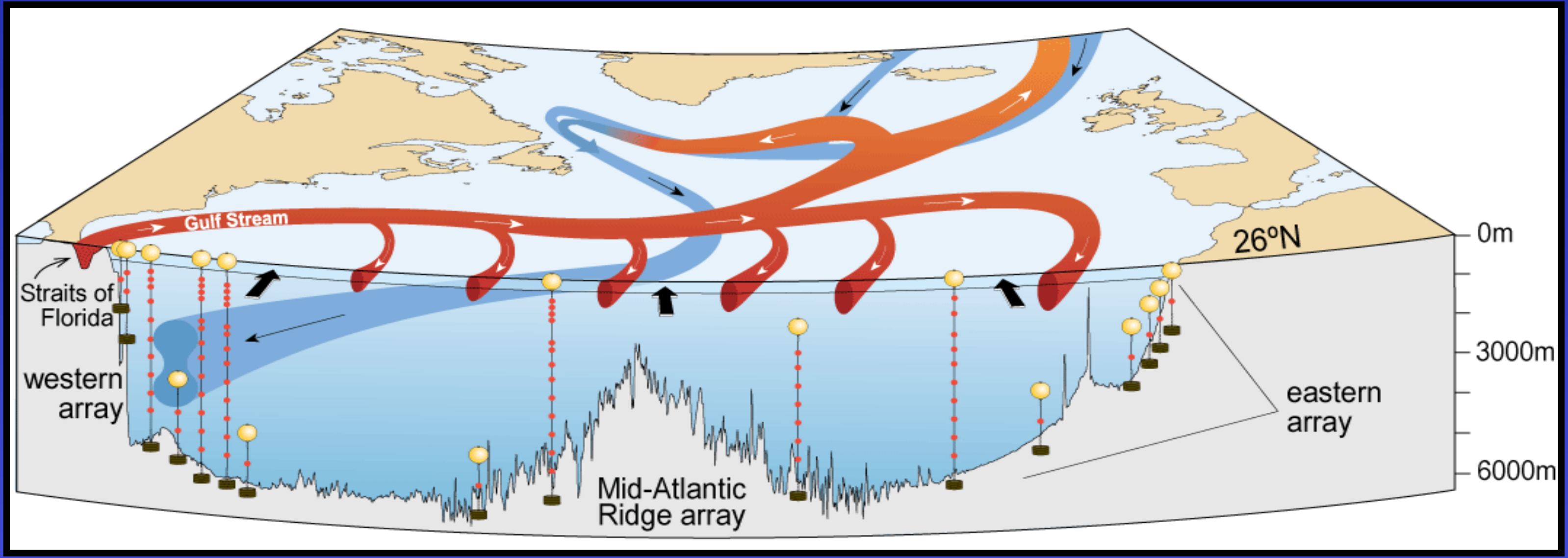
A decade of Atlantic Ocean Heat Transport estimates from the RAPID-MOCHA Array

B. Johns[1], J. Zhao[1], G. McCarthy[2], D. Smeed[2], C. Meinen[3], M. Baringer[3], E. Frajka-Williams[2], D. Rayner[2], E. McDonagh[2], and B. King[2]

[1]RSMAS, University of Miami, Miami FL
[2]National Oceanography Centre, Southampton U.K.
[3]NOAA/AOML, Miami FL



Estimating heat transport from the array

Meridional Heat Transport: $Q_{net} = \iint \rho c_p \, v\theta \, dx \, dz$

$$Q_{net} = Q_{FC} + Q_{EK} + Q_{WB} + Q_{INT} + Q_{EDDY}$$

$Q_{FC} \rightarrow$ Cable transport $*$ Seasonally varying flow-weighted FC temperature (updated from Shoosmith et al., 2005)

$Q_{EK} \rightarrow$ CCMP/ERA wind stresses $*$ Argo Ekman layer temperature

$Q_{WB} \rightarrow$ Directly calculated from moored current meters/thermistors in Abaco western boundary array

