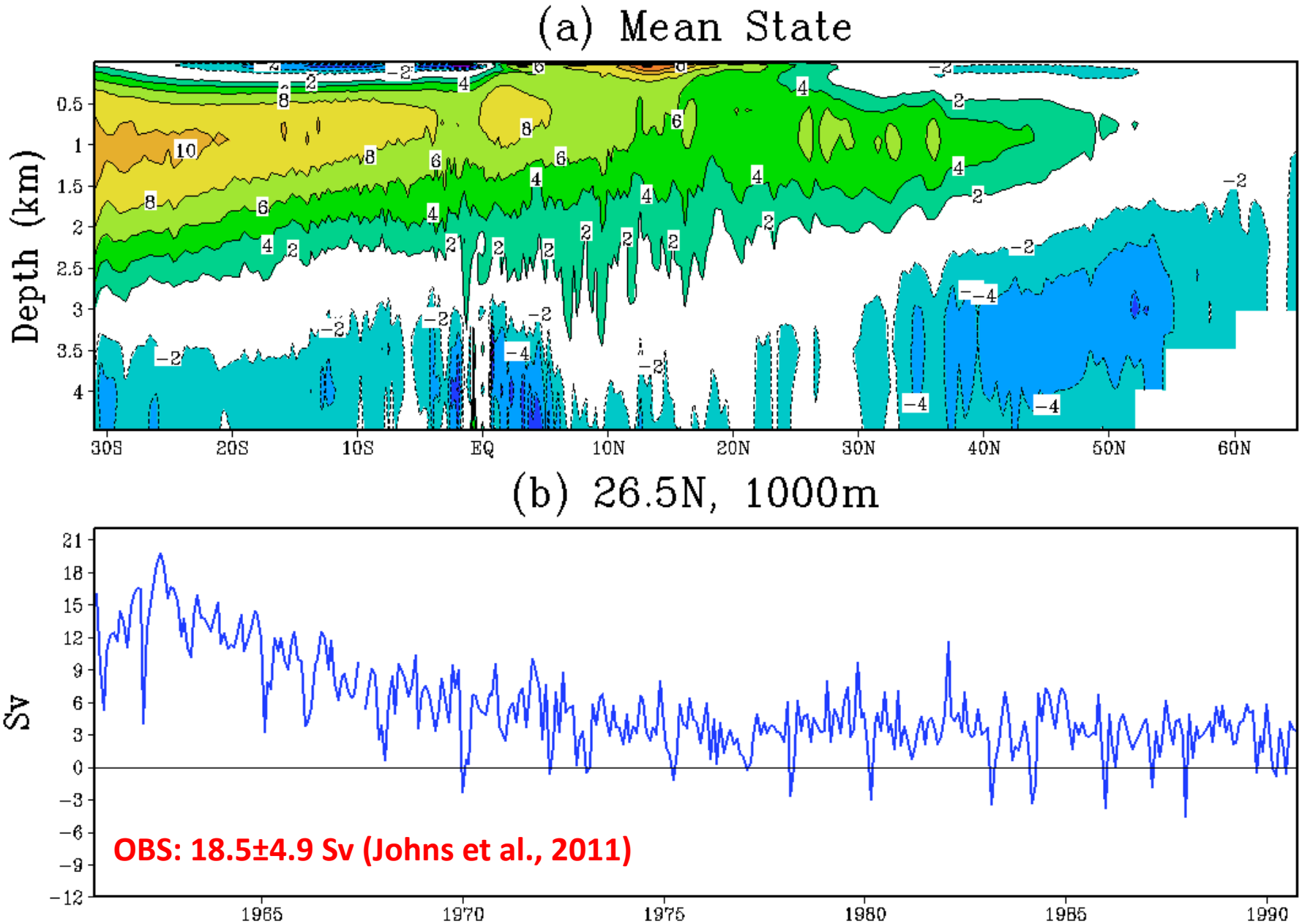


Weak AMOC in CFSR initial condition (IC)?



