Update on the Meridional Heat Transport and Overturning Circulation estimated from XBTs

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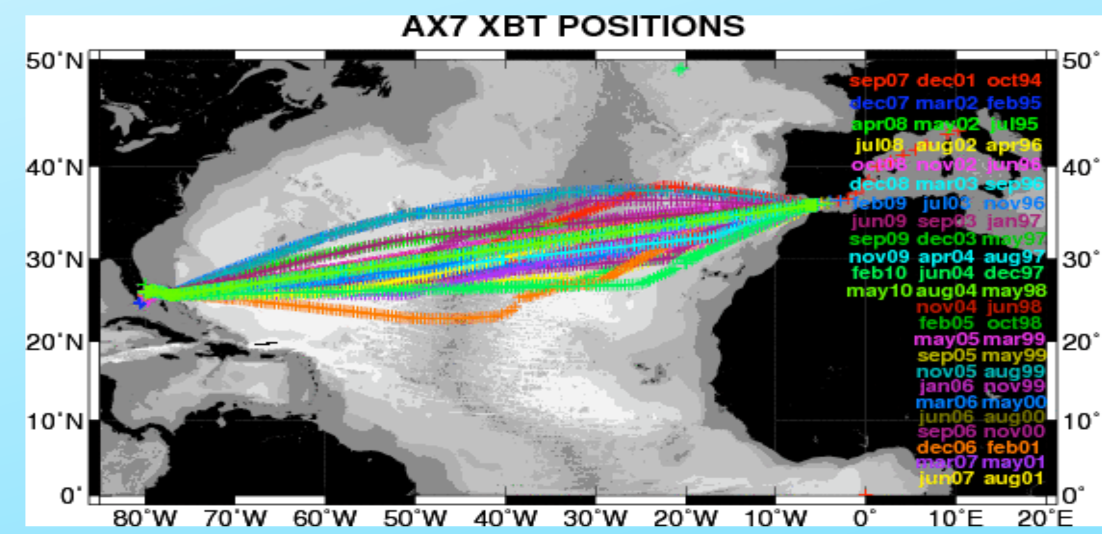
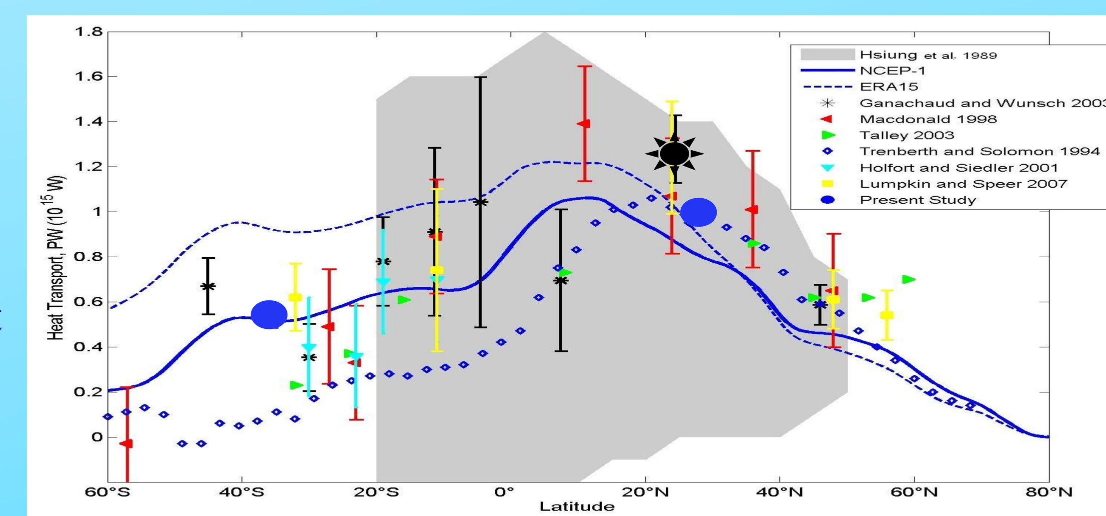
Abstract