$Q_{INT} \rightarrow$ Zonally-averaged interior transport profile from endpoint geostrophic moorings $*$ Zonally-averaged interior ocean temperature (Argo in top 2000 m merged with seasonal Hydrobase climatology below 2000 m)

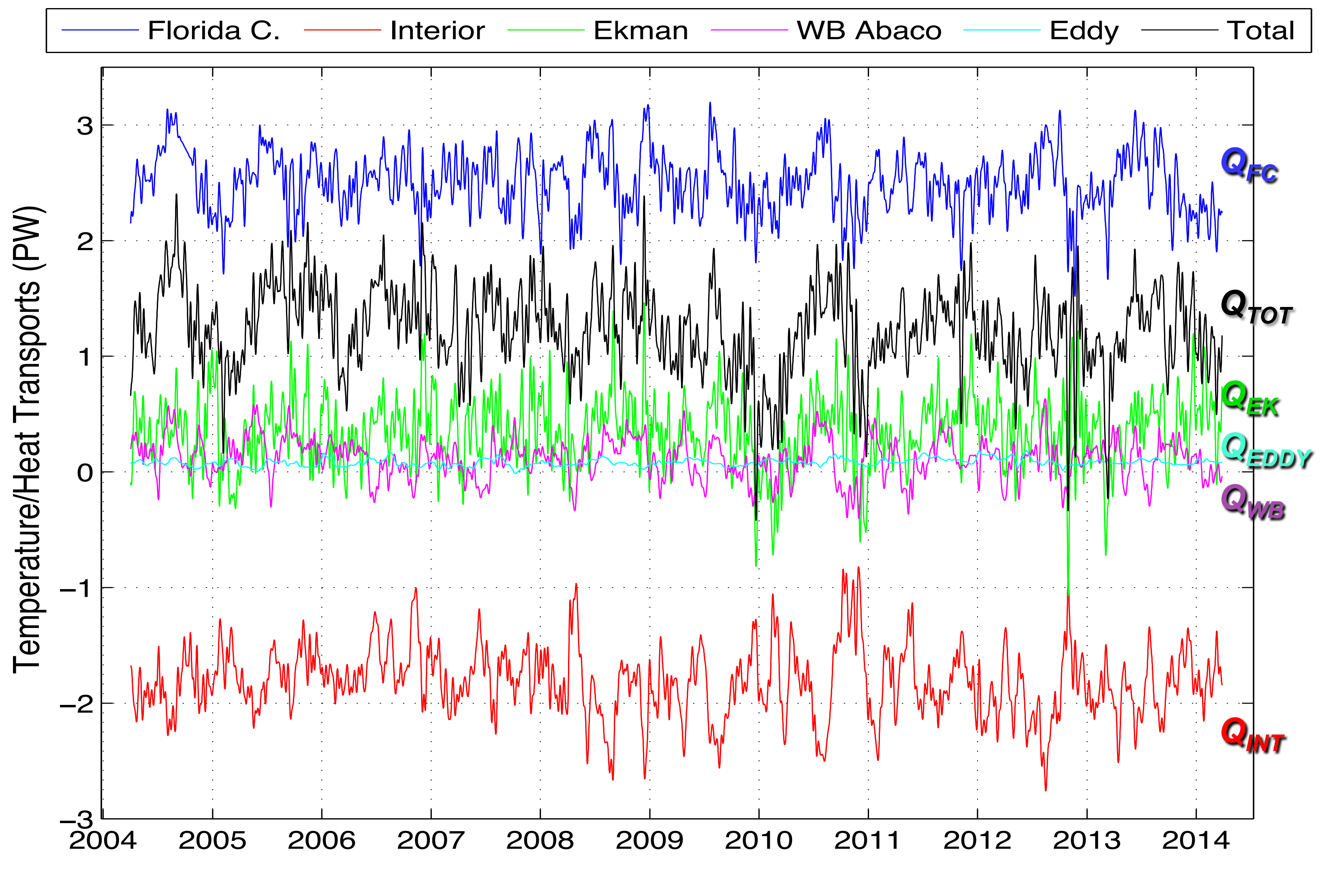
$Q_{EDDY} \rightarrow$ Contribution due to spatially correlated v,T variability across the interior (from Argo) $Q_{EDDY} = \iint \rho c_p \, v'\theta' \, dx \, dz$

