Topographic Effects on AMOC Variability and its Pathways

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WOODS HOLE OCEANOGRAPHIC INSTITUTION

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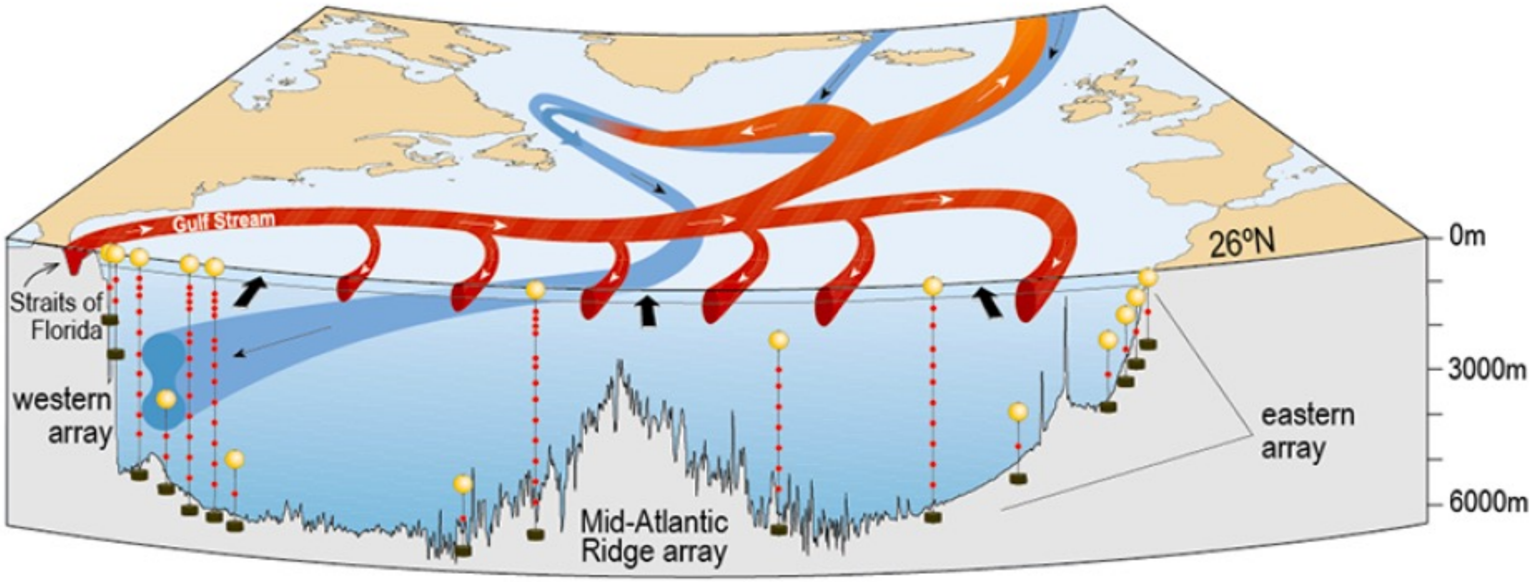
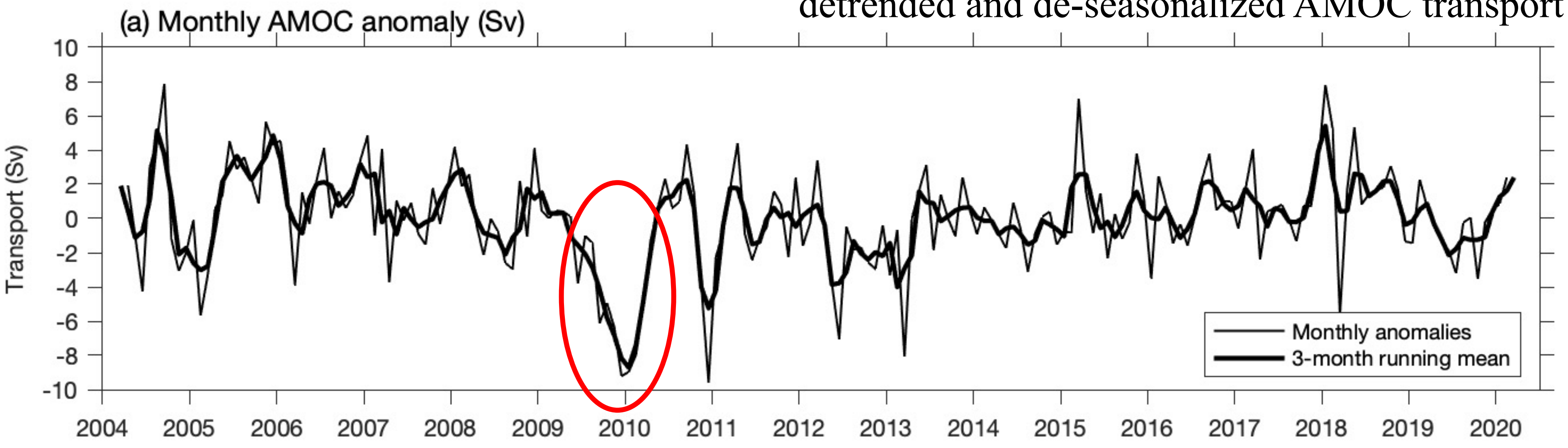
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE NOAA



(Figure: rapid.ac.uk)

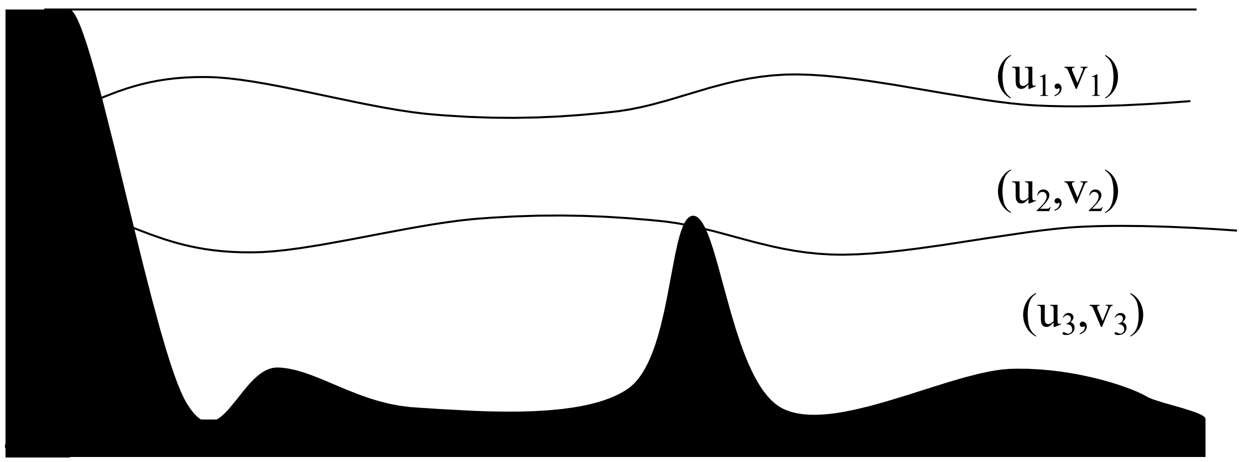
detrended and de-seasonalized AMOC transport



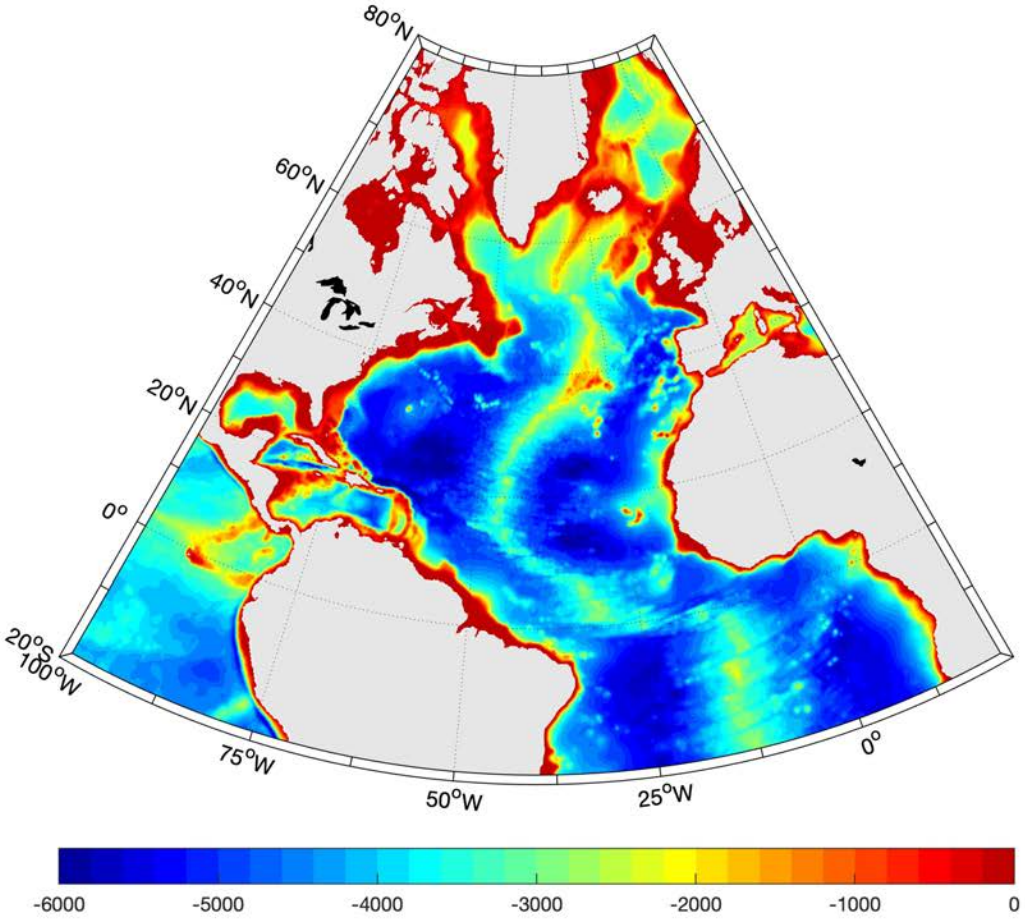
Interannual variability at RAPID array at 26.5°N:

Three-layer wind-driven model:

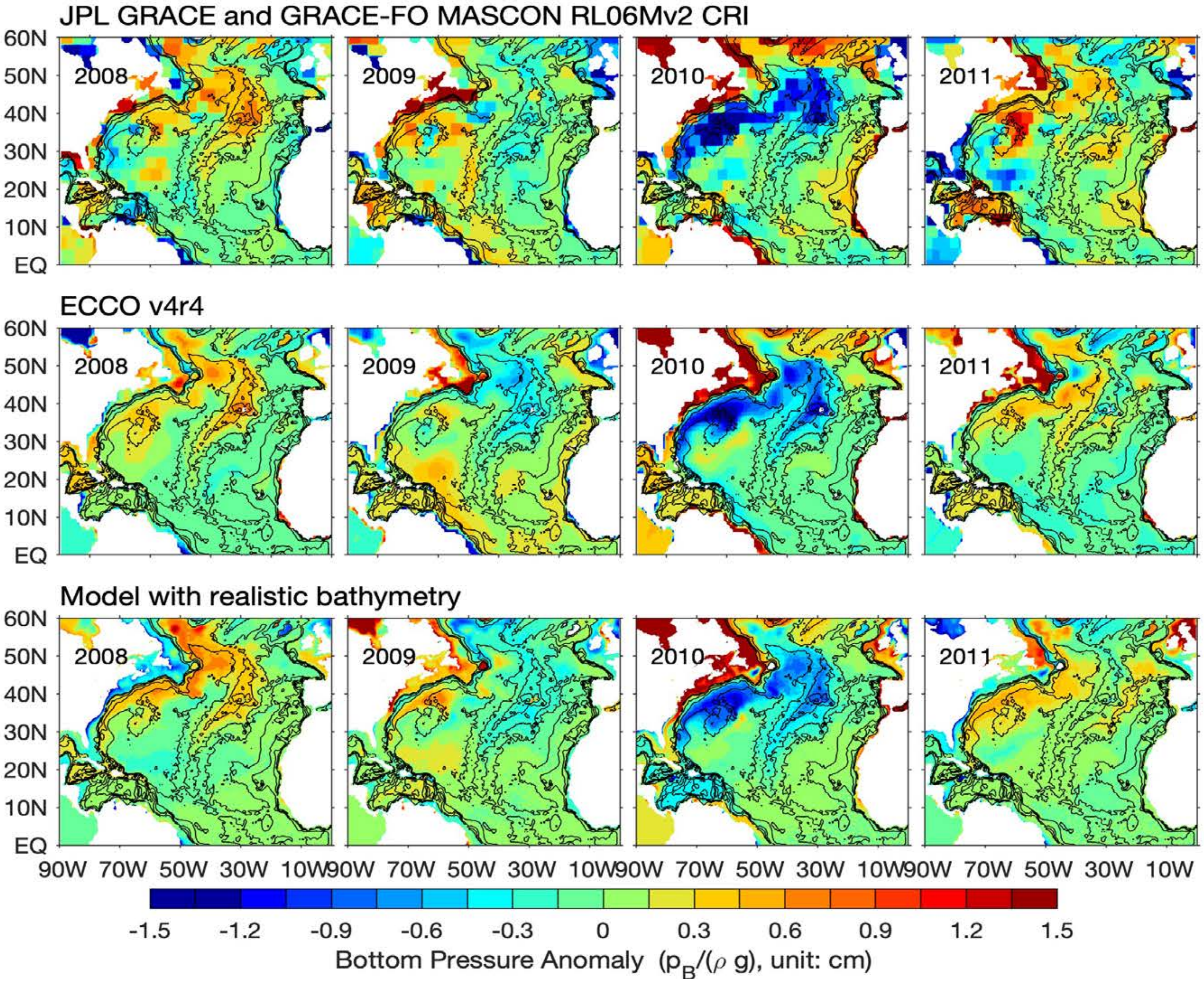
Based on 2-layer model of Yang (2015);
Fully nonlinear and primitive equation model
Model domain: 20°S-80°N and 100°W-20°E;
Resolution: 0.25°
Minimum water depth h_{min}=5m;
ERA5 wind stress forcing (1979-2020);
Realistic bathymetry (GEBCO);



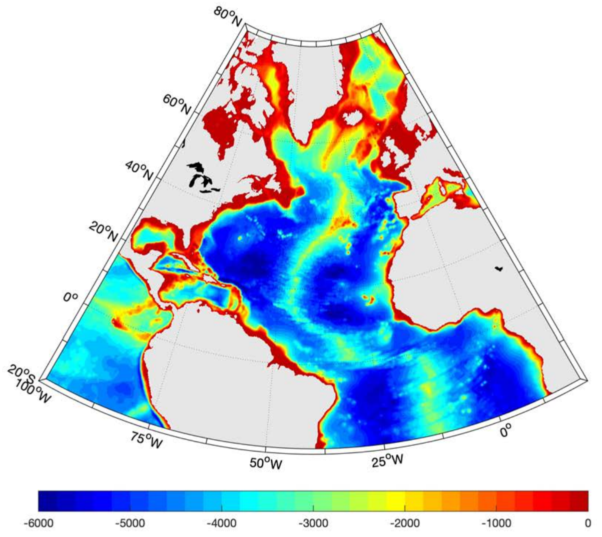
Model Schematic

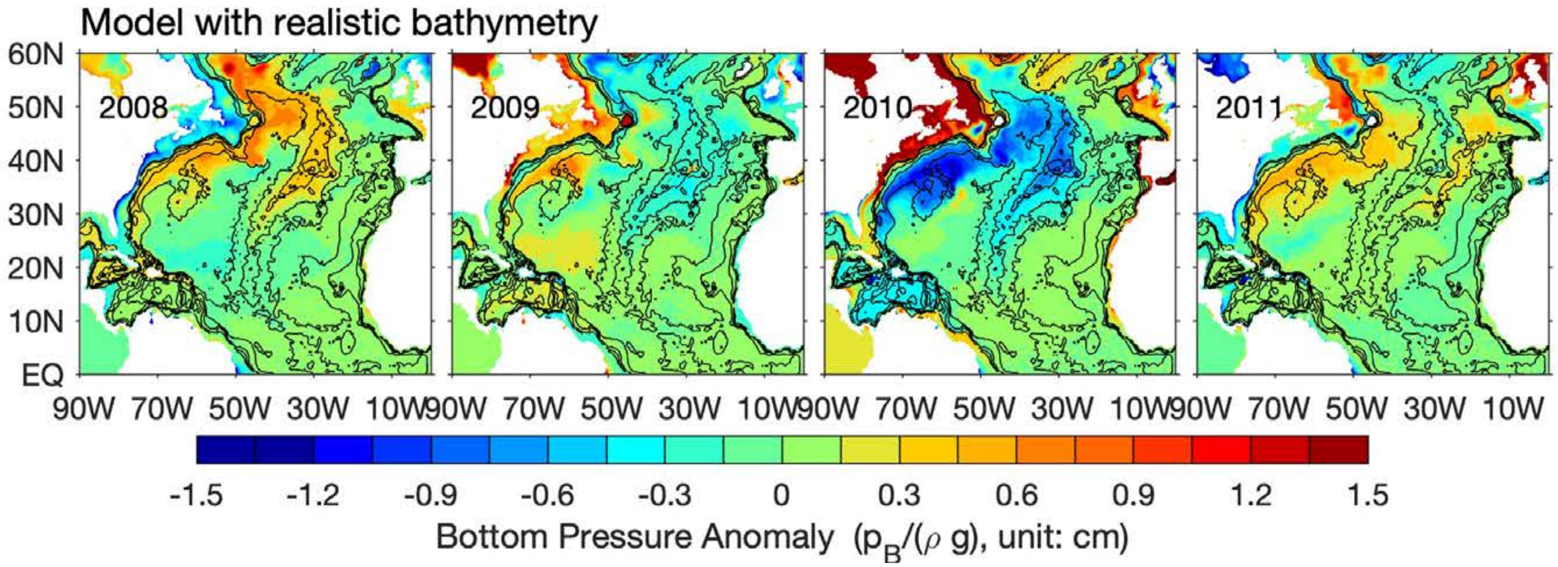


Model Domain

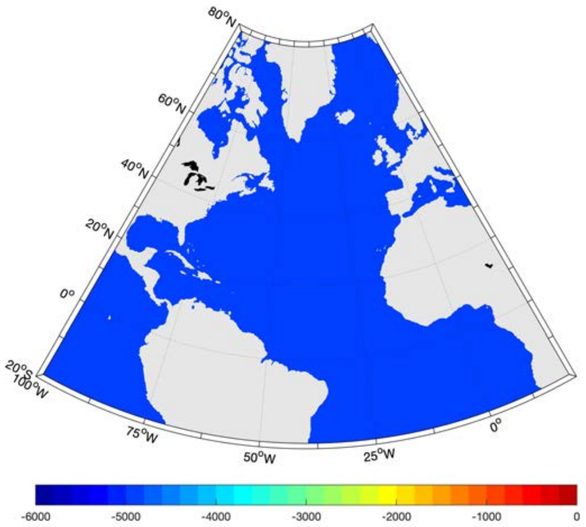


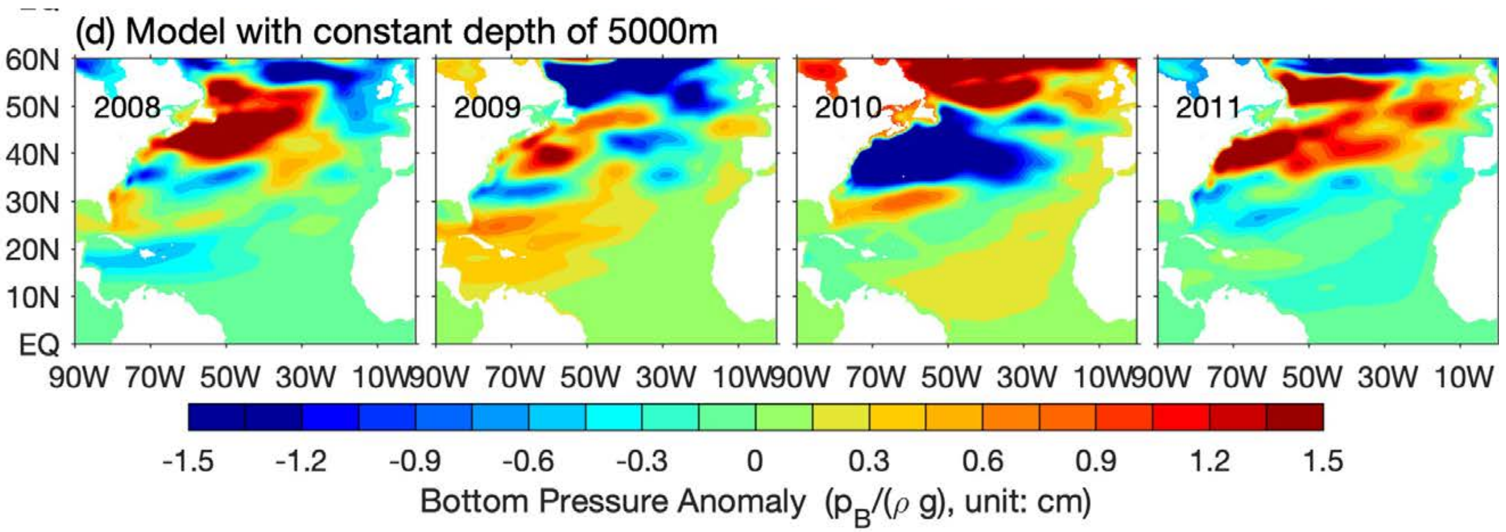
JPL GRACE and GRACE-FO MASCON RL06Mv2 CRI
ECCO v4r4
Model with realistic bathymetry
2008
2009
2010
2011
60N
50N
40N
30N
20N
10N
EQ
90W
70W
50W
30W
10W
-1.5
-1.2
-0.9
-0.6
-0.3
0
0.3
0.6
0.9
1.2
1.5
Bottom Pressure Anomaly ($p_B/(\rho g)$, unit: cm)





$$\beta_T V = \frac{1}{\rho_0} curl\vec{\tau} \quad (\text{where } \beta_T = \left| H\nabla\left(\frac{f}{H}\right) \right|)$$