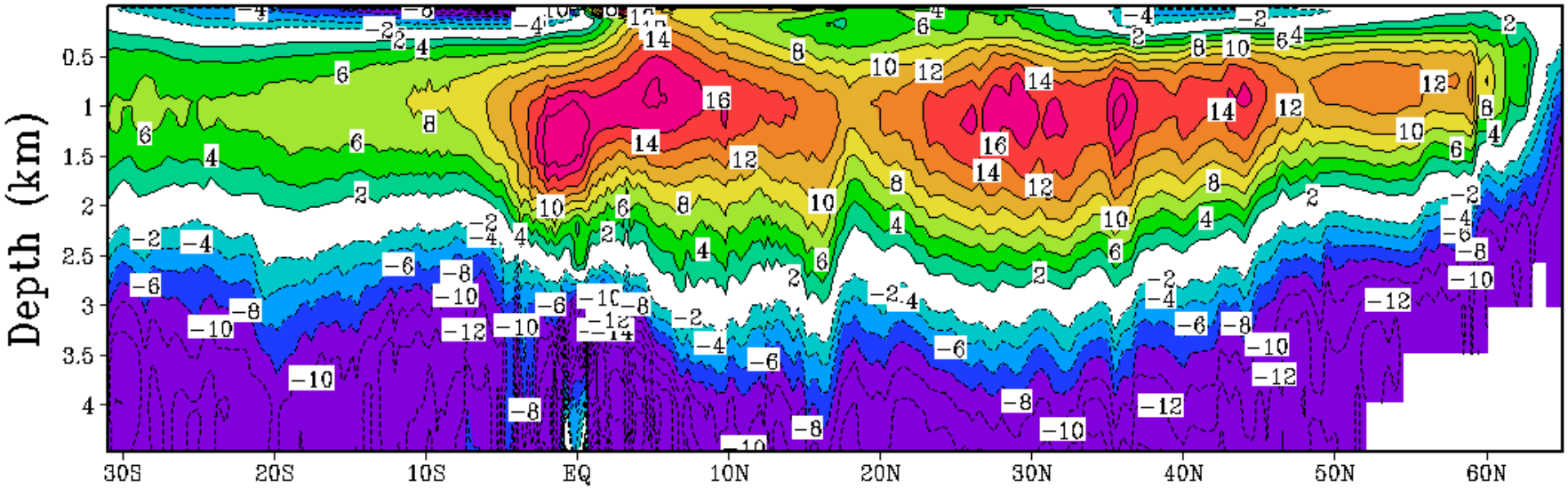


AMOC (Sv), CFS_v2, NEMO, 30-yr

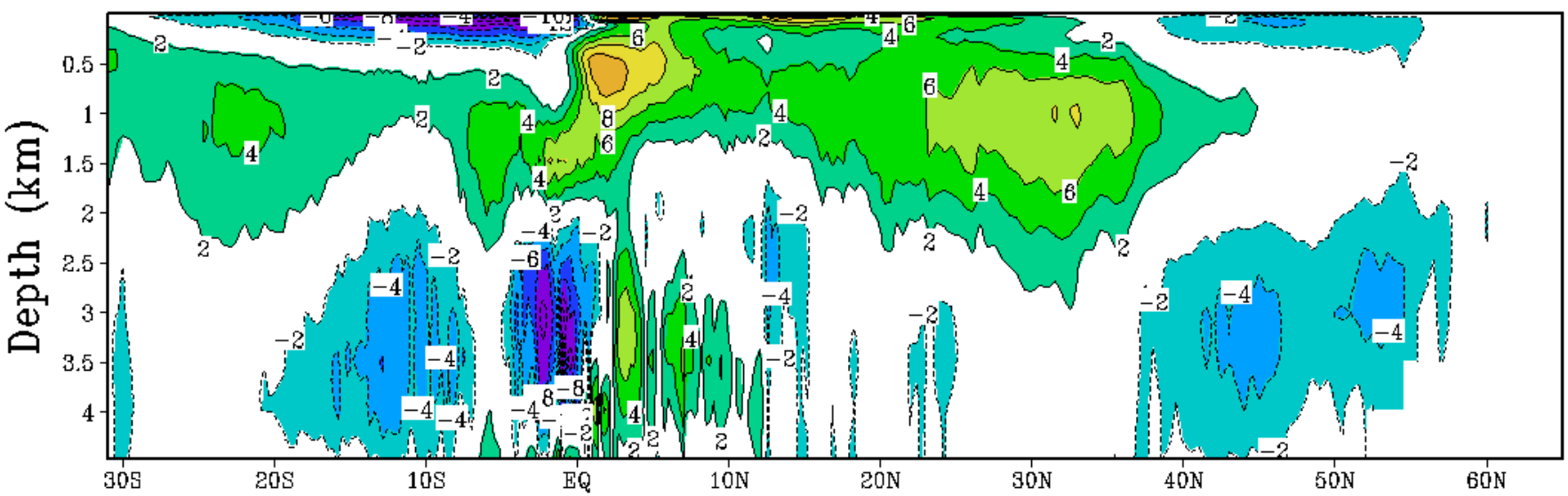


Strong initial AMOC in ECMWF IC is also weakened

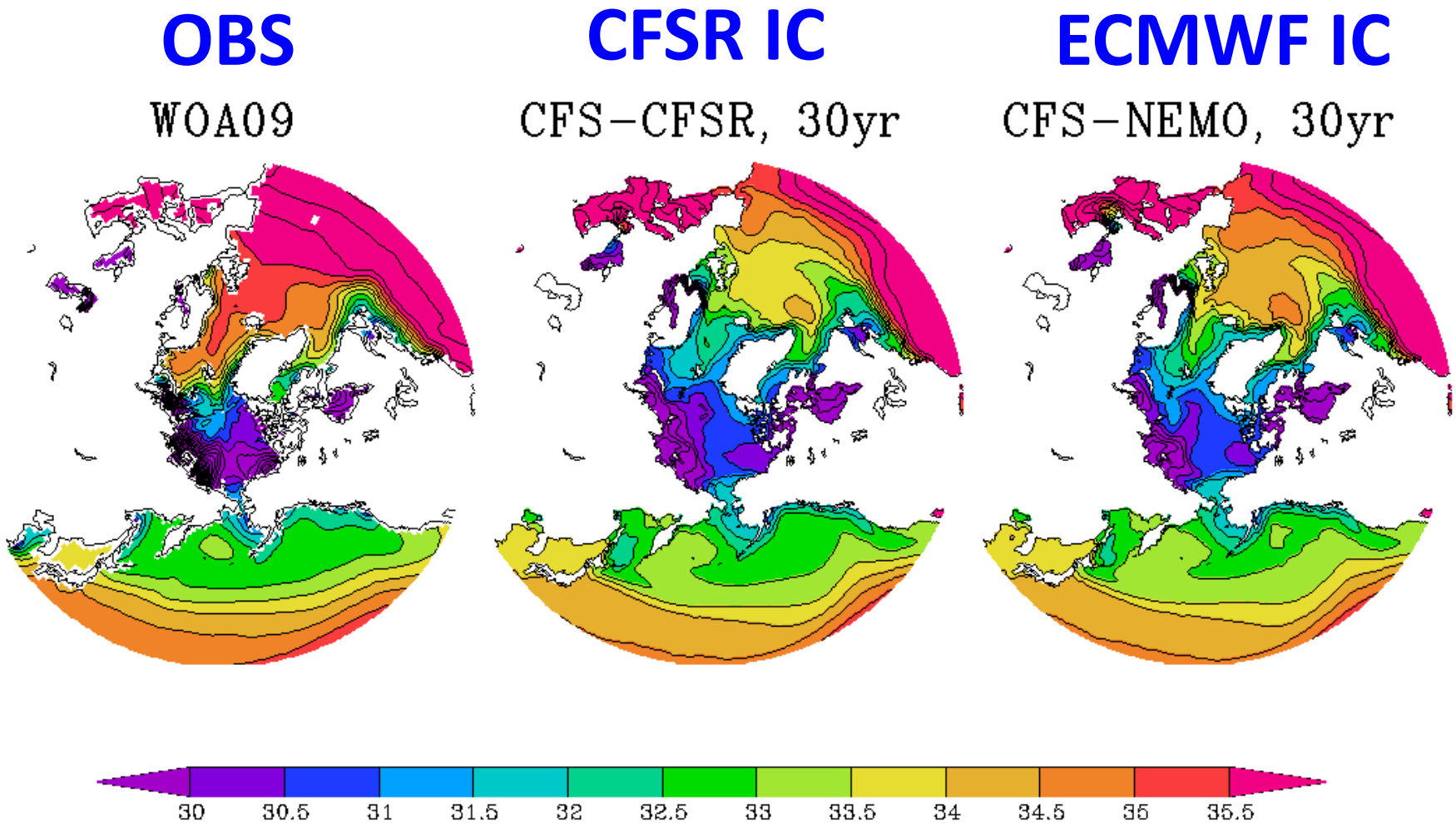
November, YR1 ***Initial month***



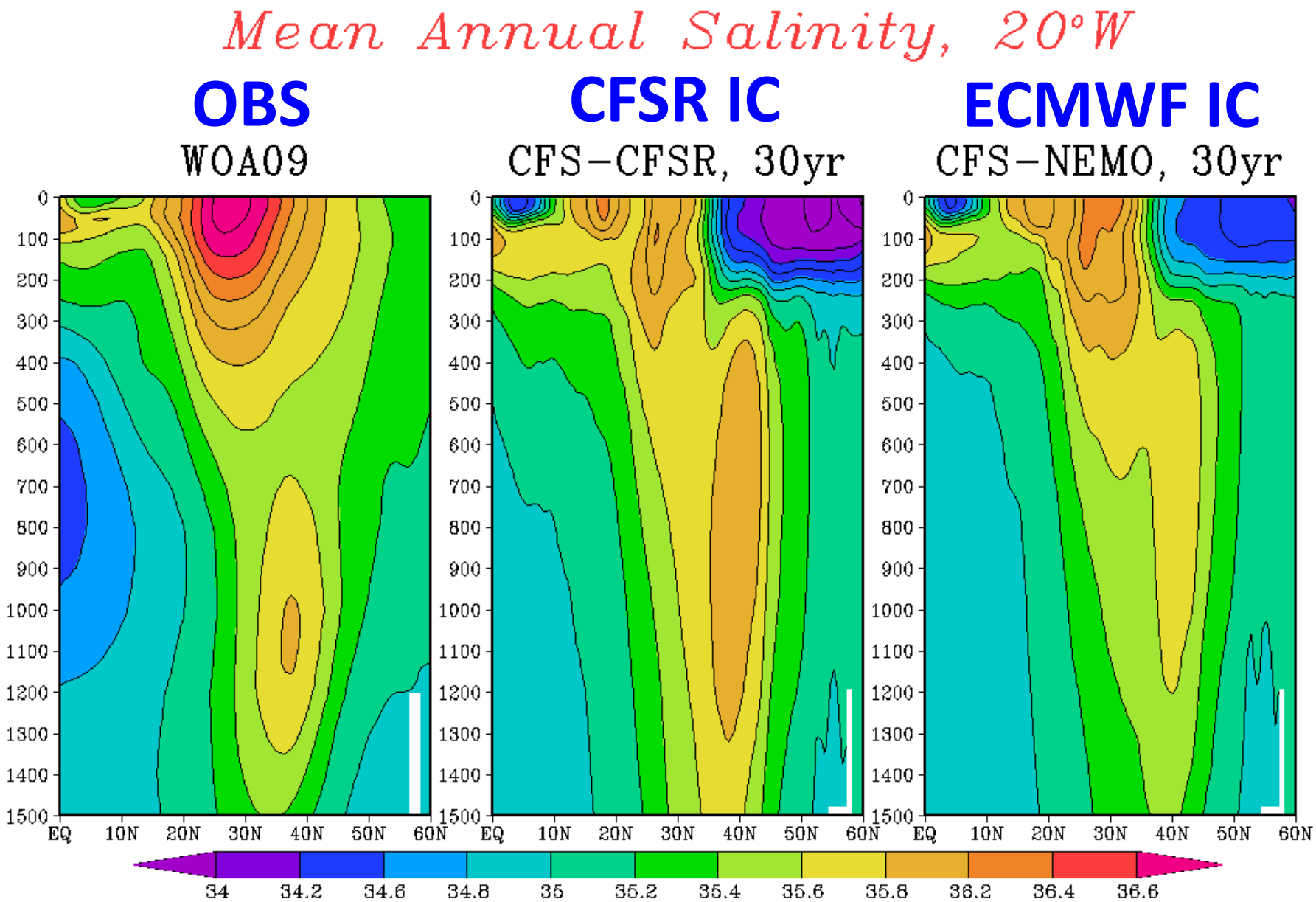
November, YR30 ***Final month***



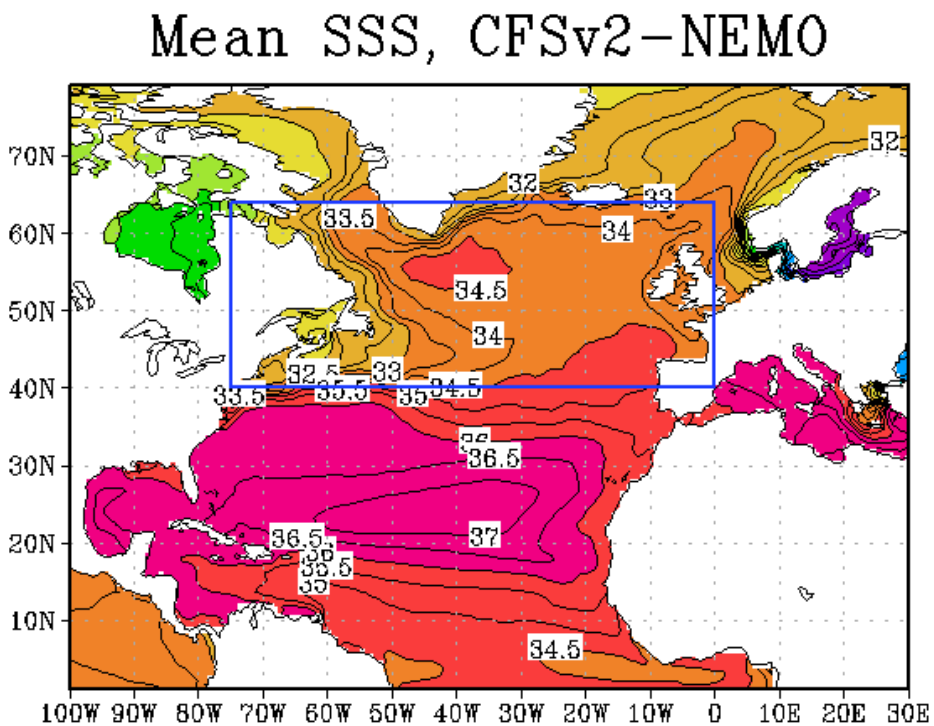
Mean Annual Sea Surface Salinity



Model surface water is too fresh in North Atlantic



Considerable freshening occurs in upper 200 meters

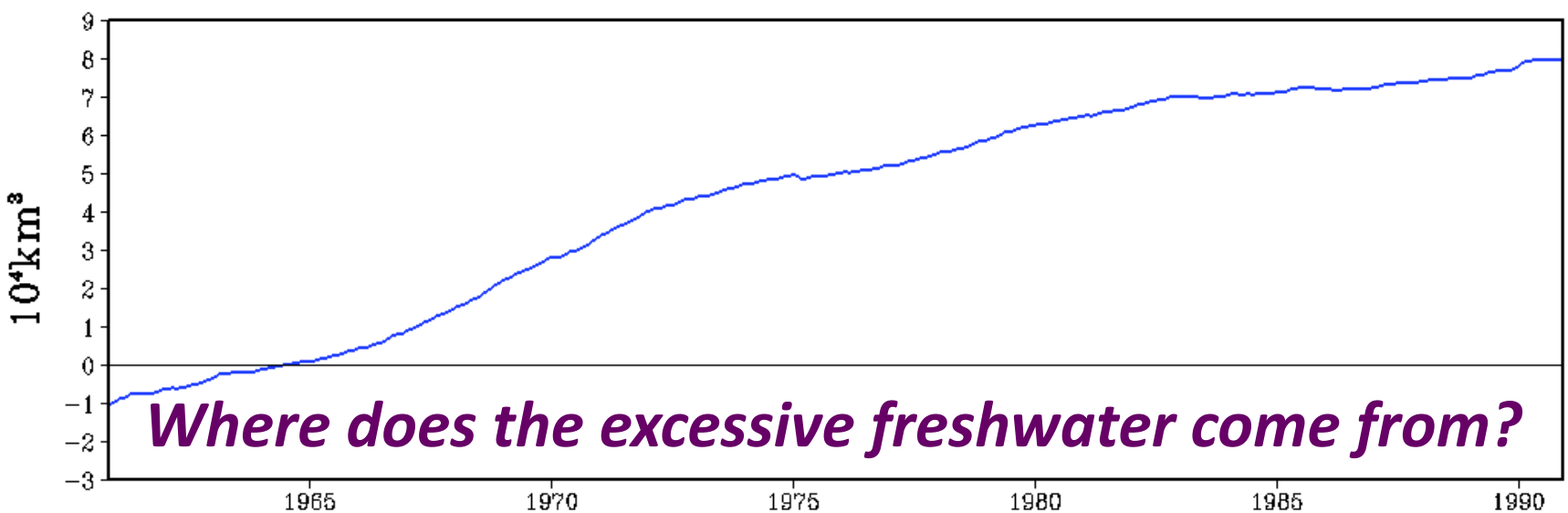


