Ocean Conveyor Belt – is it changing or not?

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with contributions from many others

Conveyor belt, or Meridional Overturning Circulation

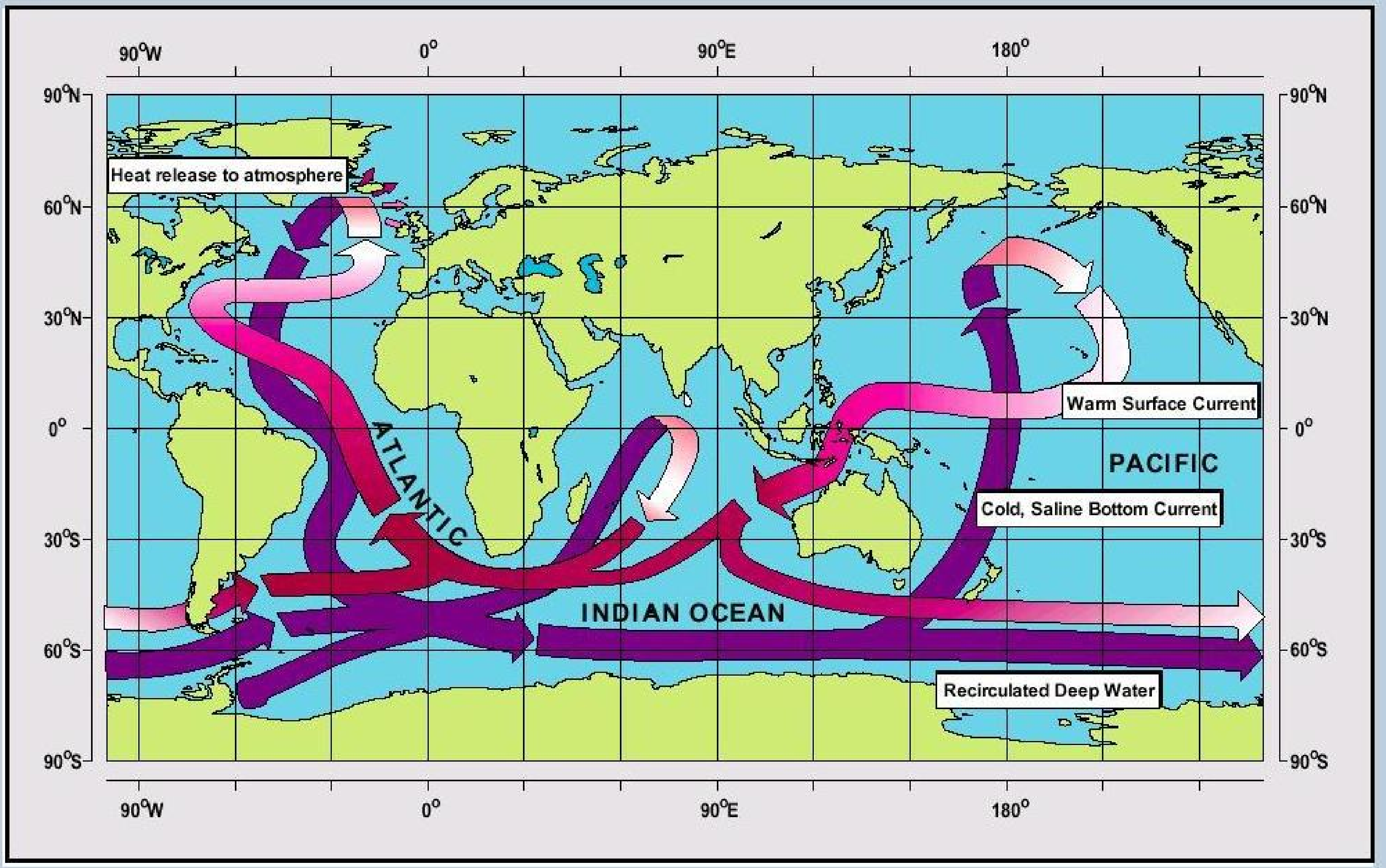
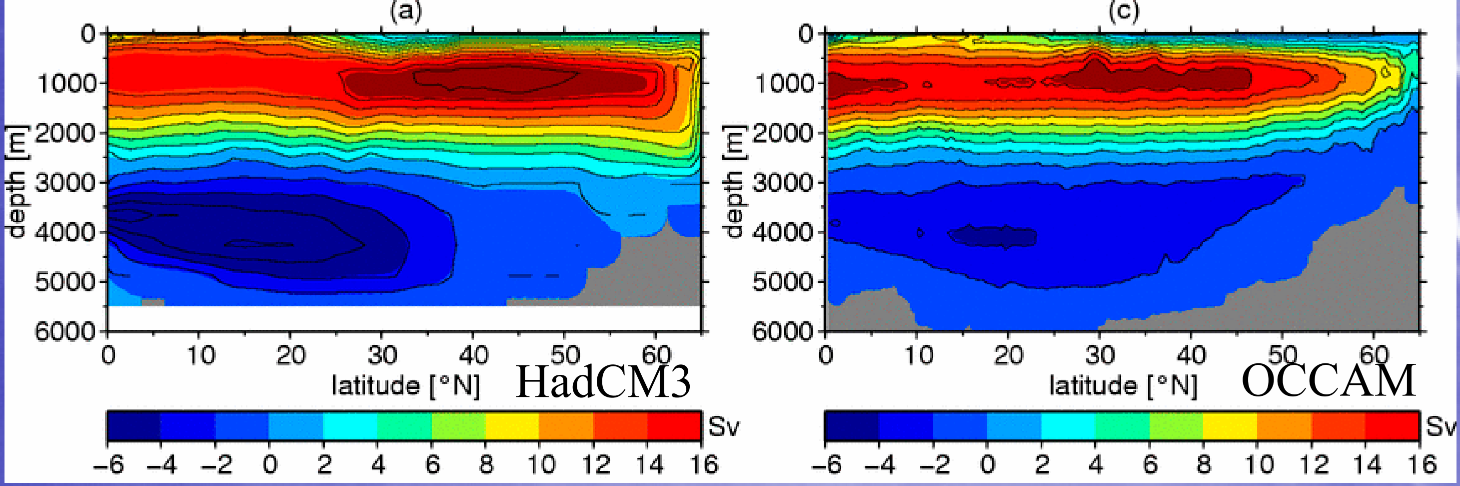


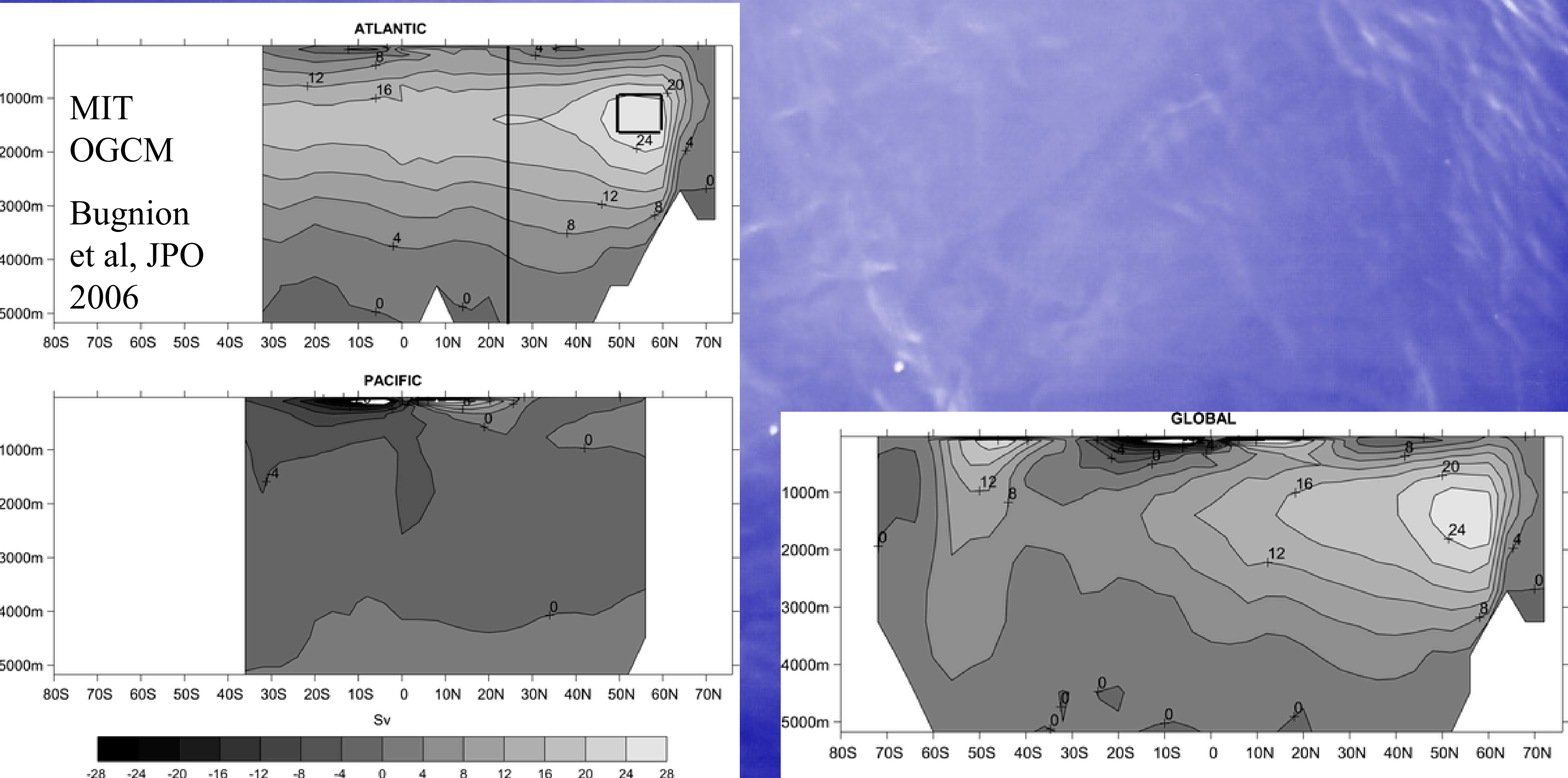
Fig. 6: Schematic diagram of the global ocean circulation pathways, the 'conveyer' belt (after W. Broecker, modified by E. Maier-Reimer).