The Atlantic Ocean Heat Transport is estimated and monitored to diagnose and understand ocean circulation variability, identify changes in the Meridional overturning circulation and to monitor for indications of possible abrupt climate change. This presentation summarizes estimates of the heat transport and meridional overturning transport from the zonal section AX07 that AOML maintains in the North Atlantic Ocean. As shown below, the heat transport in the North Atlantic was found to vary on inter-annual time scales from 0.8 ± 0.2 PW in 2003 to 1.2 ± 0.2 PW in 1996 and again in 2007, with instantaneous estimates ranging from 0.6 to 1.6 PW. Heat transport due to Ekman layer flow computed from NCEP winds was relatively small (only 0.1 PW). This variability is entirely driven by changes in the interior density field; the barotropic Florida Current transport was kept fixed (32 Sv). At low frequencies, North Atlantic heat transport variations were found to weakly correlate with the Atlantic Multidecadal Oscillation (AMO).



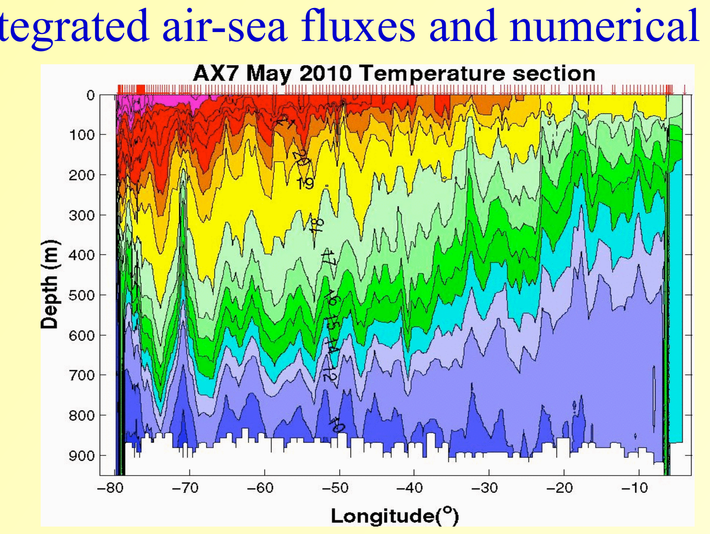


Conclusions

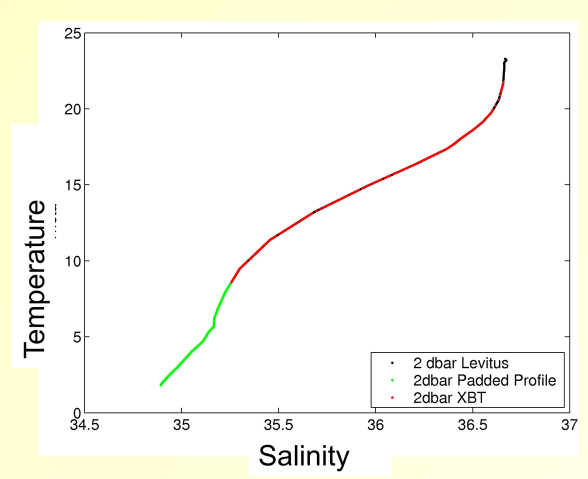
- Annual mean (1995-2014) heat transport AX7 (approximately 30°N) = 0.86 PW with a standard deviation of +/- 0.22 PW, this lies between the 26°N and 41°N MHT estimates.
- Annual mean MOC transport = 10.1 Sv with a standard deviation = +/- 3.95 Sv, which is much lower than the estimates at 26°N (17.3 Sv) and 41°N (13.8 Sv).
- 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.

Data and Methods

NOAA/AOML maintains high-density expendable bathythermograph (XBT) data from 5 lines in the Atlantic Ocean. Temperature profiles to a depth of as much as 850m, with horizontal spacing of 10-50 km. This data can provide estimates of the upper ocean currentsthat carry massive amounts of heat from the tropics to subpolar latitudes, and reflect the upper limbs of the global meridional overturning circulation. Heat transport is directly related to the role that this basin plays in the meridional overturning circulation and is an important benchmark for integrated air-sea fluxes and numerical model performance.