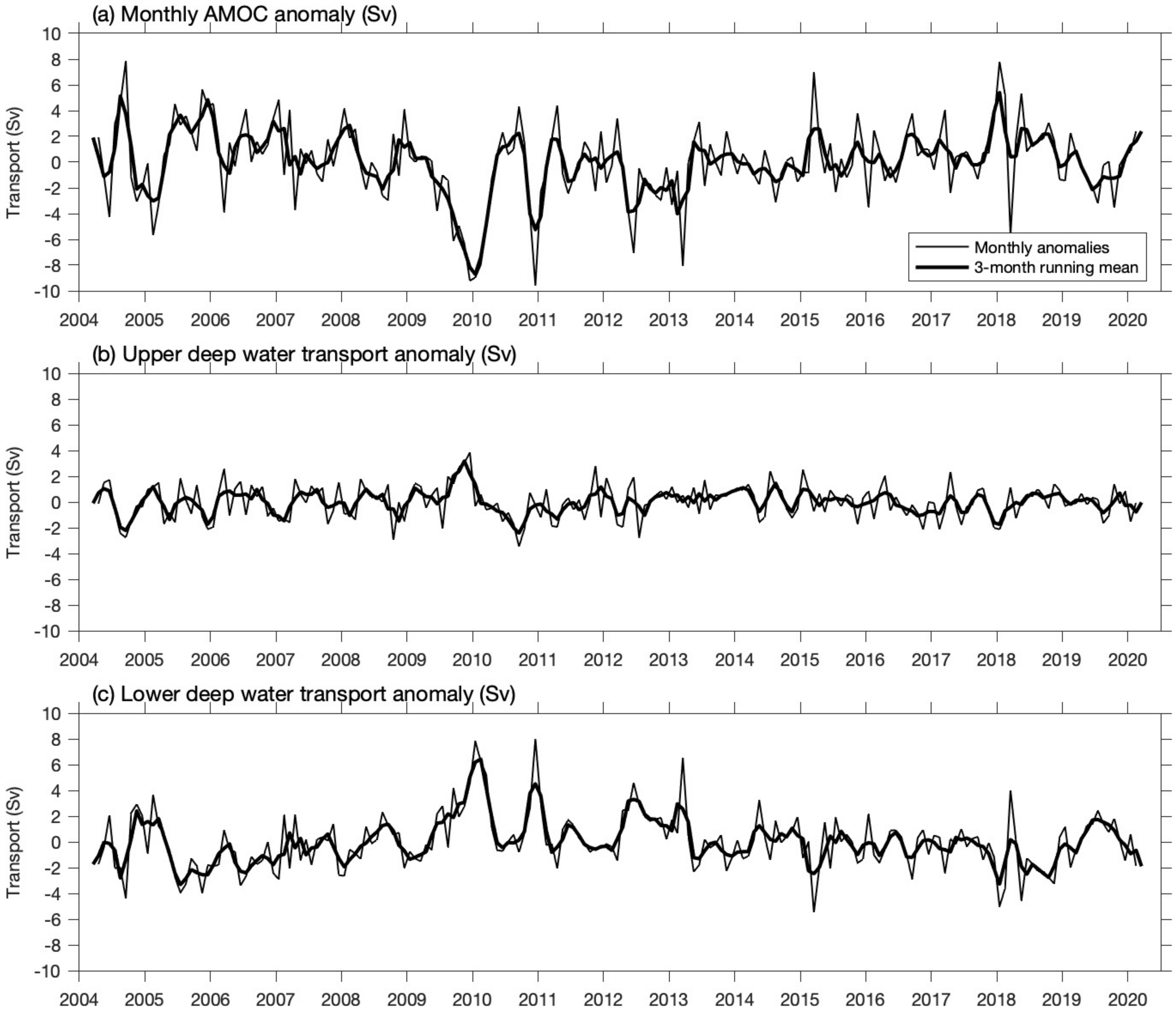




$$\beta V = \frac{1}{\rho_0} curl\vec{\tau} \quad (\text{where } \beta = \frac{df}{dy})$$

β *is typically much smaller than* β_T*, especially in high latitudes*

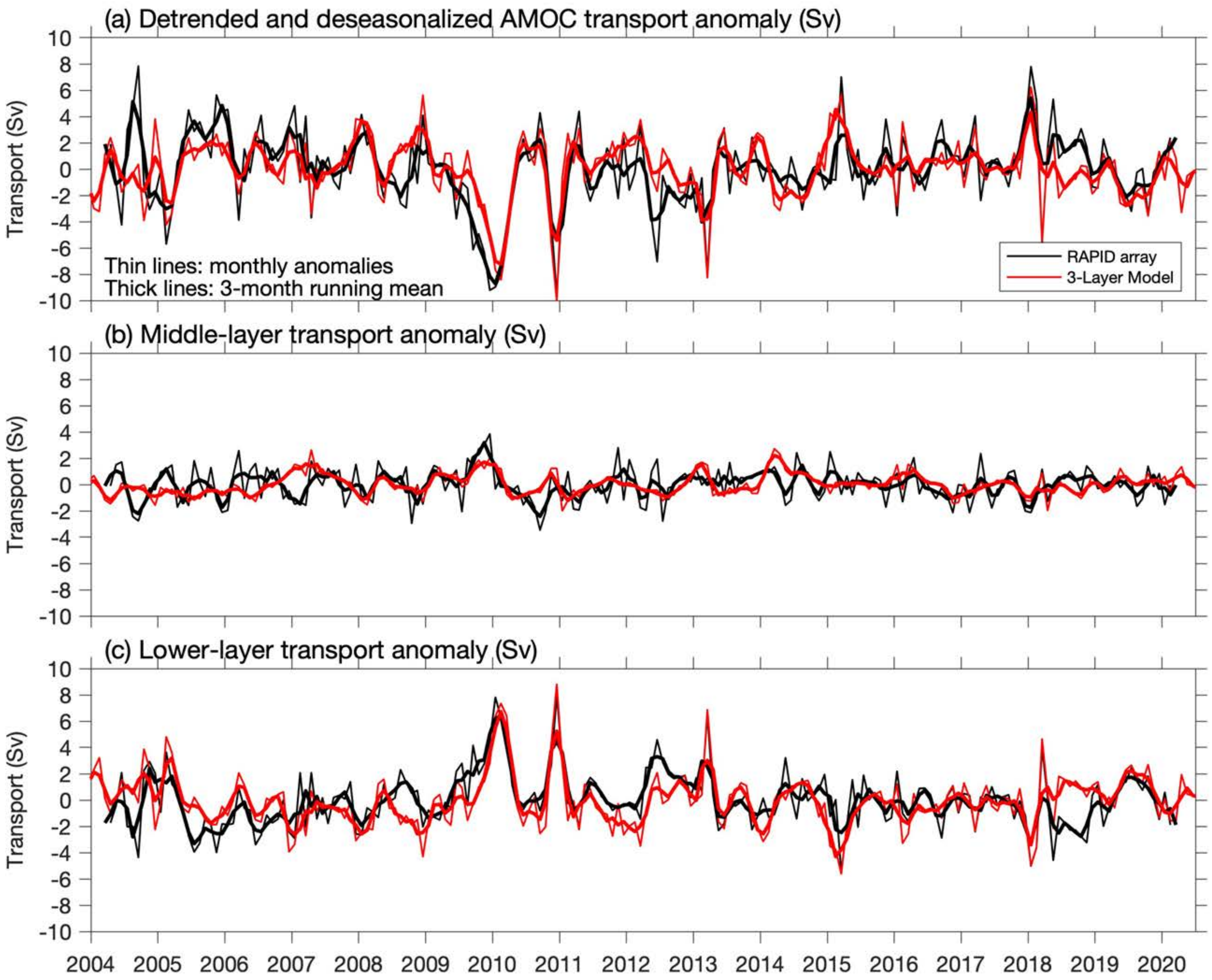
(RAPID array observation)



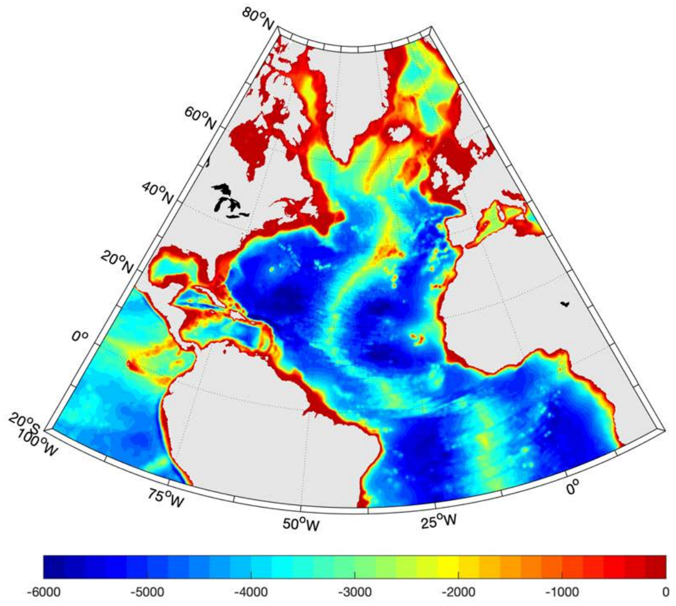
Detrended and de-seasonalized AMOC transport anomalies at RAPID array.