Source: http://www.probbins.ucsd.edu/sio210/yr2001/thermo/thermo2.html



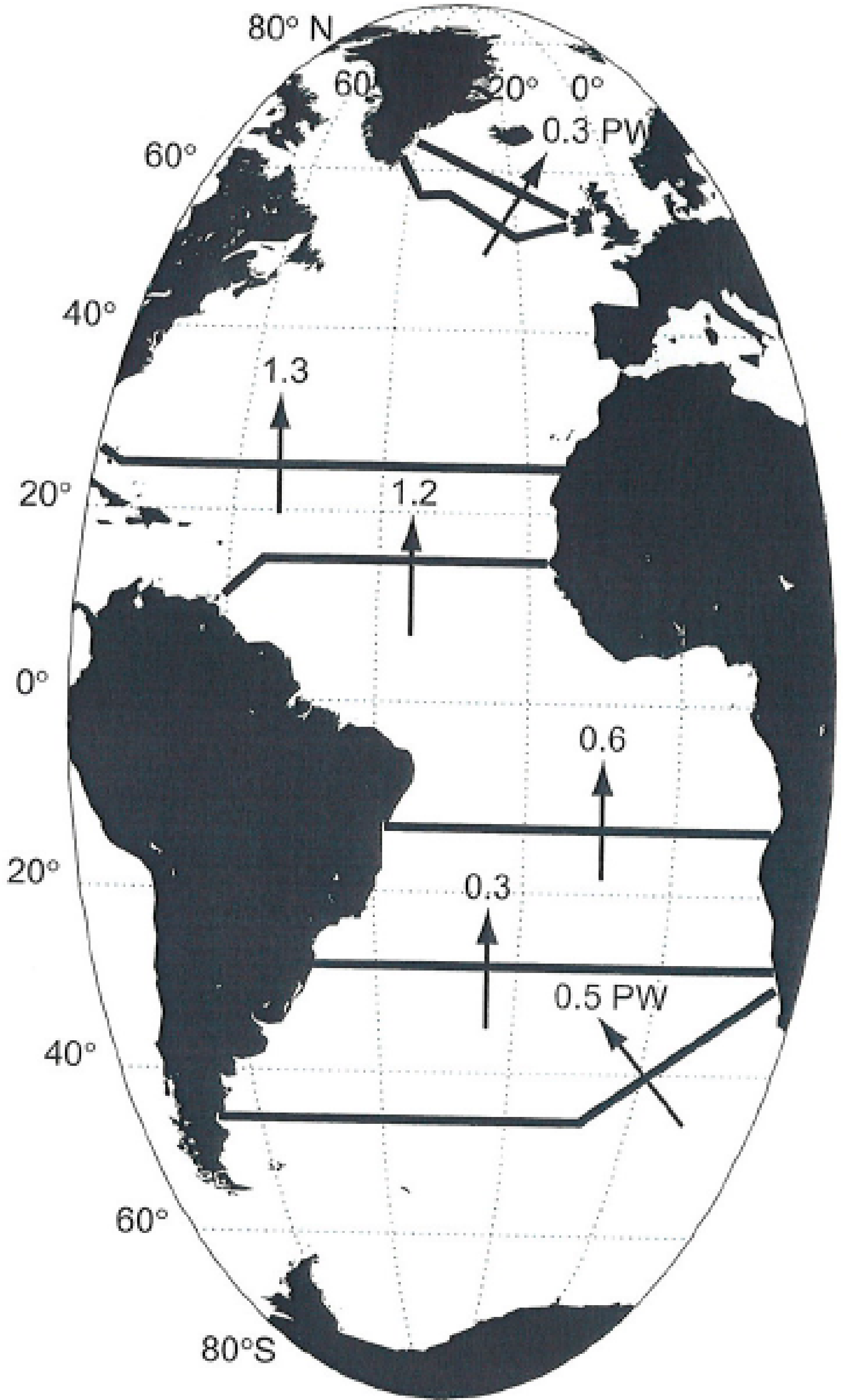
HadCM3

OCCAM



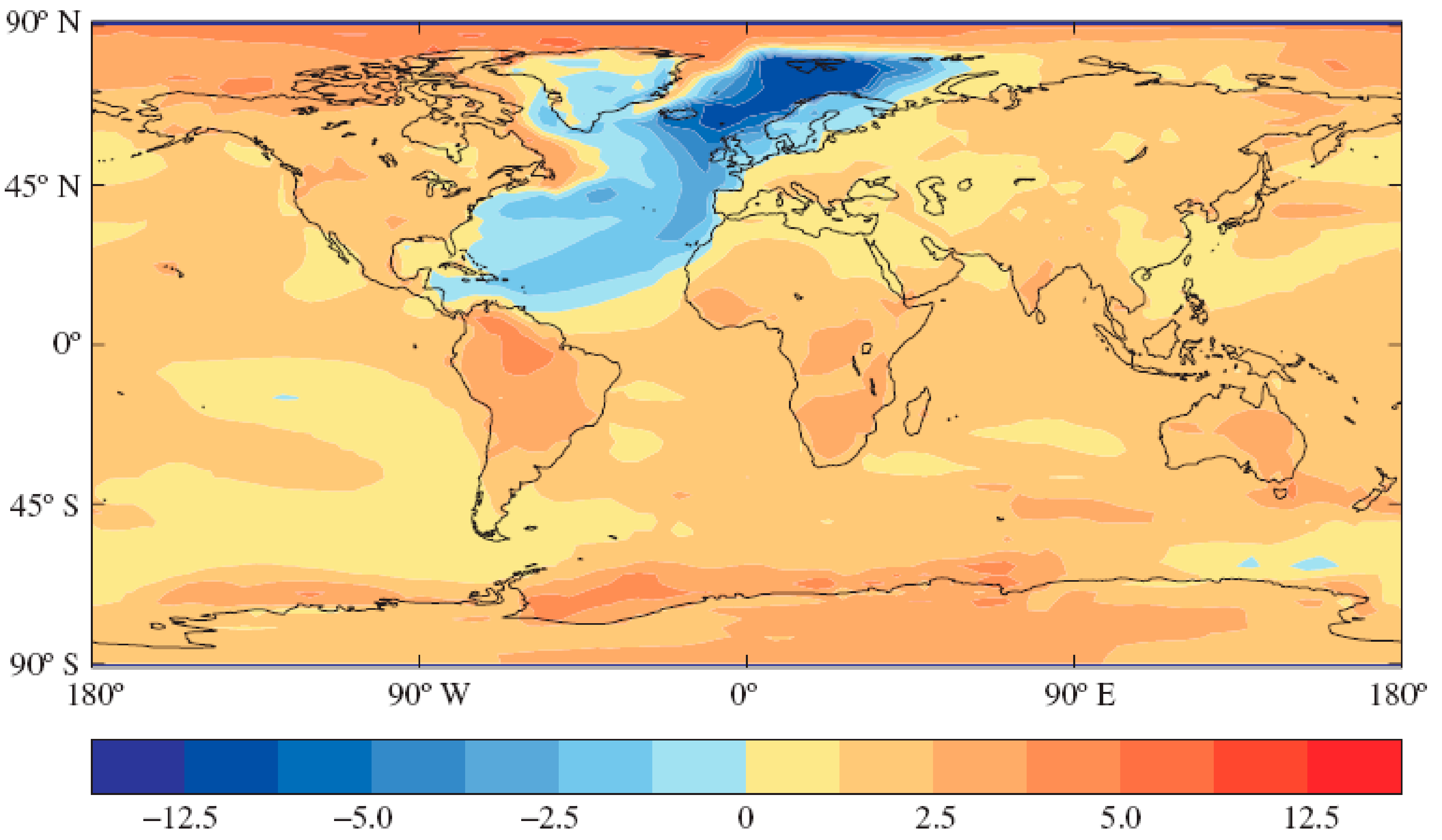
MIT
OGCM

Bugnion
et al, JPO
2006



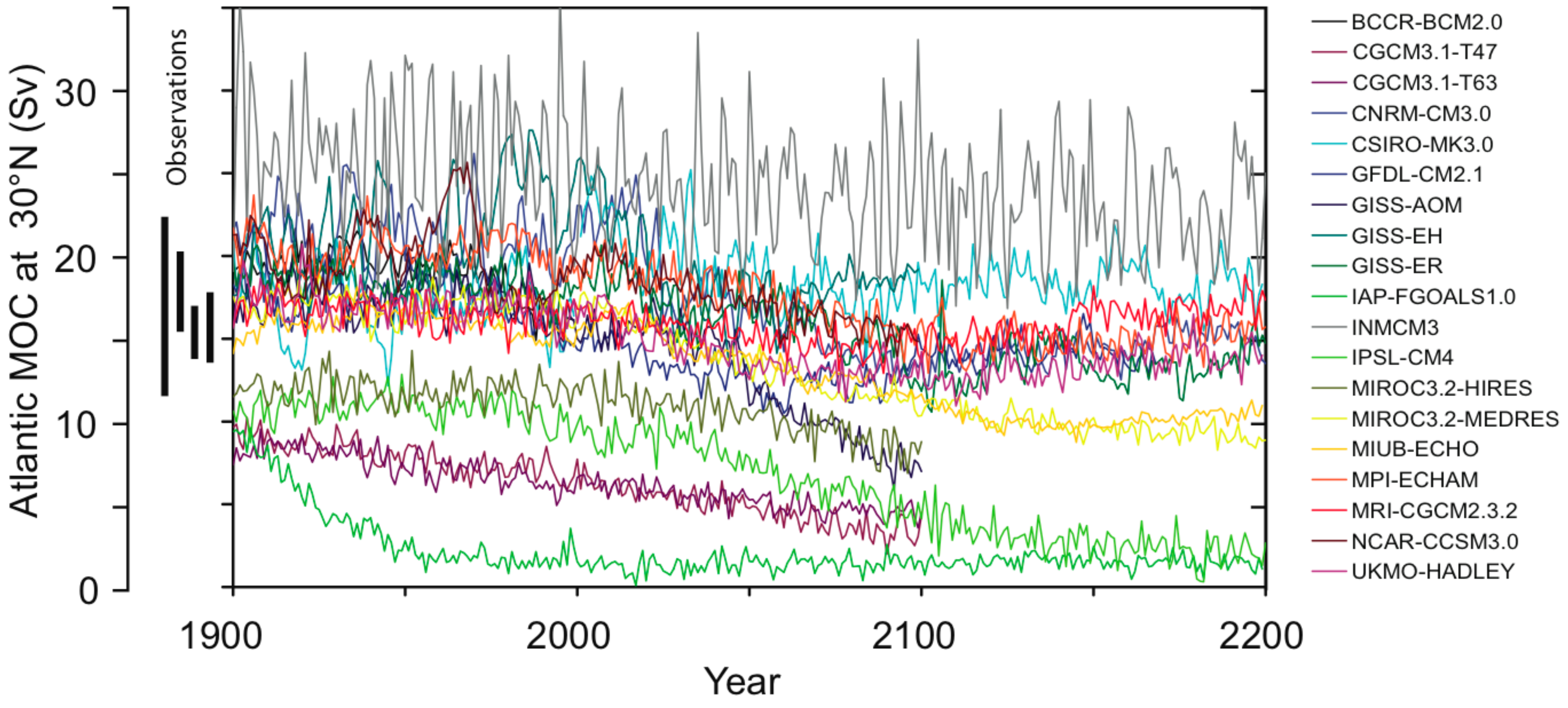
Bryden & Imawaki, in "Ocean Circulation and Climate" (the WOCE book)

1^{st} Decade after shutdown in 2049



Wood, Vellinga and Thorpe, Phil Trans 2003

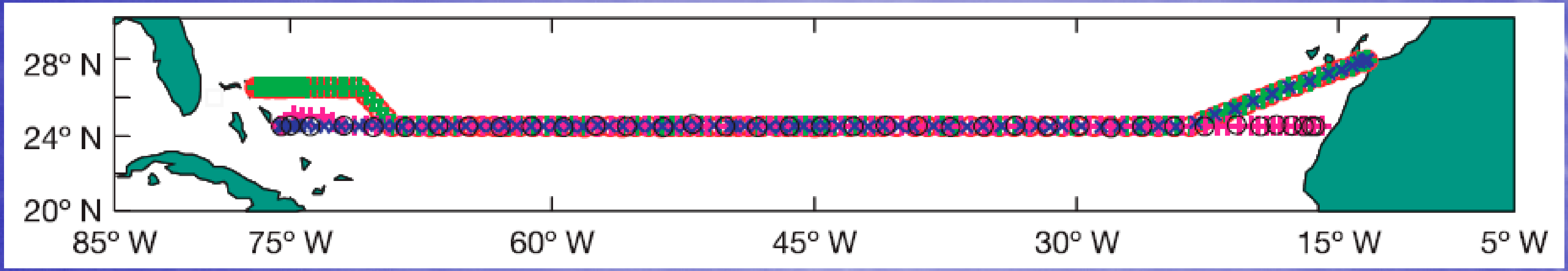
IPCC 4AR coupled GCM results

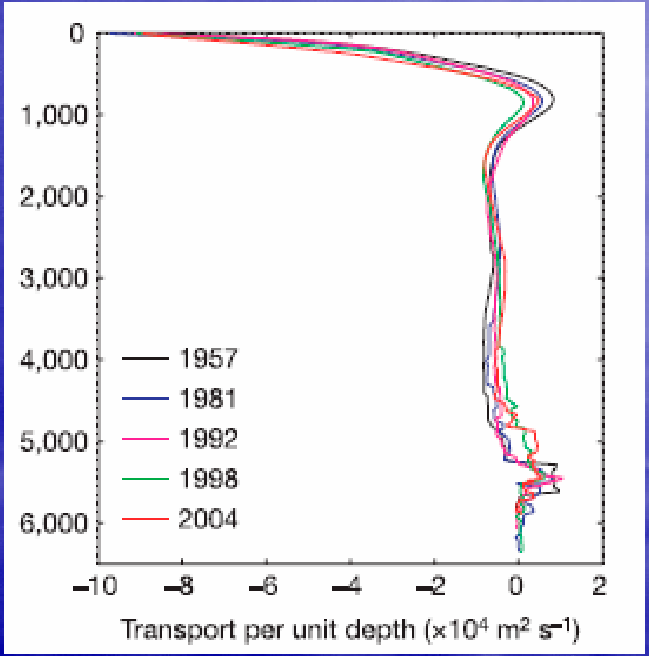


Nature, December 2005

Slowing of the Atlantic meridional overturning circulation at 25° N

Harry L. Bryden[1], Hannah R. Longworth[1] & Stuart A. Cunningham[1]





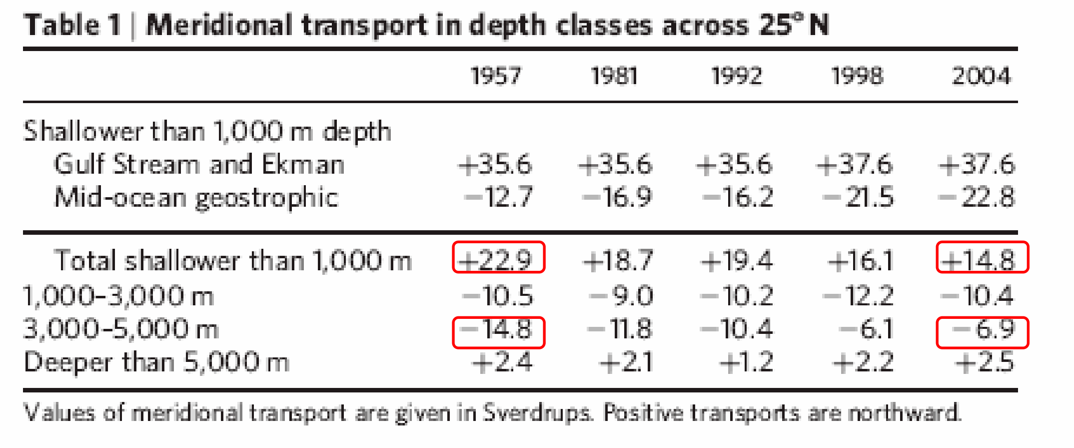


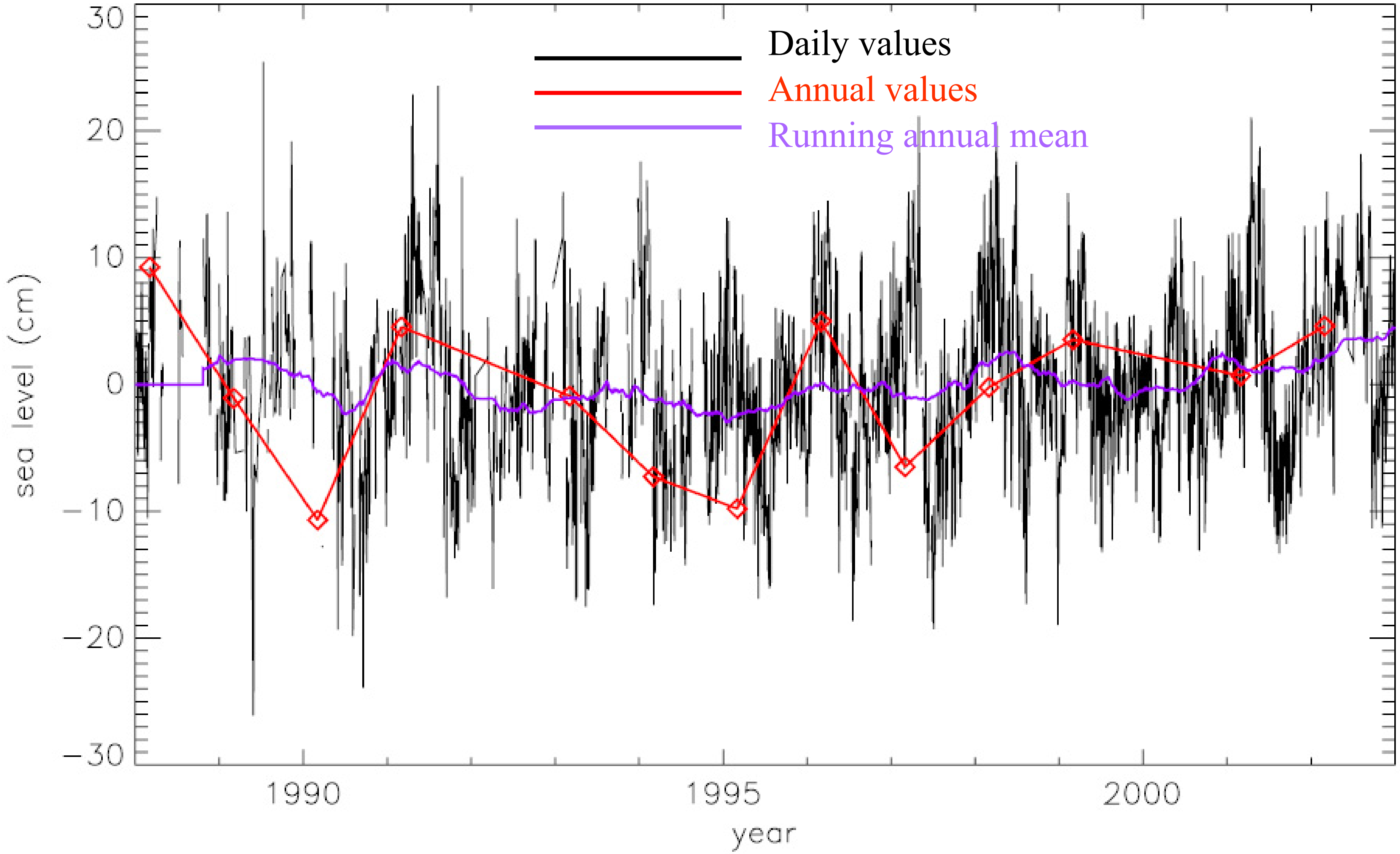
Table 1 | Meridional transport in depth classes across 25° N

	1957	1981	1992	1998	2004
Shallower than 1,000 m depth					
Gulf Stream and Ekman	+35.6	+35.6	+35.6	+37.6	+37.6
Mid-ocean geostrophic	−12.7	−16.9	−16.2	−21.5	−22.8
Total shallower than 1,000 m	+22.9	+18.7	+19.4	+16.1	+14.8
1,000–3,000 m	−10.5	−9.0	−10.2	−12.2	−10.4
3,000–5,000 m	−14.8	−11.8	−10.4	−6.1	−6.9
Deeper than 5,000 m	+2.4	+2.1	+1.2	+2.2	+2.5

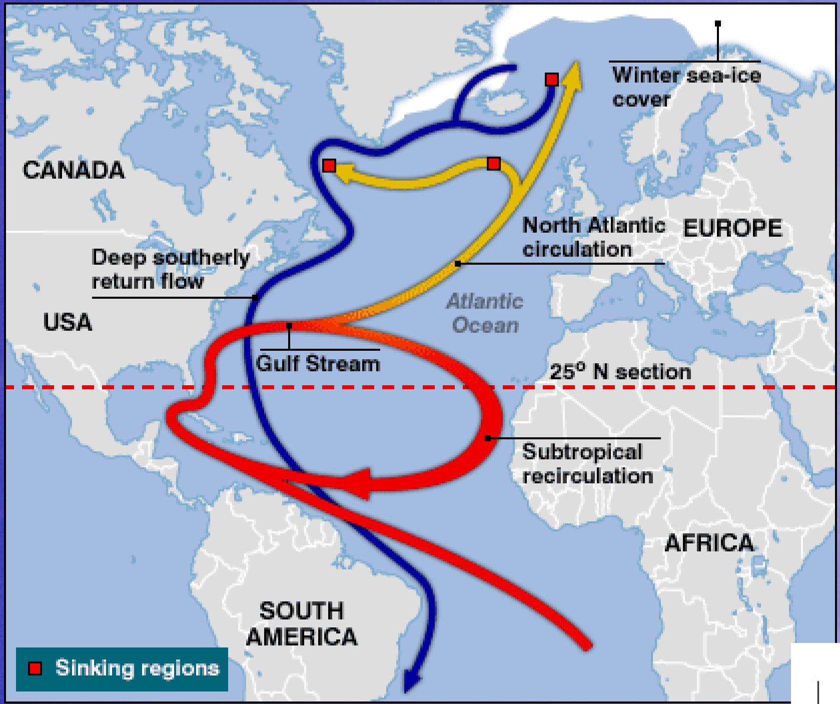
Values of meridional transport are given in Sverdrups. Positive transports are northward.