73 complete sections along AX7 since 1995



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

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

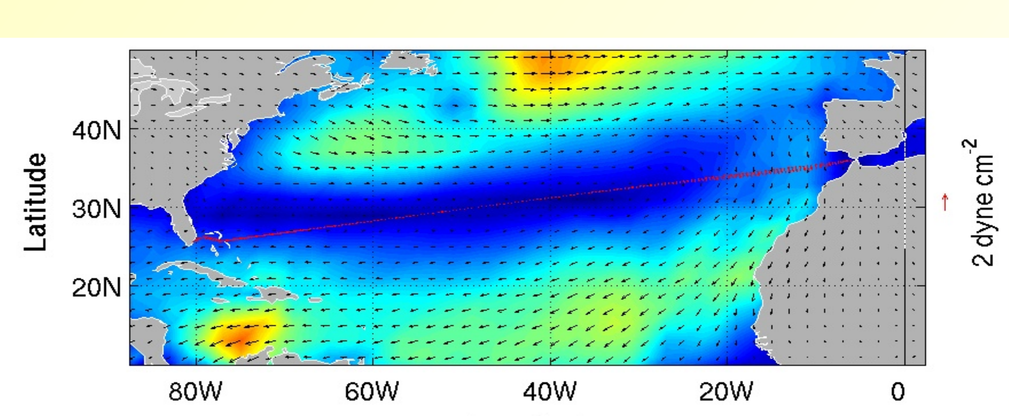
$$v = v_g + v_{ag} + v_b$$

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

Wind products (NCEP)

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

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



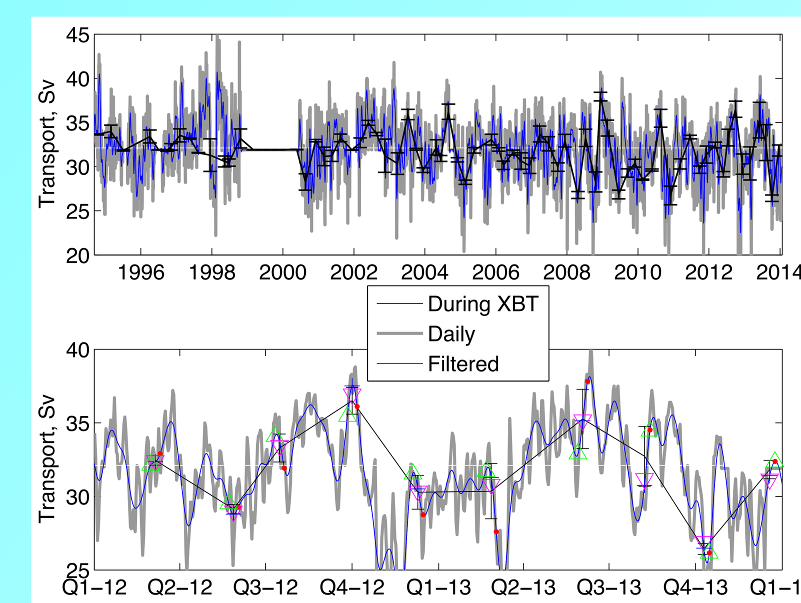
Using full hydrographic sections along 24°N using this methodology to estimate transport as if there was only XBT data to 850 m gives a mean error of 0.07 +/- 0.14 PW.

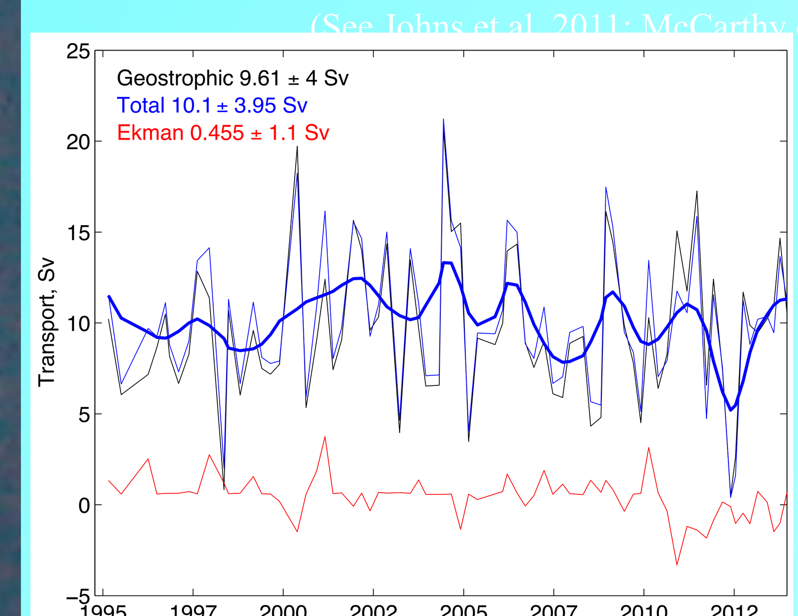
Time Series.