$$FW = 1 - \frac{S}{S_{ref}}$$

$$FWC = \int_{-h}^{0} \oiint_{A} FW \, dA \, dz$$

where $S_{ref} = 35.0\,psu$

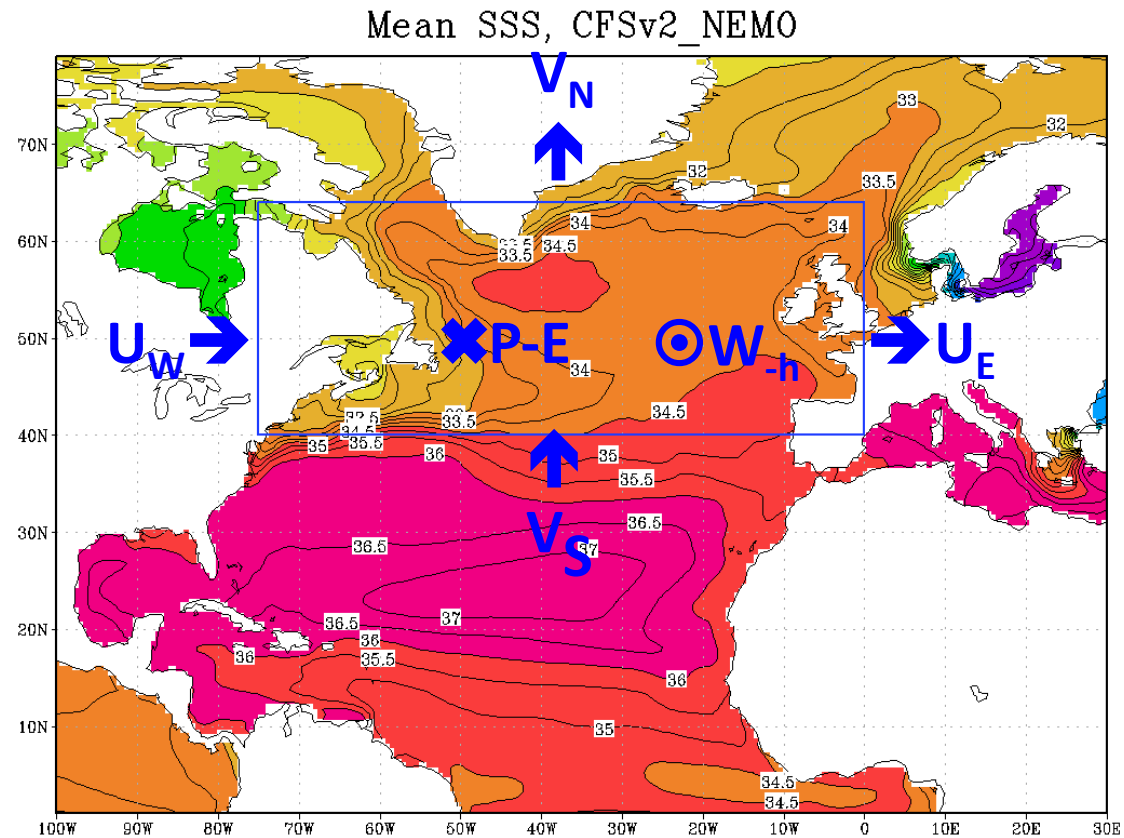
$h = 335m$



Where does the excessive freshwater come from?

Freshwater Budget

$$FW = 1 - \frac{S}{S_{ref}}$$



$$\frac{\partial}{\partial t}\left(\int_{-h}^{0}\oiint_{A} FW\, dA\, dz\right)$$

Tendency (Storage)

$$= \int_{-h}^{0}\left\{\int_{y_S}^{y_N} u_W FW\, dy - \int_{y_S}^{y_N} u_E FW\, dy + \int_{x_W}^{x_E} v_S FW\, dx - \int_{x_W}^{x_E} v_N FW\, dx\right\} dz$$