Thin lines: monthly anomalies

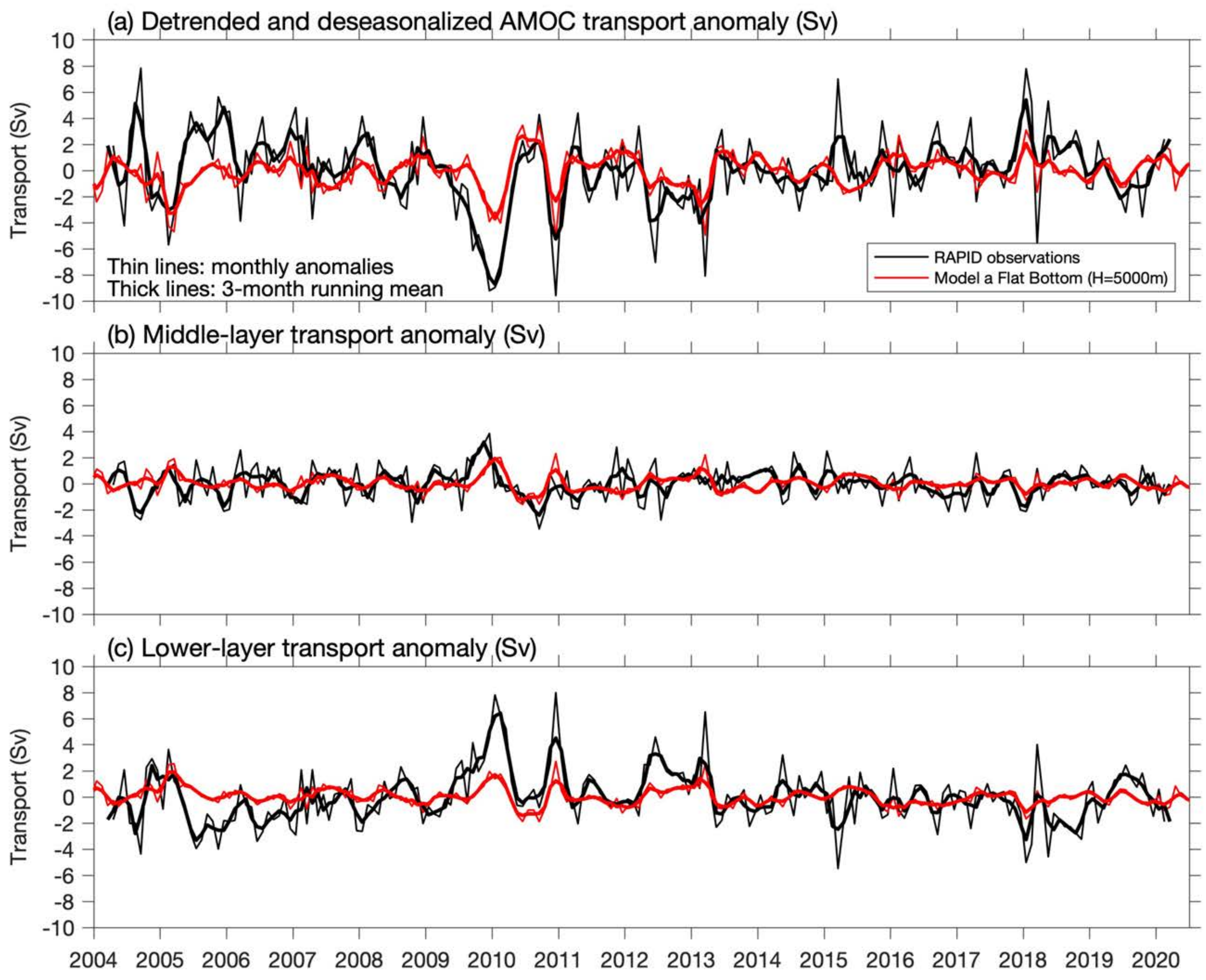
Thick lines: 3-month running mean

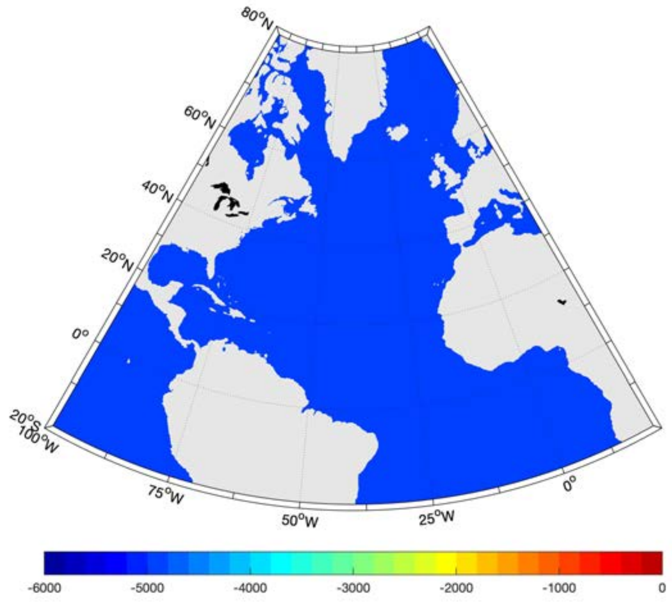


RAPID Array at 26.5°N



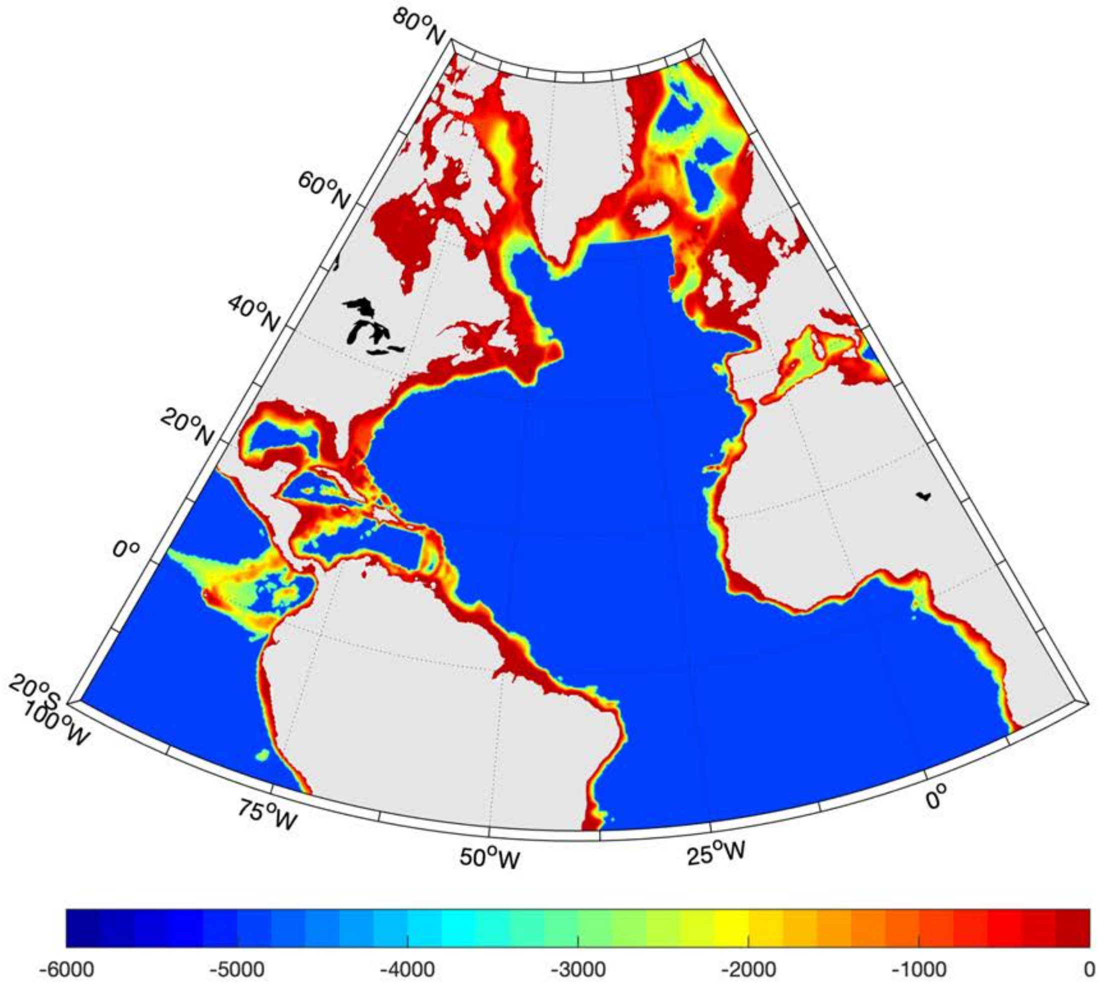
Model Control Run

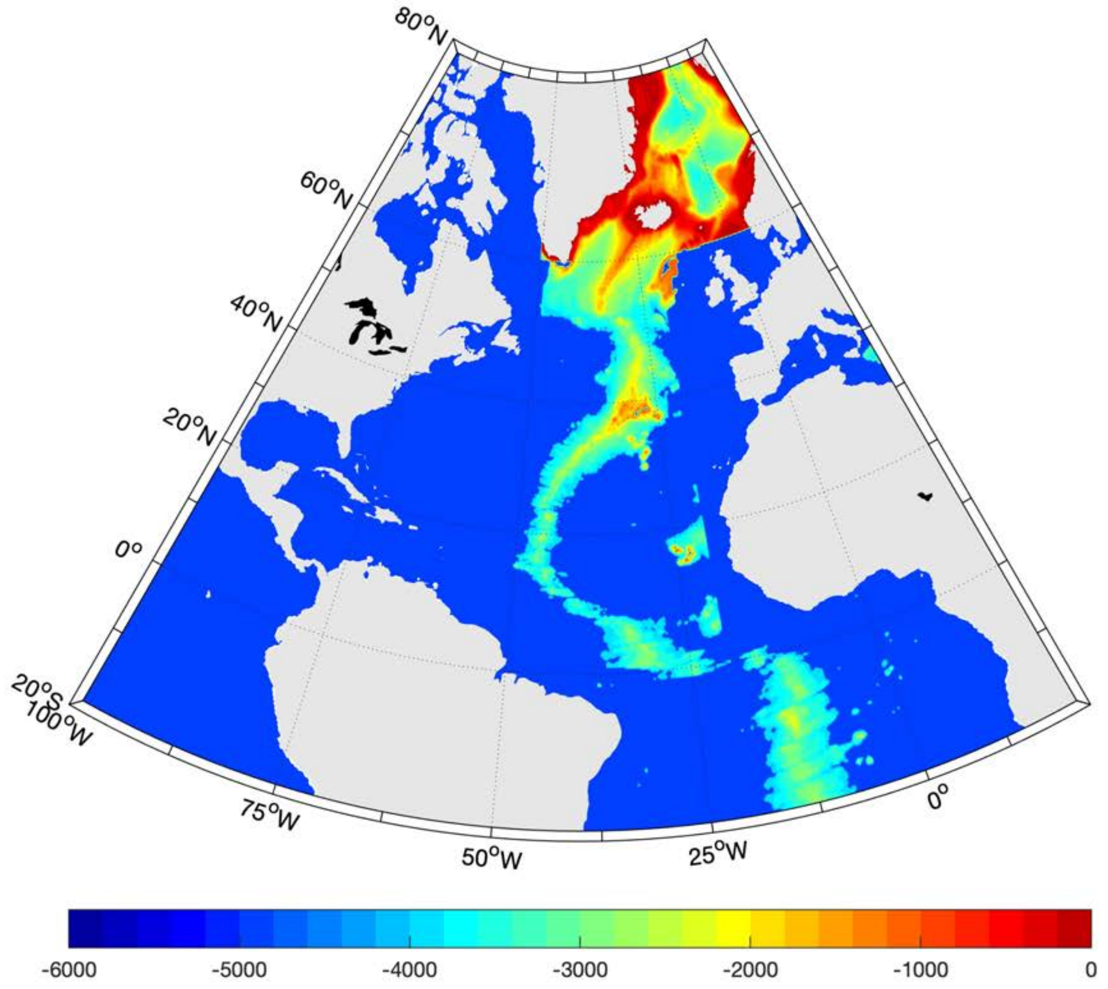


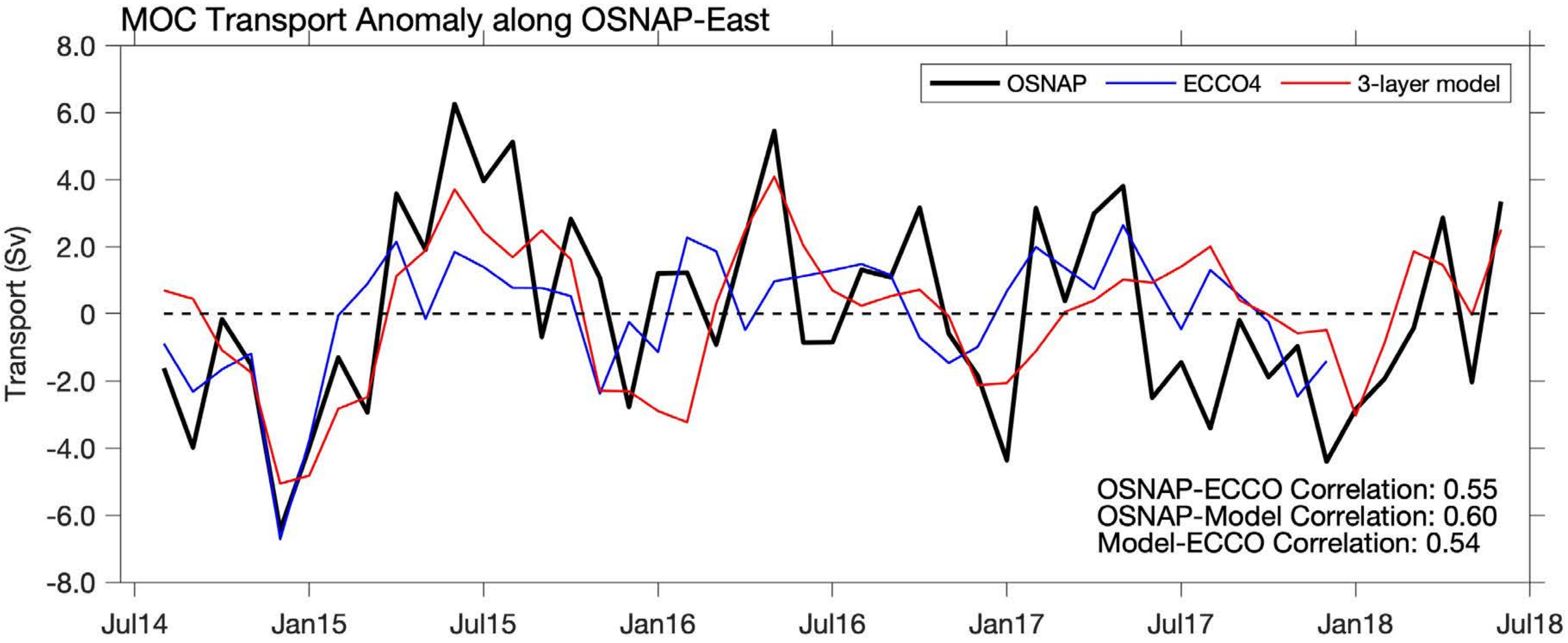


Model using a constant depth H=5000m

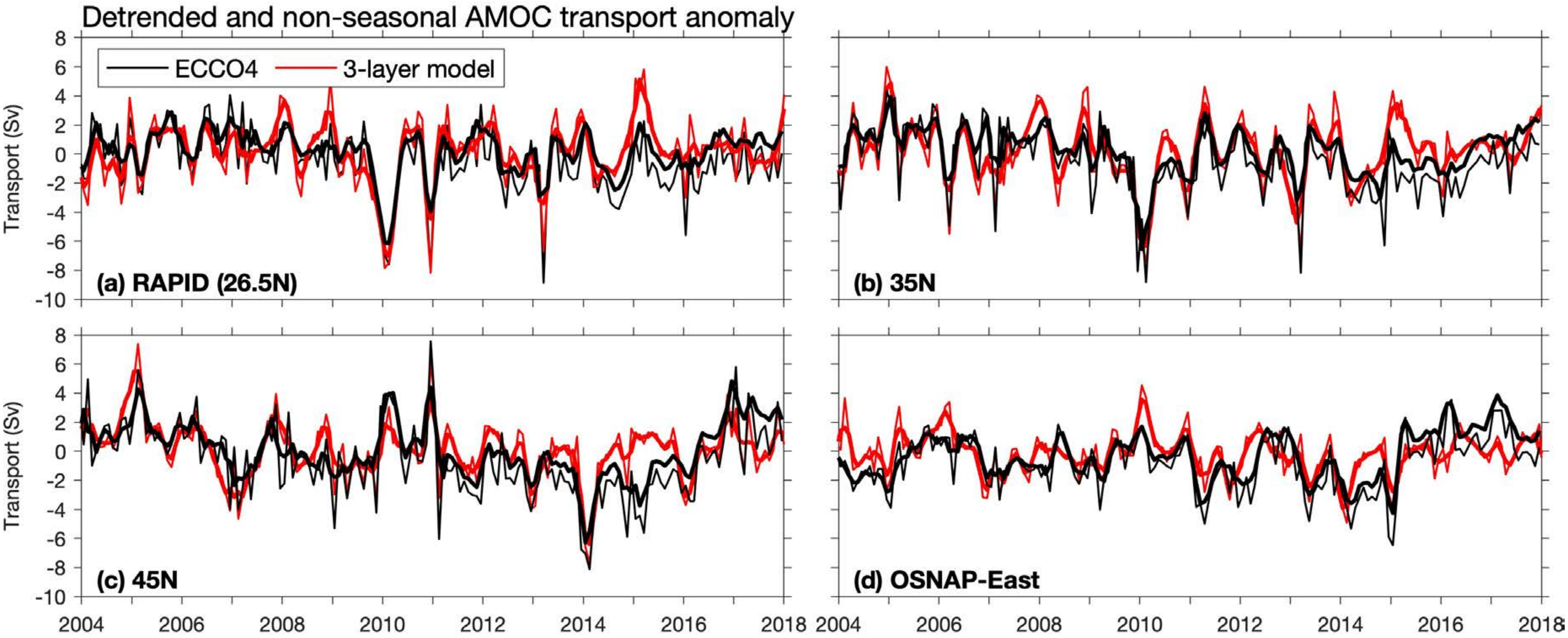
Additional experiments:






MOC Transport Anomaly along OSNAP-East
OSNAP
ECCO4
3-layer model
Transport (Sv)
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
-8.0
Jul14
Jan15
Jul15
Jan16
Jul16
Jan17
Jul17
Jan18
Jul18
