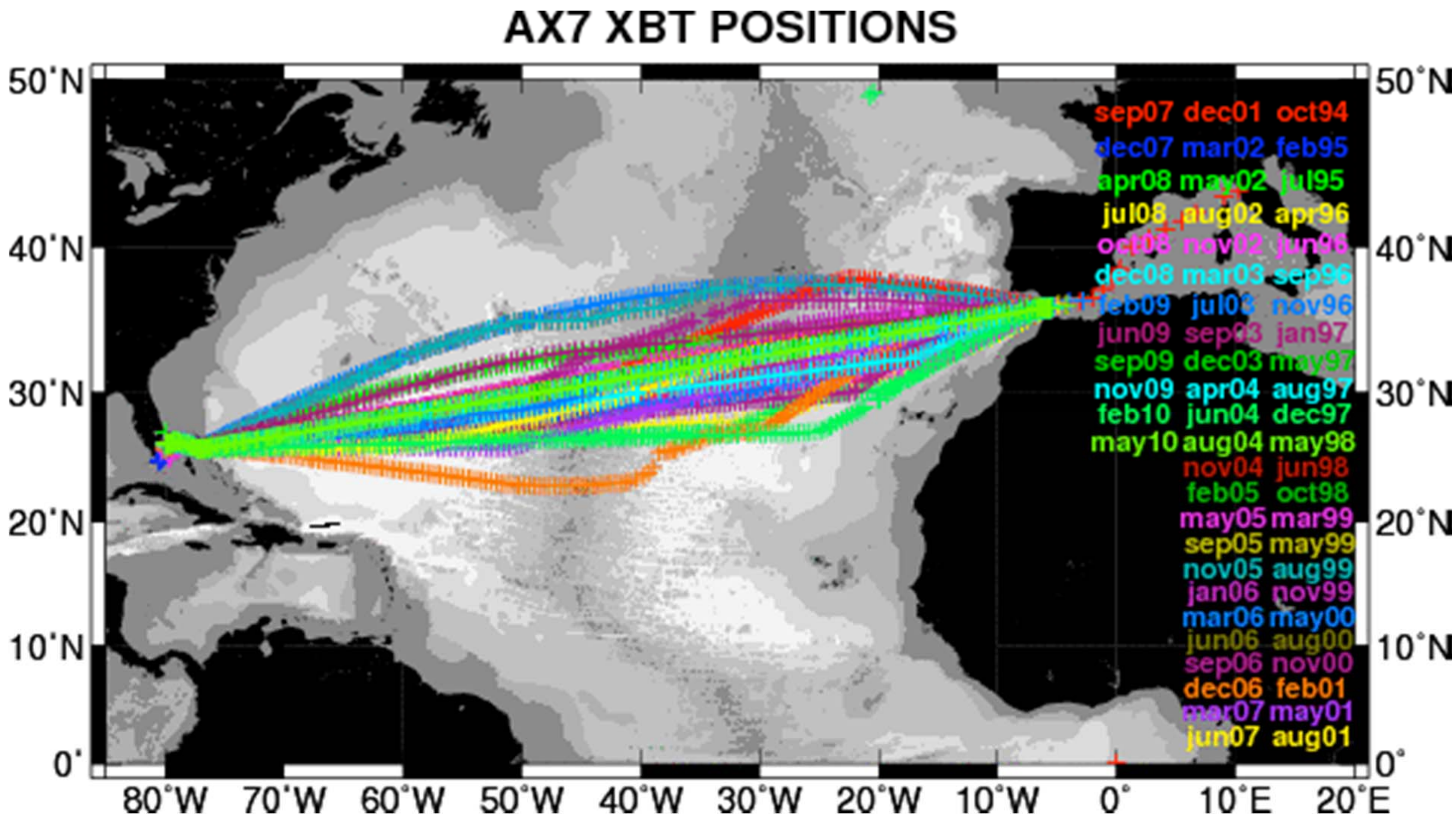
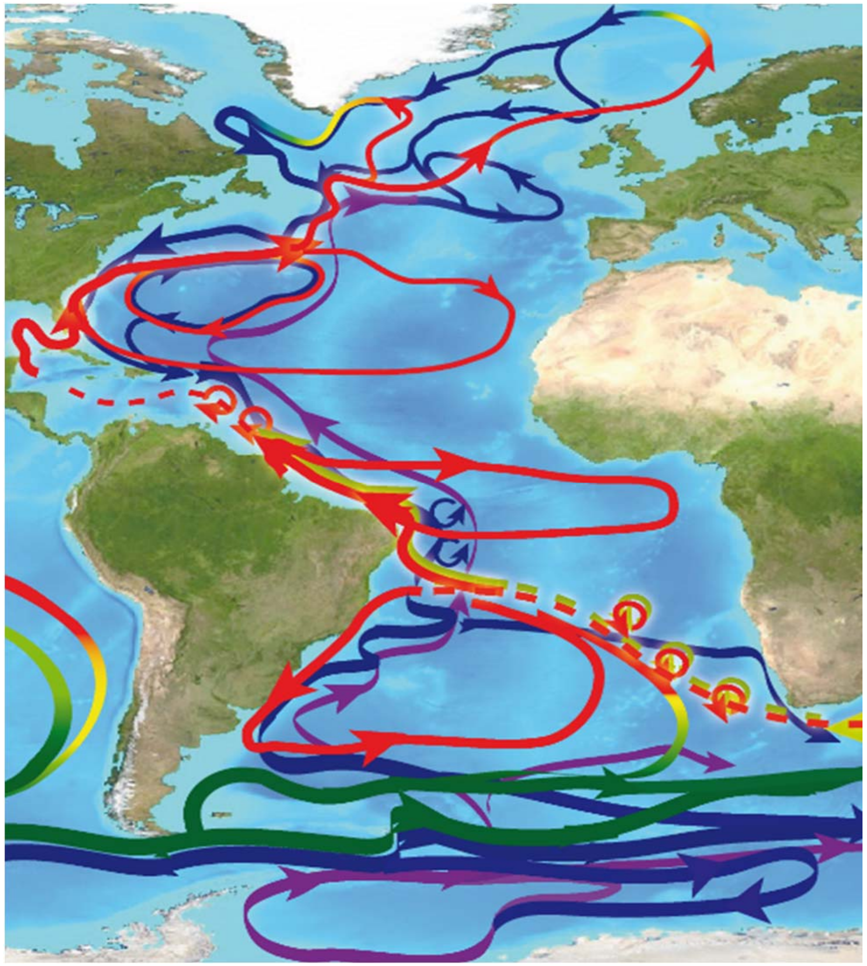
Estimating the meridional heat transport and overturning circulation from XBTs

Molly Baringer



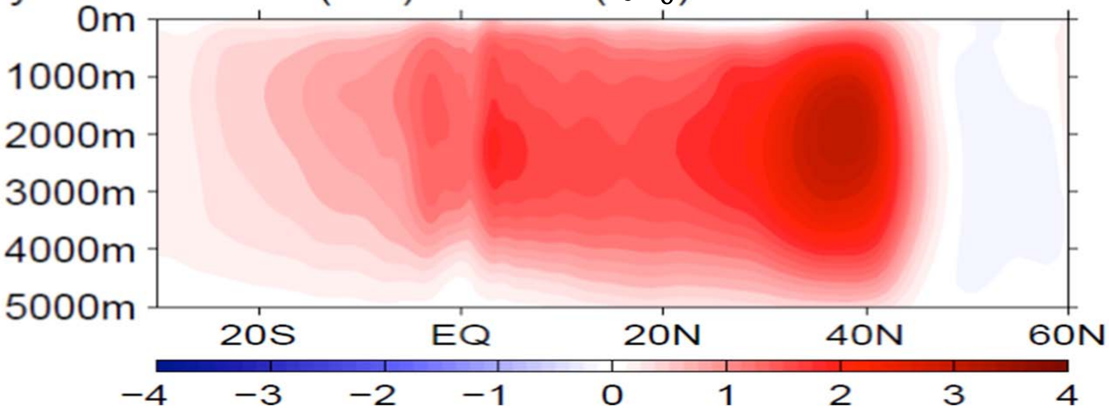
Motivation

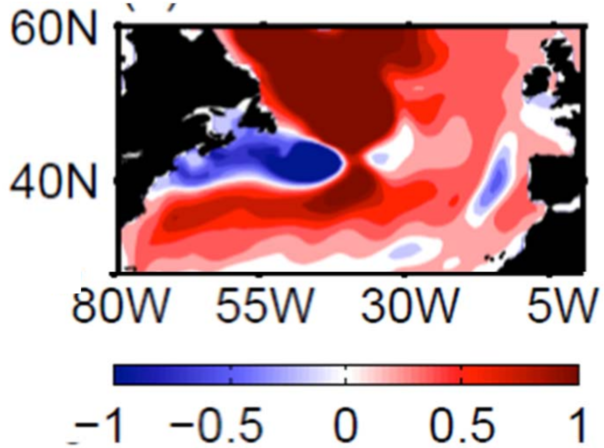
<u>The MOC/MHT can impact temperature, salinity, sea-level and ecosystems</u>