Infer a reduction in overturning of 30%

Sea level time series from Faraday/Vernadsky, Antarctica (a proxy for ACC transport)



The RAPID-MOC 26°N array



Objective:

To provide a timeseries of absolute meridional transport as a function of depth

Why 26N?

- Gulf Stream determined by cable voltage measurements
- Latitude of maximum heat transport
- Historical record on hydrographic

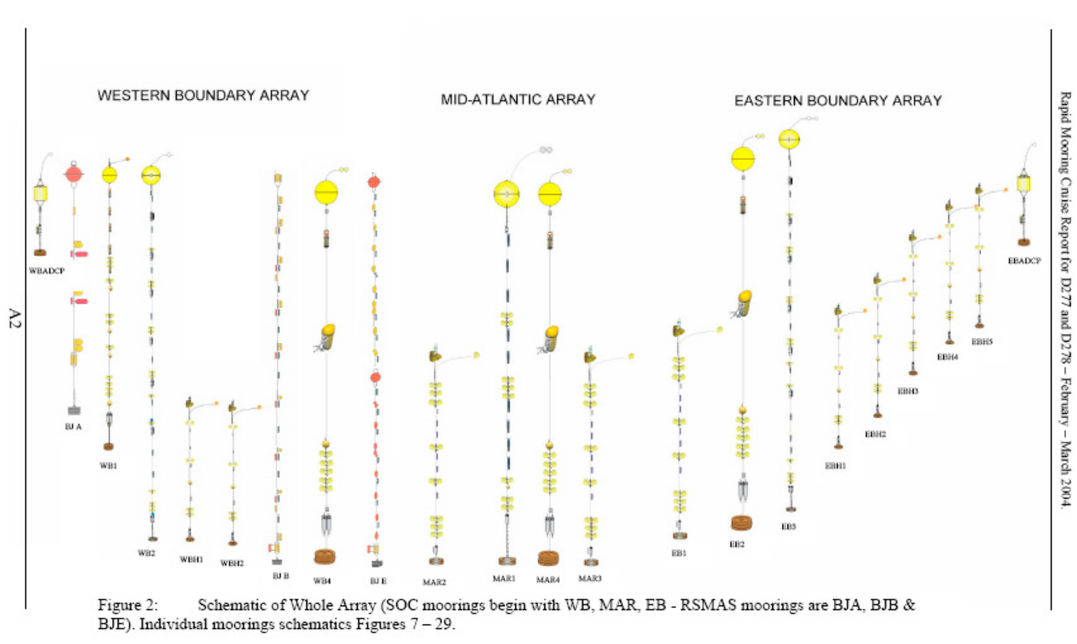

Rapid Mooring Cruise Report for D277 and D278 – February – March 2004.

Figure 2: Schematic of Whole Array (SOC moorings begin with WB, MAR, EB - RSMAS moorings are BJA, BJB & BJE). Individual moorings schematics Figures 7 – 29.

A2

Early results from the 26.5N array

Fig. 2. Year-long time series of layer transports for thermocline recirculation (red), intermediate water (green), UNADW (light blue), and LNADW (dark blue). Negative transports correspond to southward flow.

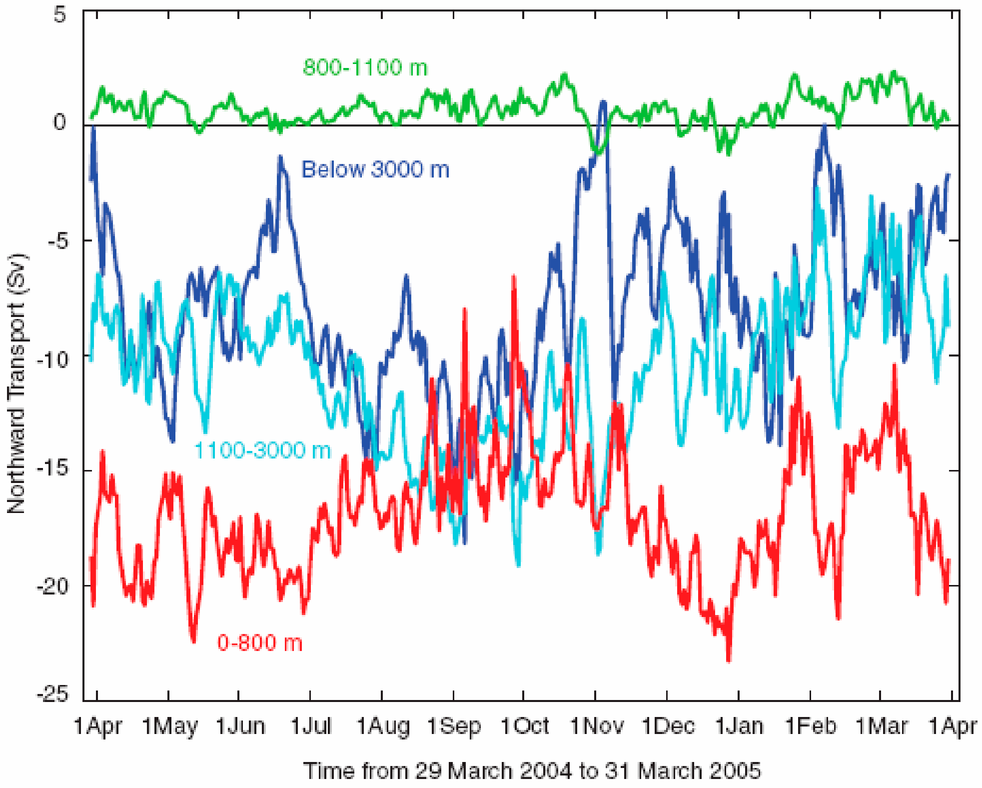
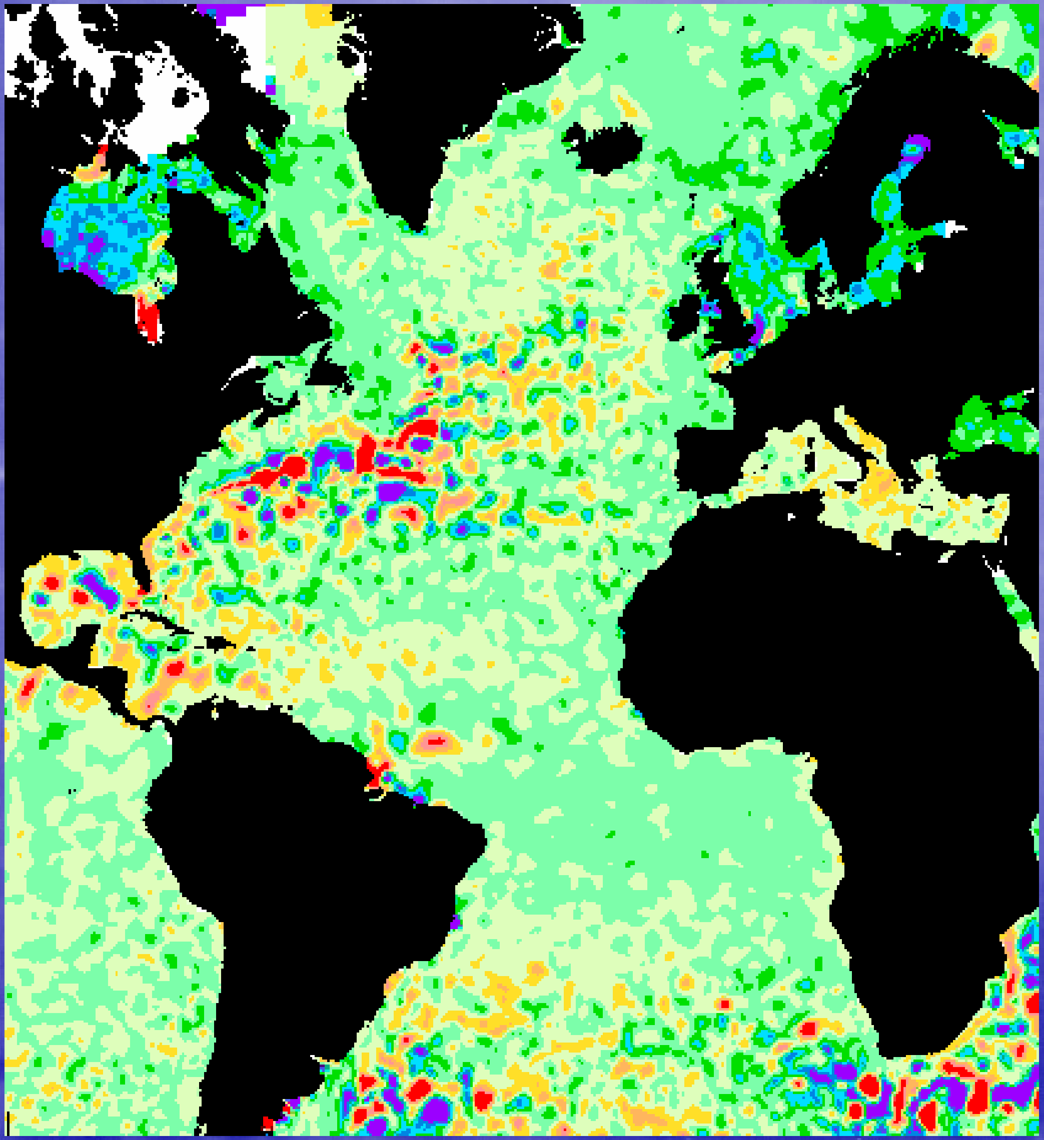
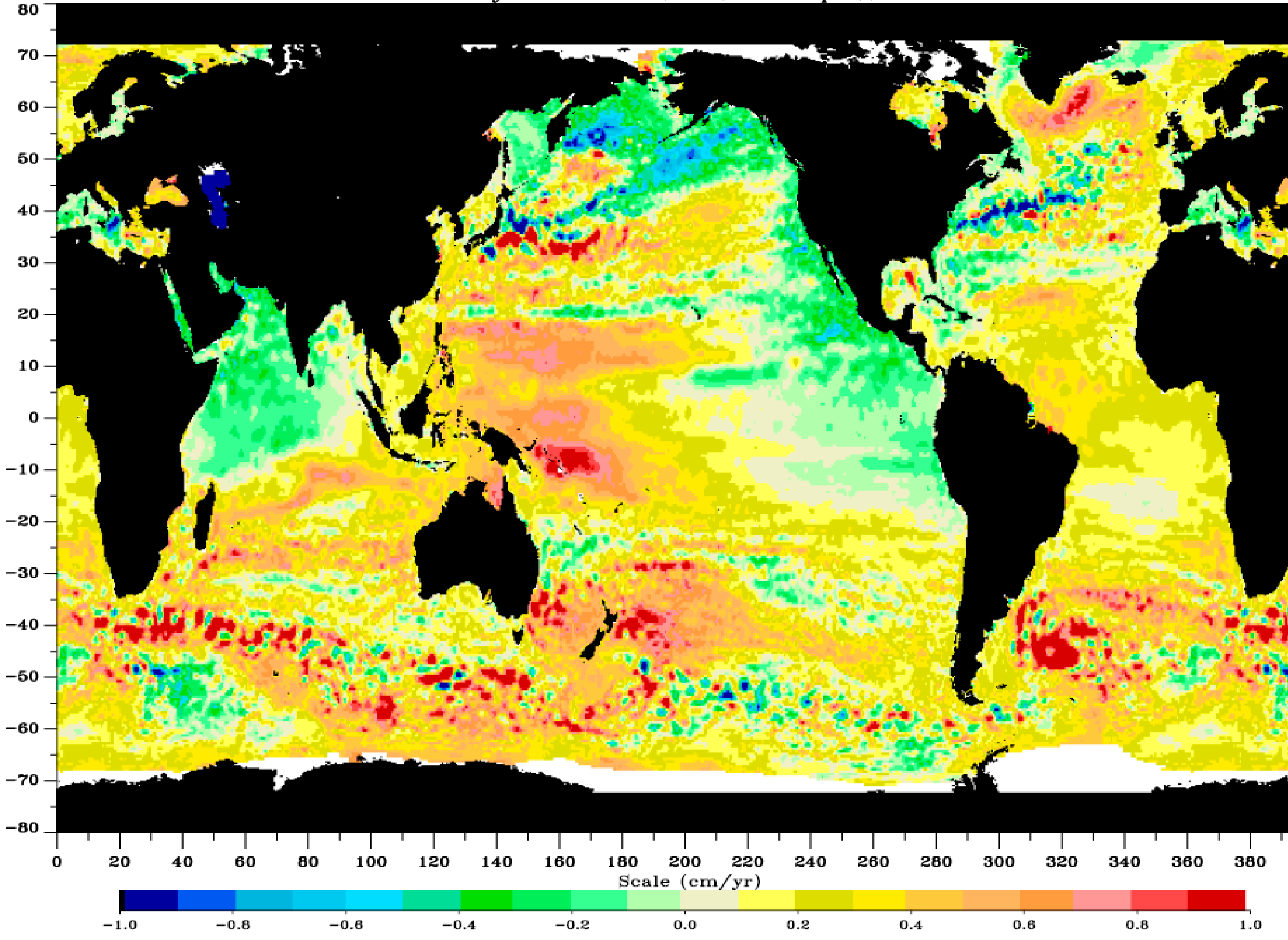


Table 1. Mid-ocean layer transports (data reported in Sv).

Water depth	Mean	SD	Minimum	Maximum
0 to 800 m (thermocline recirculation)	−16.9	2.7	−23.3	−6.6
800 to 1100 m (intermediate water)	0.7	0.6	−1.3	2.3
1100 to 3000 m (UNADW)	−10.7	3.1	−19.2	−2.7
Below 3000 m (LNADW)	−7.8	3.5	−18.2	1.0