OSNAP-ECCO Correlation: 0.55
OSNAP-Model Correlation: 0.60
Model-ECCO Correlation: 0.54

Comparison with ECCO4v4



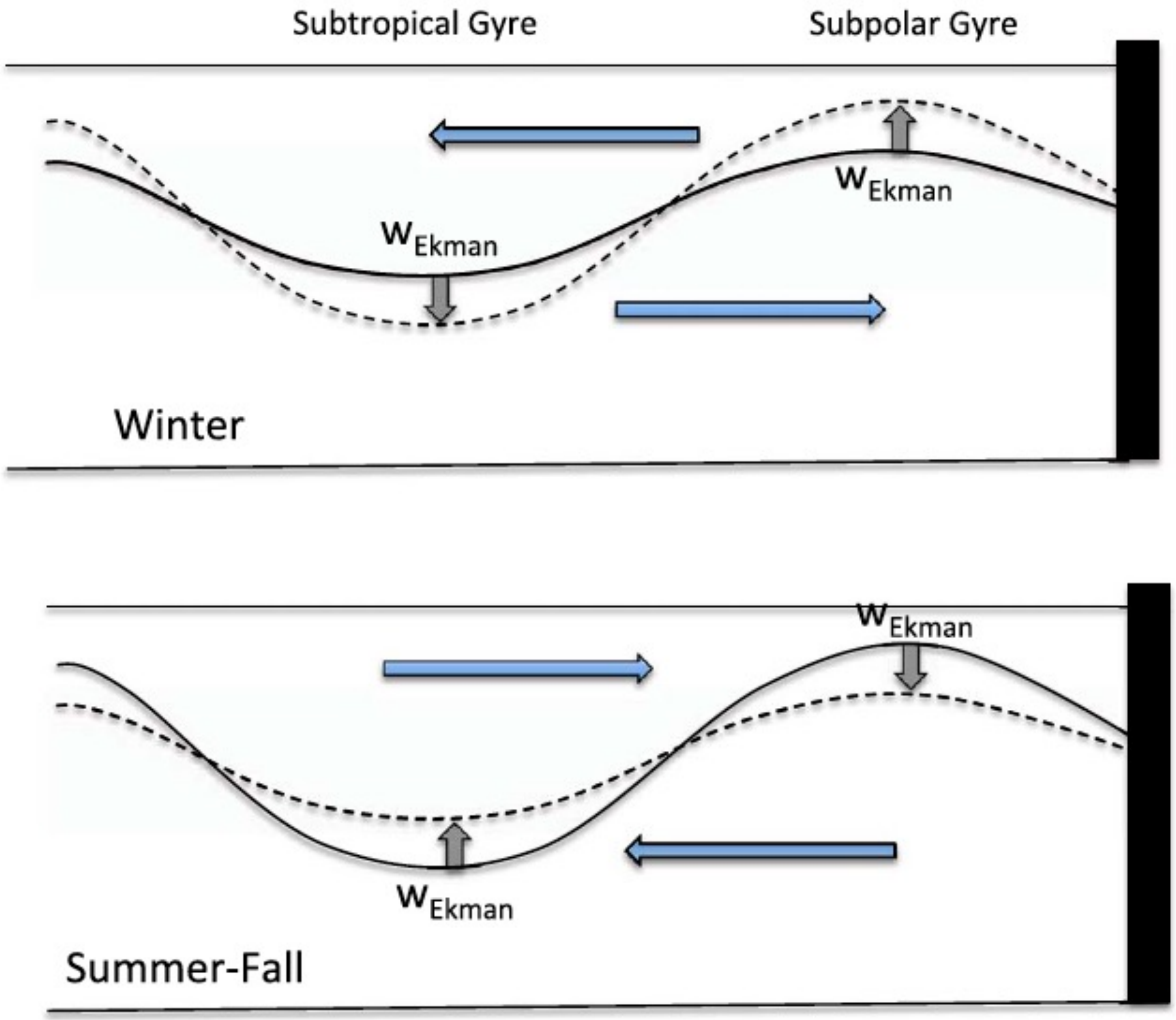
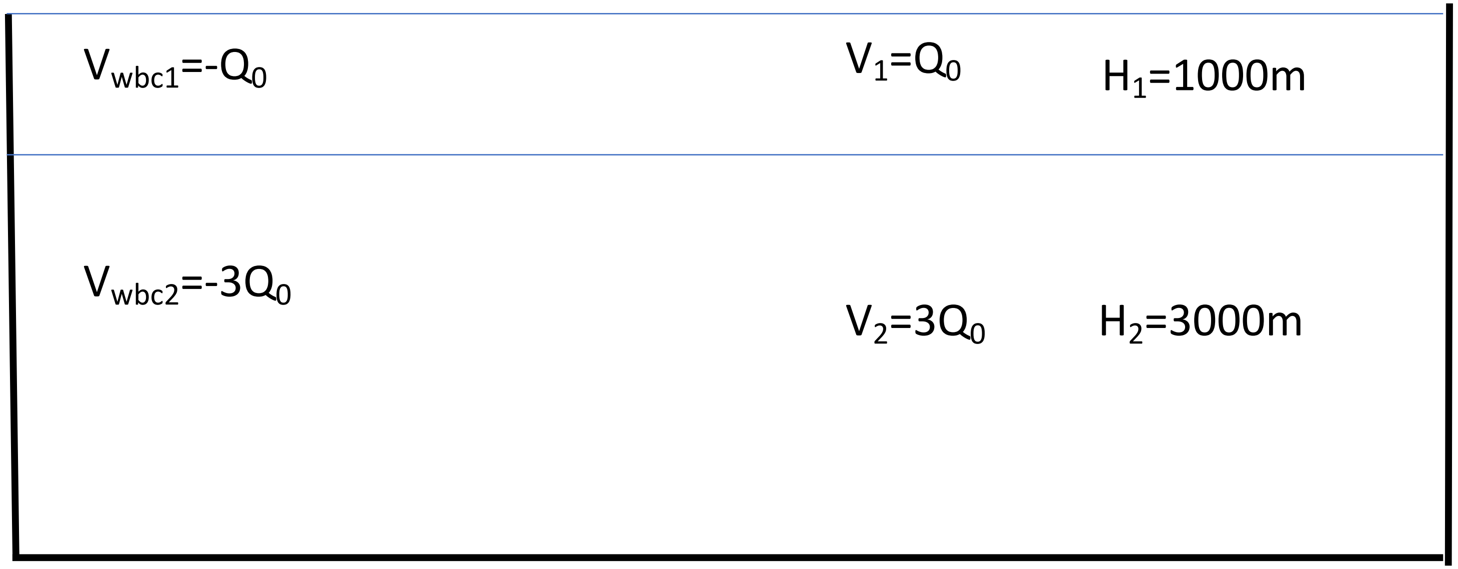


Figure 7. The schematics of interactions between subtropical and subpolar gyres. (top) There is southward transport in the upper layer when either the Ekman pumping in the subtropics or Ekman suction in the subpolar basin intensifies. This would lead to a weakening of the mean AMOC. (bottom) Likewise, the AMOC would increase when either the Ekman pumping in the subtropics or suction in the subpolar basin weakens.