Courtesy R. Lumpkin

$$\text{MOC} = max \int_0^z \int_0^L \vec{v}(x,z)\ dx\ dz$$

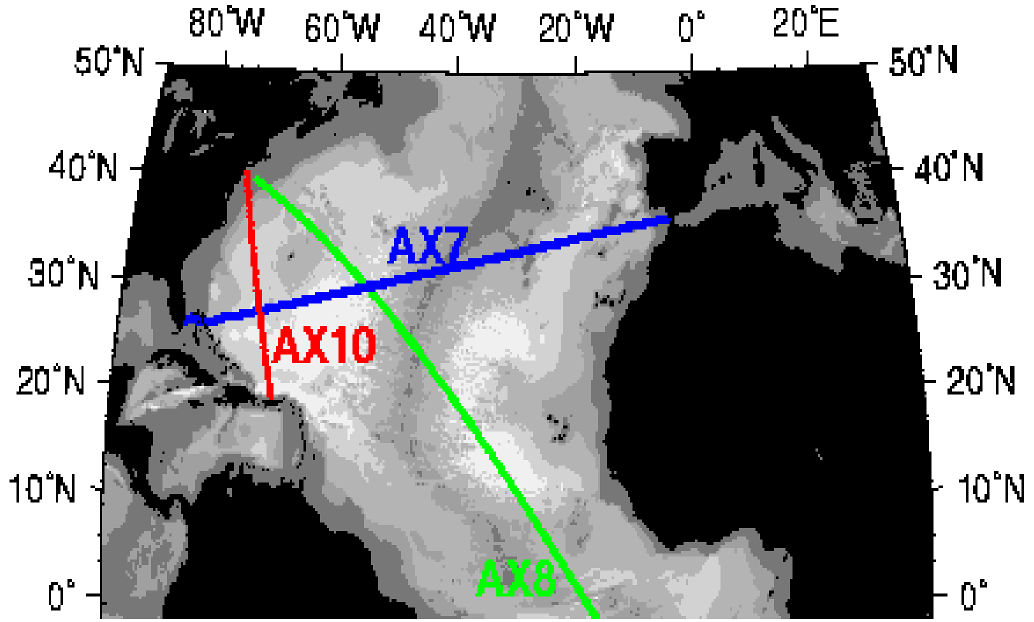


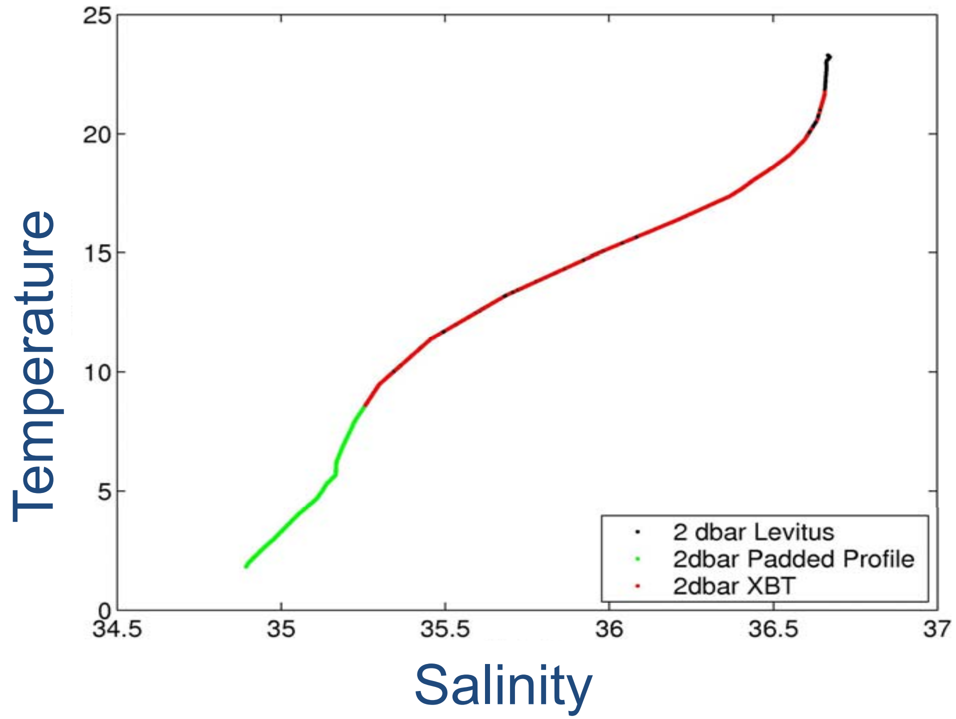


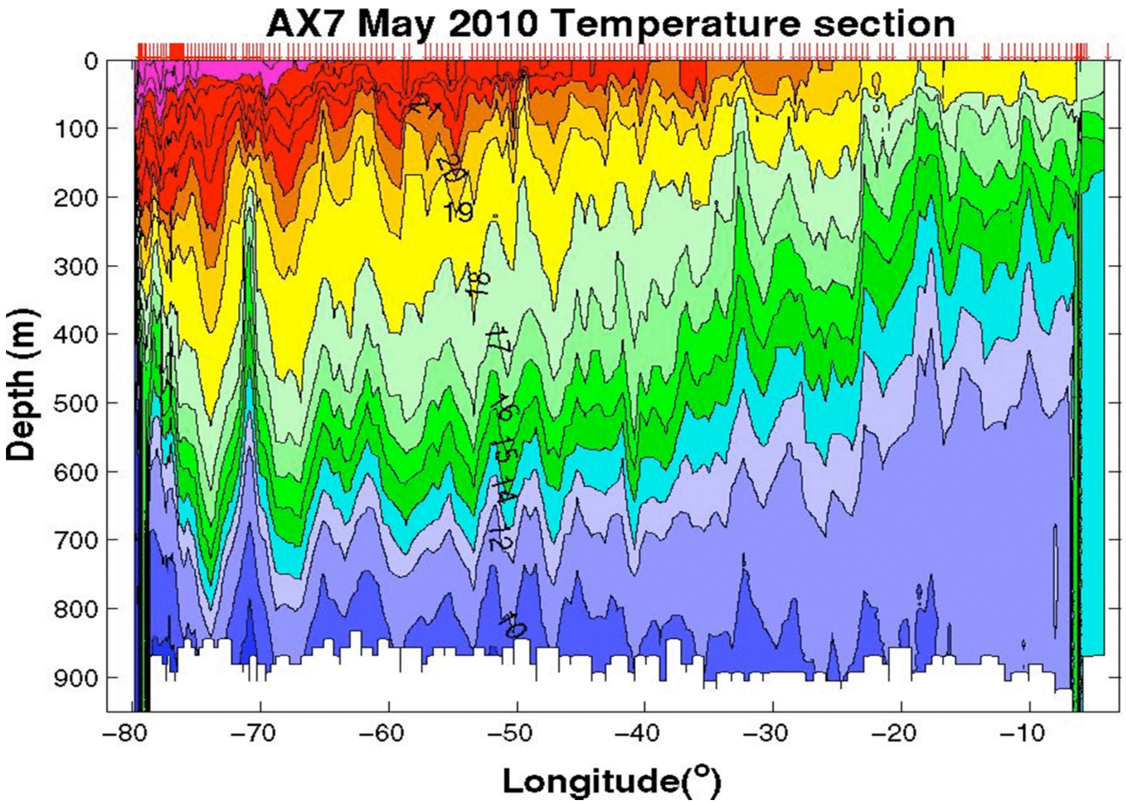
- A strong MOC is associated with warm SST in the North Atlantic.