Cunningham et al., Science, 2007





14-year trend in sub-surface pressure

The WAVE array

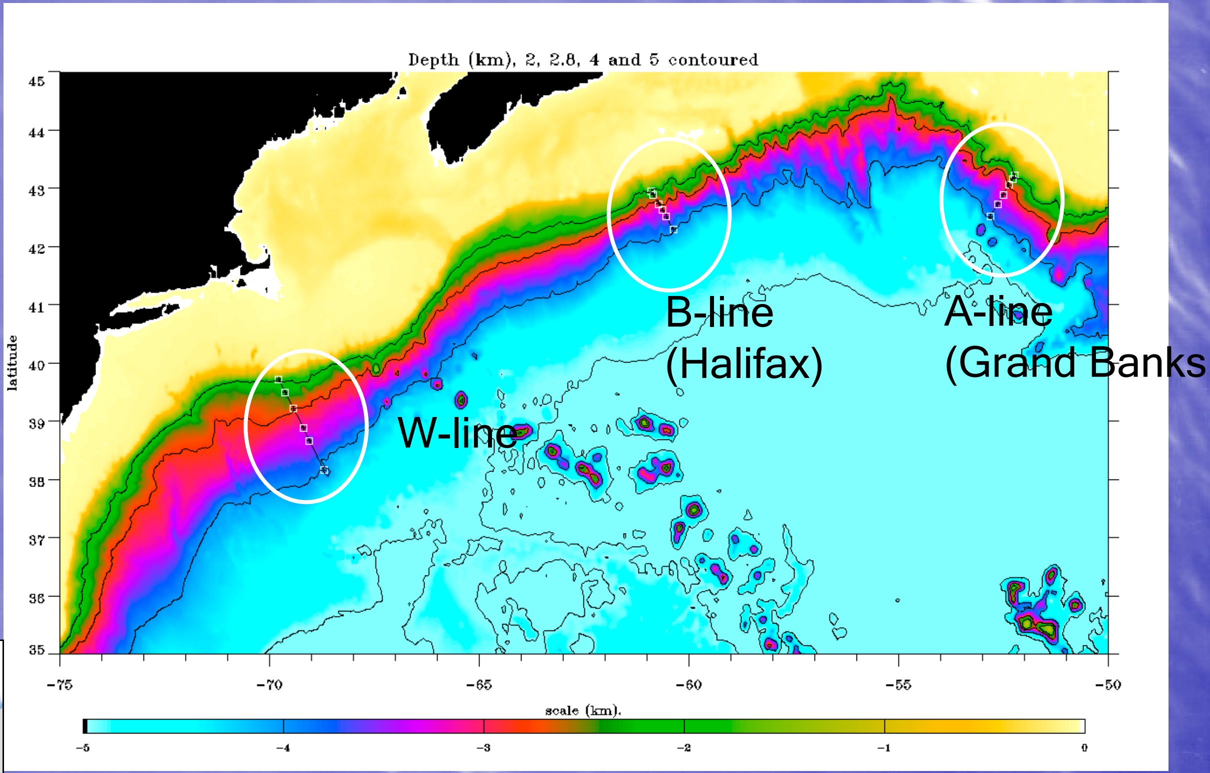
POL

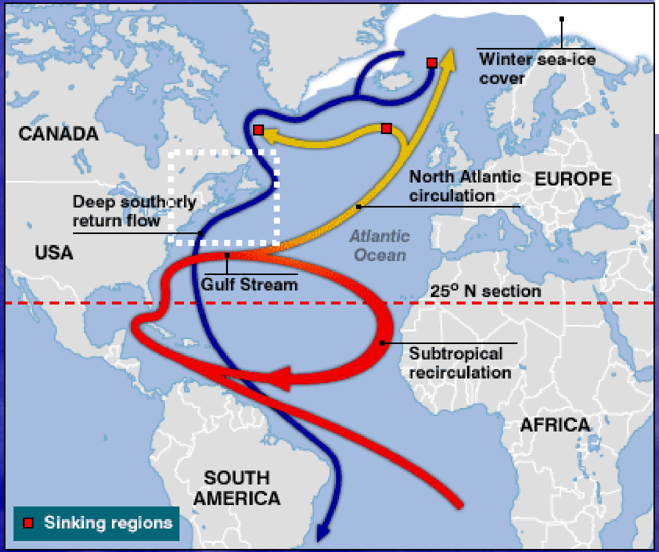
Liverpool University

Oxford University

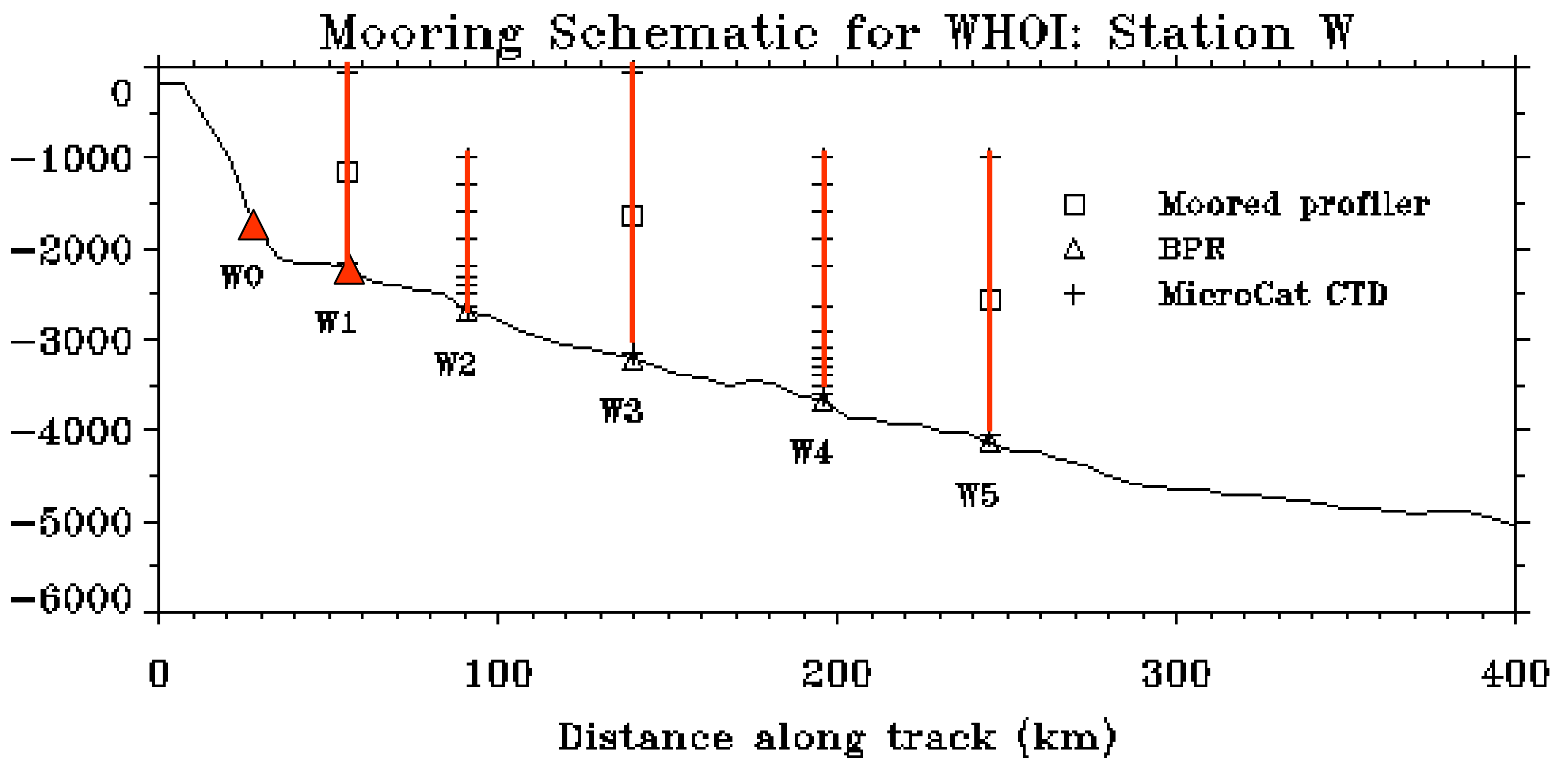
WHOI

BIO

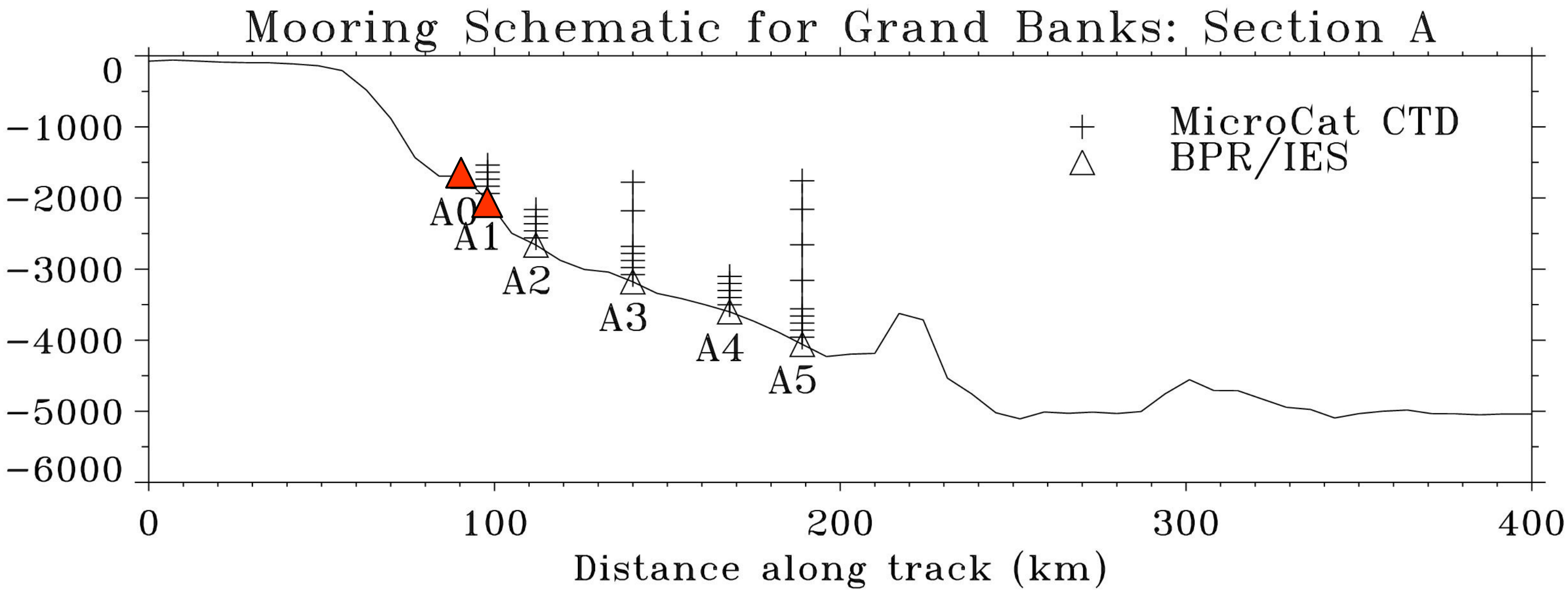


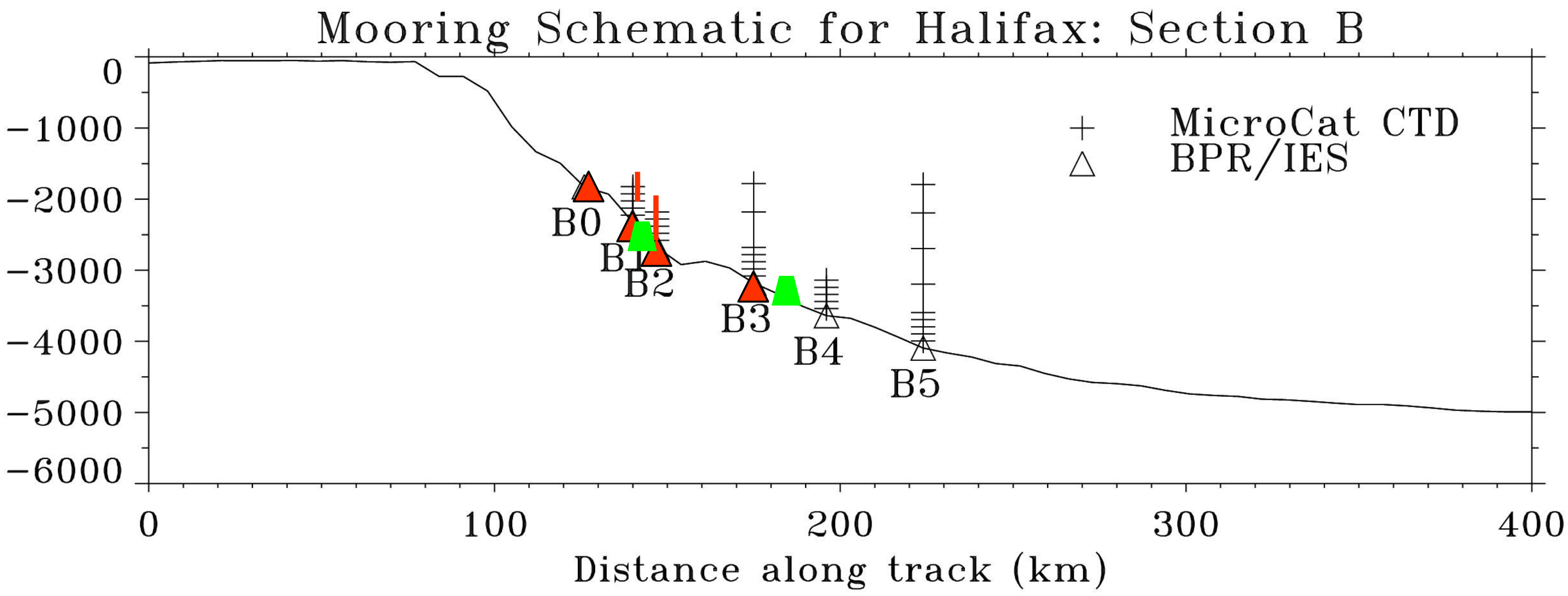


Objective: To detect propagating signals/spatial coherence of changes in the THC



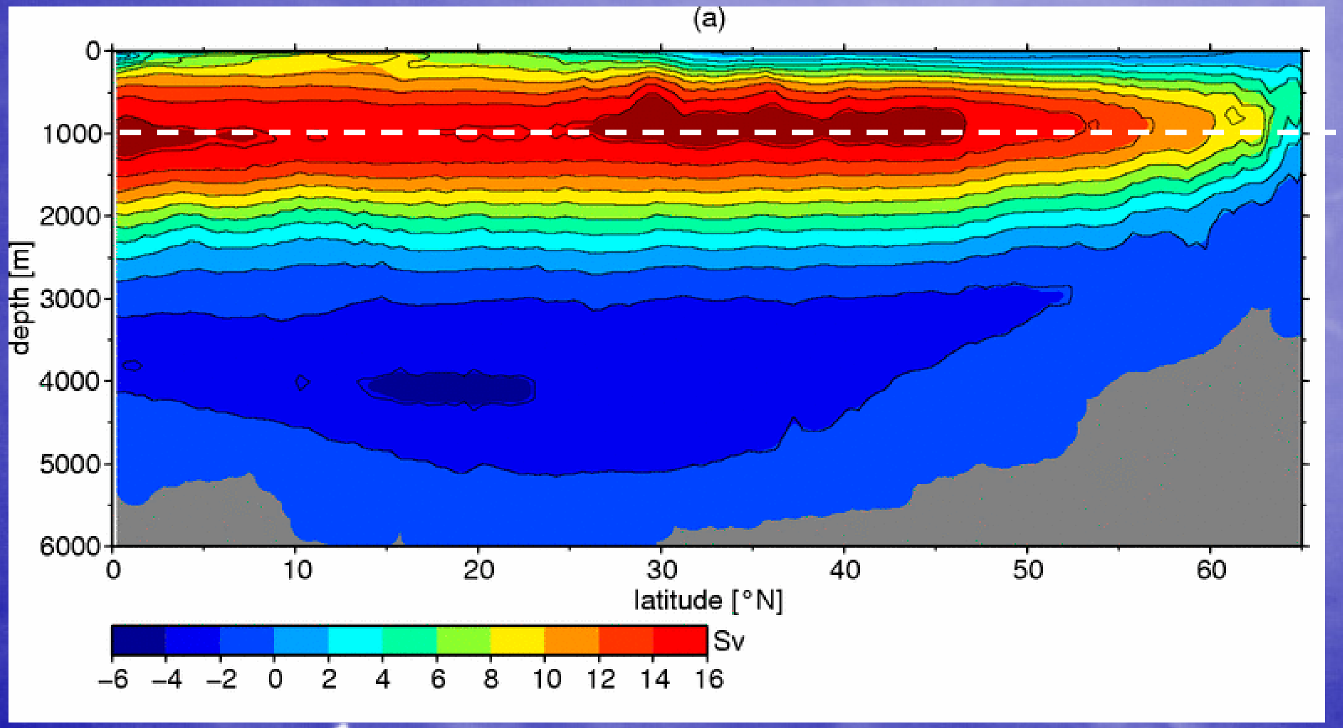
Mooring Schematic for WHOI: Station W


Mooring Schematic for Grand Banks: Section A


Mooring Schematic for Halifax: Section B

Statistical analysis: The MOC streamfunction

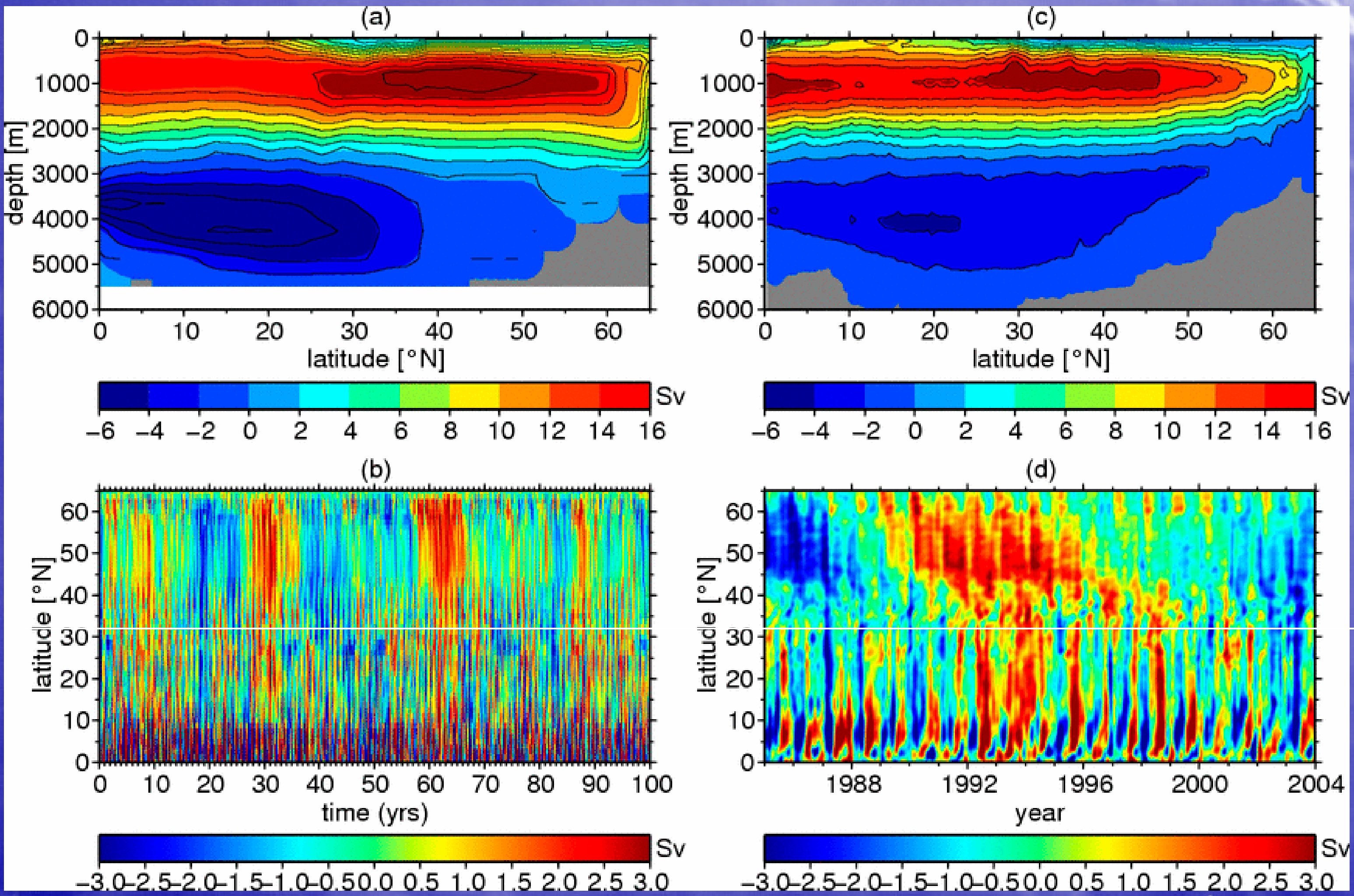
OCCAM North Atlantic MOC streamfunction (1985-2003)



Mean northward transport occurs above 1000m

This is the mean state, but what are the spatial and temporal scales of MOC variability?

Statistical analysis: Upper layer transport



Low freq. dominates

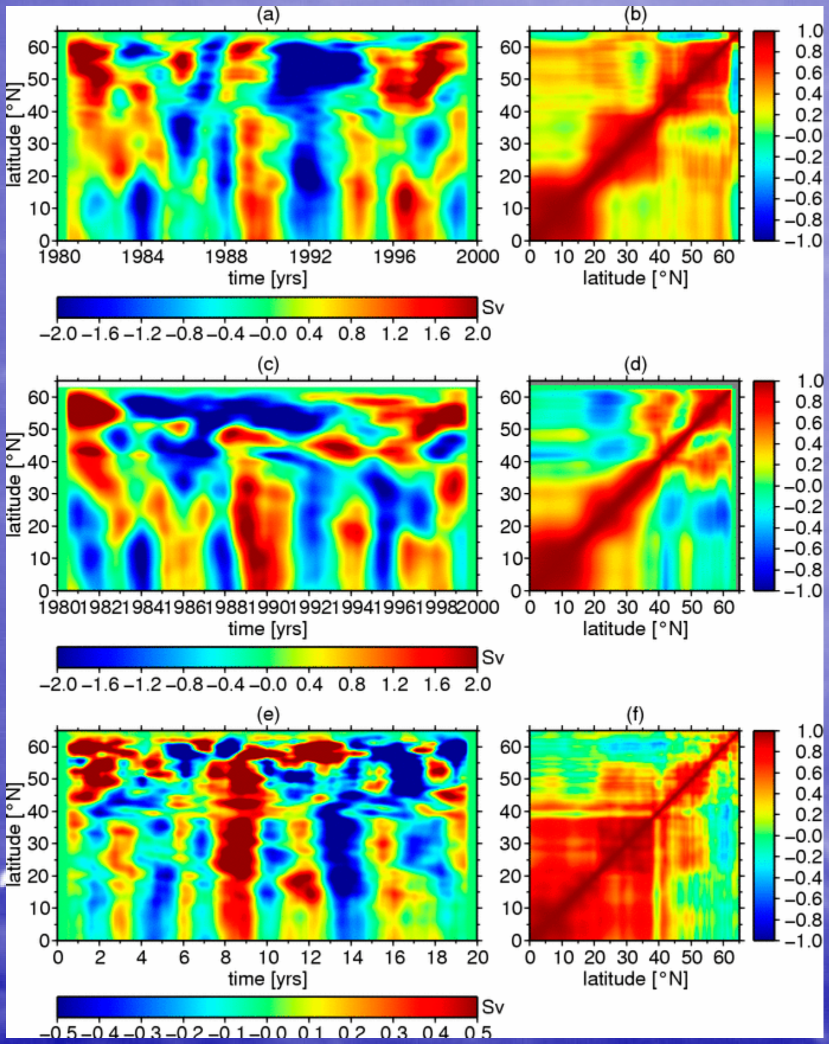
High freq. dominates

HadCM3 OCCAM

Meridional transport anomaly between 100m and 1000m depth

Isopycnal model experiments (Ric Williams + Vassil Roussenov)

Are the results robust to different model formulations and forcing scenarios?