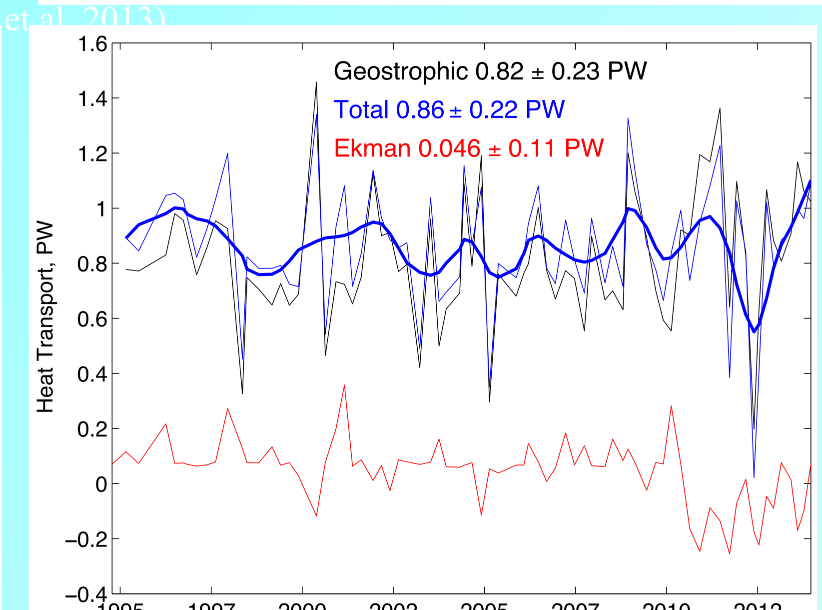
Florida Current time series provides reference velocity and error estimates

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

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





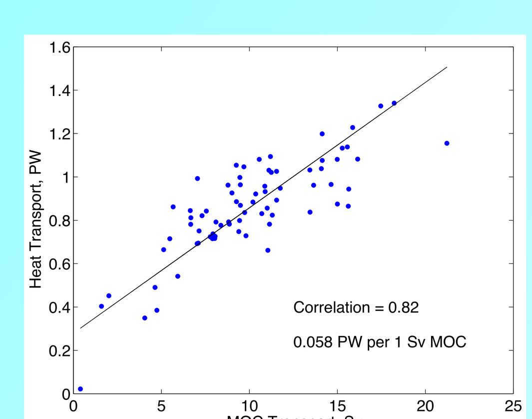


MHT dominated by geostrophic flow

- 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.