Zhang and Wang (2013)

We need more *insitu* estimates of the MOC/MHT





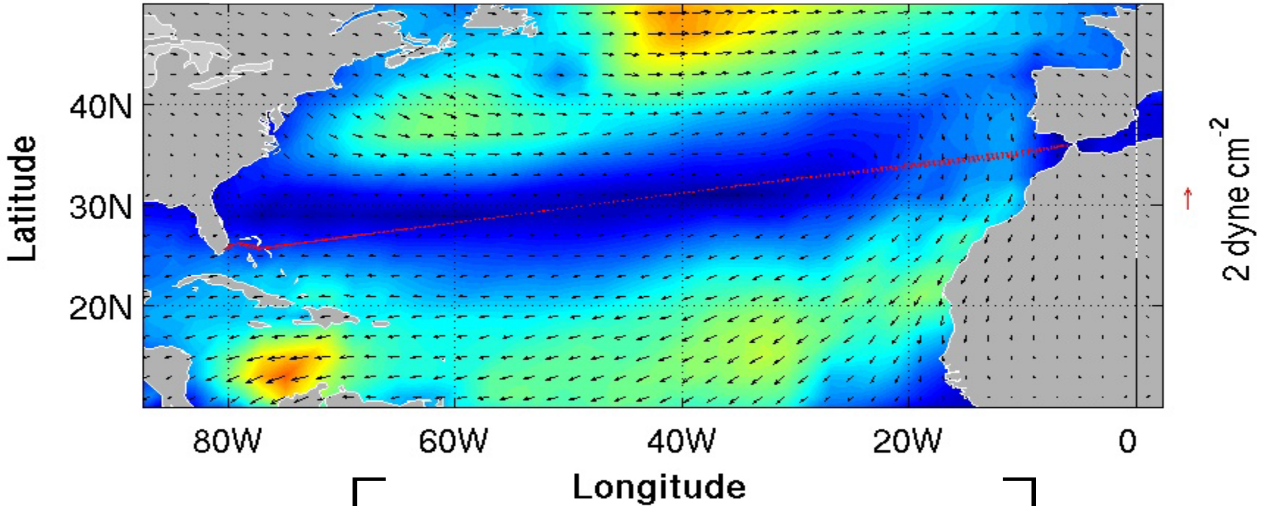


<u>73 complete sections along AX7 since 1995</u>

Levitus climatology provides a T/S look-up for missing salinity and any data below the depth of the XBT.

Methodology

Direct estimates of meridional volume, mass and heat transport across a section require T, S and velocity observations:



$$H = \int \int \rho c_p \theta v \, dx \, dz \quad \left[PW = 10^{15} Watts \right]$$

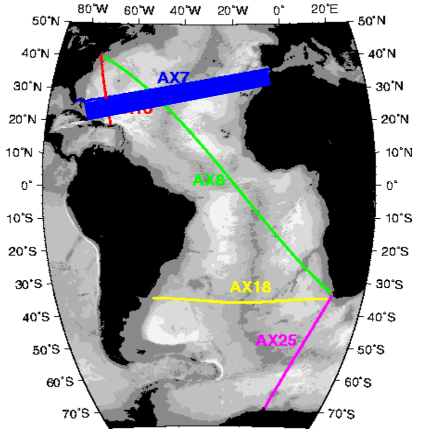
$$v = v_g + v_{ag} + v_b$$

XBT observations
V_{ref} uses σ_o=27.6
or bottom

Wind products
(NCEP)

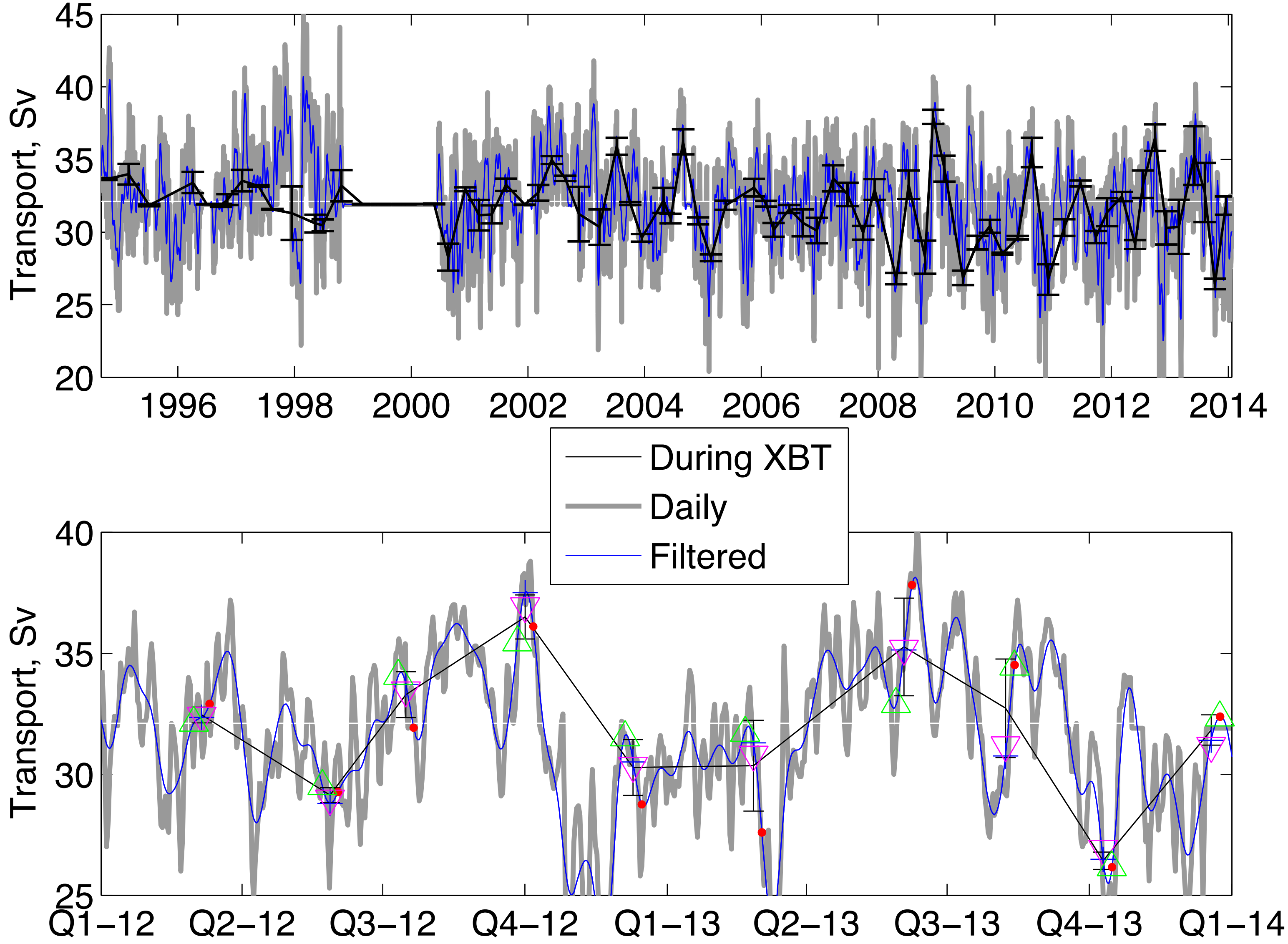
Florida Current
(cable)
Mass Adjustments
(Mass=0)

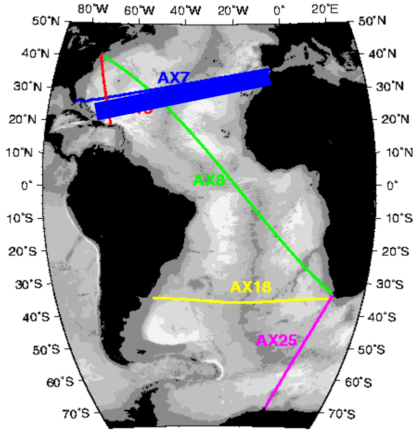
<u>Using full hydrographic sections along 24°N using this methodology to estimate transport as if there was only XBT data to 850 m gives a mean error of 0.07 +/- 0.14 PW.</u>



Florida Current time series provides reference velocity and error estimates

- Barotropic adjustments of boundary transport increases transport from 27 to 32 Sv.
- XBT sections occupied every three months resolve only the longer time scales.