(E1)
Model resolution: 0.23 degrees
Forcing: winds and surface fluxes from ECMWF

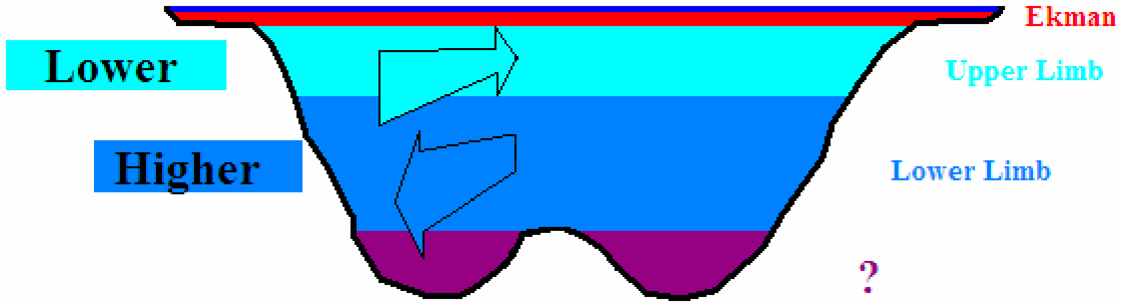
(E2)
Model resolution: 1.4 degrees
Forcing: winds and surface fluxes from ECMWF

(E3)
Model resolution: 0.23 degrees
Forcing: monthly climatological winds and surface fluxes from ECMWF, repeating each year.

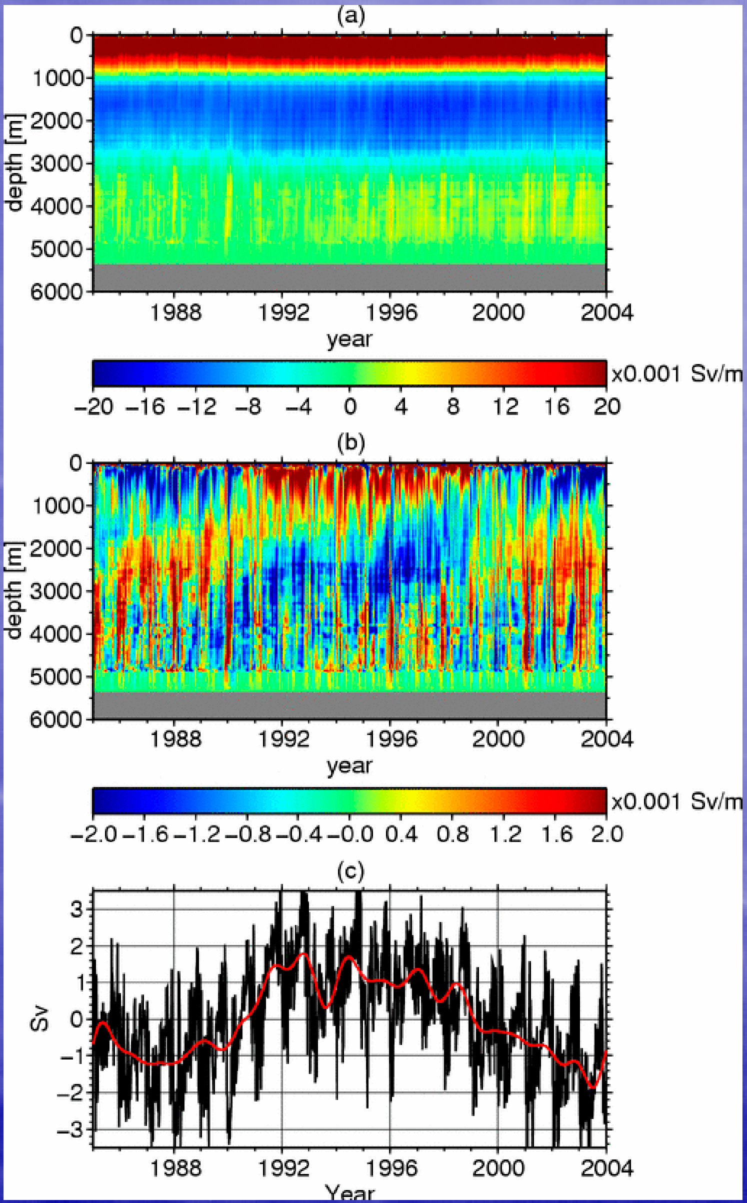
Figure 4. Analysis of several runs of the MICOM model: (a) The interannual northward transport anomaly integrated over layers 1 to 8 for experiment E1; (b) The cross-correlation of the transport shown in (a); (c,d) Repeat of (a,b) for experiment E2; (e,f) Repeat of (a,b) for experiment E3. (See text for descriptions of experiments.)

Geostrophy $\int_{\text{West}}^{\text{East}} \rho f v \, dx = p_e - p_w$

Compared to eastern boundary at the same depth, pressure on the western boundary is



Dynamics: The meridional transport at 42N (OCCAM)



Absolute transport

Anomalous transport

Anomalous transport
(100m-1000m)

Dynamics: The geostrophic calculation at 42N

Actual model transport and transport from geostrophic calculation

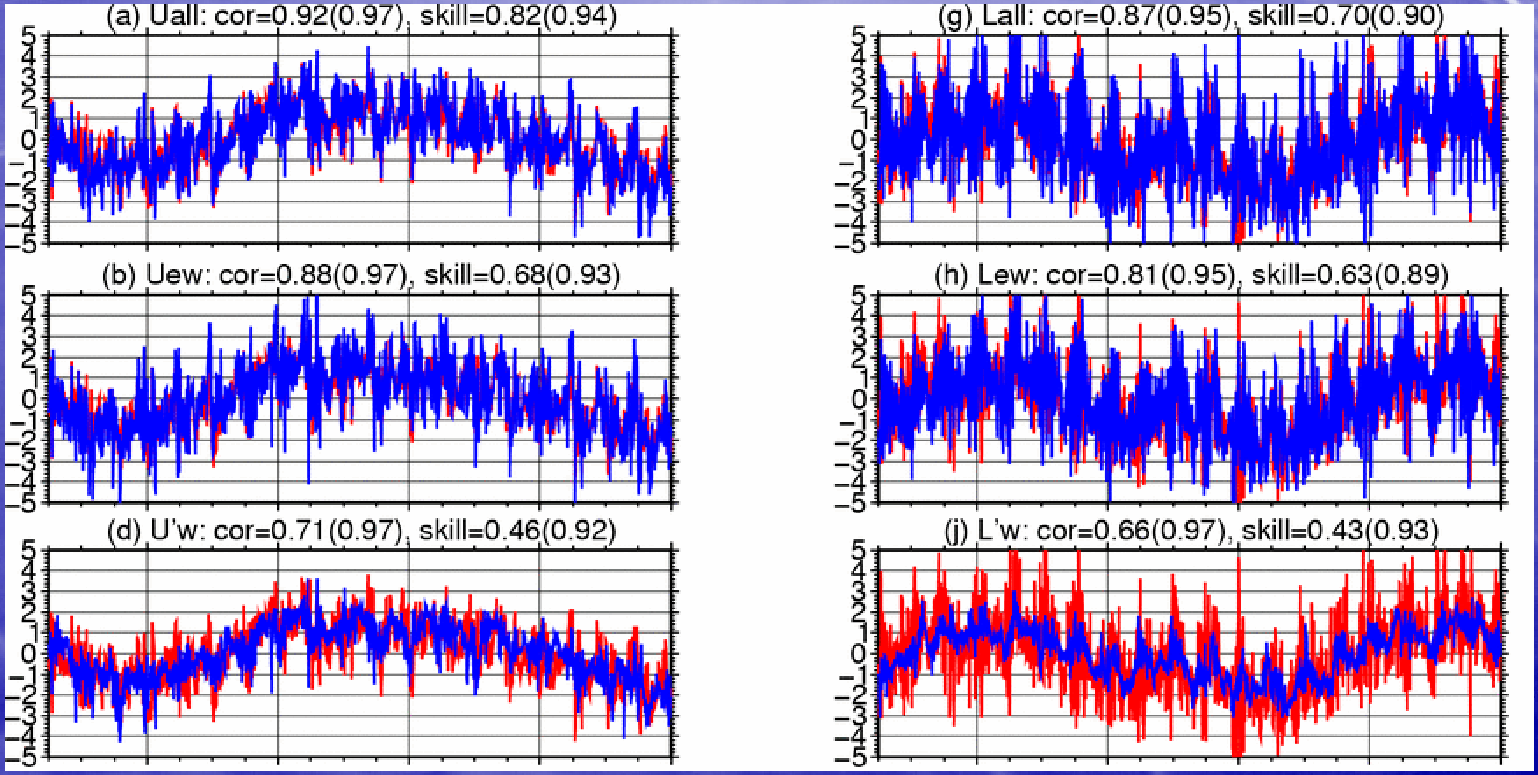
Upper layer (100-1000m)

Lower layer (1000-3000m)