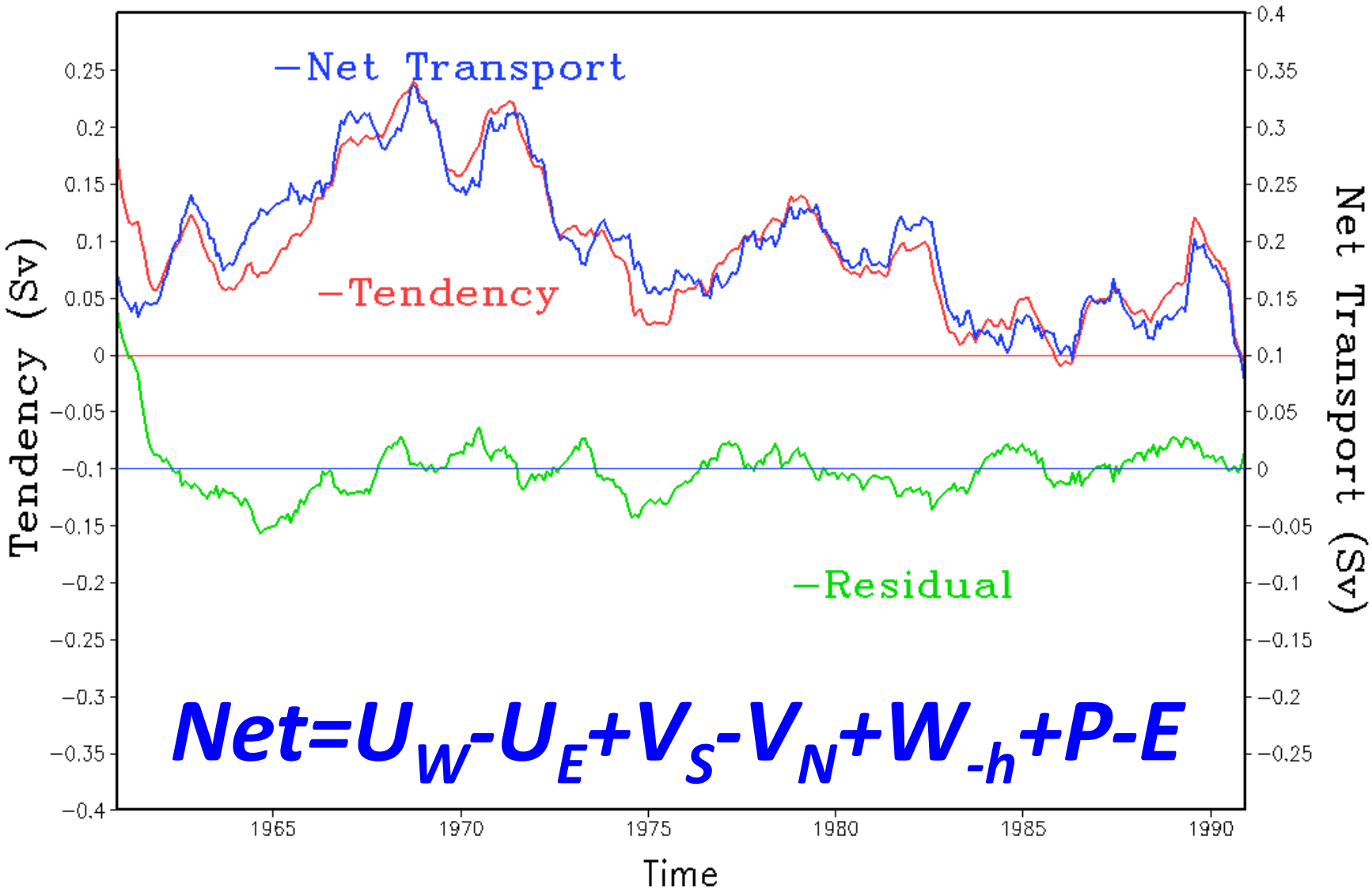
U_W U_E V_S V_N

$$+ \oiint_{A} w_{-h} FW\, dA + \oiint_{A} (P - E)\, dA + R$$

W_{-h} P-E Residual

Freshwater Budget, CFSv2–NEMO

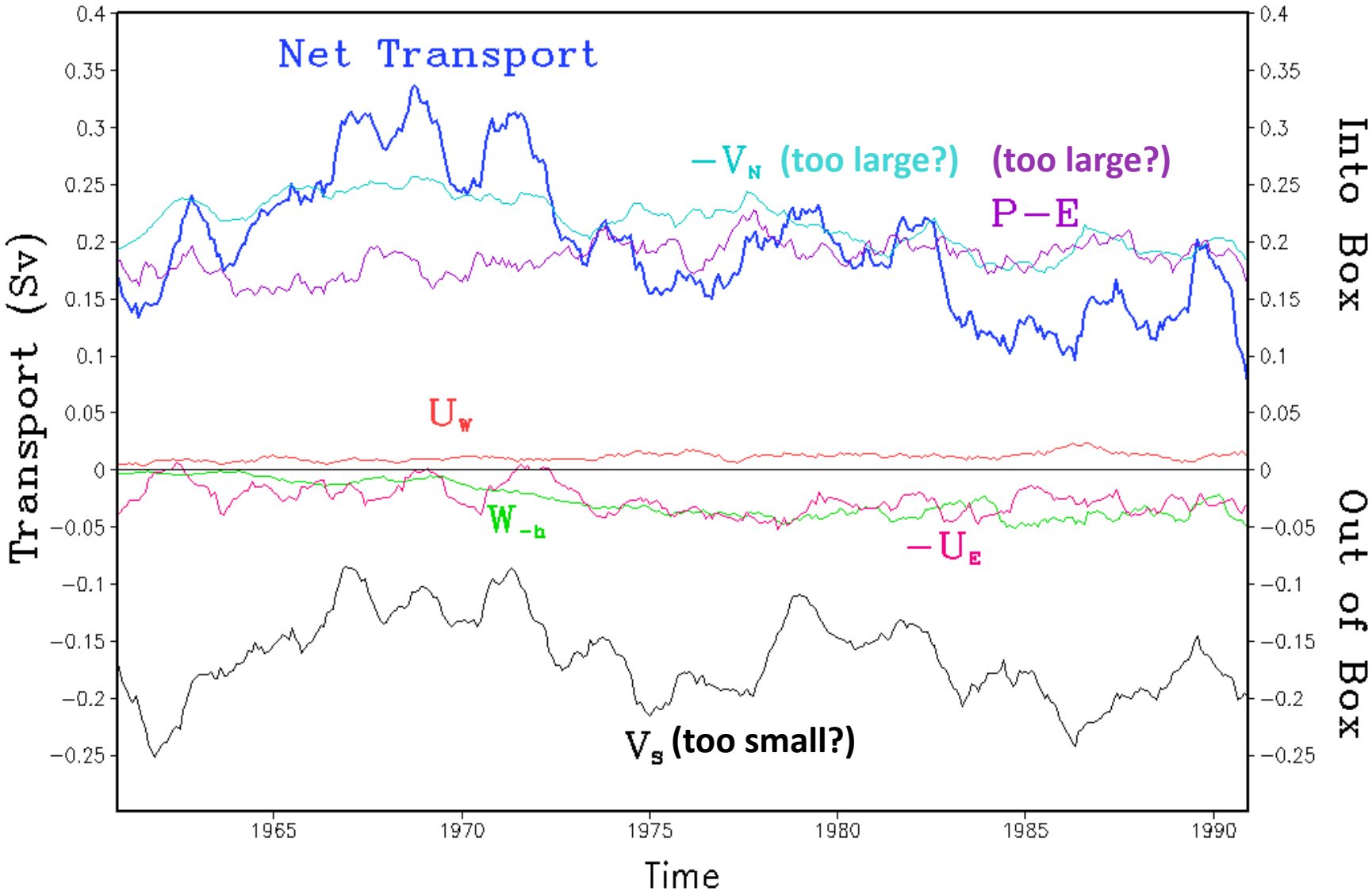
13–mo running mean

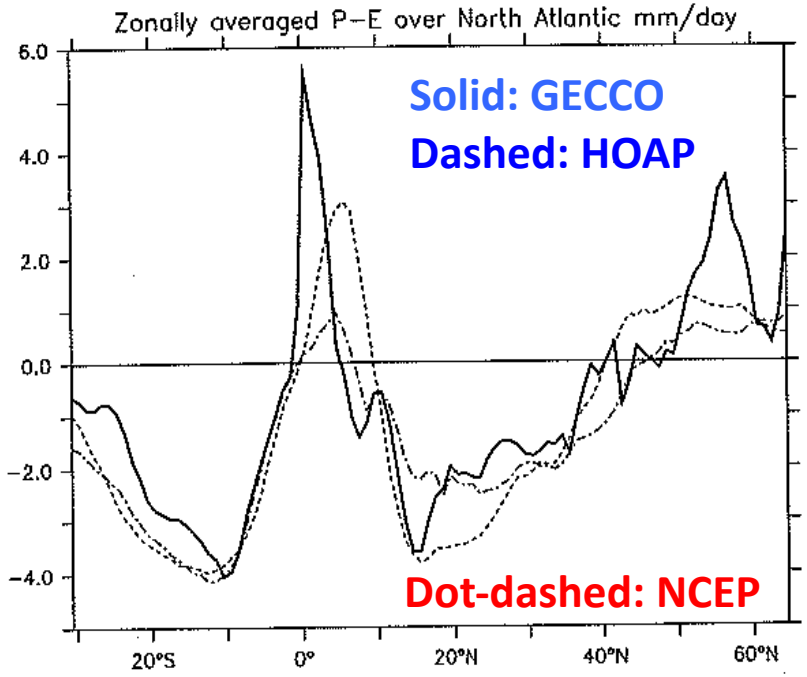


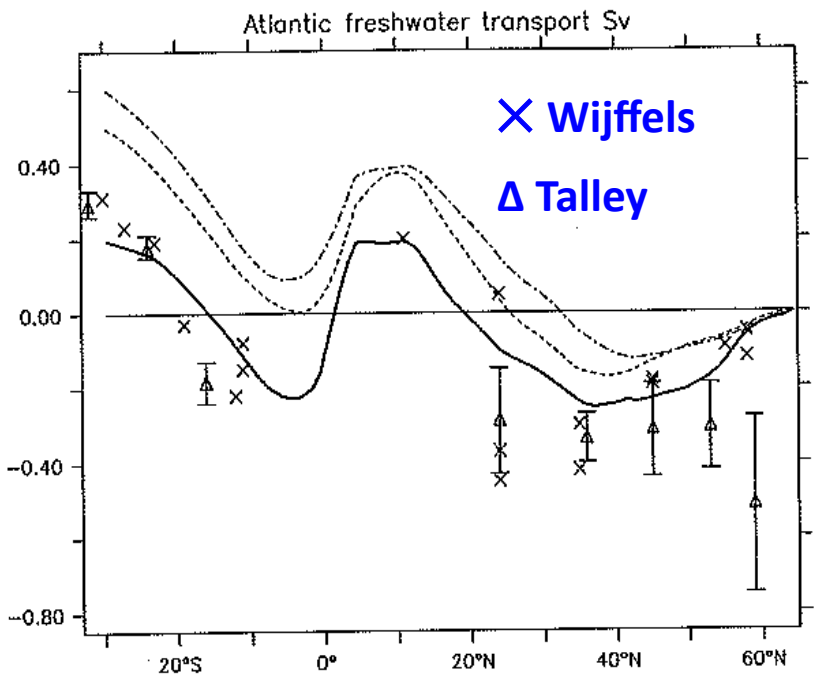
$$Net = U_W - U_E + V_S - V_N + W_{-h} + P - E$$

Freshwater Transport Terms, CFSv2_NEMO

13-mo running mean







Top panel: OBS-based zonally averaged surface freshwater fluxes over the North Atlantic

Lower panel: Freshwater transport integrated from 65◦N (bottom panel), with estimates for different latitudes summarized in Wijffels (2001) and Talley (2008).

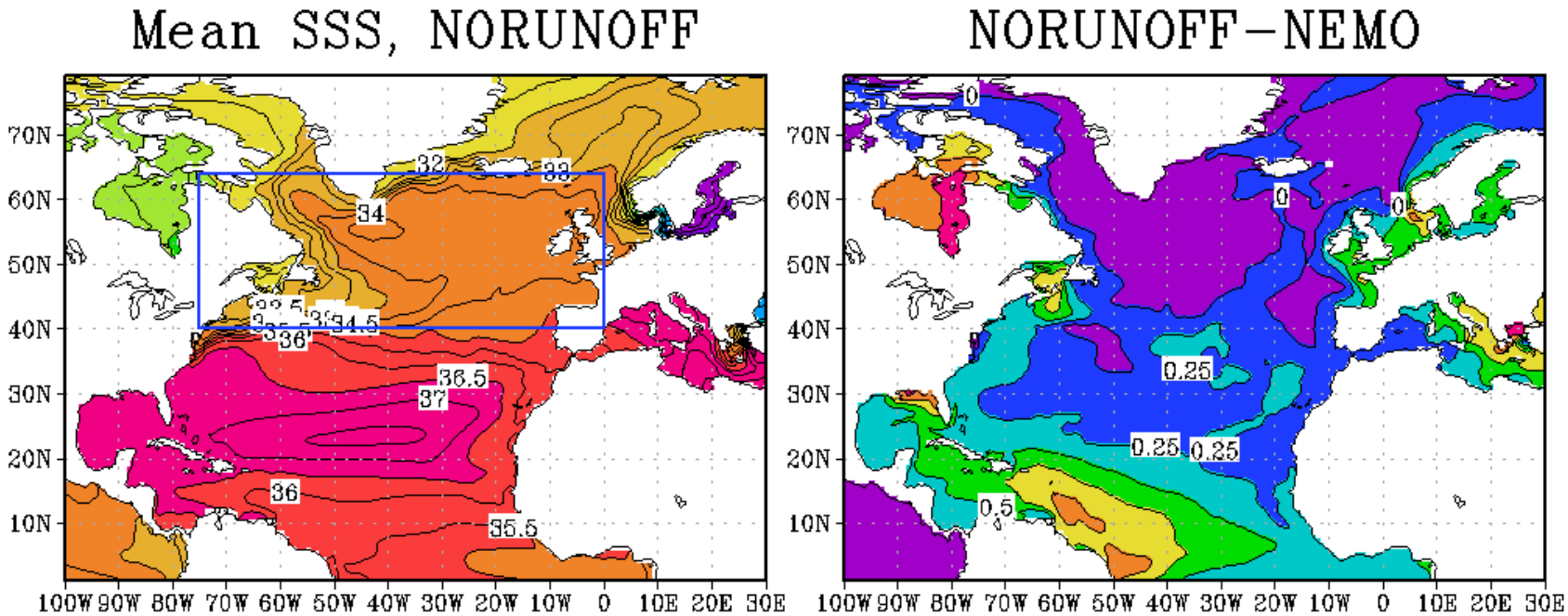
From Romanova et al. (2010, Tellus, Fig.14)

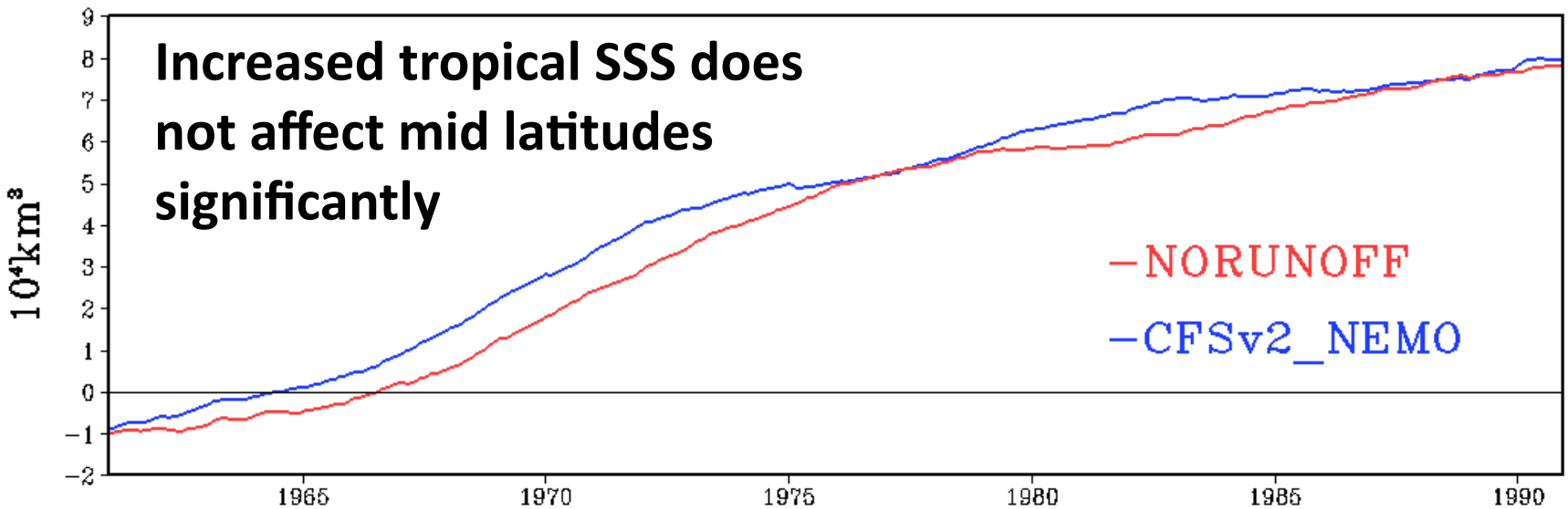
Compare with CFSv2:

$V_N(64^oN) \approx 0.2Sv$ *(over-estimated?)*

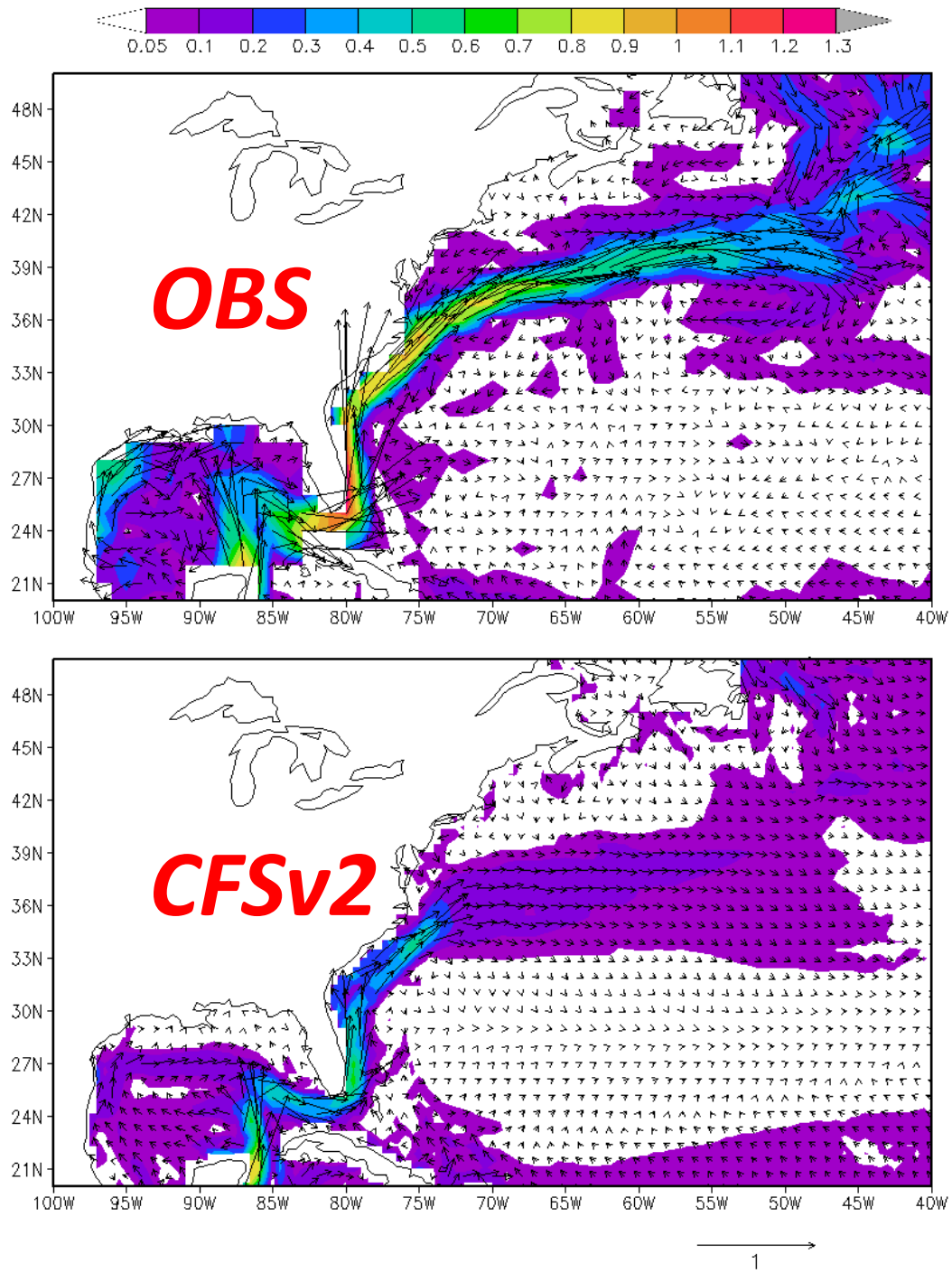
$V_S(40^oN) \approx 0.1\text{-}0.2Sv$ *(under-estimated?)*

Is the subtropical water transported northward too fresh?