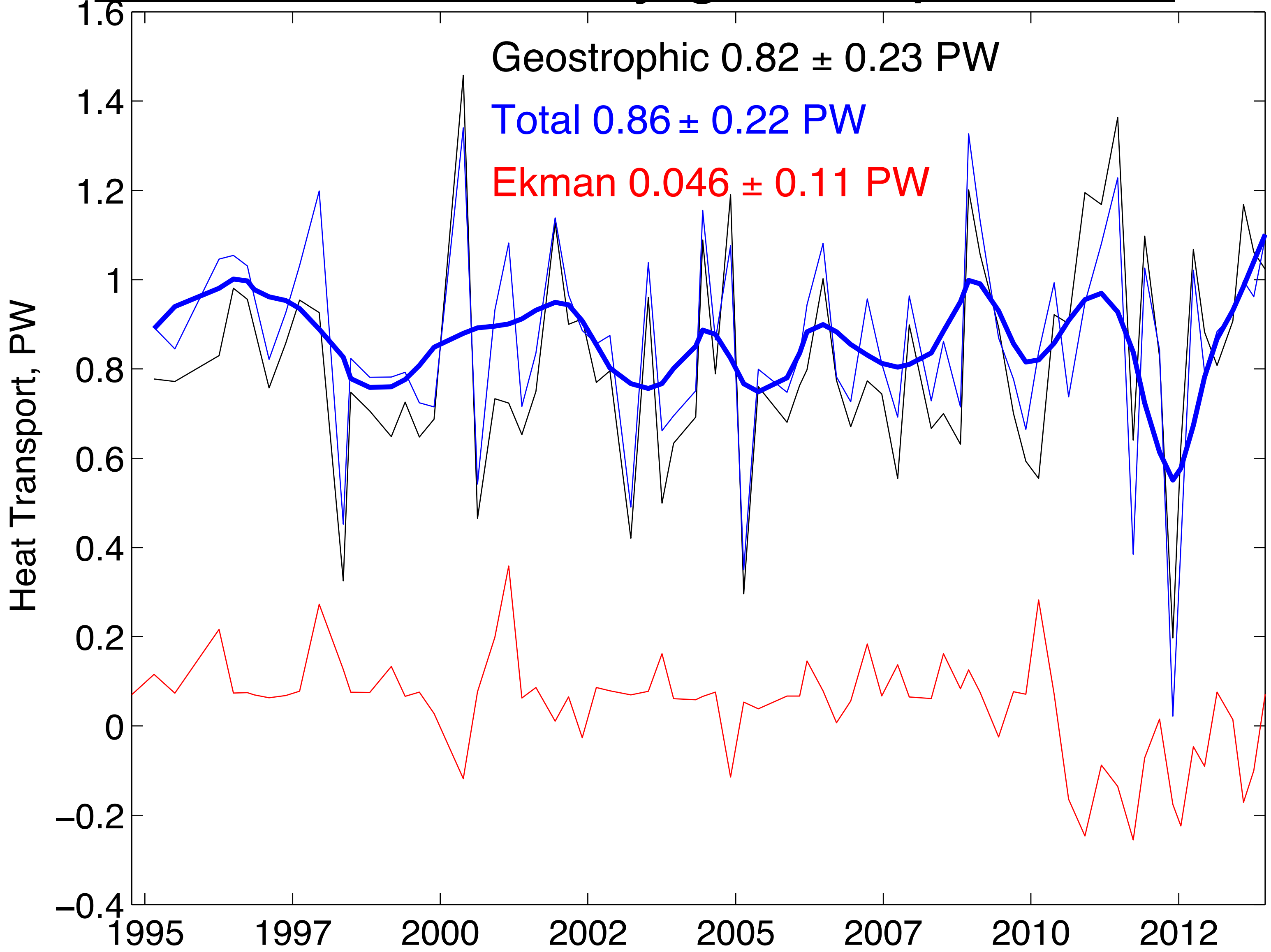




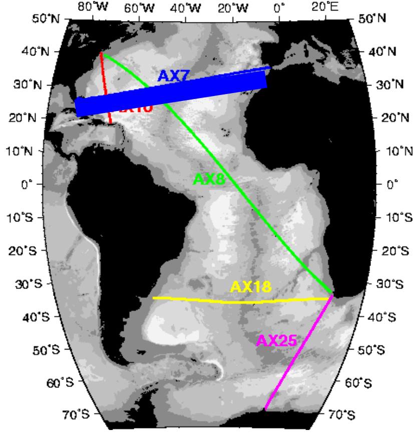
MHT TIME SERIES

MHT dominated by geostrophic flow

- MHT ranges from 0.02 to 1.34 PW.
- Ekman HT contribution to MHT is minimal.
- XBT observations form a lower bound on the true variability.



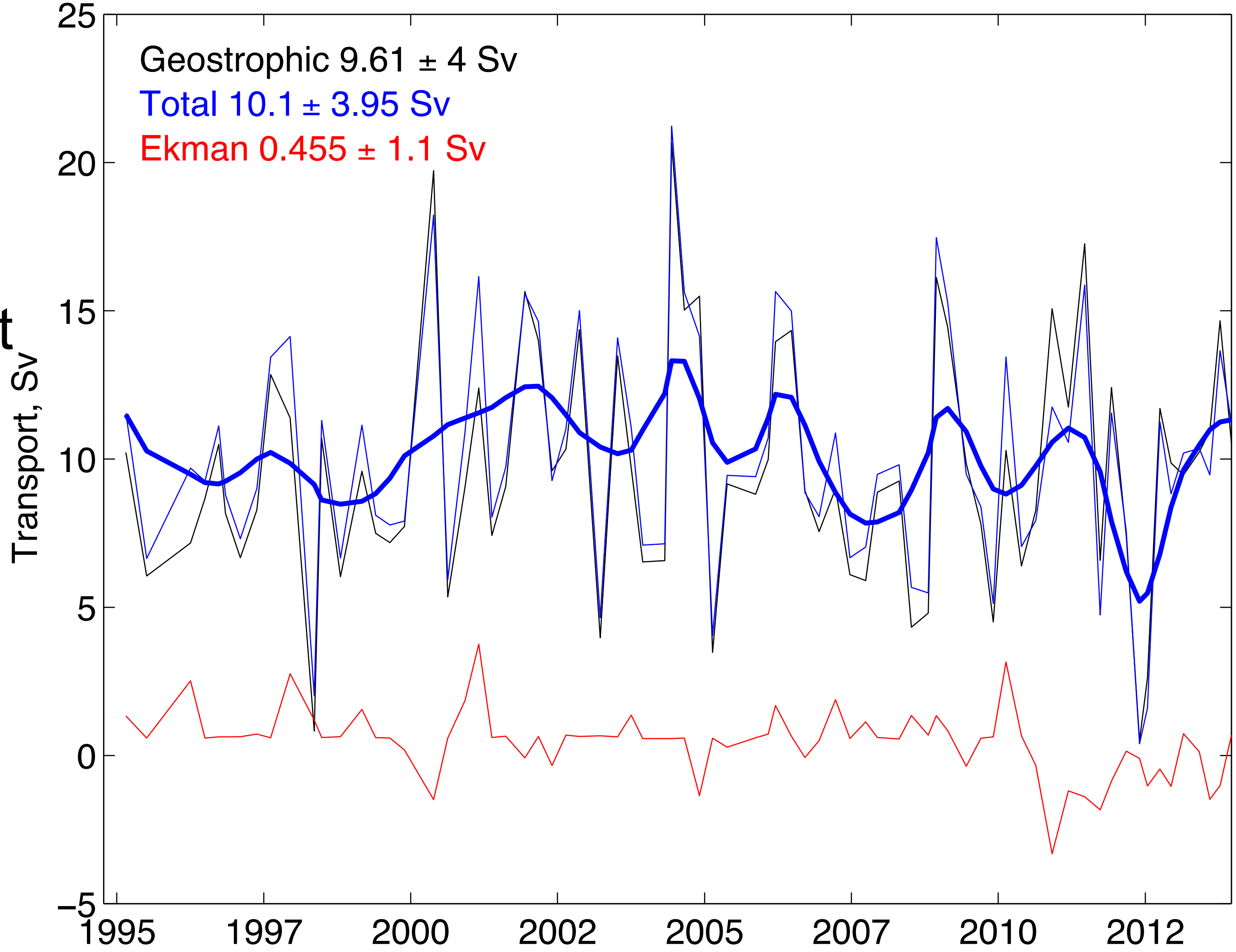
Heavy line is 24 month low pass filter of total MHT