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

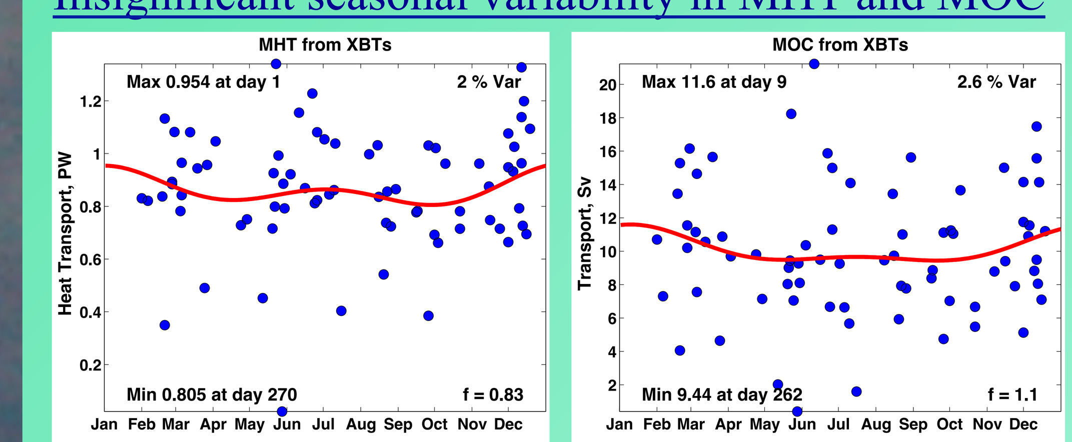


MHT is highly correlated with MOC

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

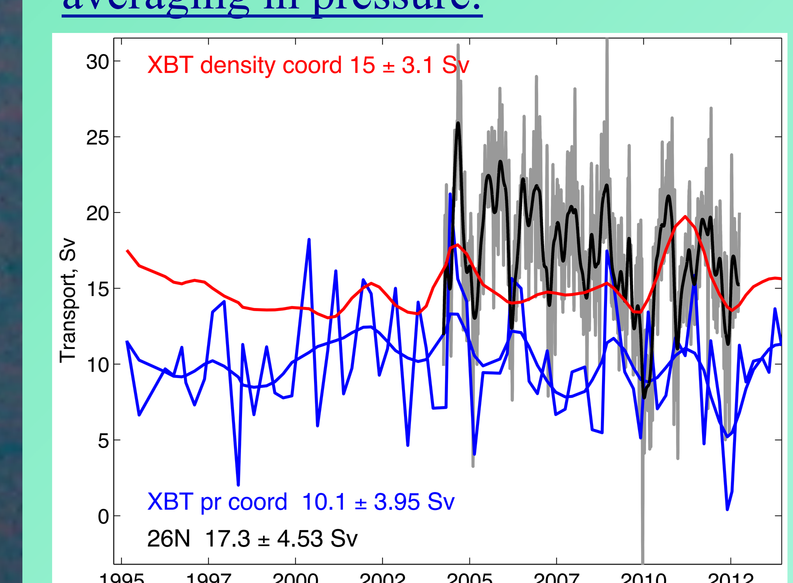
Seasonal Variability and Density Coordinates

Insignificant seasonal variability in MHT and MOC



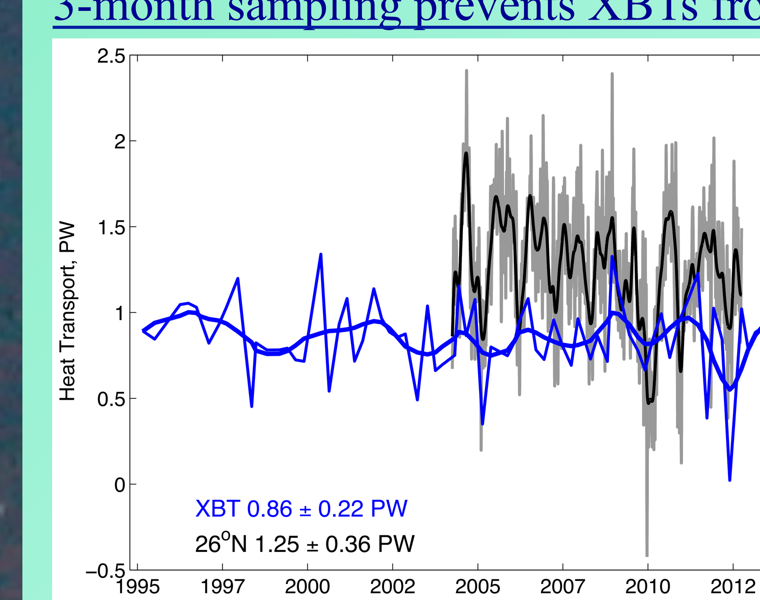
With only 2004-2014 data, the MHT had a seasonal cycle similar to 26°N results (amplitude of 0.3 PW, summertime maximum).

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).

3-month sampling prevents XBTs from resolving MOC/MHT events.



- 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