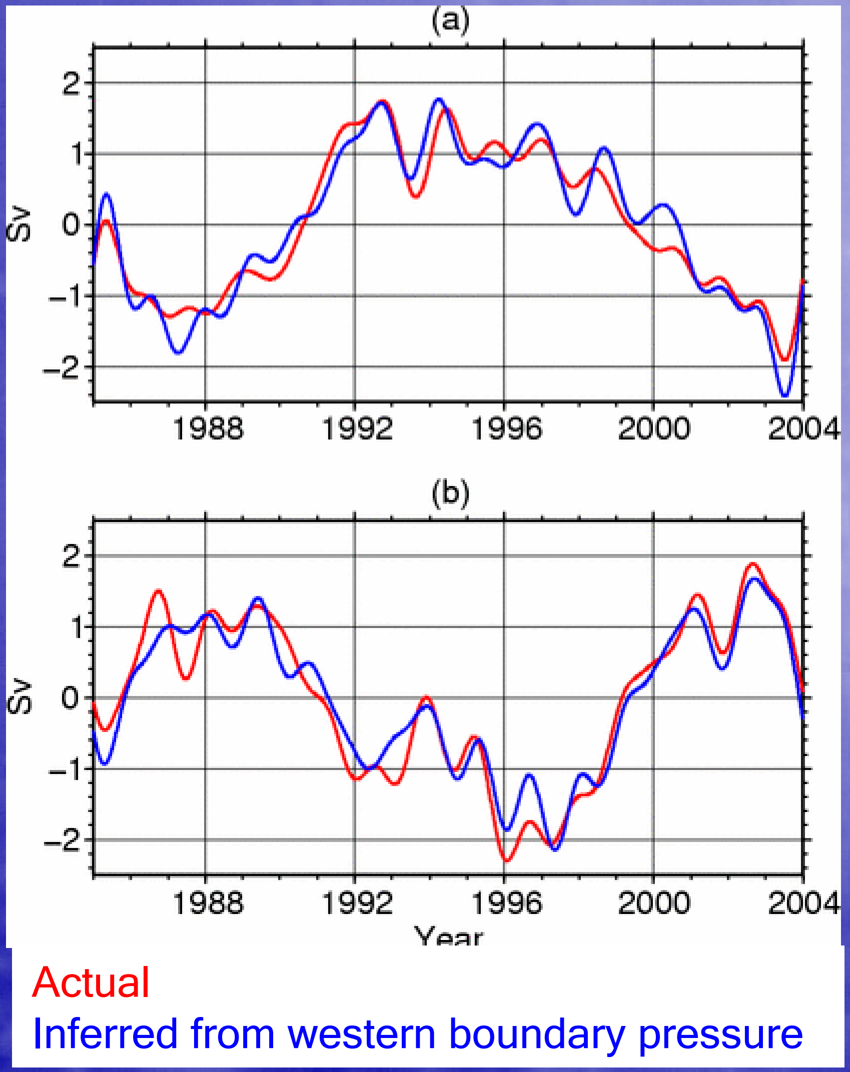
Using all east-west pairs

Using boundary east-west pairs only

Using western boundary points only



Dynamics: The geostrophic calculation at 42N



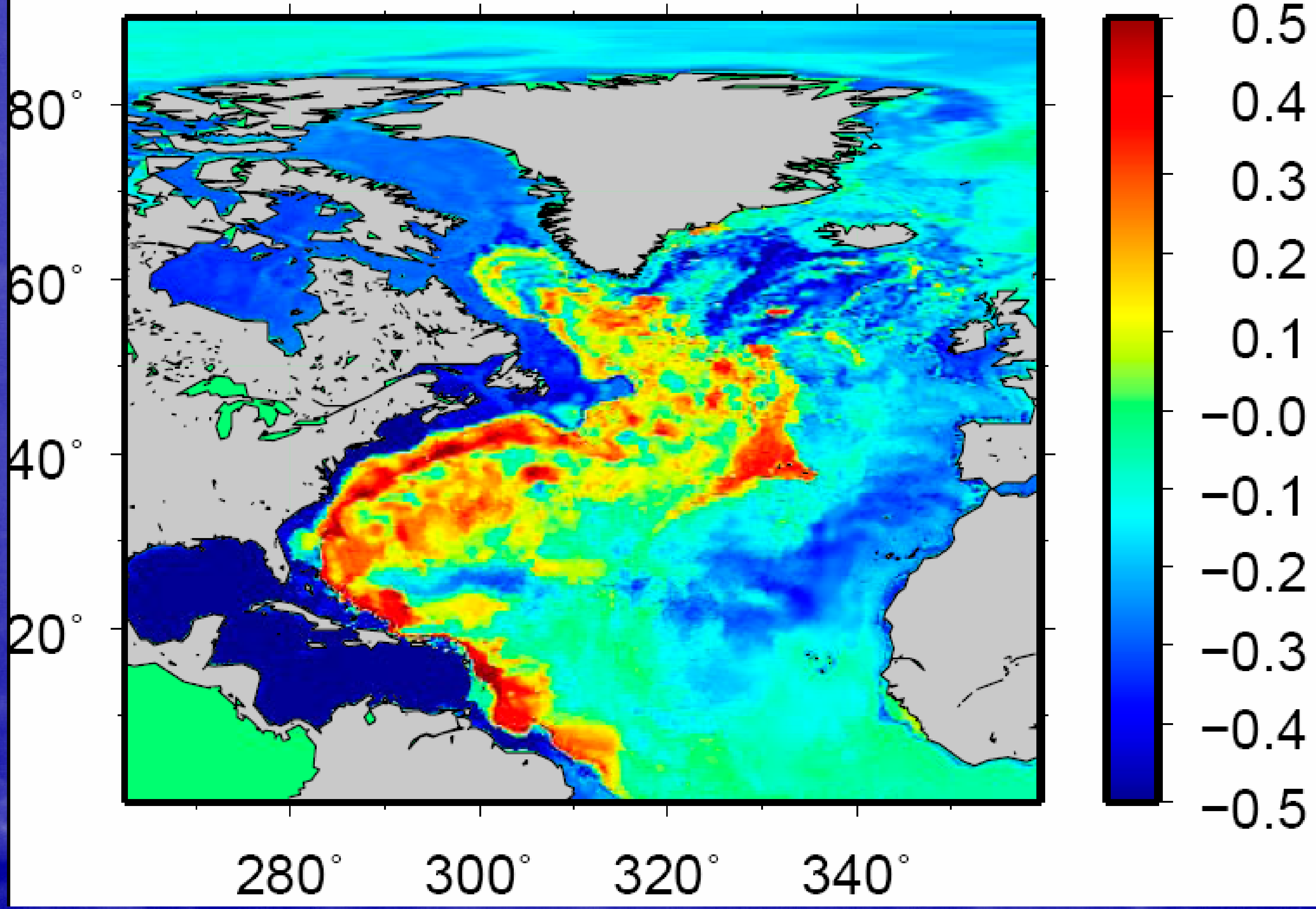
Upper layer transport
RMS error: 0.28Sv

Lower layer transport
RMS error: 0.31Sv

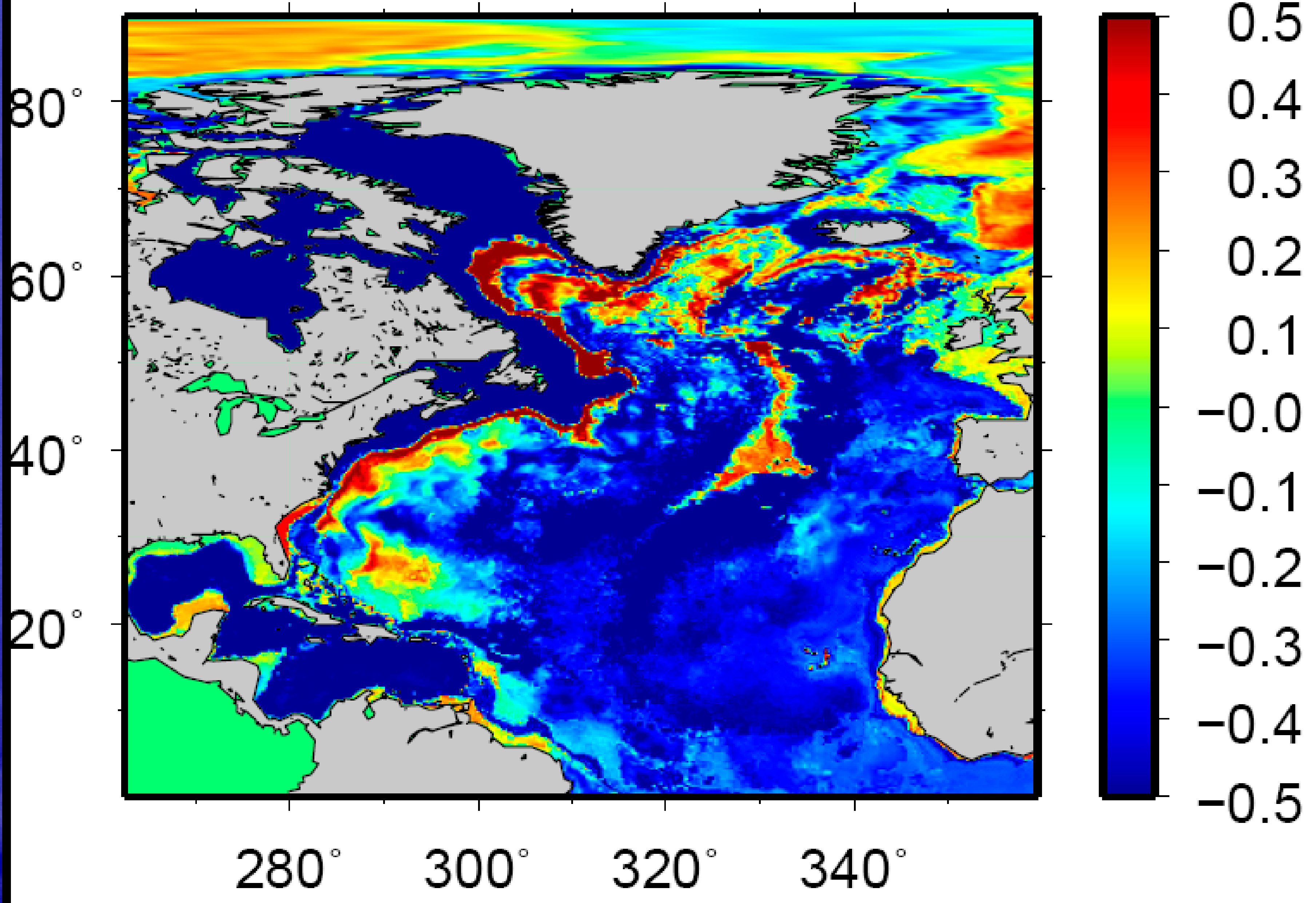
Conclusion:

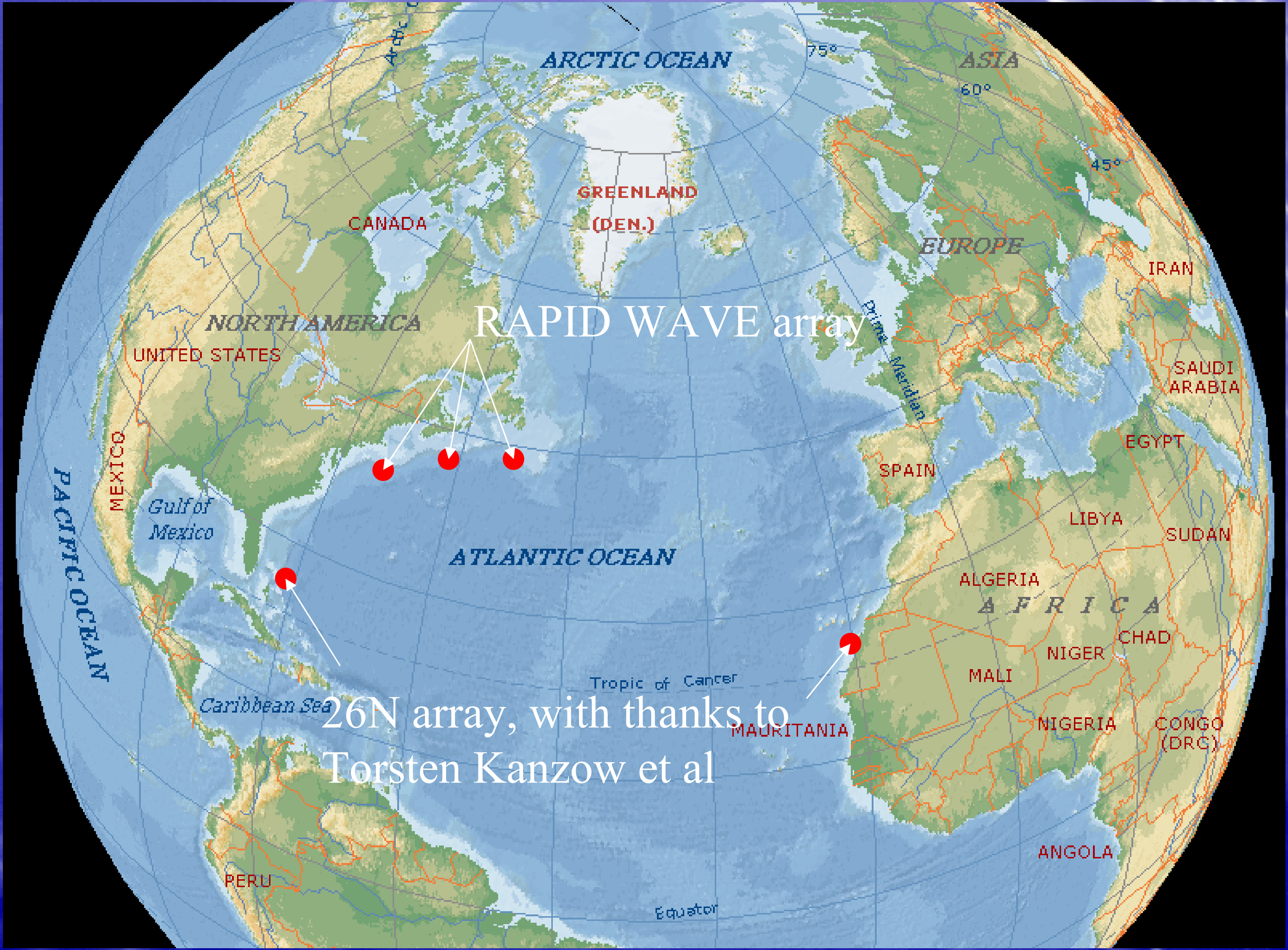
Knowledge of western boundary pressure variations are sufficient to monitor to interannual variability of the MT at 42N