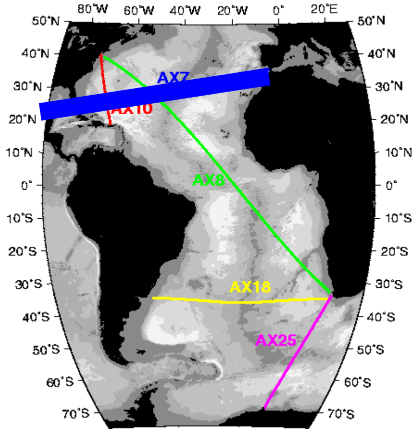


MOC TIME SERIES

MOC is also dominated by the geostrophic transport

- MOC is computed as a maximum of the volume transport integrated zonally along p surfaces.
- Total MOC is 10 +/- 4 Sv
- MOC ranges from 4 to 21 Sv.

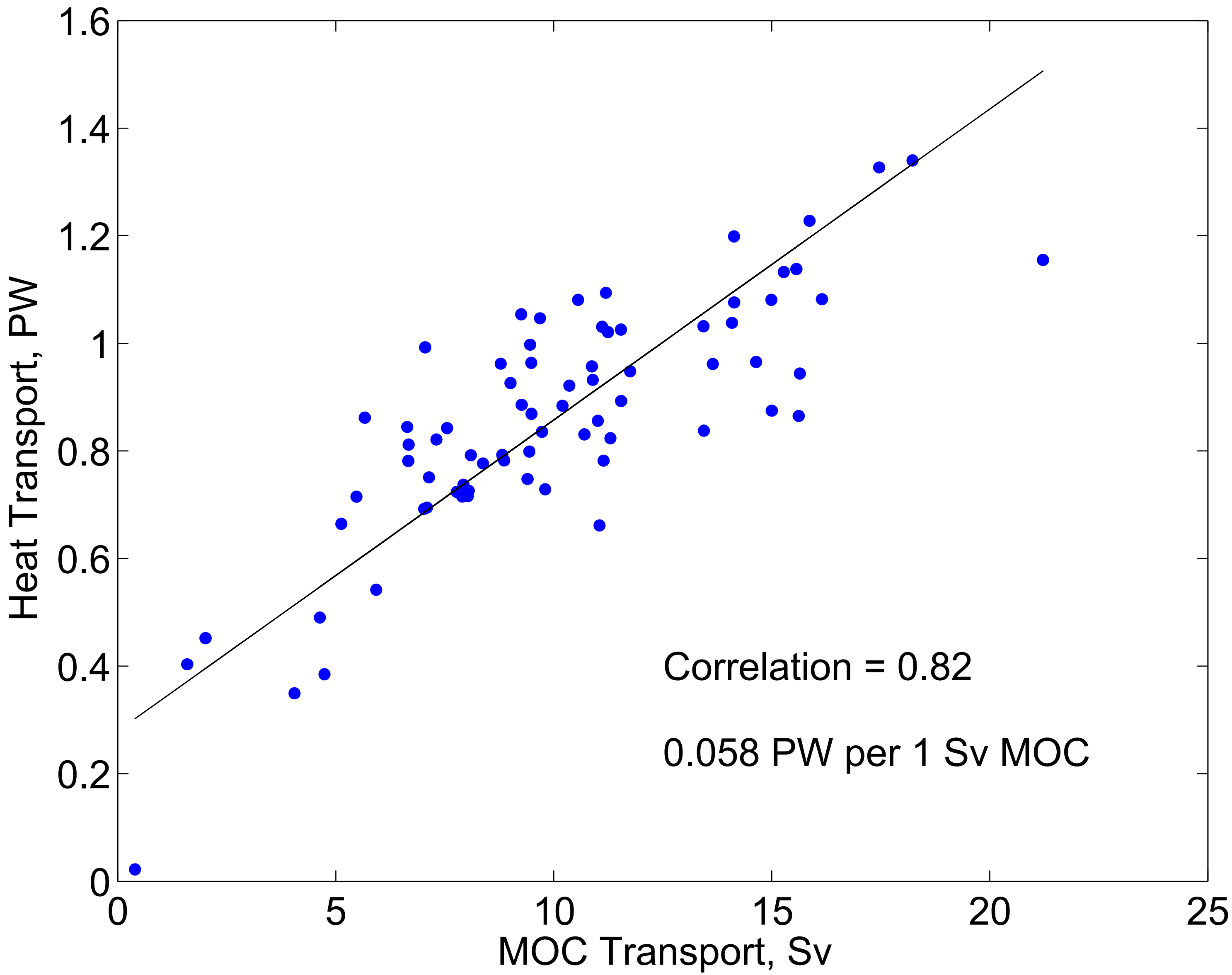


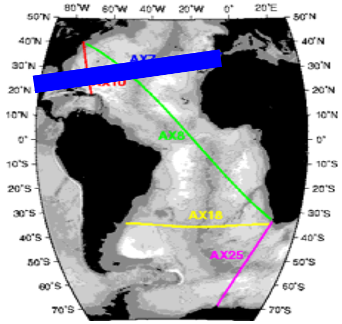


Relationship between MHT and MOC

MHT is highly correlated with MOC

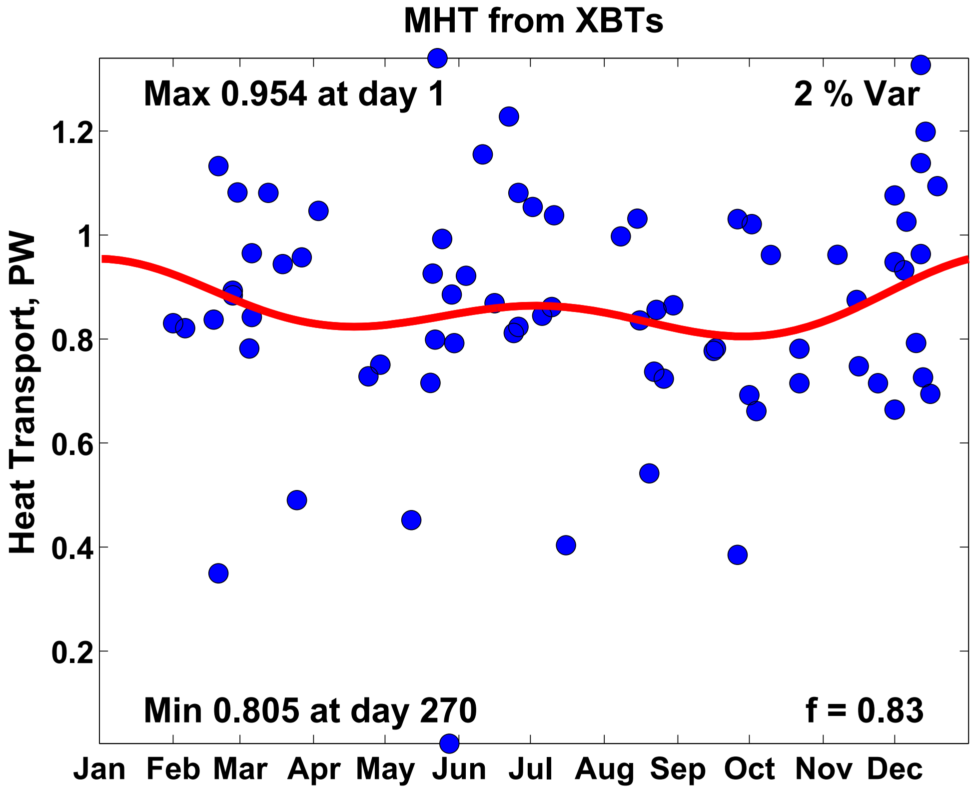
- MHT increases/decreases 0.58 PW for every 1 Sv change in the MOC
- This sensitively is slightly lower than 26°N (0.64 PW/Sv) and slightly higher than 35°S (0.05 PW/Sv)