Johns et al., J.Clim. (2011)

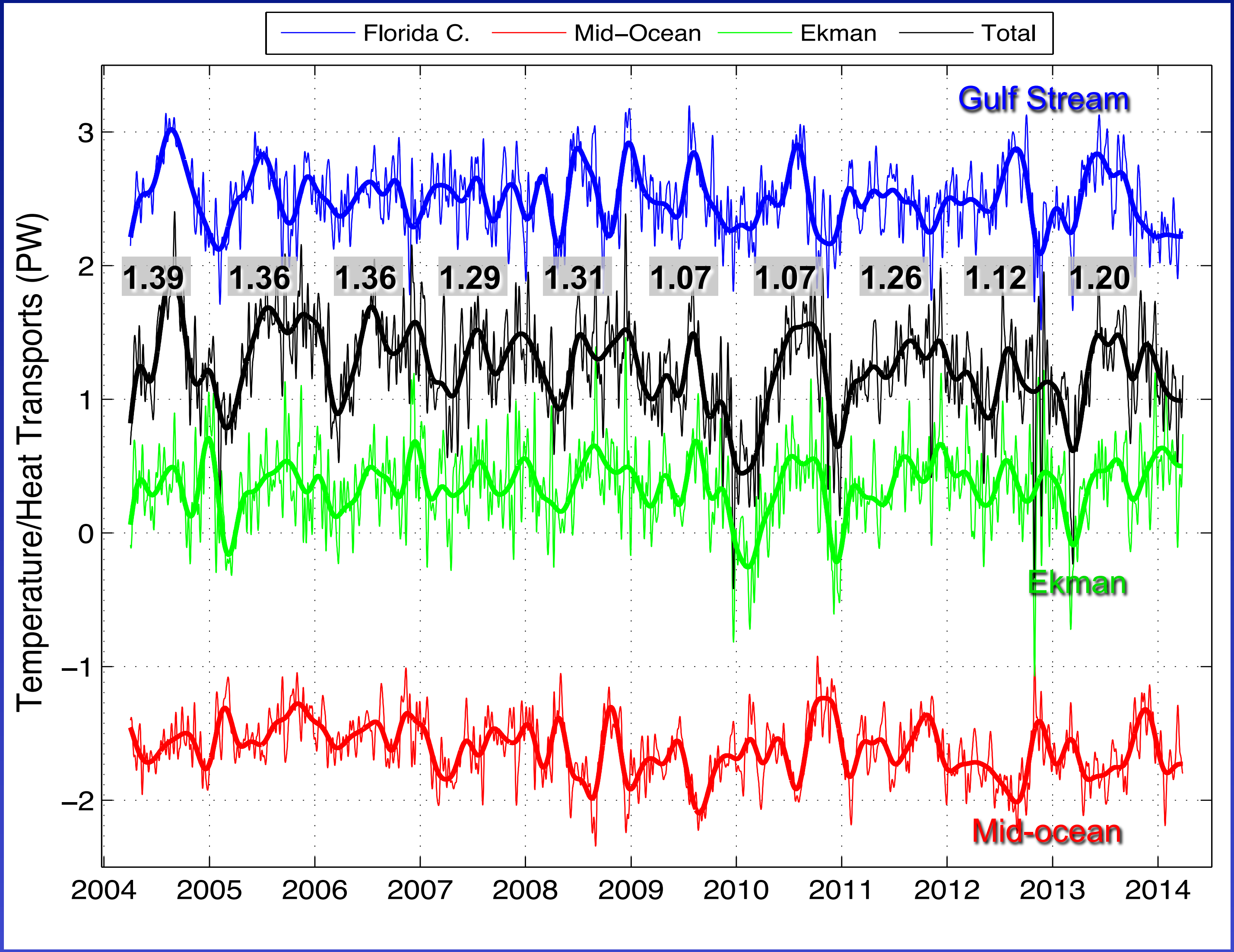
What's New?