Bottom Pressure Cor with MOC LF TS1



Bottom Pressure Cor with MOC LF TS2

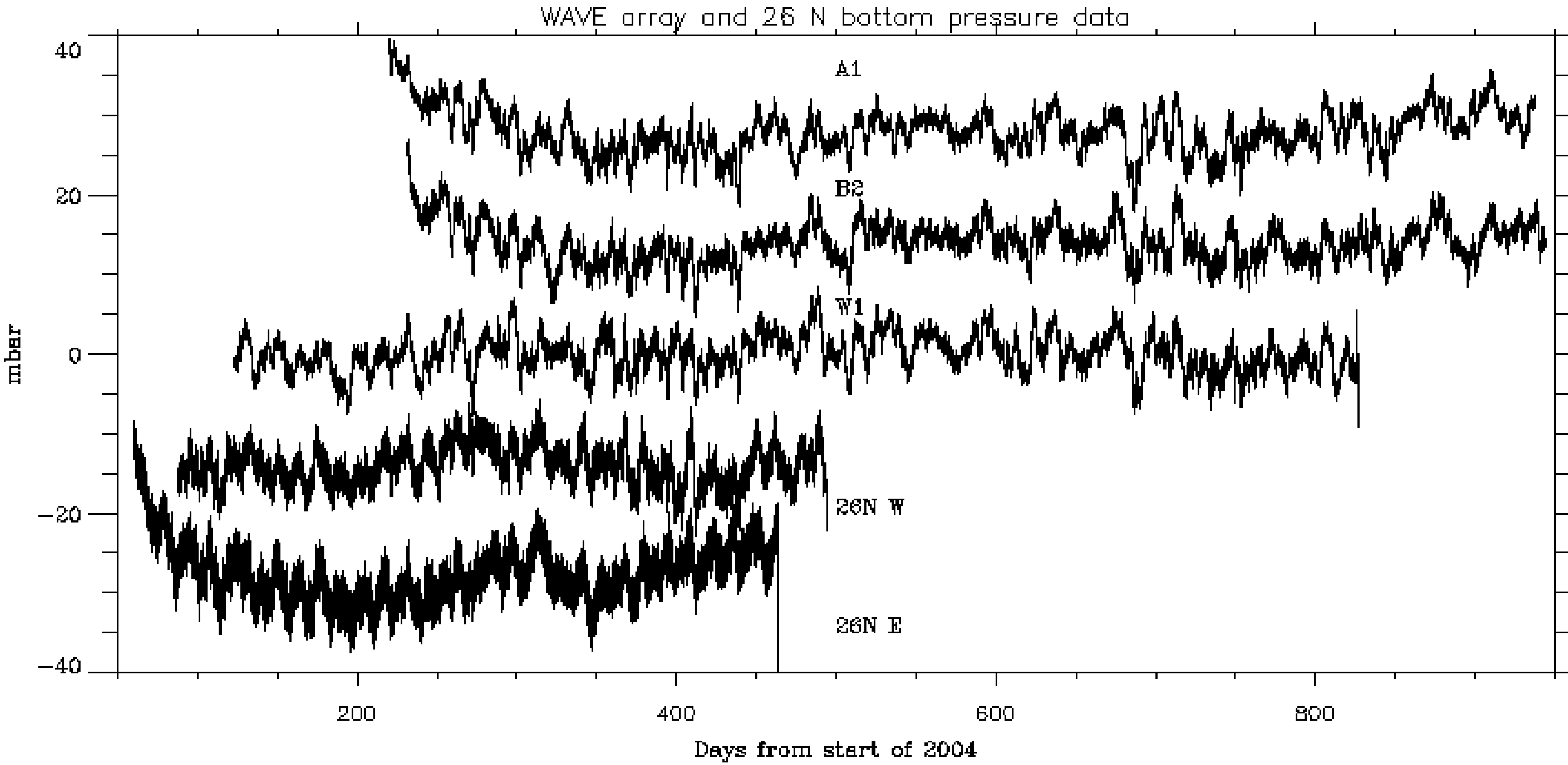




RAPID WAVE array

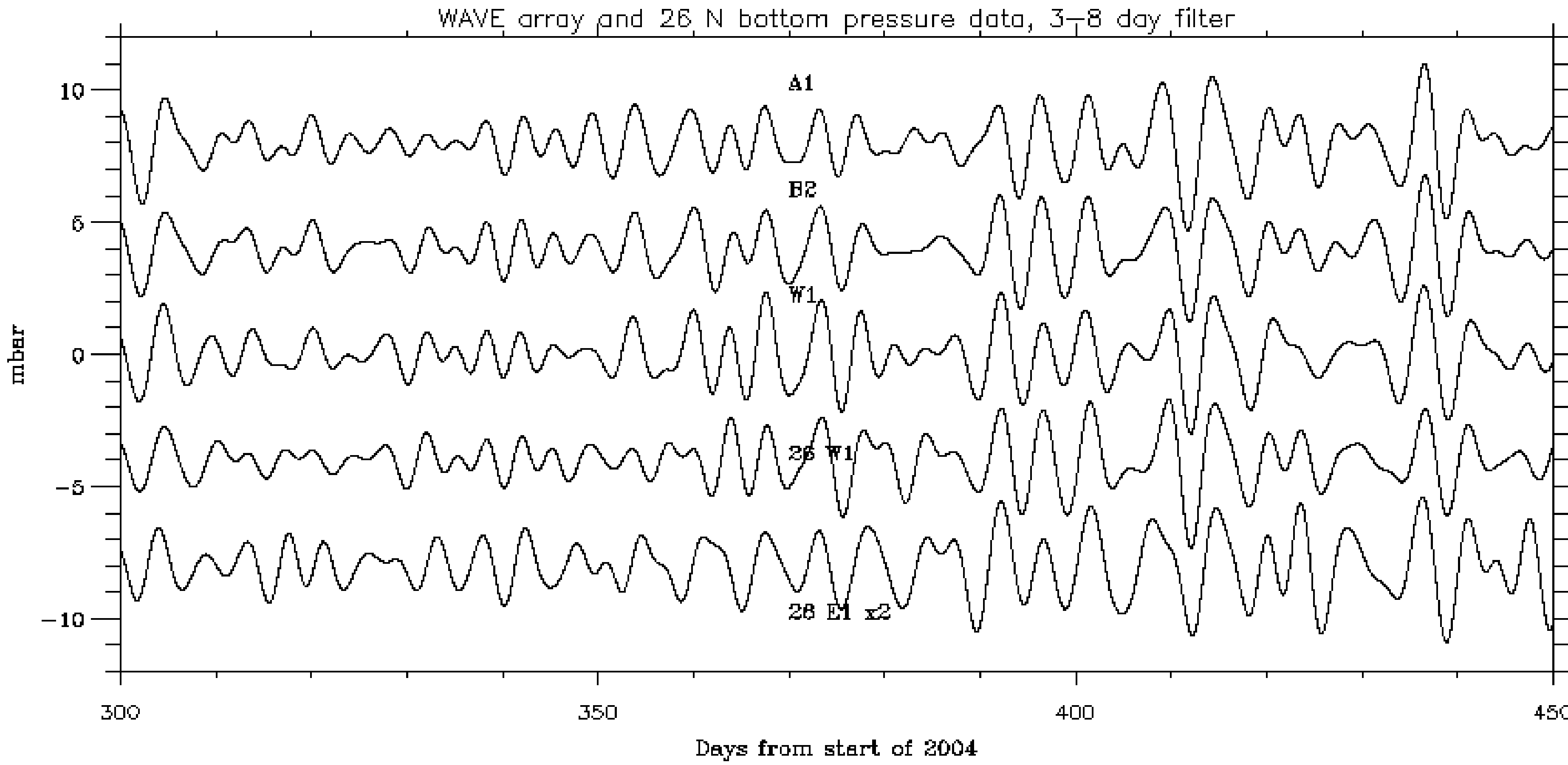
26N array, with thanks to Torsten Kanzow et al

Bottom pressure (mbar) at three of the WAVE array positions and at the Western and Eastern end at 26.5ºN

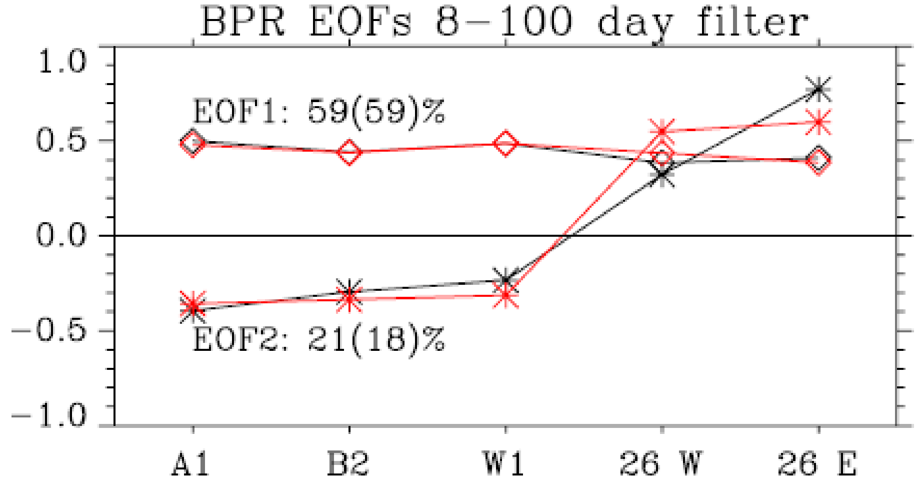


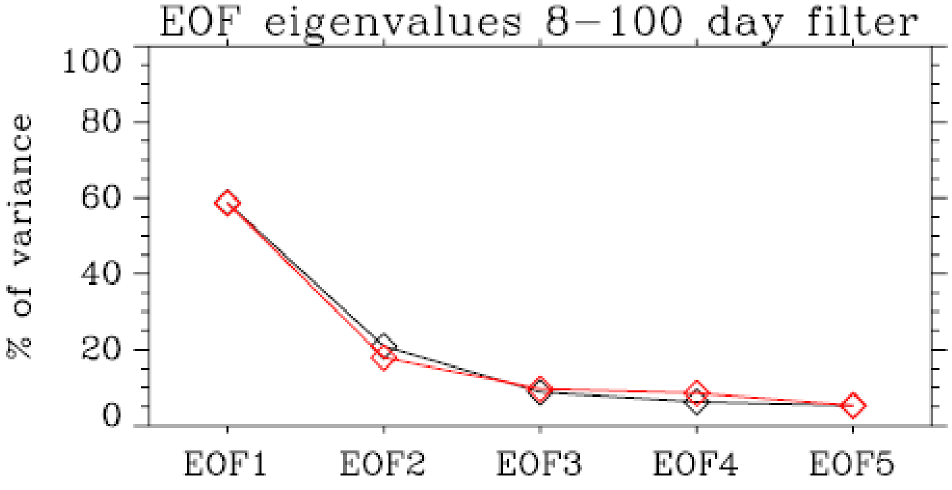
Many thanks to Torsten Kanzow and the 26.5ºN team for BPR data

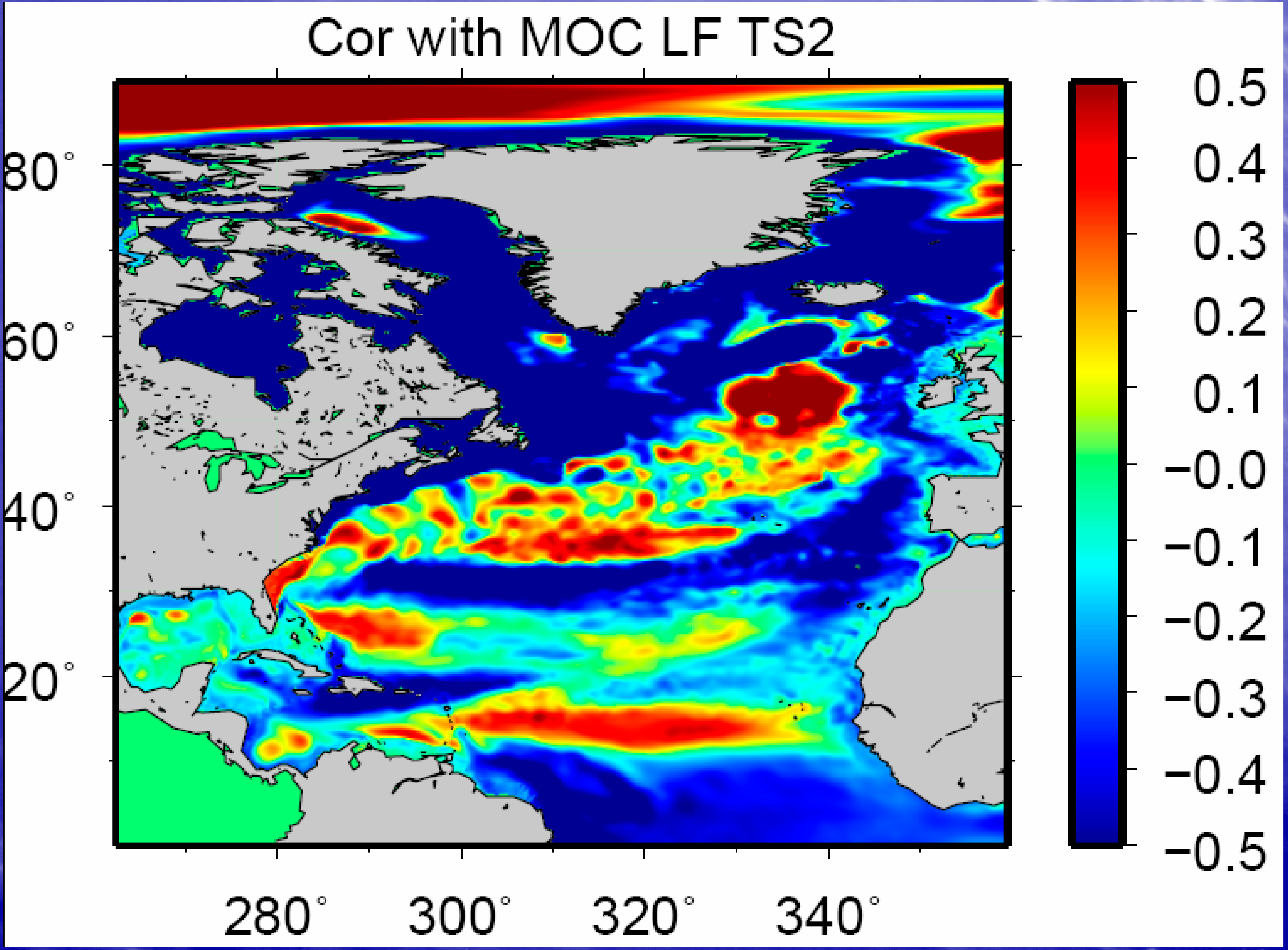
Near-five-day bottom pressure (mbar) at three of the WAVE array positions and at the Western and Eastern end at 26º N