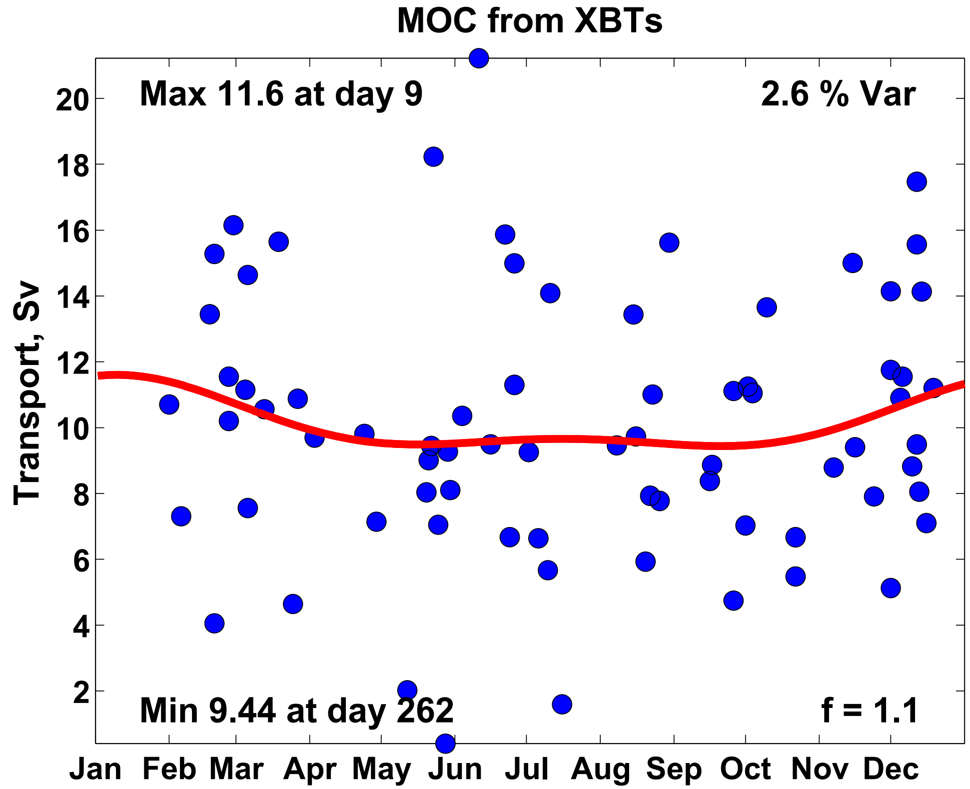




Seasonal Variability

Insignificant seasonal variability in MHT and MOC

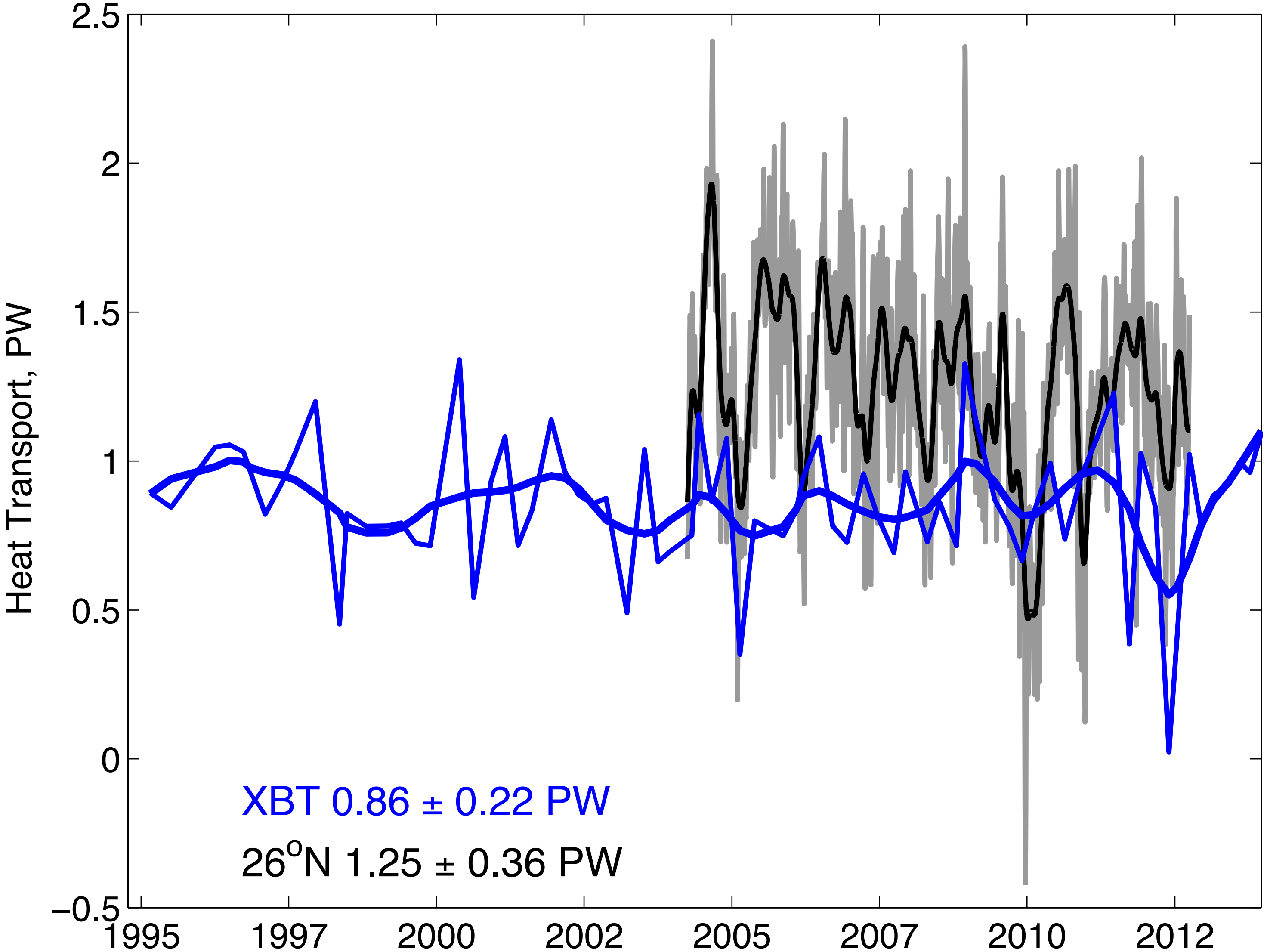




With only 15 years of data, the MHT had a seasonal cycle similar to 26°N (amplitude of 0.3 PW, summertime maximum).

Comparison with 26°N

<u>3-month sampling prevents XBTs from resolving MHT events.</u>



- MHT is -0.4 PW lower than at 26°N and +0.4 PW higher than the 0.5 PW reported at 41°N

Trends:

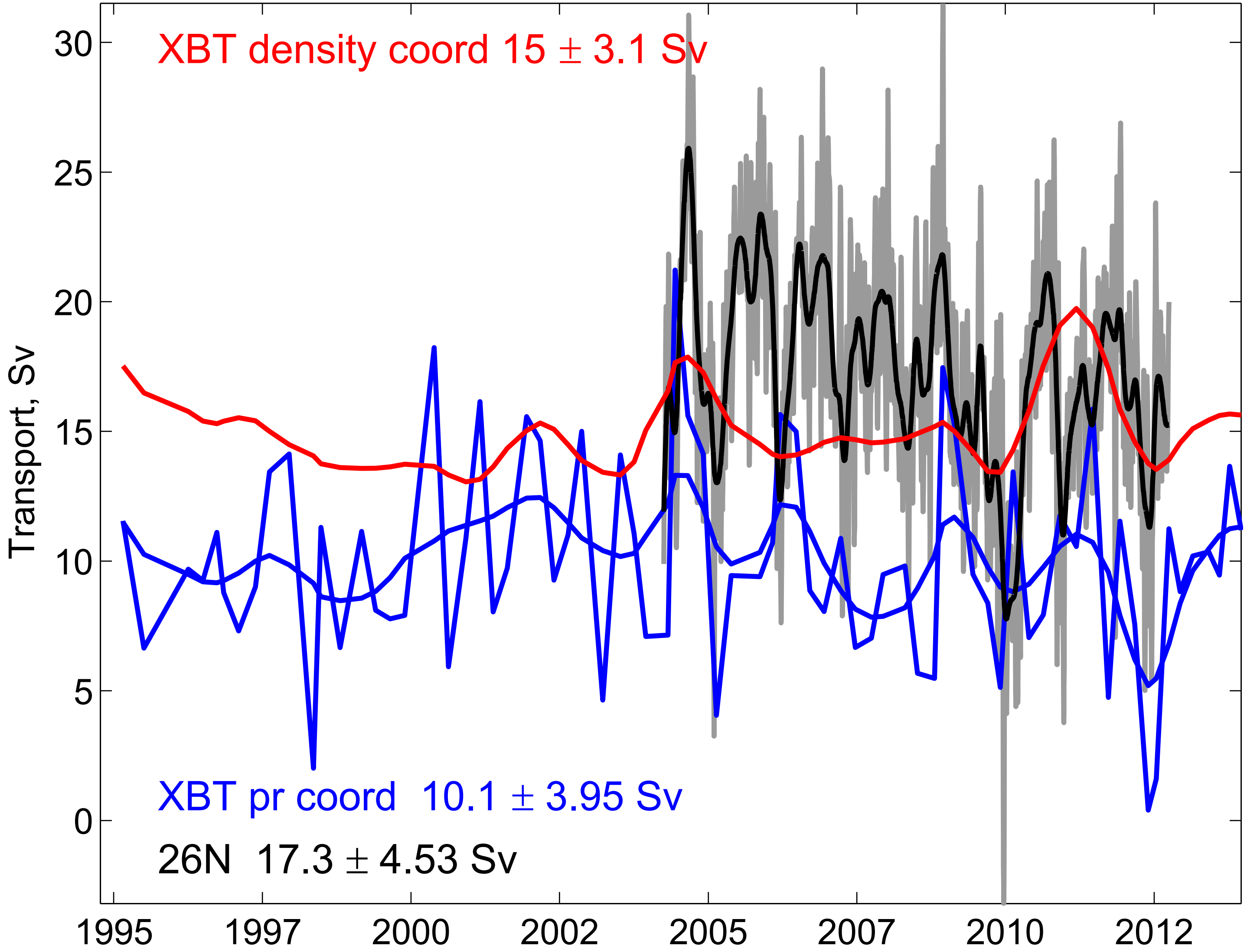
- 26°N
  - -0.3 +/- 0.25 PW/decade
- XBT during 26°N array
  - -0.13 +/- 0.28 PW/decade
- XBT full record
  - -0.03 +/- 0.08 PW/decade

(See Johns et al. 2011; McCarthy et al. 2013)

MOC in density coordinates

MOC in density coordinates is substantially larger than MOC computed by averaging in pressure.

- MOC is 50% larger when computed in density coordinates vs. pressure coordinates.
- MOC at 26°N decreases -5.2 +/- 2.7 Sv/decade.
- XBT decreased -5.6 +/- 4.6 Sv during the same period.
- However over full record insignificant changes (-0.5 +/- 1.7 PW).

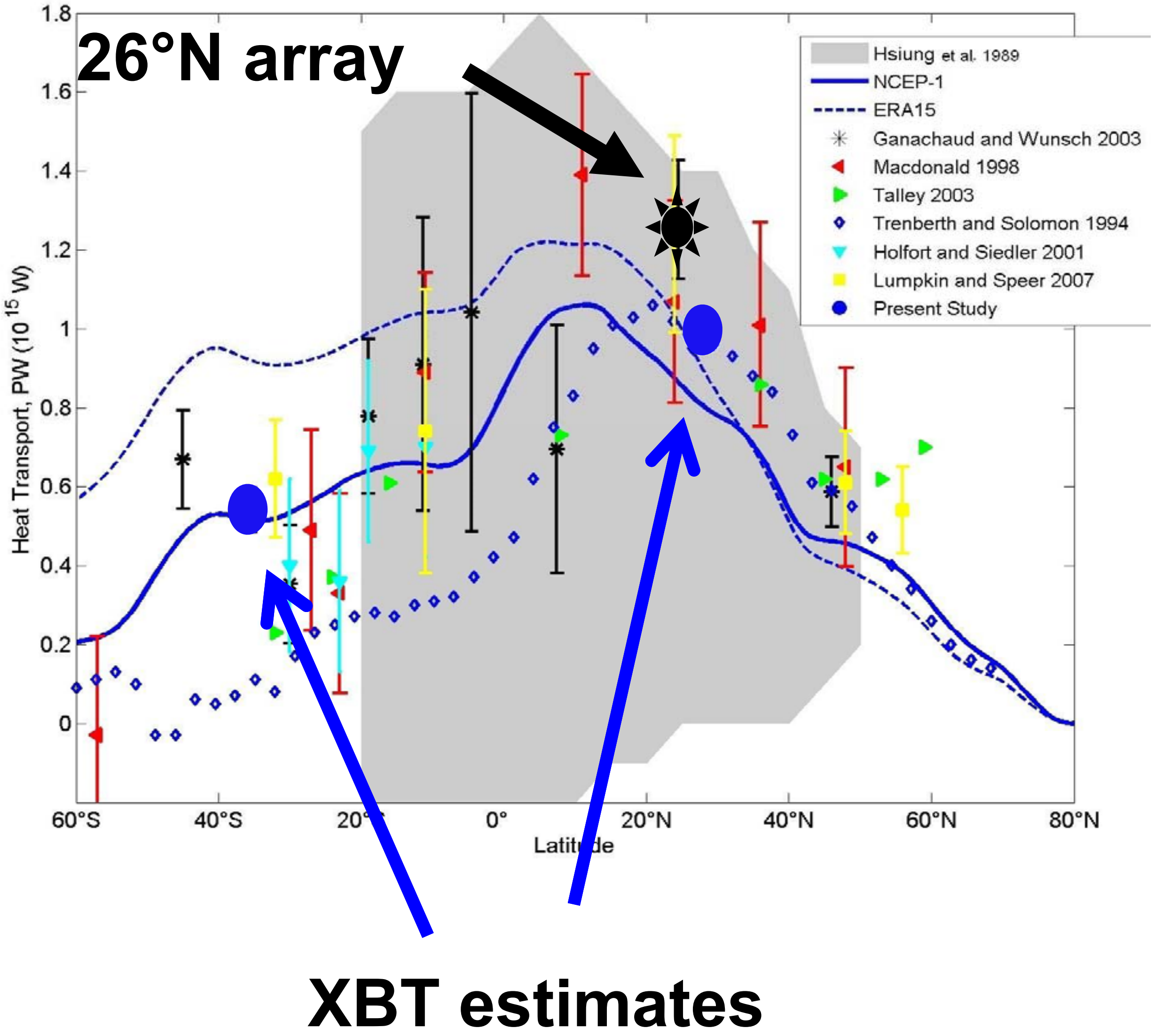


(See Smeed et al 2014)

CONCLUSION

- Annual mean (1995-2014) heat transport AX7 (approximately 30°N) = 0.86 PW with a standard deviation of +/- 0.22 PW, this lies between the 26°N and 41°N MHT estimates.

- Annual mean MOC transport = 10.1 Sv with a standard deviation = +/- 3.95 Sv, which is much lower than the estimates at 26°N (17.3 Sv) and 41°N (13.8 Sv).