1. *Weekly Argo/Rapid OI for interior, used in:*
   - Q_{INT} (replaces Hydrobase seasonal temperature climatology)
   - Q_{EDDY} (replaces estimate from historical sections and widely-spaced geostrophic moorings)
   - Q_{EK} (replaces Reynolds SST)
2. *Updated Florida Current seasonal flow-weighted temperature (more sections)*
3. *Other improvements (McCarthy et al. 2014, Prog. Oceanogr.)*
   - better surface extrapolation of interior geostrophic velocities
   - TEOS-10 equation of state

Meridional Heat Transport and Components



Low-frequency Variability of Gulf Stream, Ekman, Mid-ocean, and total Heat Transport

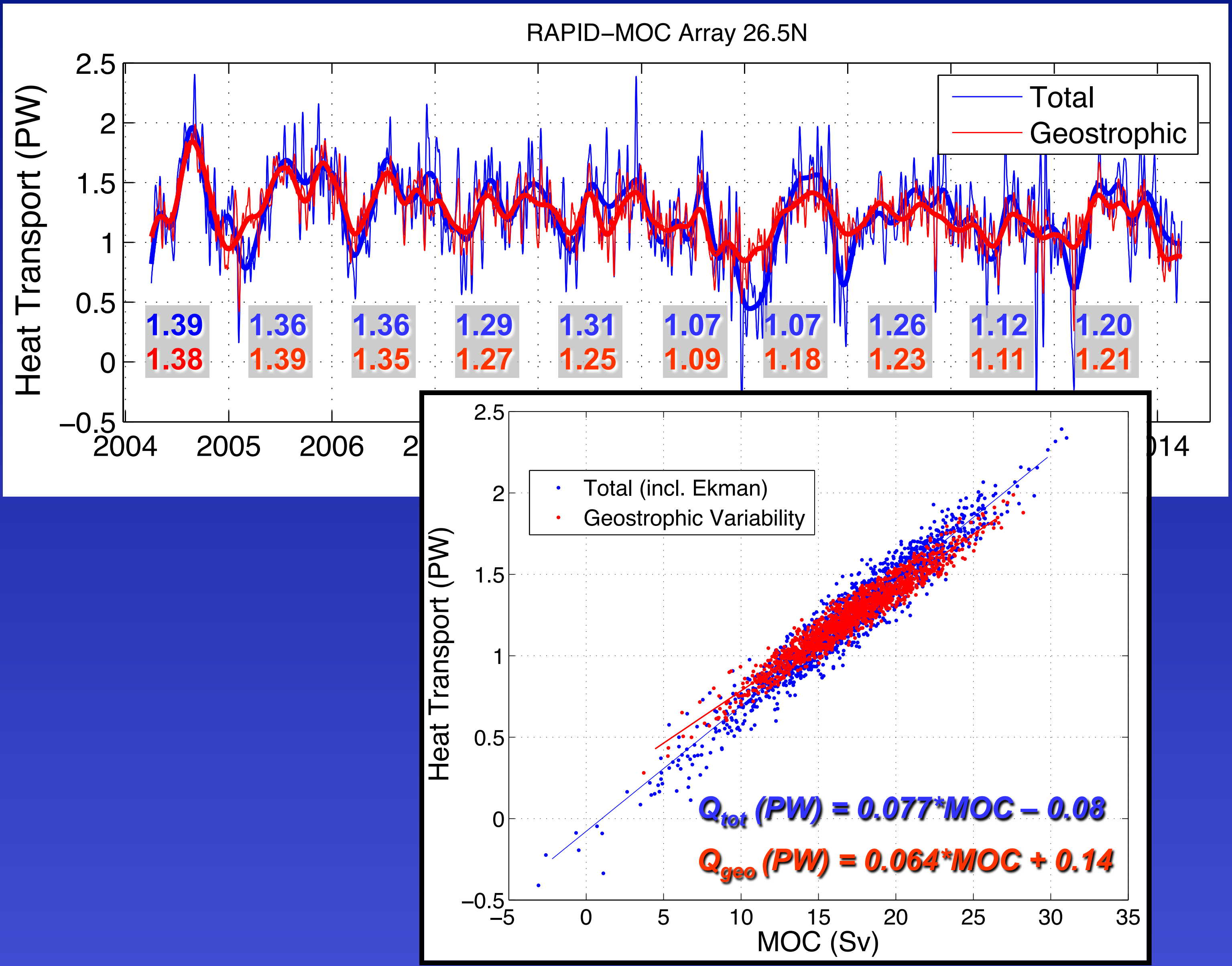


2004-2013 mean heat transport: *1.24 PW*

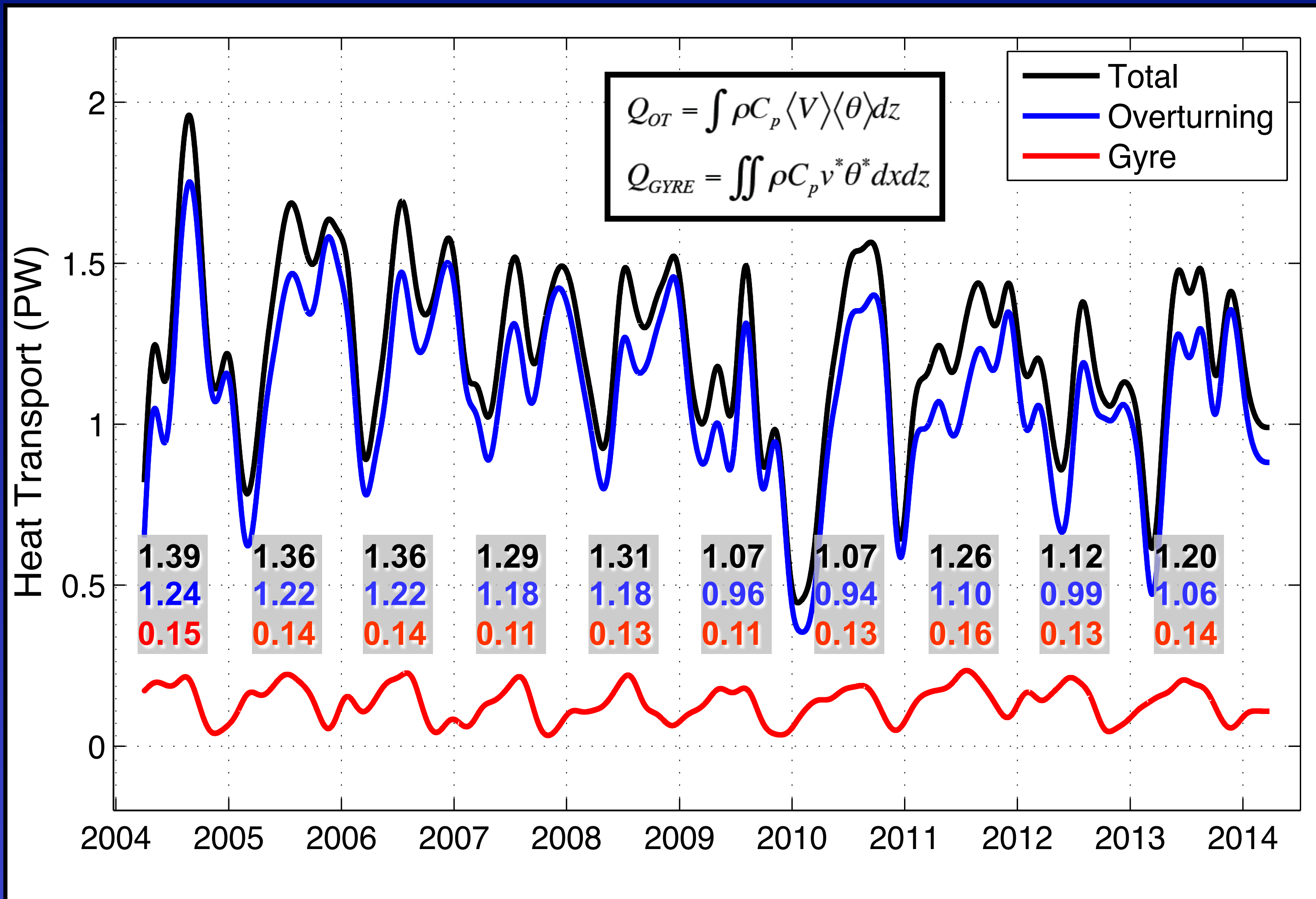
5-yr means:

2004-2008 *1.34±0.04 PW*
2009-2013 *1.14±0.08 PW*

Geostrophic (non-Ekman) Heat Transport Variability



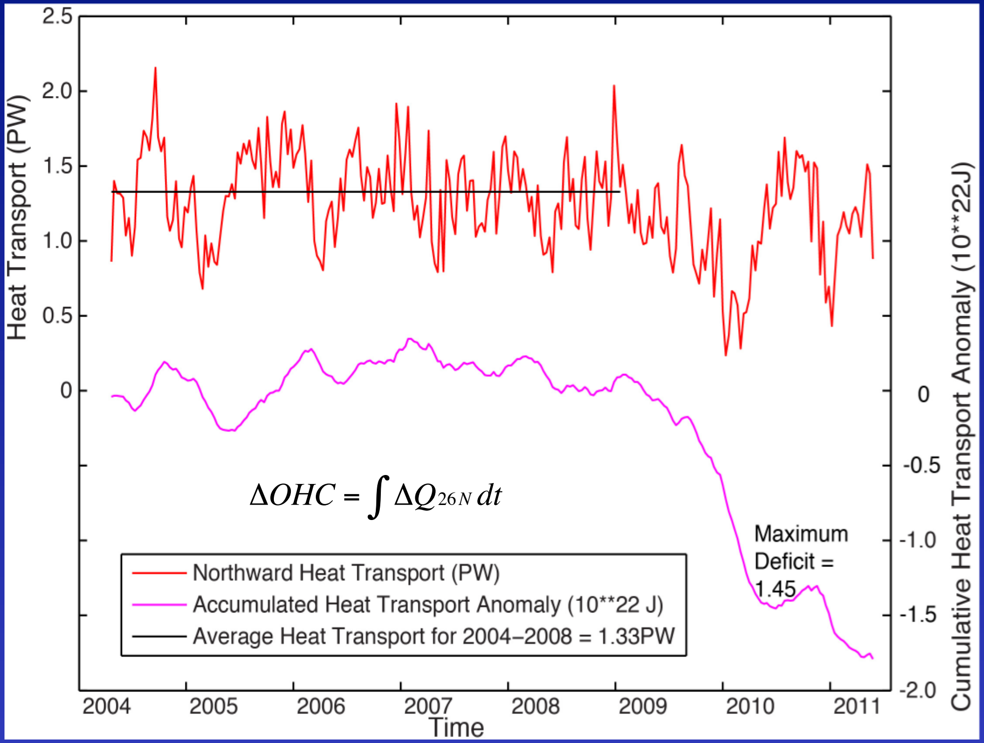
Overturning and Gyre Heat Transports

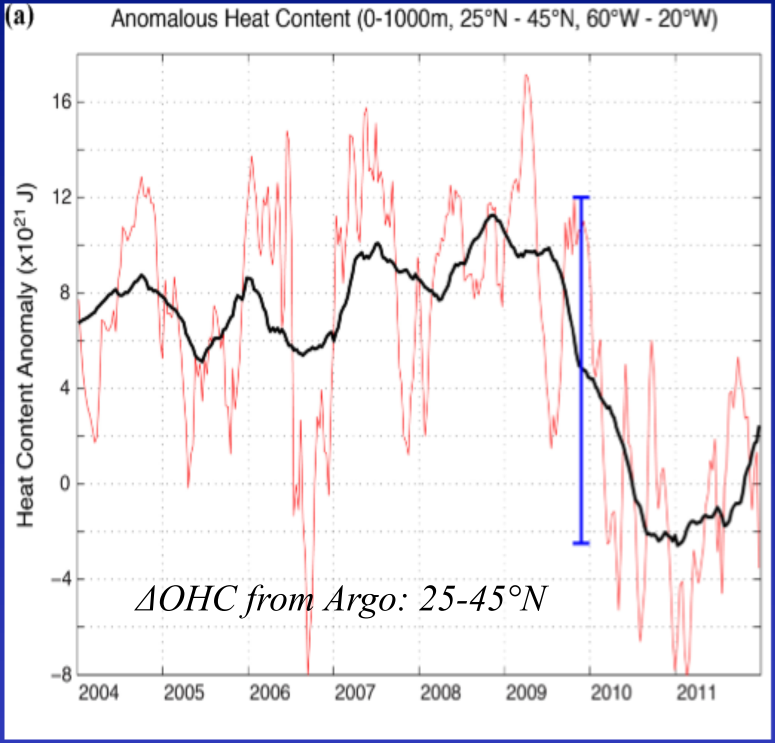


Mean Overturning HT = 1.11 PW

Mean Gyre HT = 0.13 PW

What are the impacts of these heat transport changes?