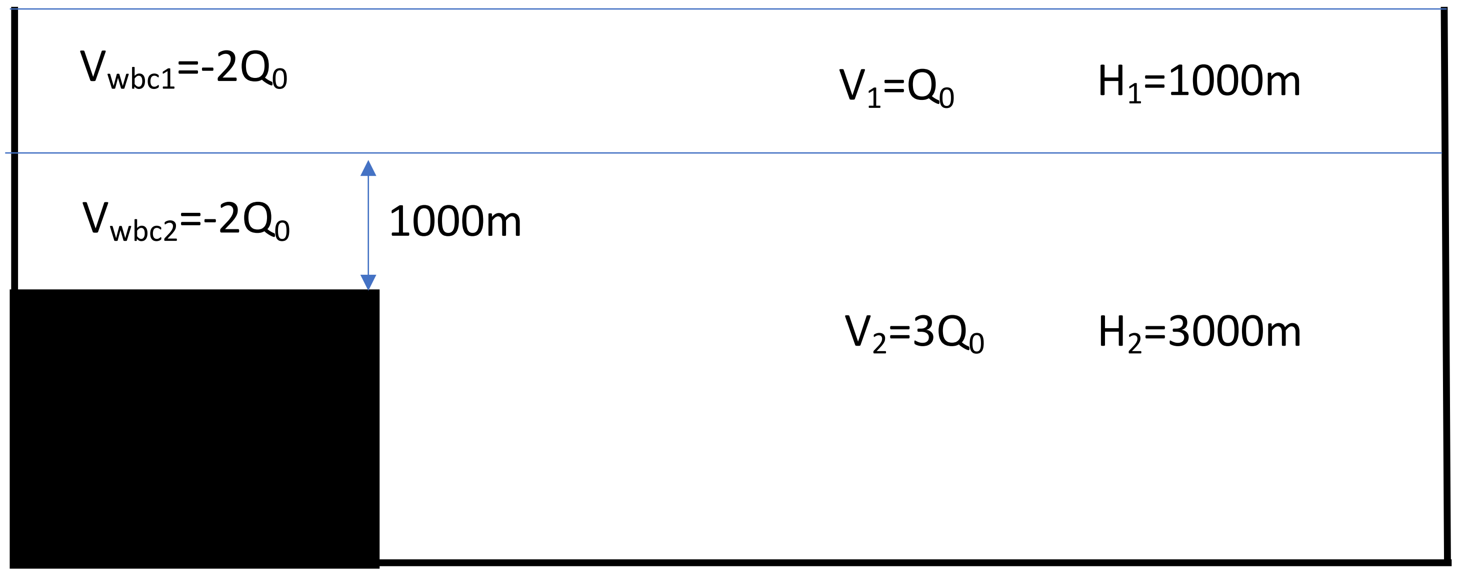
Figure from Yang (2015 JGR-Oceans)

A potential topographic effect on barotropic component of AMOC:



Net transport in layer 1: 0

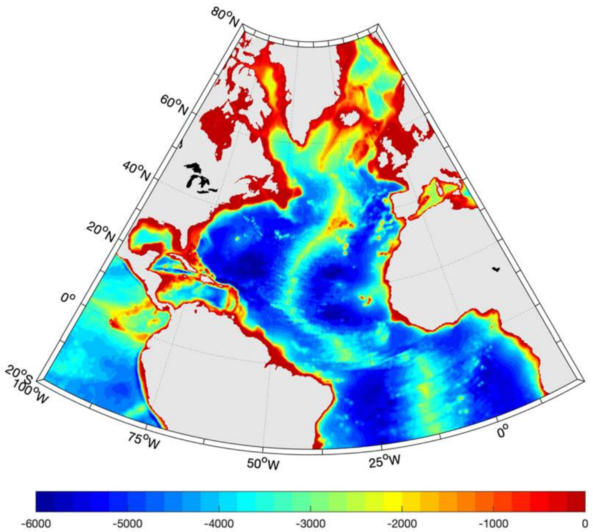
Net transport in layer 2: 0

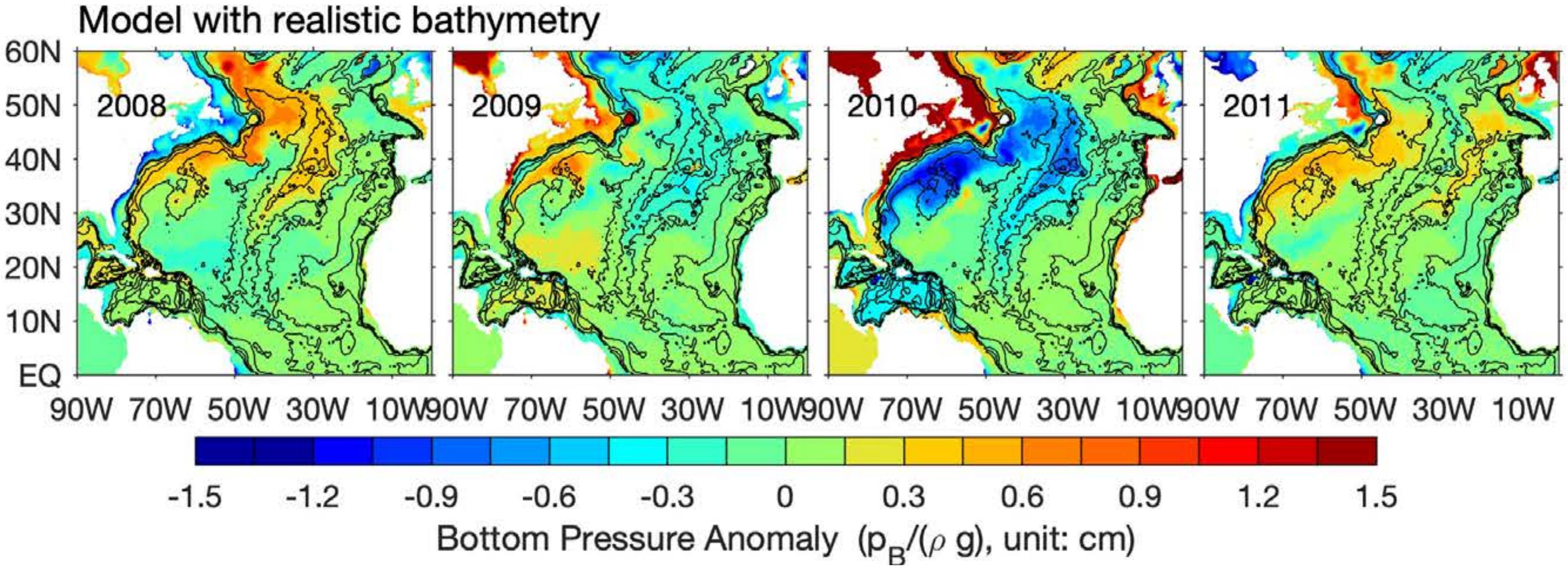


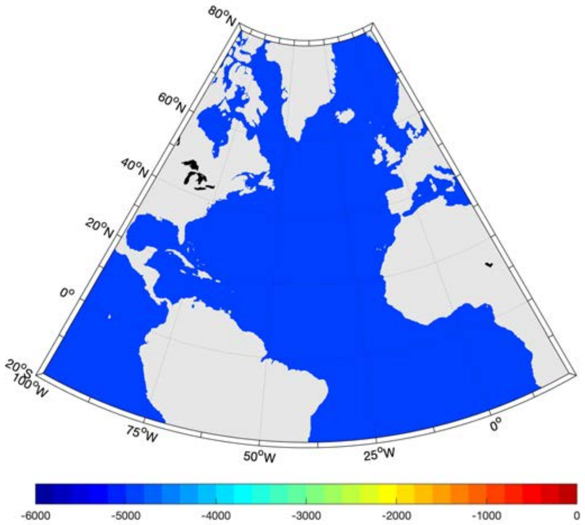
Net transport in layer 1: -Q_0

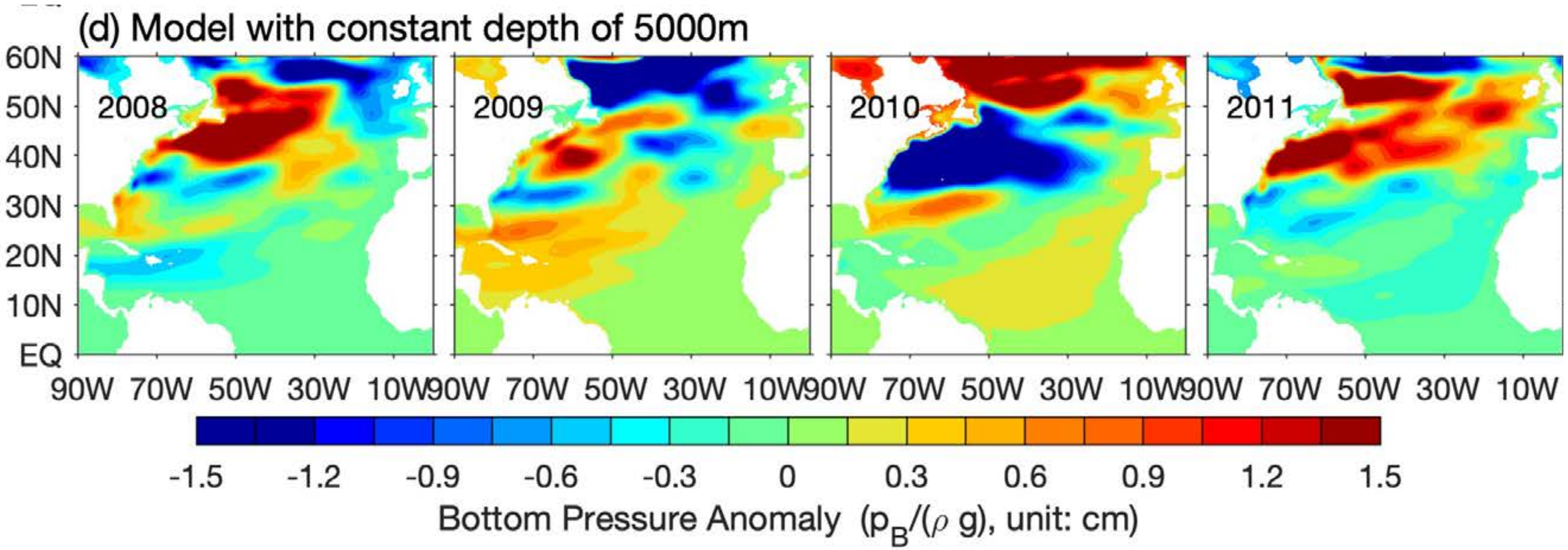
Net transport in layer 2: Q_0

Topographic effects AMOC variability pathways:

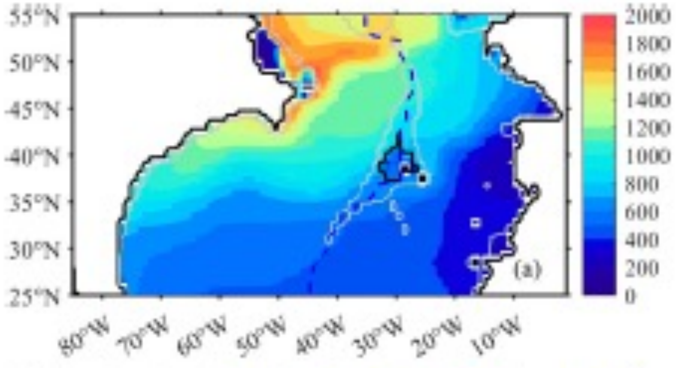




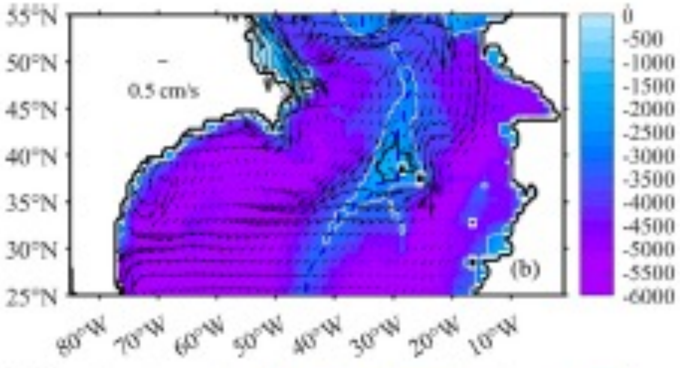




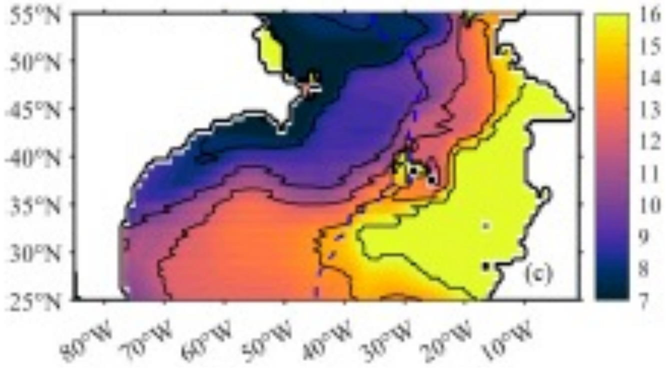
Topographic effects on mean transport pathways based on ECCO4 release 4:



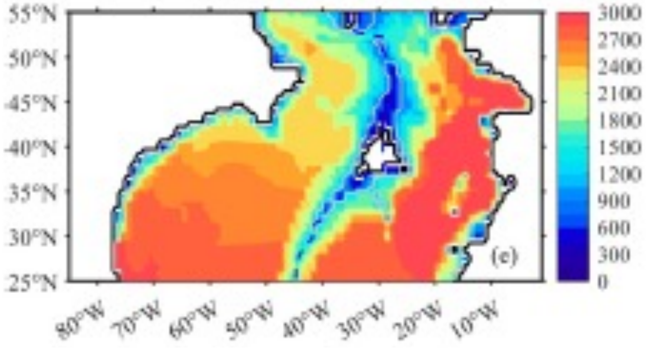
$H_{upper-NADW}$



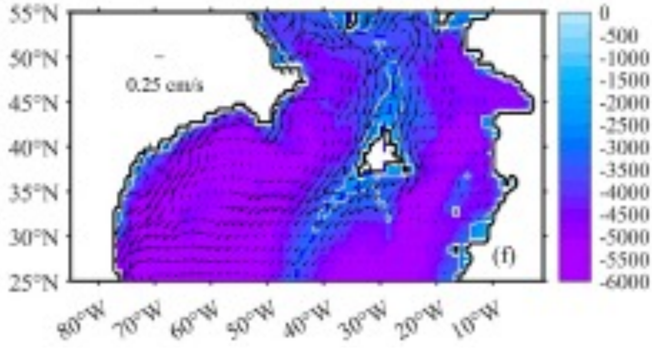
$mean\ velocity$



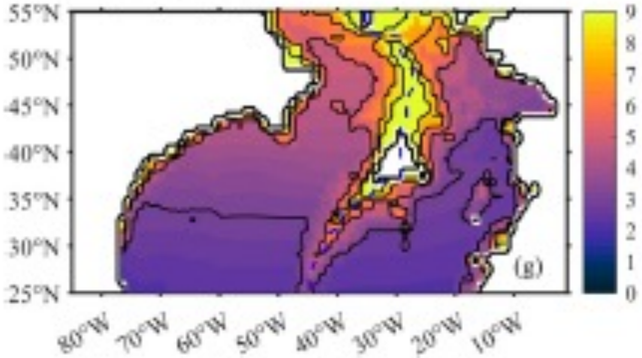
$f/H_{upper-NADW}$



$H_{lower-NADW}$



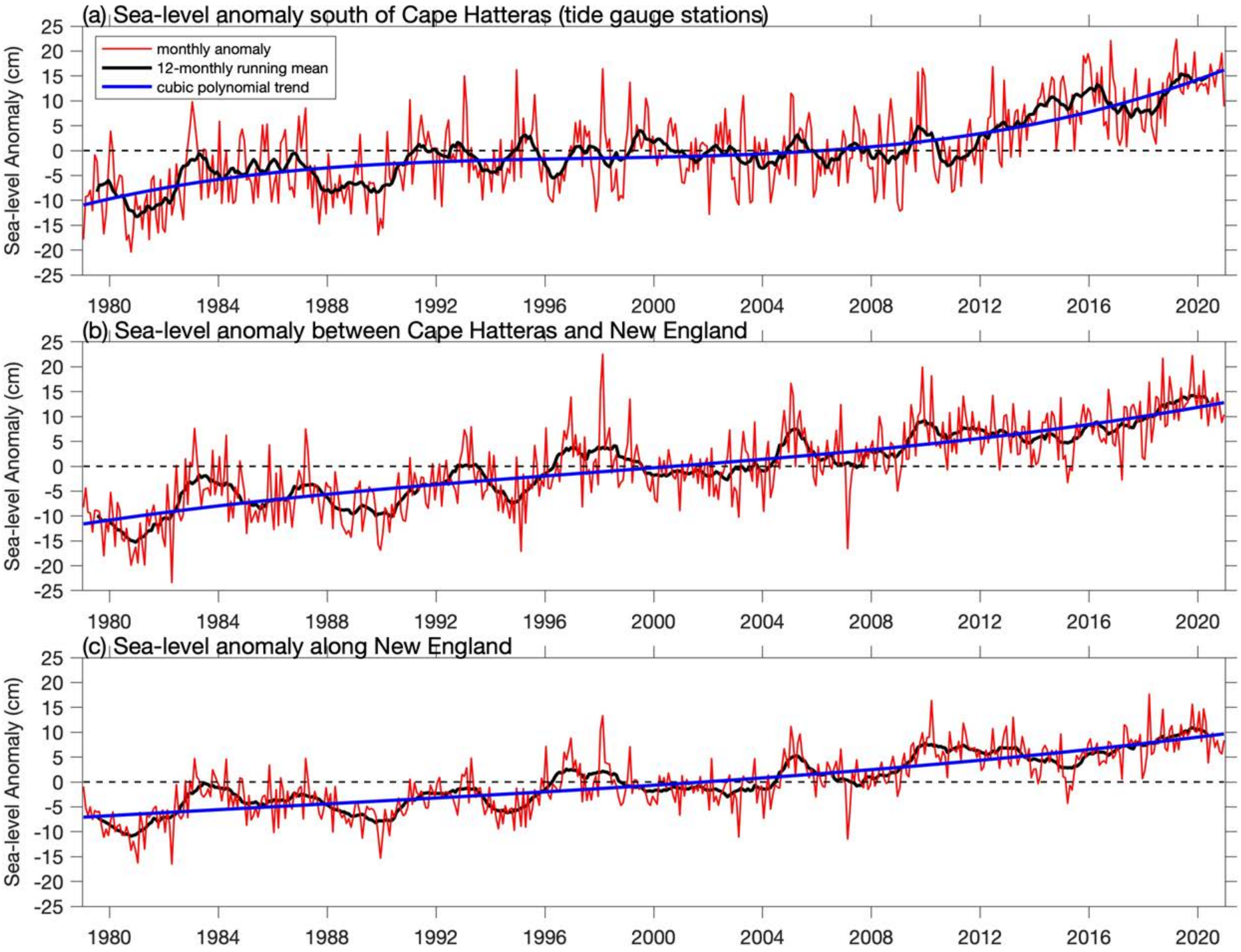
$mean\ velocity$

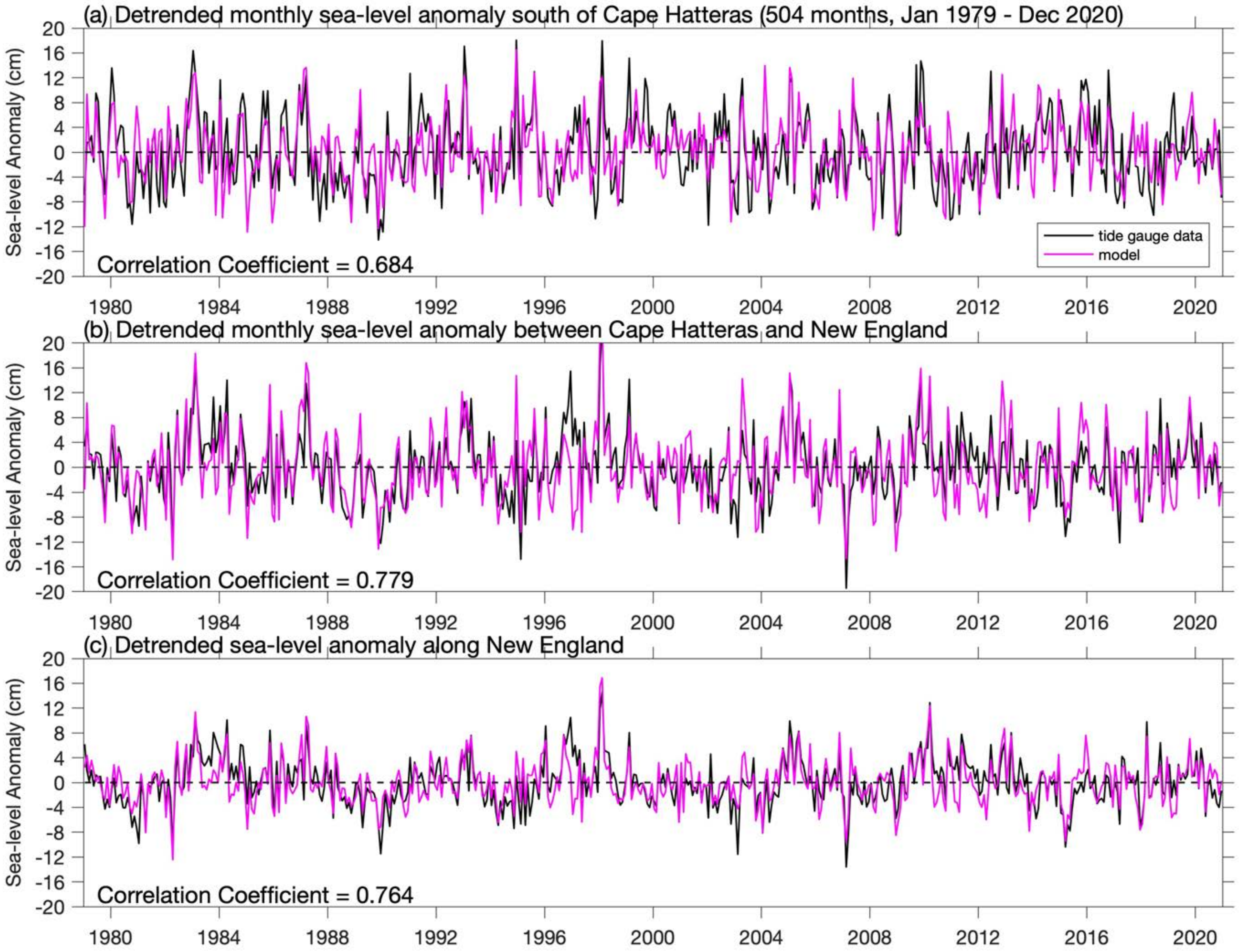


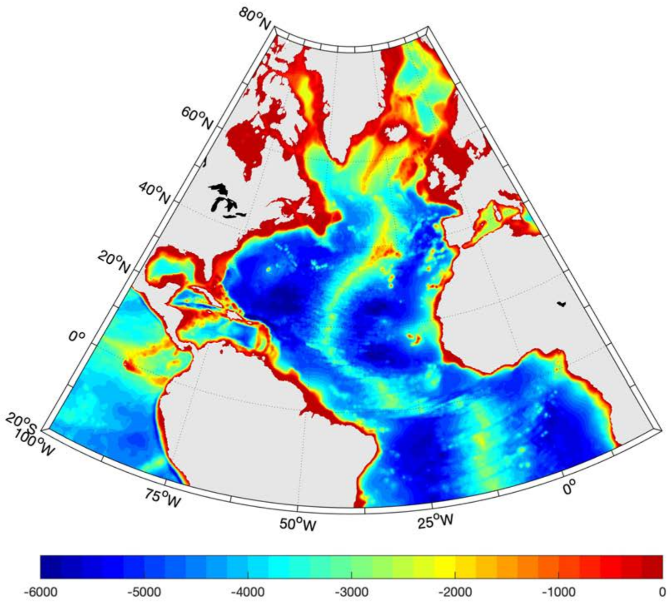
$f/H_{lower-NADW}$

Zhai et al. (2021, GRL)

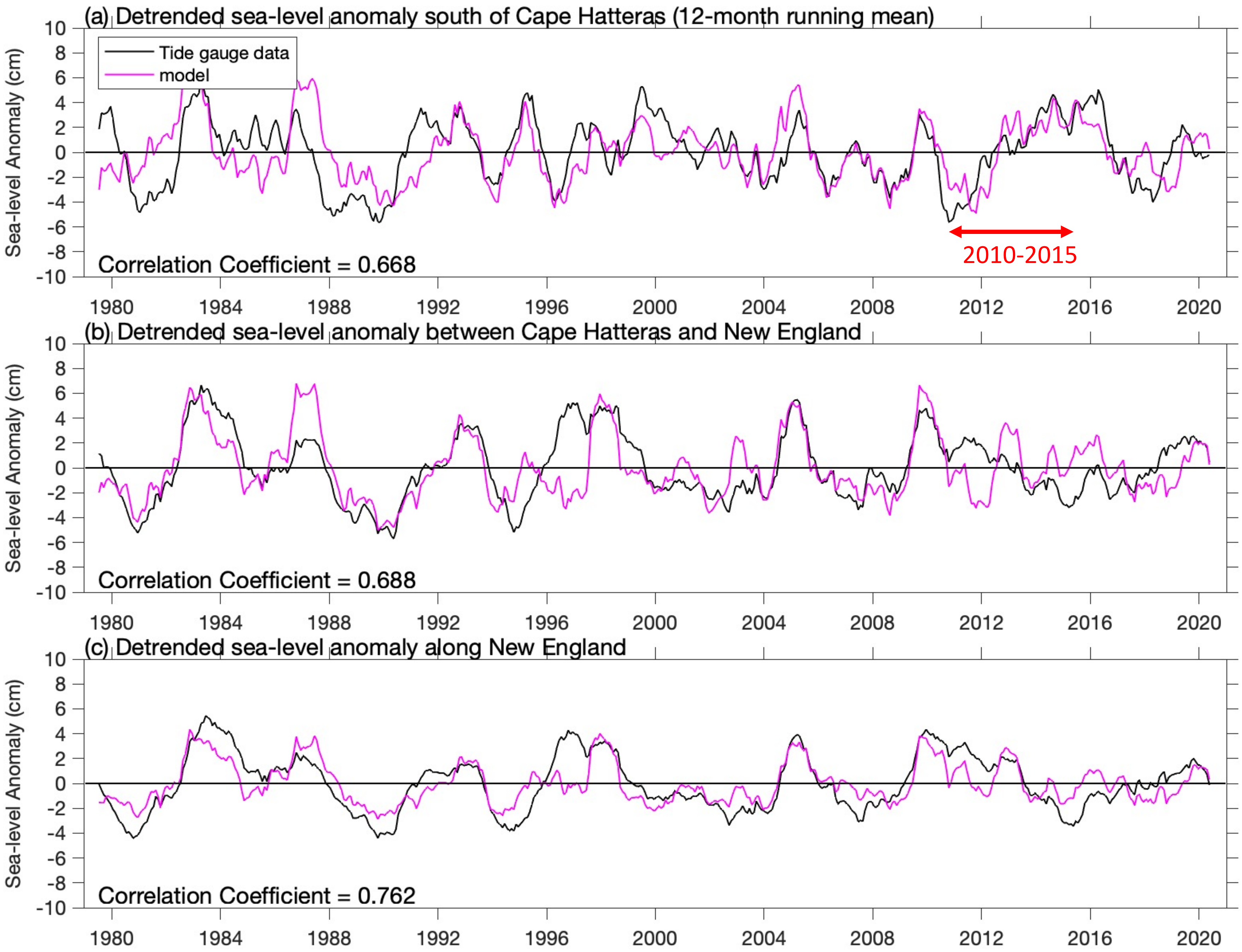
Topographic effects on coastal sea-level variability:

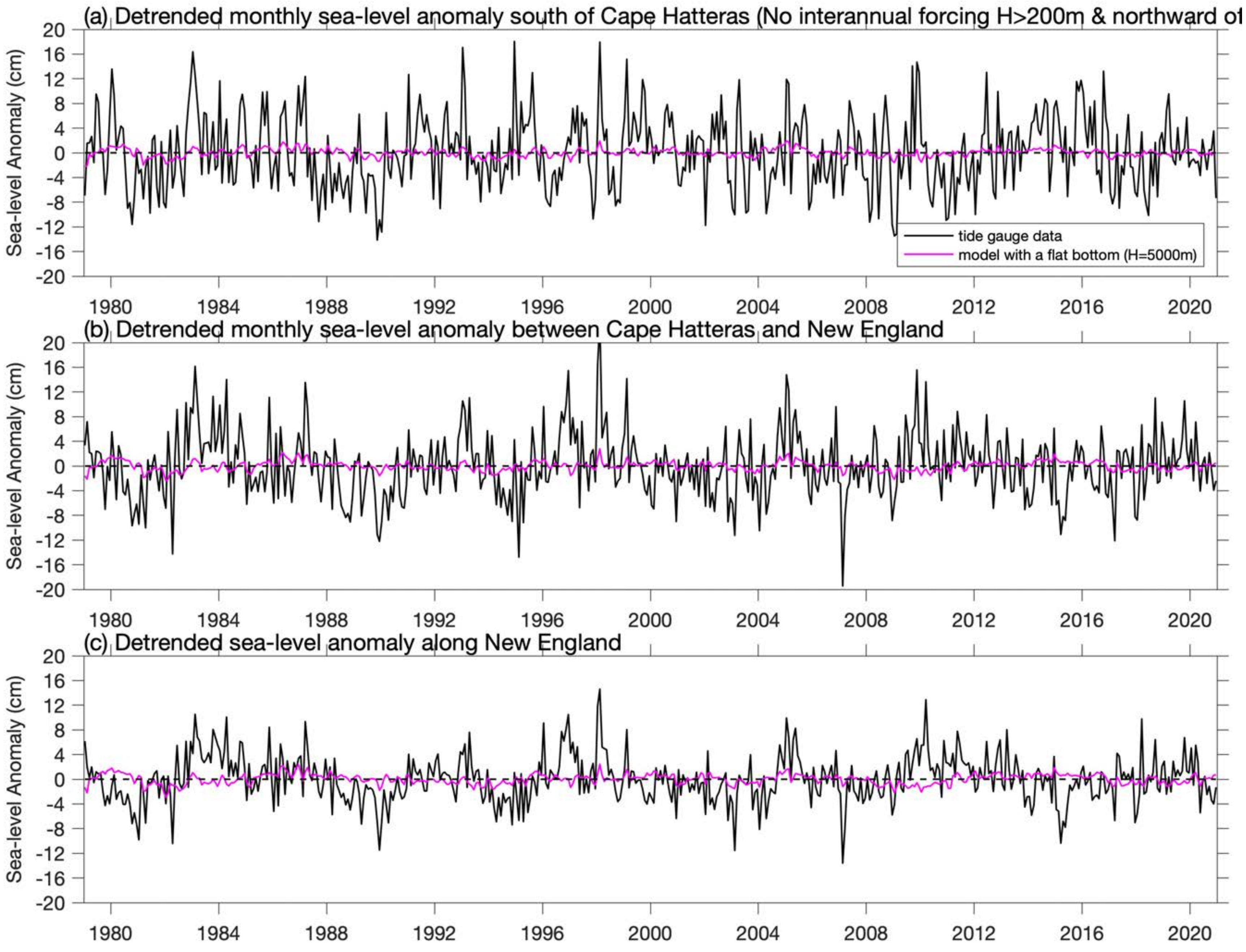


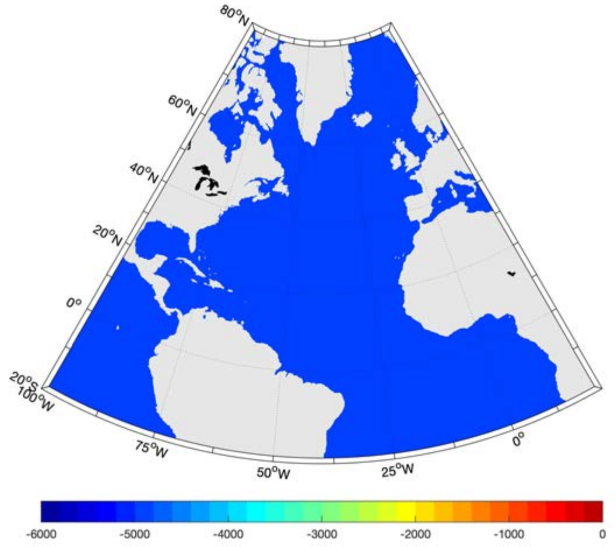




Model Control Run


(a) Detrended sea-level anomaly south of Cape Hatteras (12-month running mean)
Tide gauge data
model
Sea-level Anomaly (cm)
Correlation Coefficient = 0.668
2010-2015
(b) Detrended sea-level anomaly between Cape Hatteras and New England
Correlation Coefficient = 0.688
(c) Detrended sea-level anomaly along New England
Correlation Coefficient = 0.762
1980
1984
1988
1992
1996
2000
2004
2008
2012
2016
2020





Model using a constant depth H=5000m

Summary:

(1) Topography affects both the shapes and magnitudes of AMOC's responses to wind-stress forcings;

(2) The amplified variability of the lower NADW layer transport at RAPID array is mainly due to topographic effects;

(3) Latitudinal communication of AMOC variability is mainly along geostrophic contours when topographic effects are included, which is different from the boundary wave mechanisms in classic models without topography;

(3) Topography strongly affects how AMOC variability influences the coastal sea level changes;