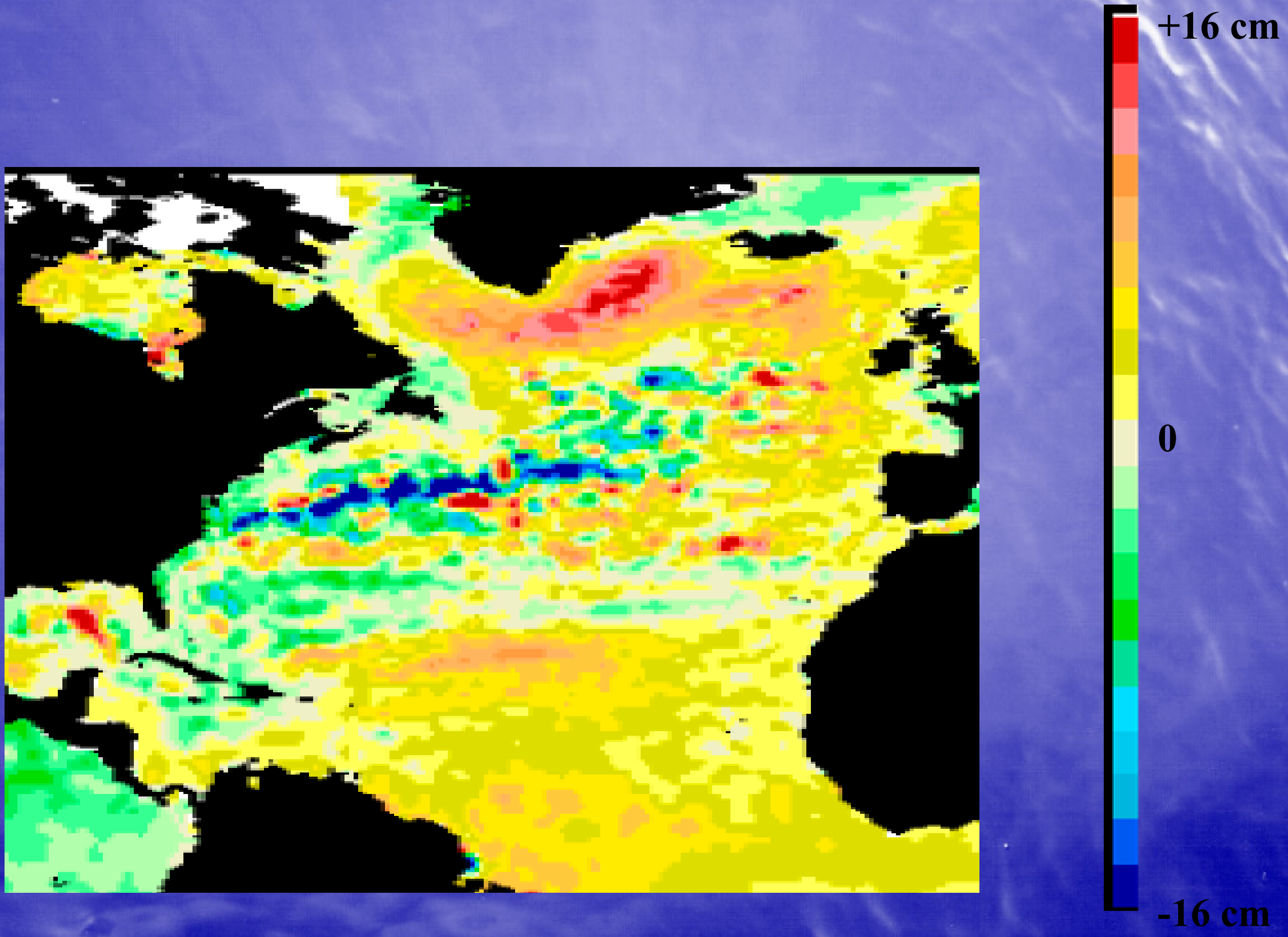


EOFs of BPR data

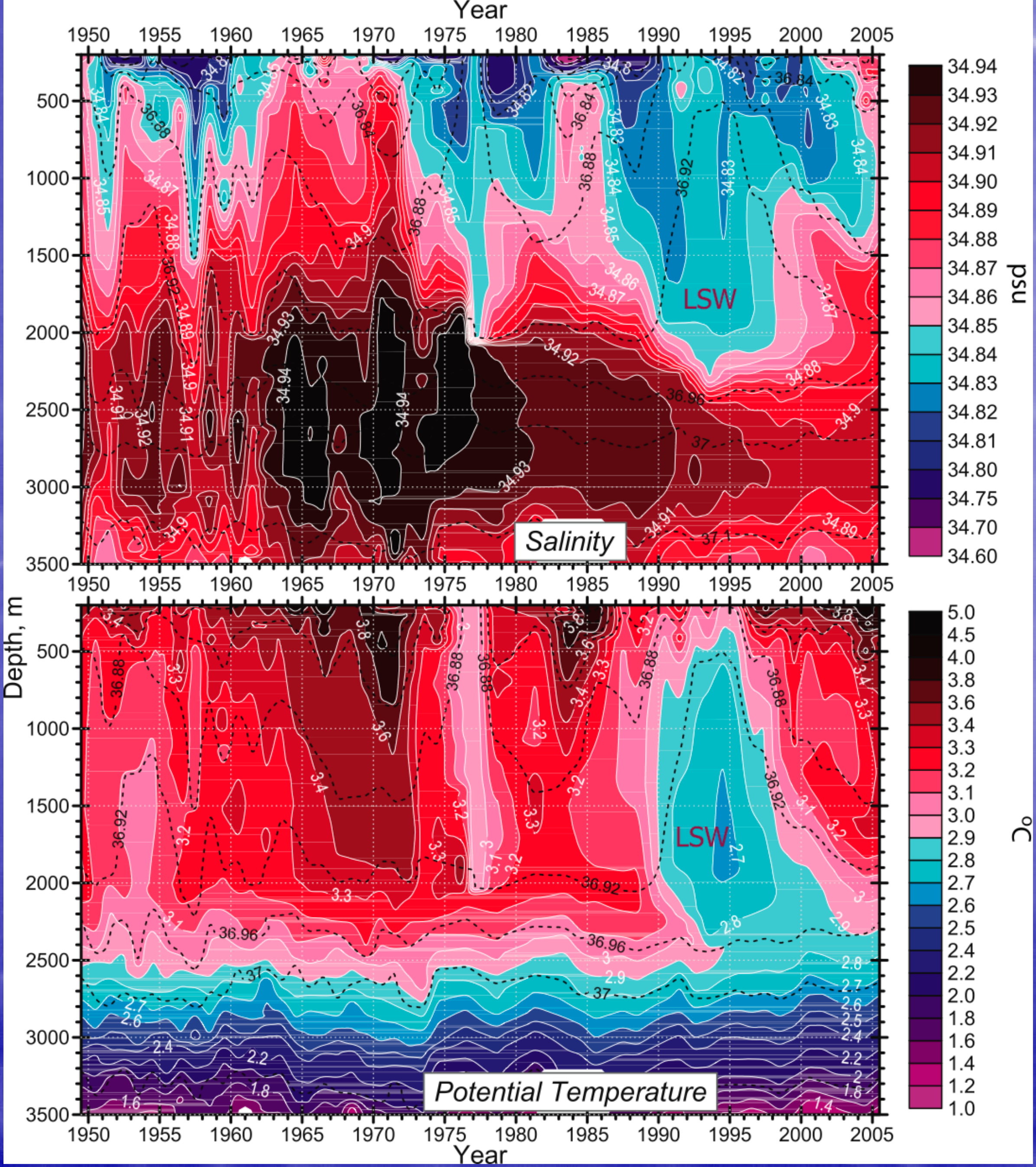





Cor with MOC LF TS2
80°
60°
40°
20°
280°
300°
320°
340°
0.5
0.4
0.3
0.2
0.1
−0.0
−0.1
−0.2
−0.3
−0.4
−0.5



Linear trend in sea level over 14 years (Oct 1992 – Oct 2006)

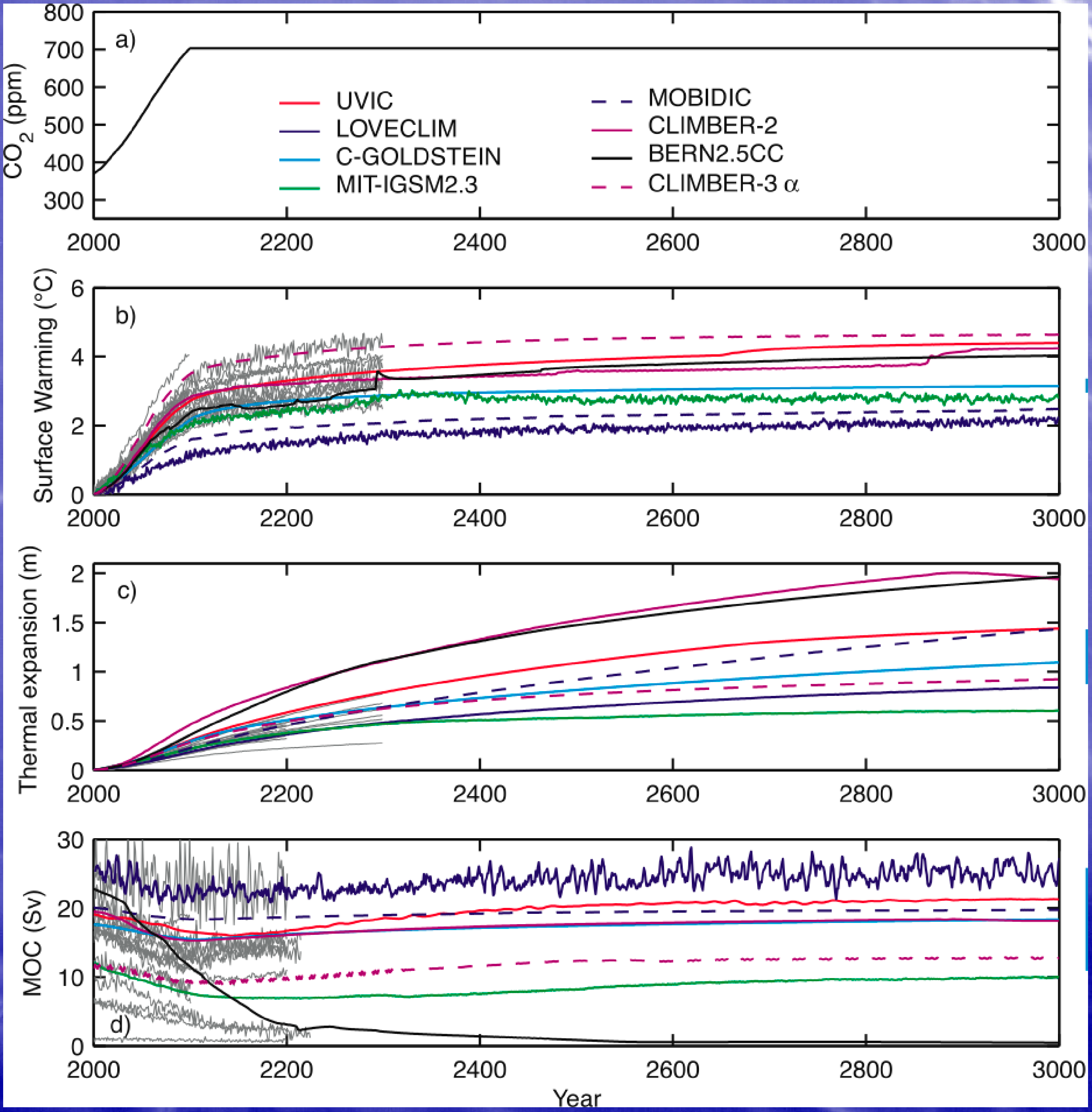


IPCC 4AR from Yashayaev et al., 2003

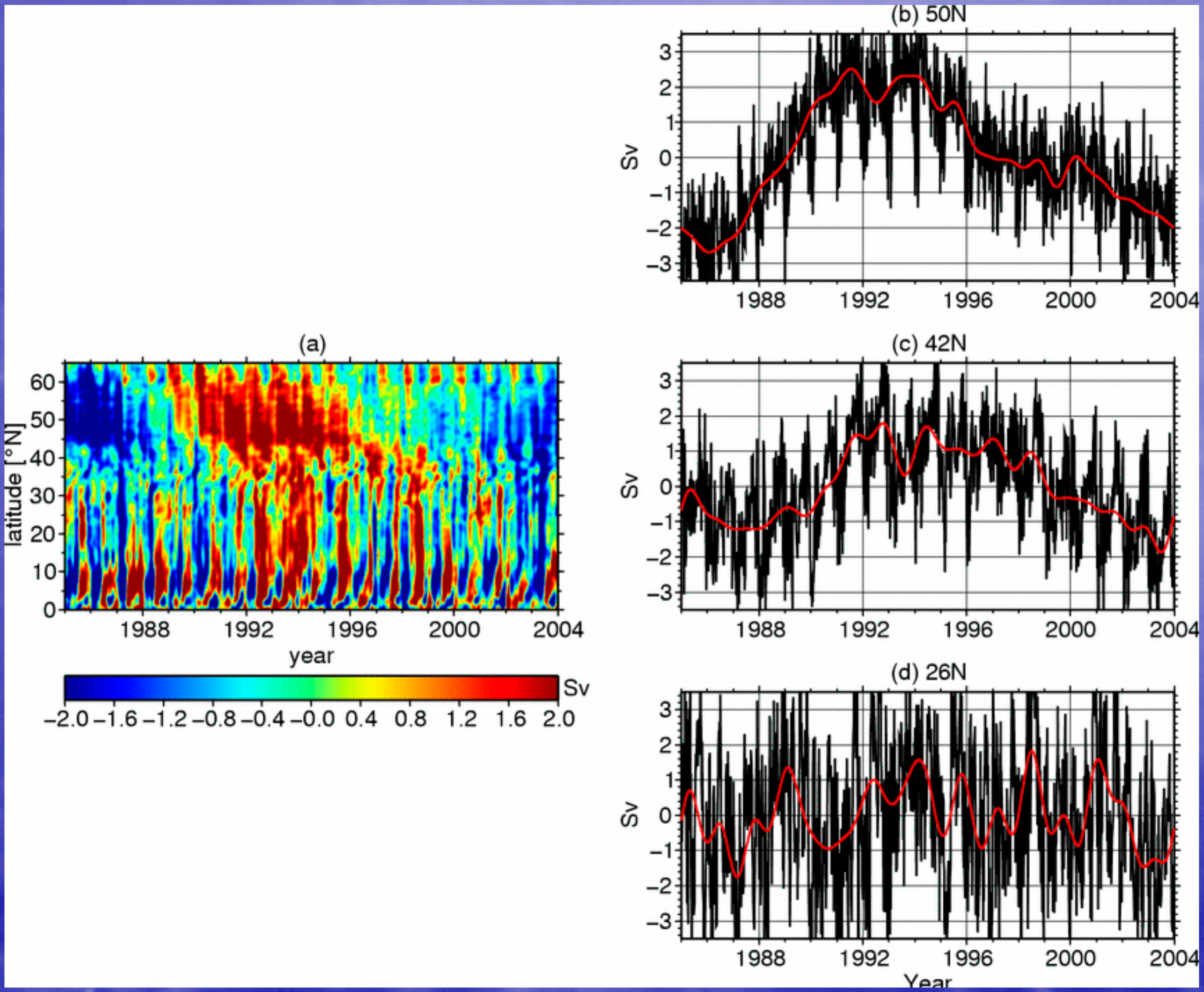
Conclusions

- Coherent change in MOC over the whole N. Atlantic only occurs on decadal time scales at shortest.
- There is more high frequency variability at 26°N than north of the Gulf Stream.
- Bottom pressure measurements at the western boundary alone are sufficient to measure variations in the MOC.
- Longer time series and a combination of measurements at different latitudes will be required before we can claim to have detected any meaningful change in `the’ MOC.
- There may be a lot of information about the MOC in sea level.

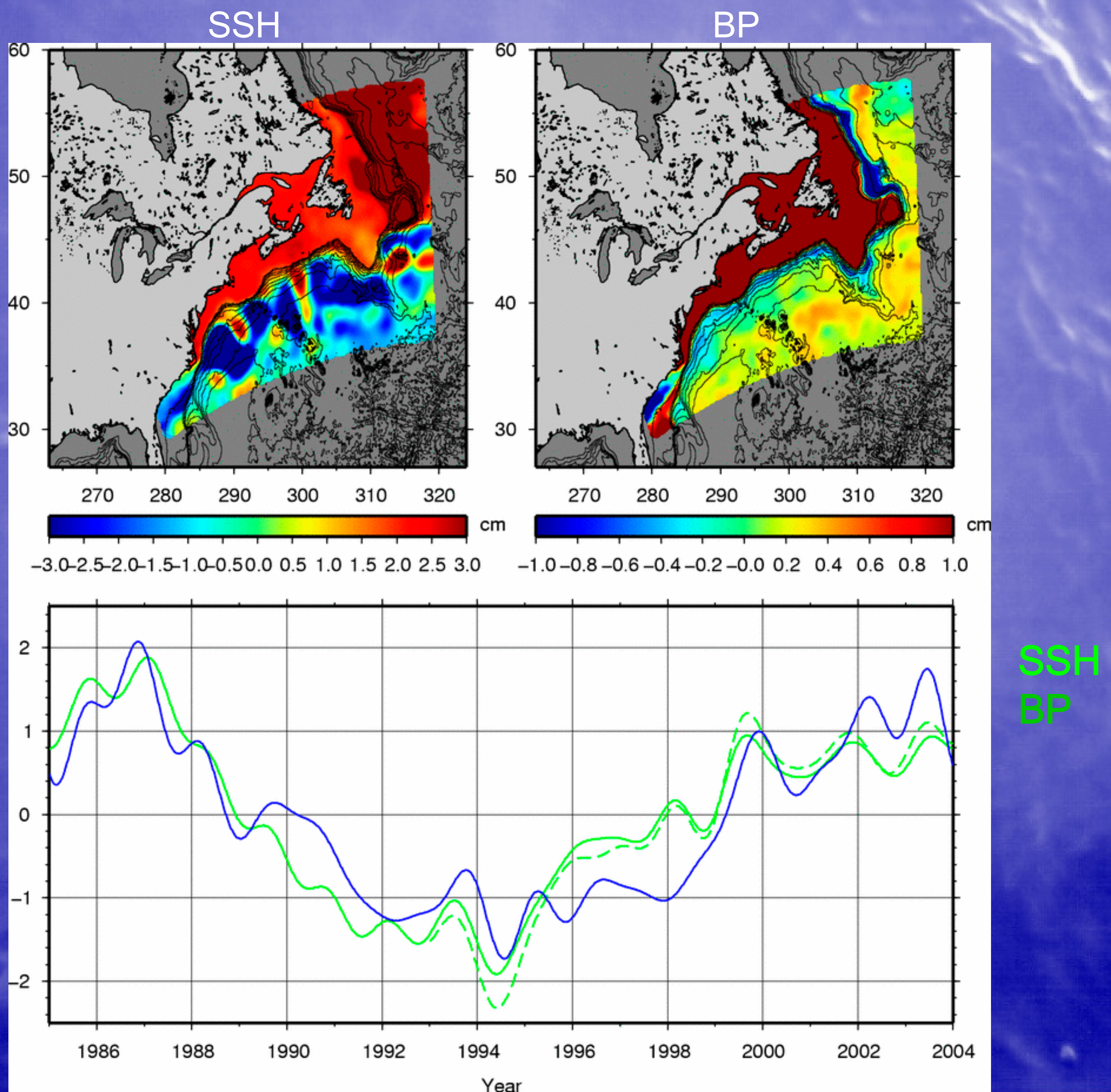
IPCC 4AR EMIC results



Origin of meridional differences: Key latitudes



Leading EOFs of interannual sea-surface height and bottom pressure



Leading EOFs of interannual sea-surface height