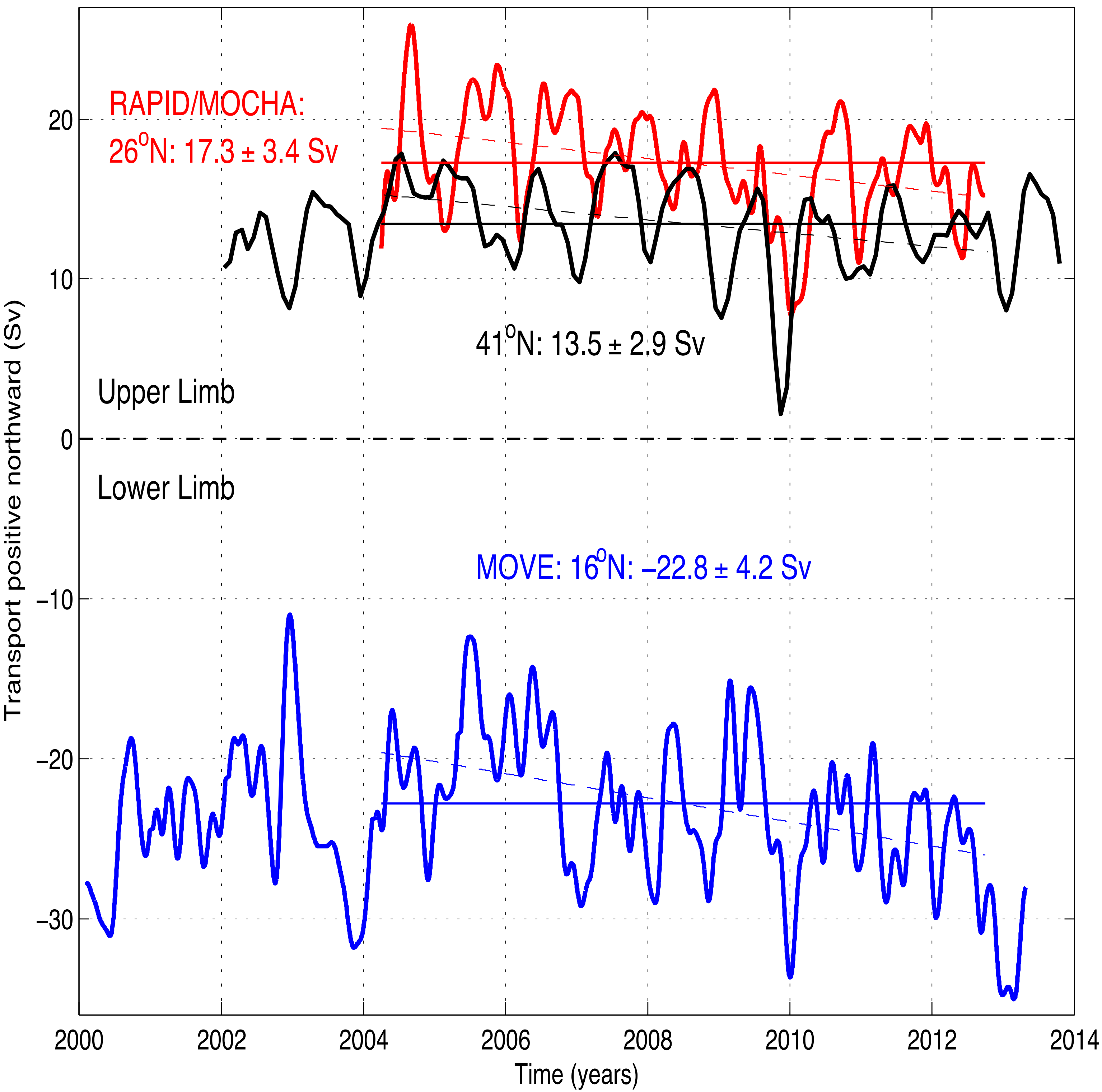


<u>How can the MHT attain such high values when the MOC is so low?</u>

CONCLUSION

- No secular trend in MOC or MHT from XBT data and there is clear interannual/decadal variability.
- MOC in density coordinates 50% larger than in pressure coordinates. Variability similar, yet different.
- The heat transport mean and variability is dominated by the geostrophic heat transport (0.82 PW +/- 0.32 PW).
- Ekman transport is low: 0.046 PW +/- 0.11.
- Short term variability is large: MHT ranging from 0.02 to 1.34 PW and the MOC from 4 to 21 Sv.
- The annual cycle appears to be insignificant.

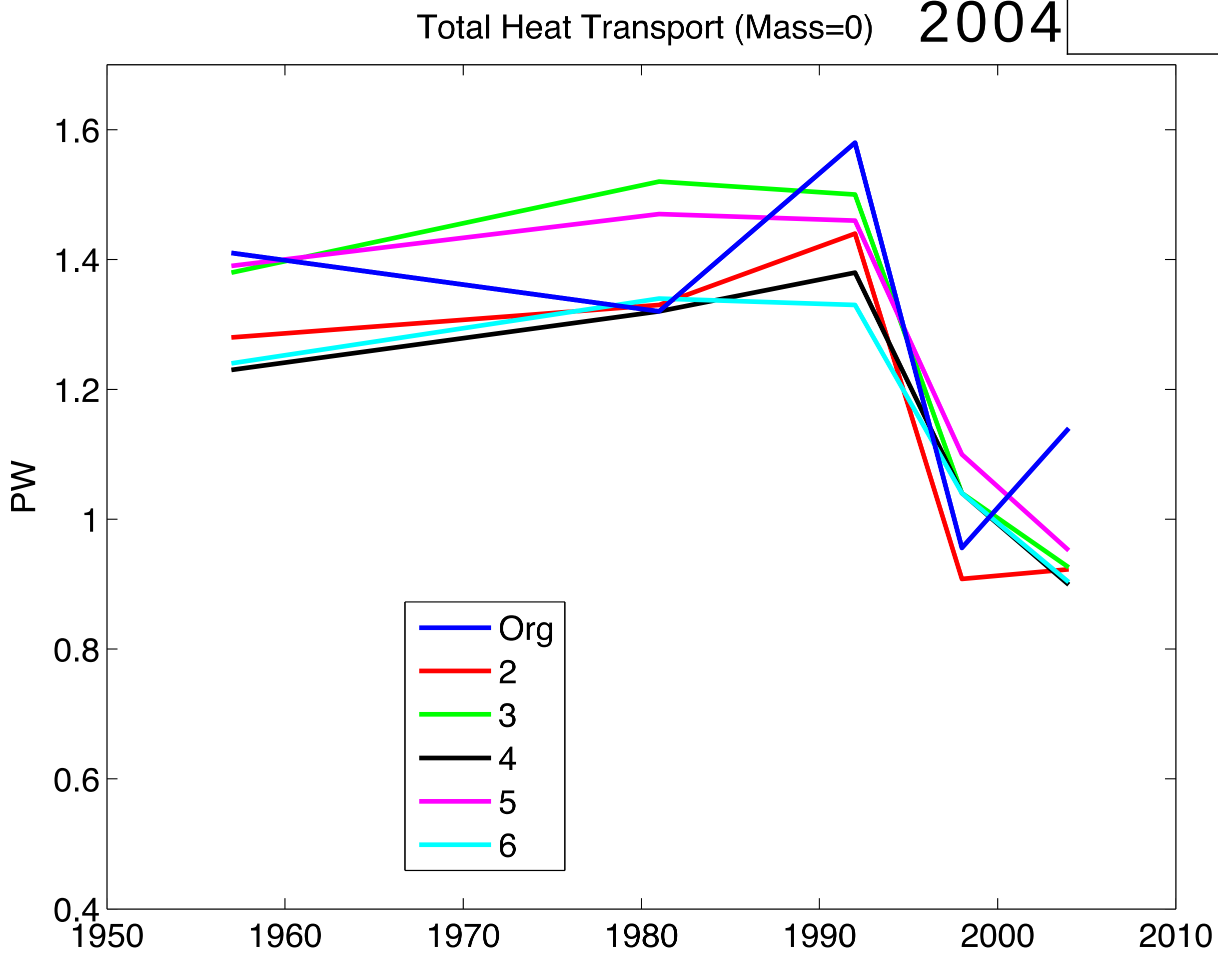
<u>Why are some events reproduced in both calculations of the MOC, while others are not?</u>



RAPID/MOCHA:
26°N: 17.3 ± 3.4 Sv
41°N: 13.5 ± 2.9 Sv
Upper Limb
Lower Limb
MOVE: 16°N: −22.8 ± 4.2 Sv
Transport positive northward (Sv)
20
10
0
−10
−20
−30
2000
2002
2004
2006
2008
2010
2012
2014
Time (years)

24N Hydrographic Sections Verify Method

	Full Section	Mean Diff	Stnd Dev
1957	1.41	0.12	0.07
1981	1.32	-0.06	0.09
1992	1.58	0.16	0.06
1998	0.96	-0.07	0.06
2004	1.1	0.22	0.02
		0.07	0.14



Using full hydrographic sections along 24N using various choices to estimate transport as if there was only XBT data to 800 m gives a mean error of 0.07 +/- 0.14 PW