Surface Current Climatology

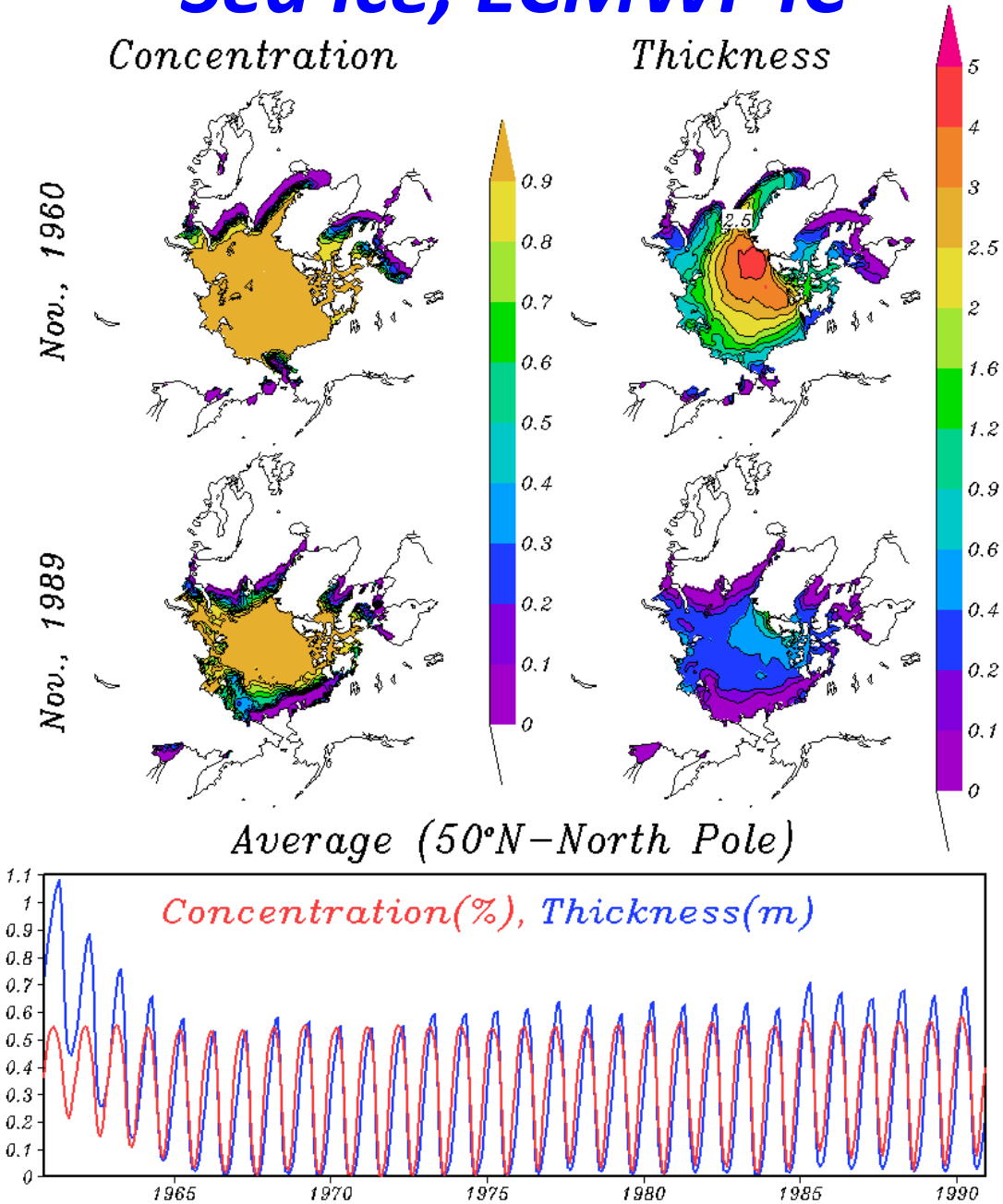


🡐Surface drifter data

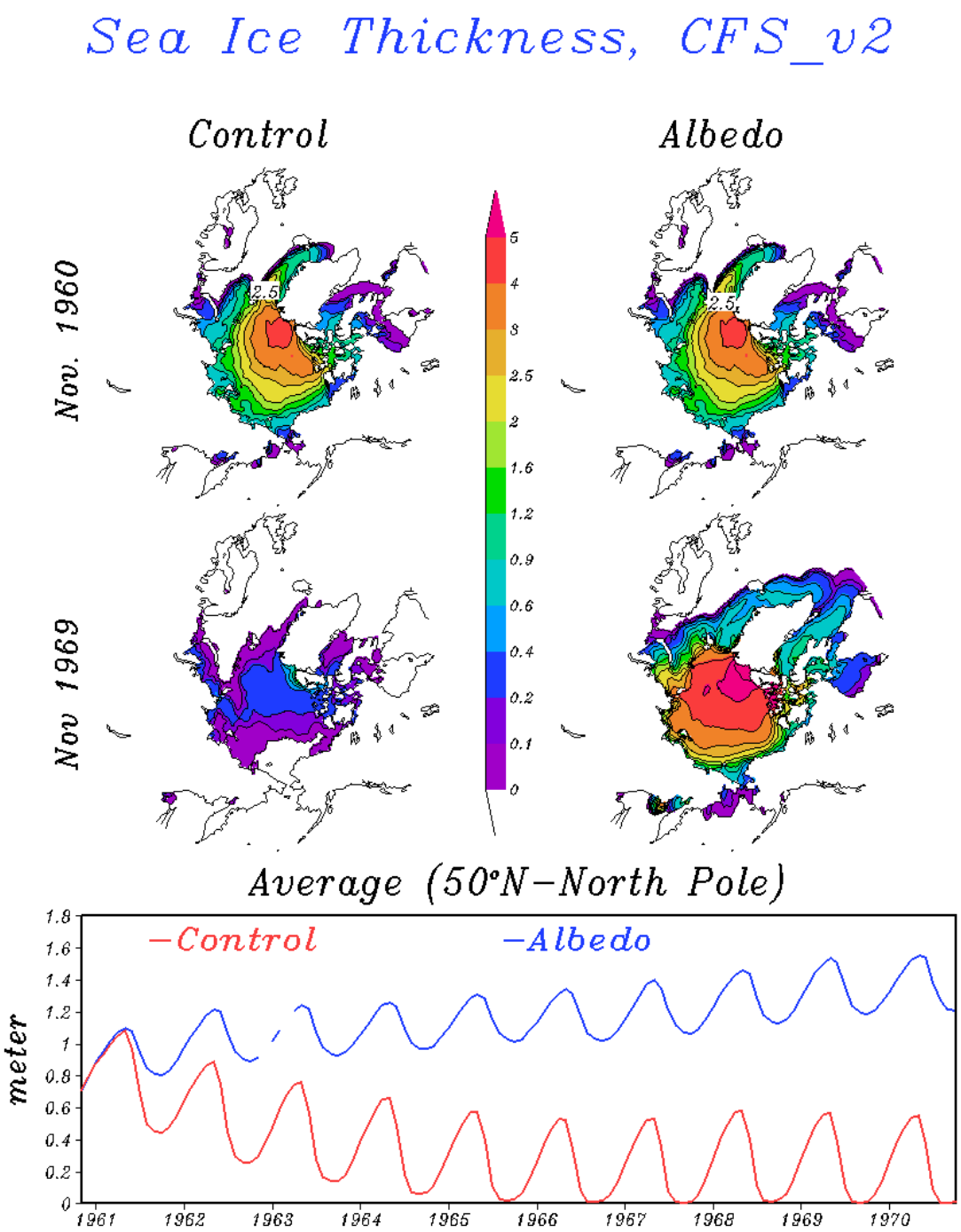
Lumpkin and Garraffo (2005)

🡐CFSv2-NEMO

Sea Ice, ECMWF IC



Artificial Sea Ice melting in Arctic Ocean could be a source of freshwater flux into North Atlantic

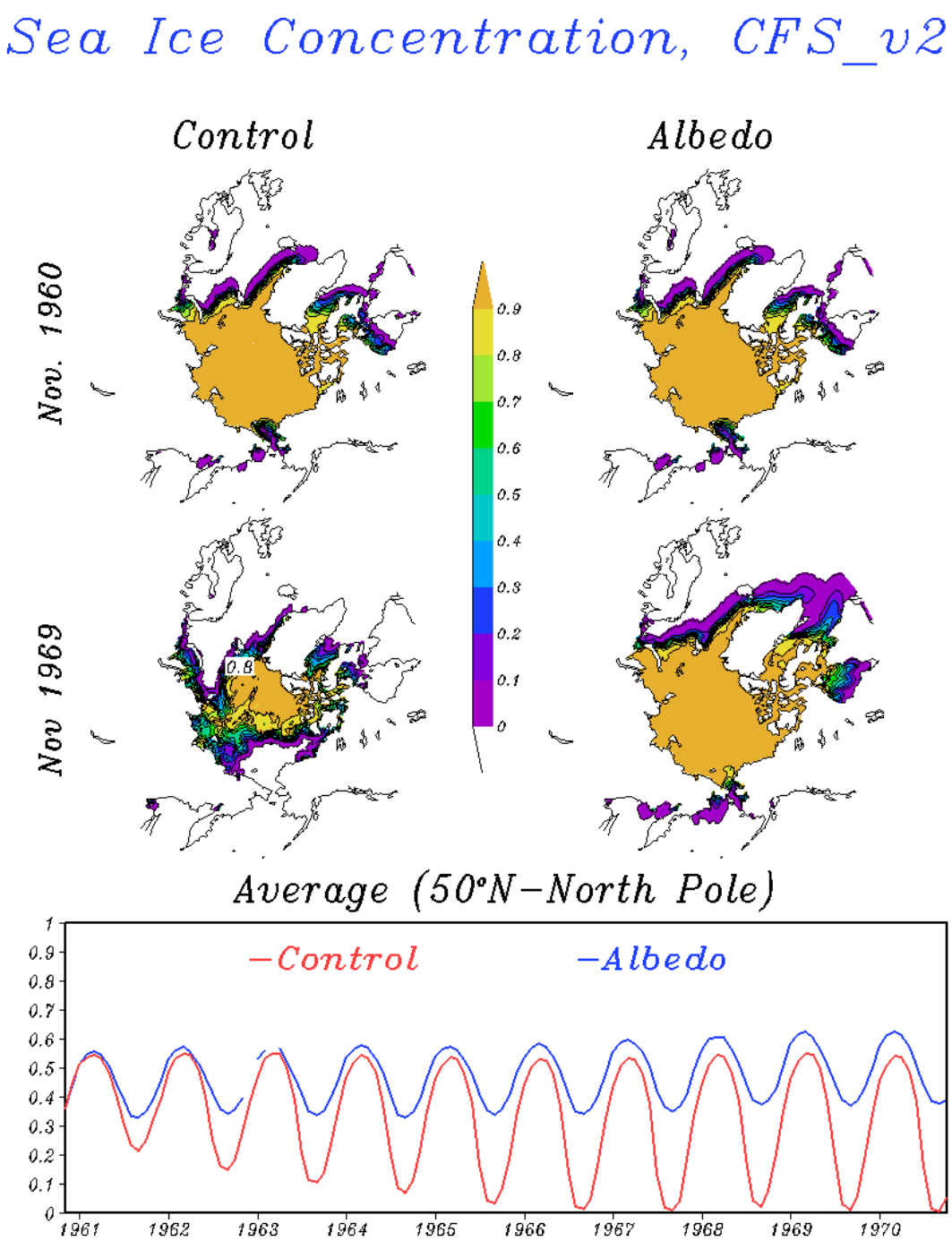


Sensitivity Experiment Albedo (ICE) Run (10-yr)

Sea Ice Albedo 0.8
(Control 0.6)

Temperature range of albedo change with ice melt
1.0°C (Control 10.0°C)

Based on suggestions from Dr. Xingren Wu (EMC/NCEP)



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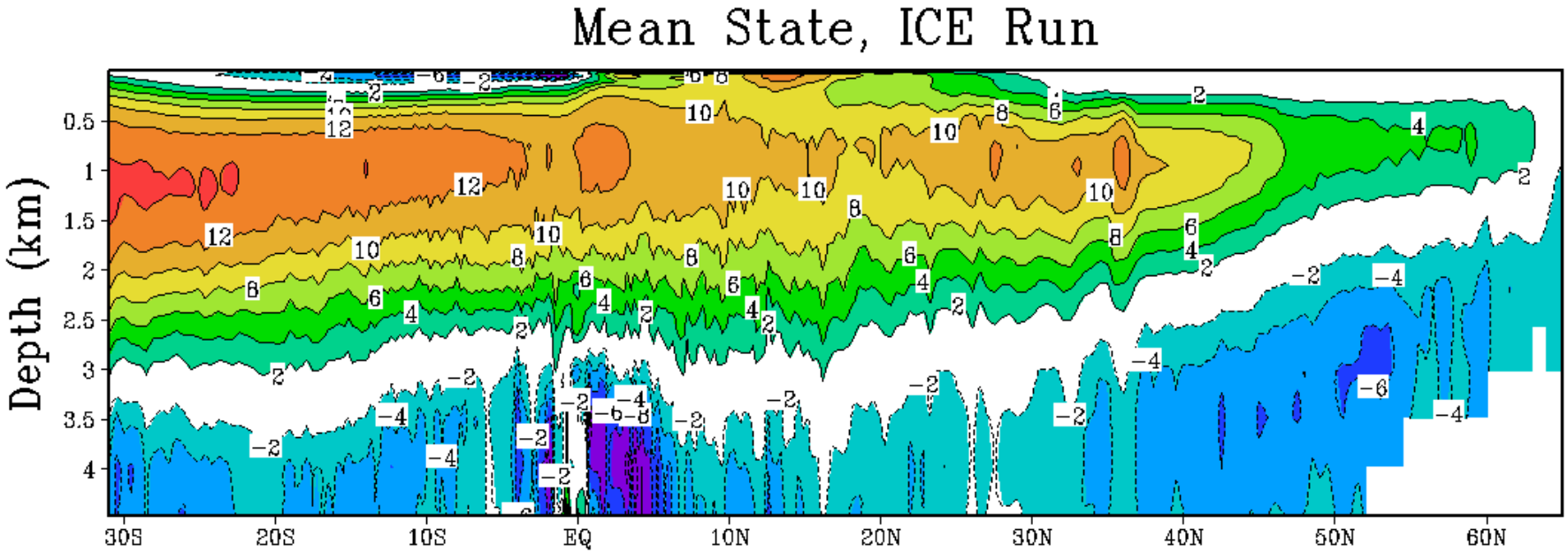
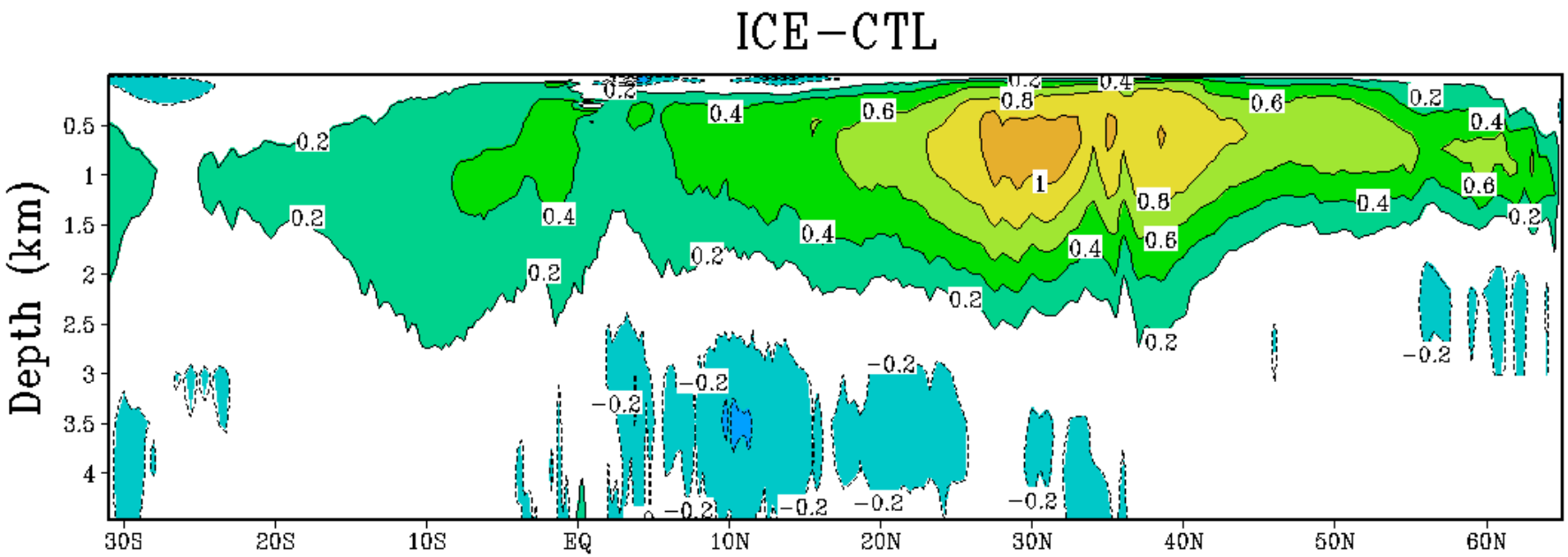
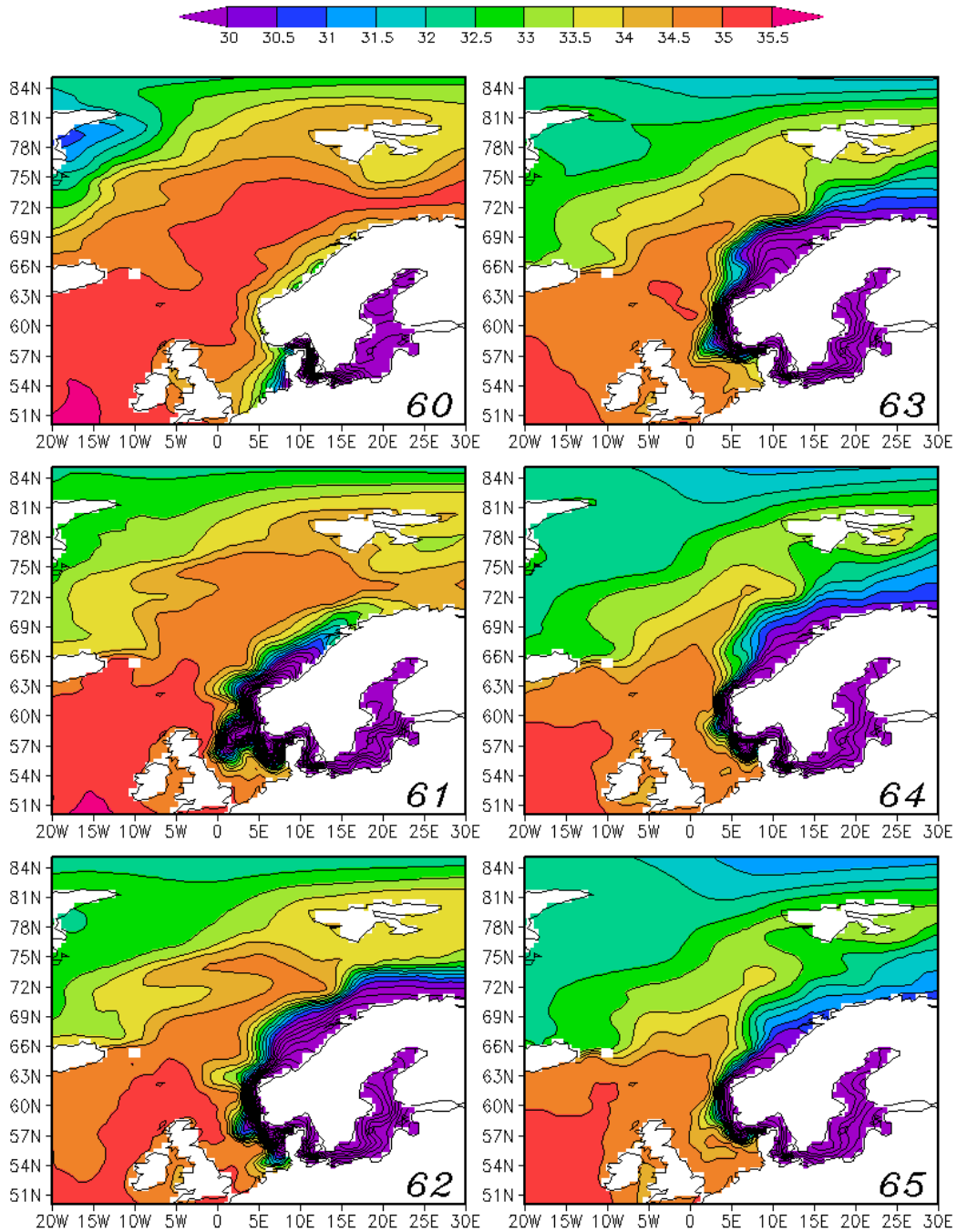
Improved Sea Ice increases AMOC (but not enough)

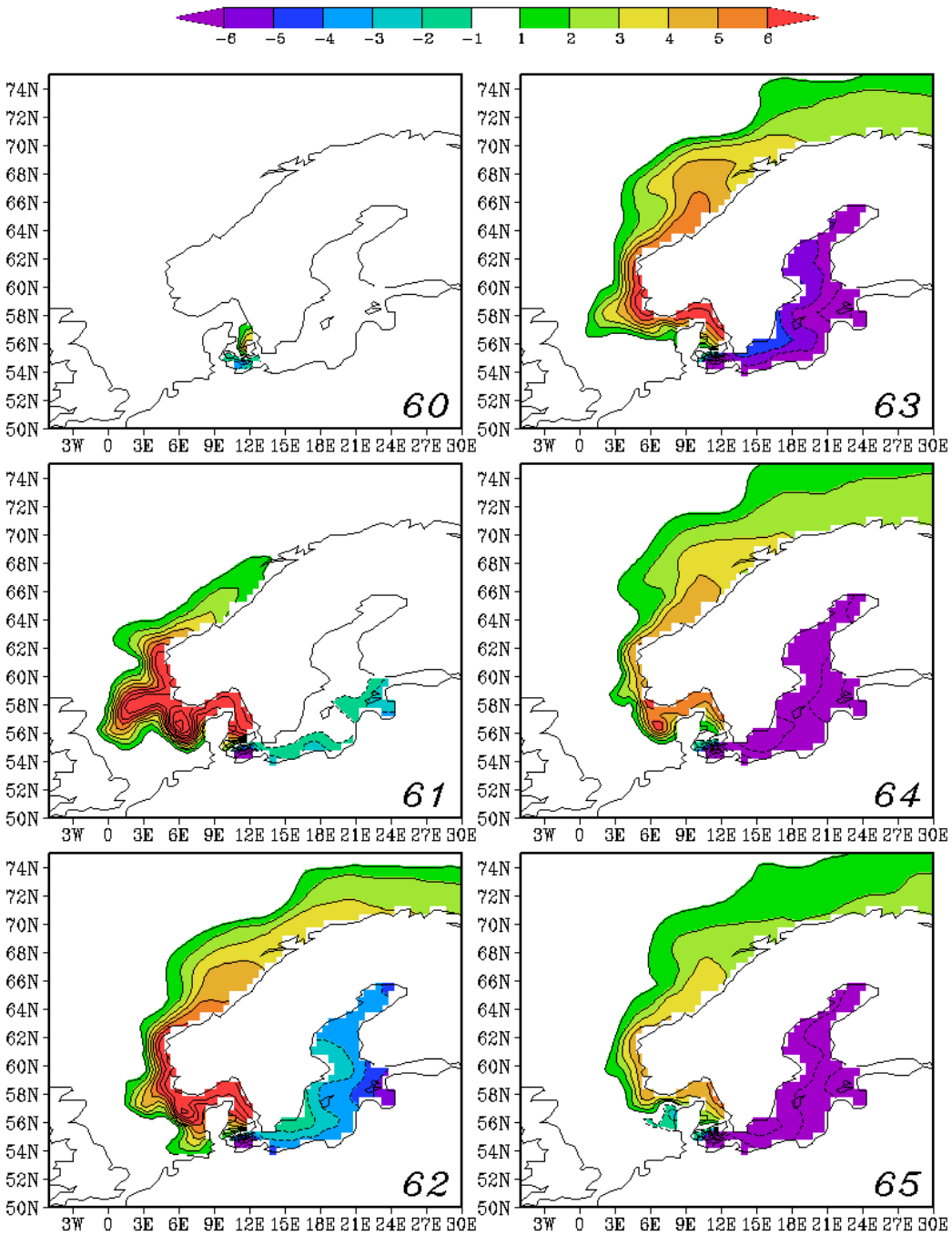




Sea Surface Salinity November Ice Run



Brackish water "leaked" from Baltic Sea may also cause the North Atlantic freshening



Sensitivity Experiment TOPO Run (10-yr):

Sill depth between Baltic Sea and North Atlantic is raised from 100m (Control) to 30m

The freshening in the eastern part of North Atlantic is reduced

Sea Surface Salinity Difference TOPO-ICE

Summary

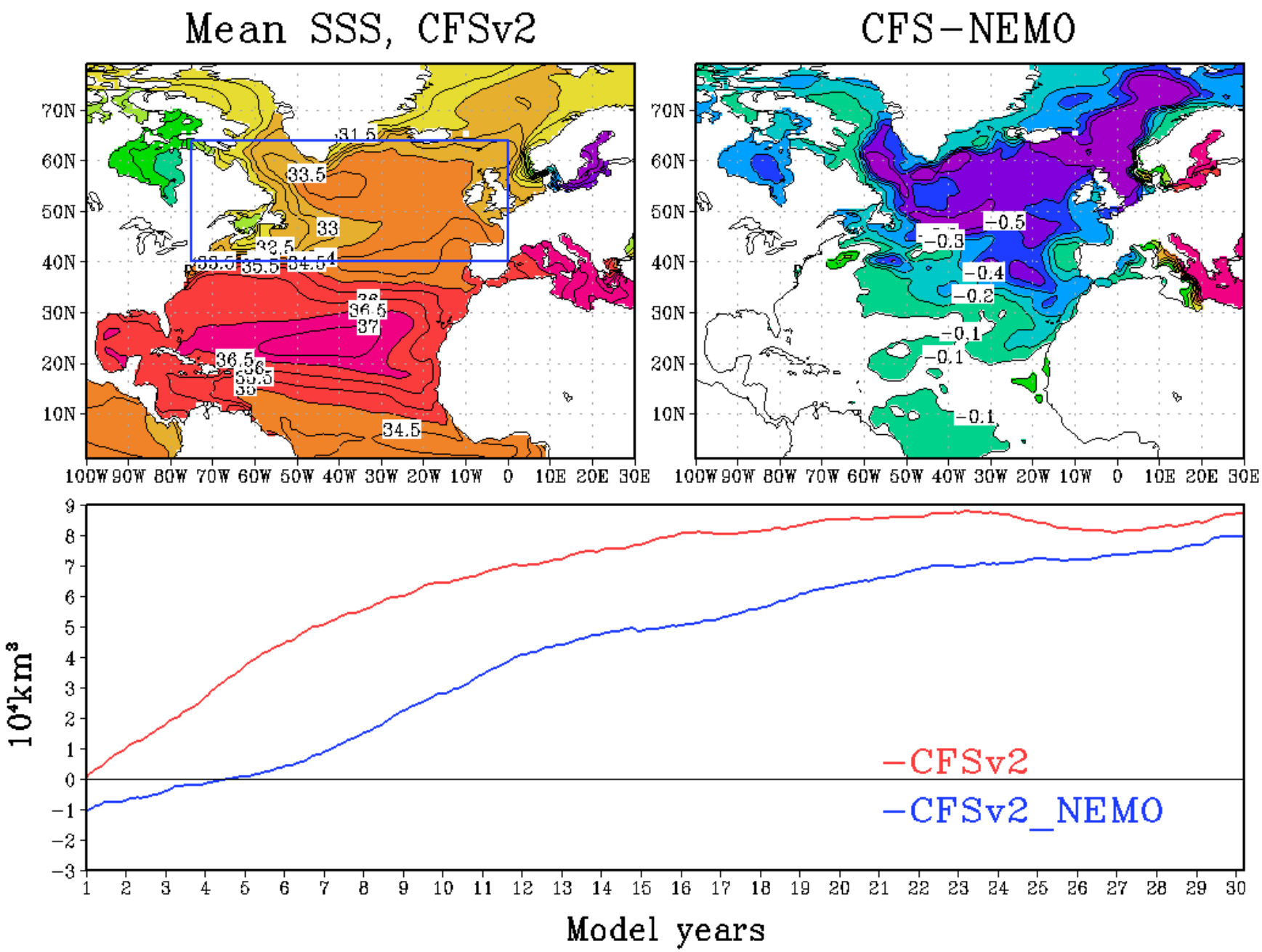
Atlantic meridional overturning circulation (AMOC) is weakened in CFSv2

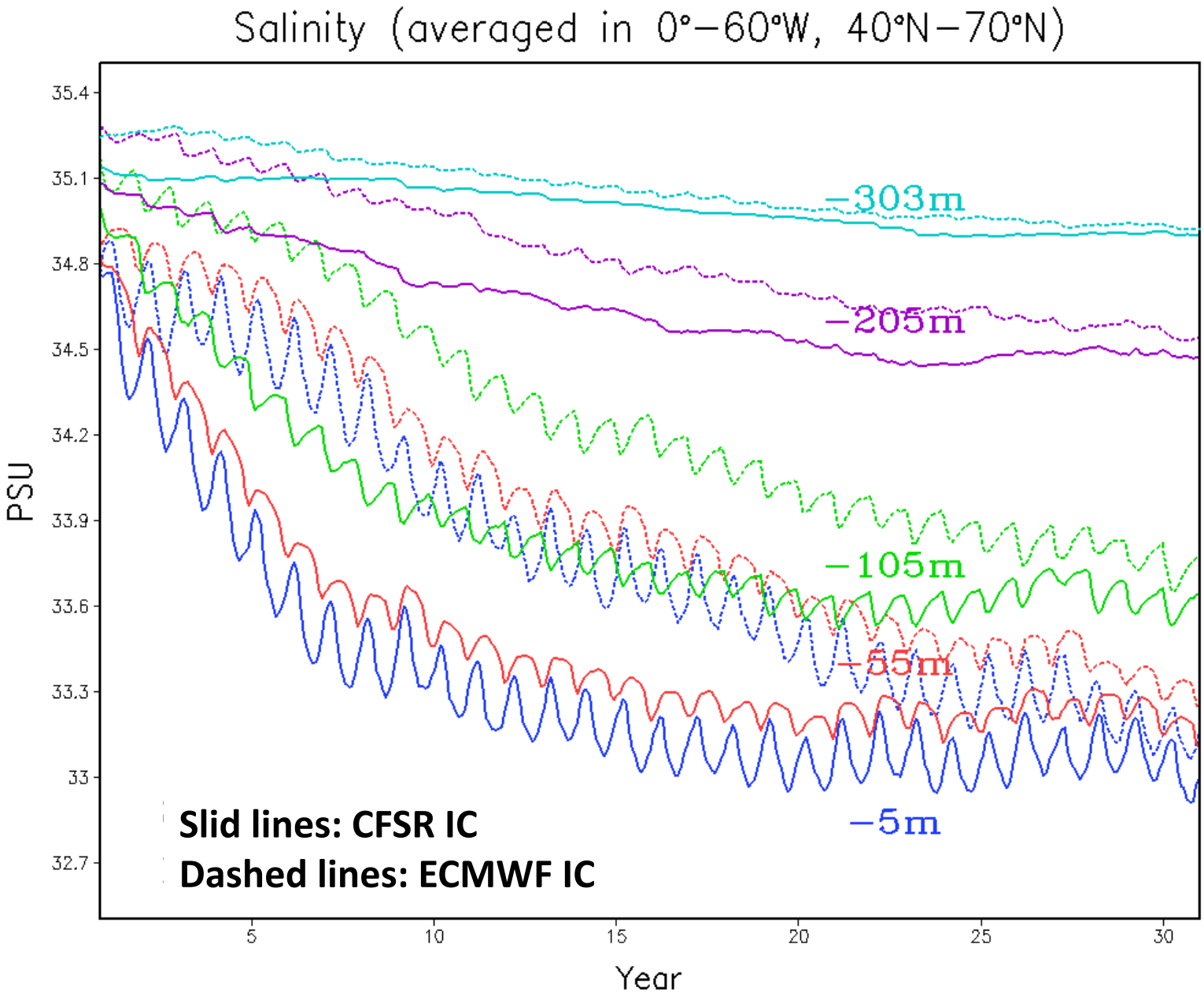
A freshening trend in northern North Atlantic shuts down deep convection in Greenland and Labrador Seas

Extra freshwater storage is associated with weak (excessive) subtropical (arctic) transport and strong regional precipitation

Arctic sea ice thickness can be maintained with increased sea ice albedo

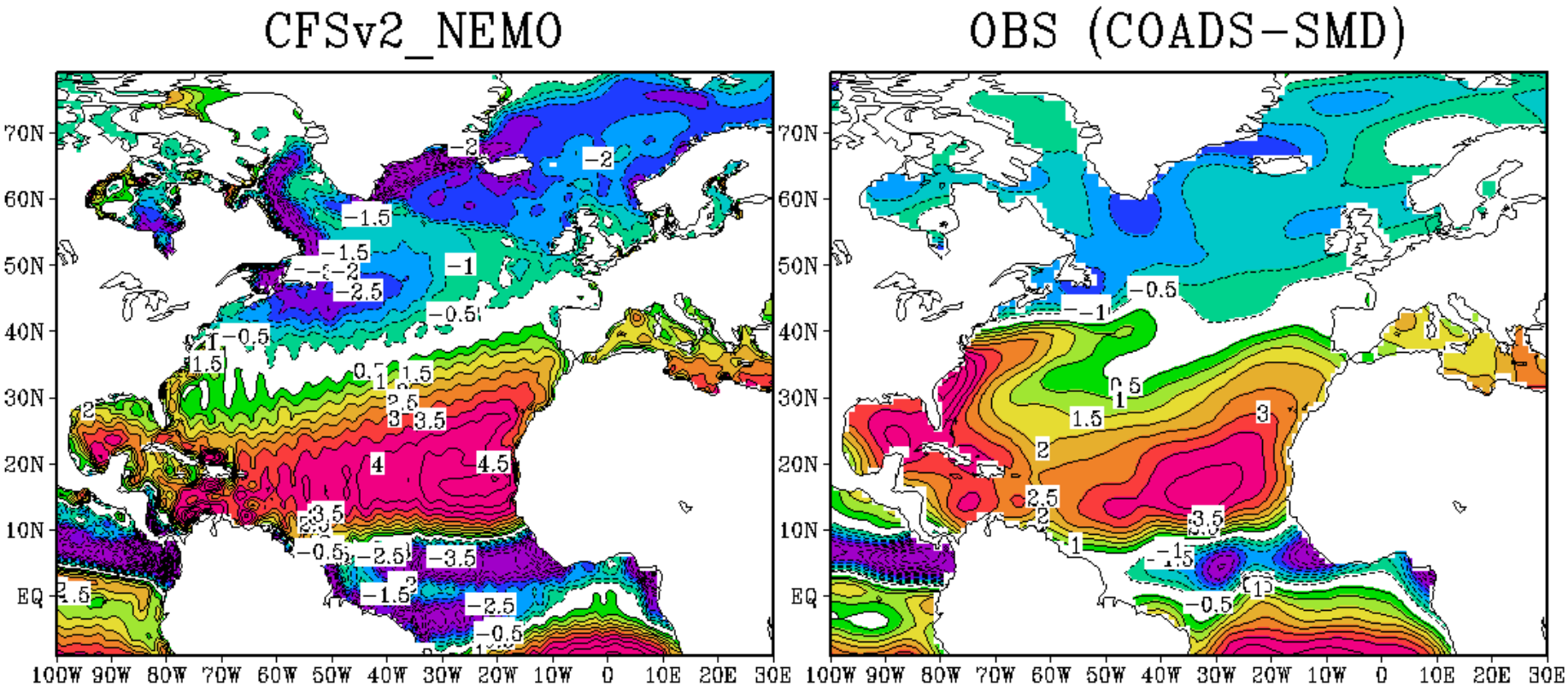
Improved sea ice and marginal sea outflow only have transient influence on AMOC strength in CFSv2


Mean SSS, CFSv2
CFS−NEMO
70N
60N
50N
40N
30N
20N
10N
100W 90W 80W 70W 60W 50W 40W 30W 20W 10W 0 10E 20E 30E
33.5
33
34.5
36.5
37
−0.5
−0.3
−0.4
−0.2
−0.1
10⁴km³
Model years
−CFSv2
−CFSv2_NEMO



Where does the excessive freshwater come from?

Mean E−P Climatology (mm/day)



CFSv2 pattern similar to OBS

Equatorial and mid-lat precip excessive?