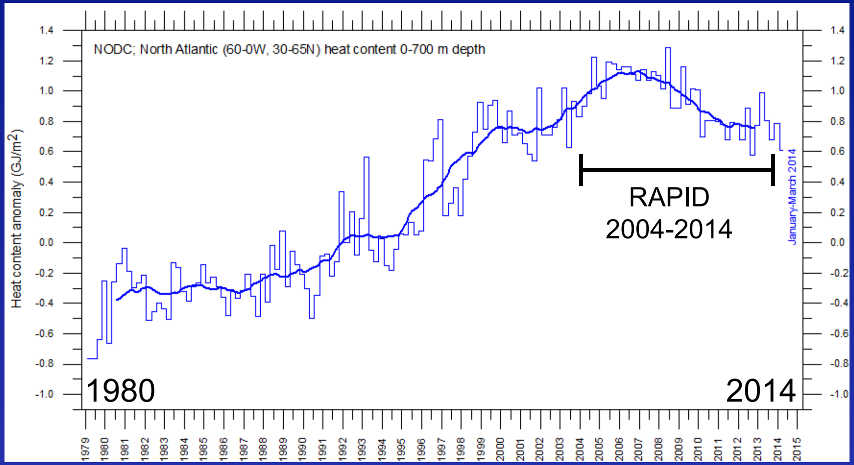
Bryden et al. (2014)

⇒ *Significant cooling occurred in the N. Atlantic following the heat transport reduction in 2009*

⇒ *A decrease in heat transport of 0.2 PW is equivalent to a 7 W/m^2 change in surface heat flux over the entire Atlantic north of 26°N.*

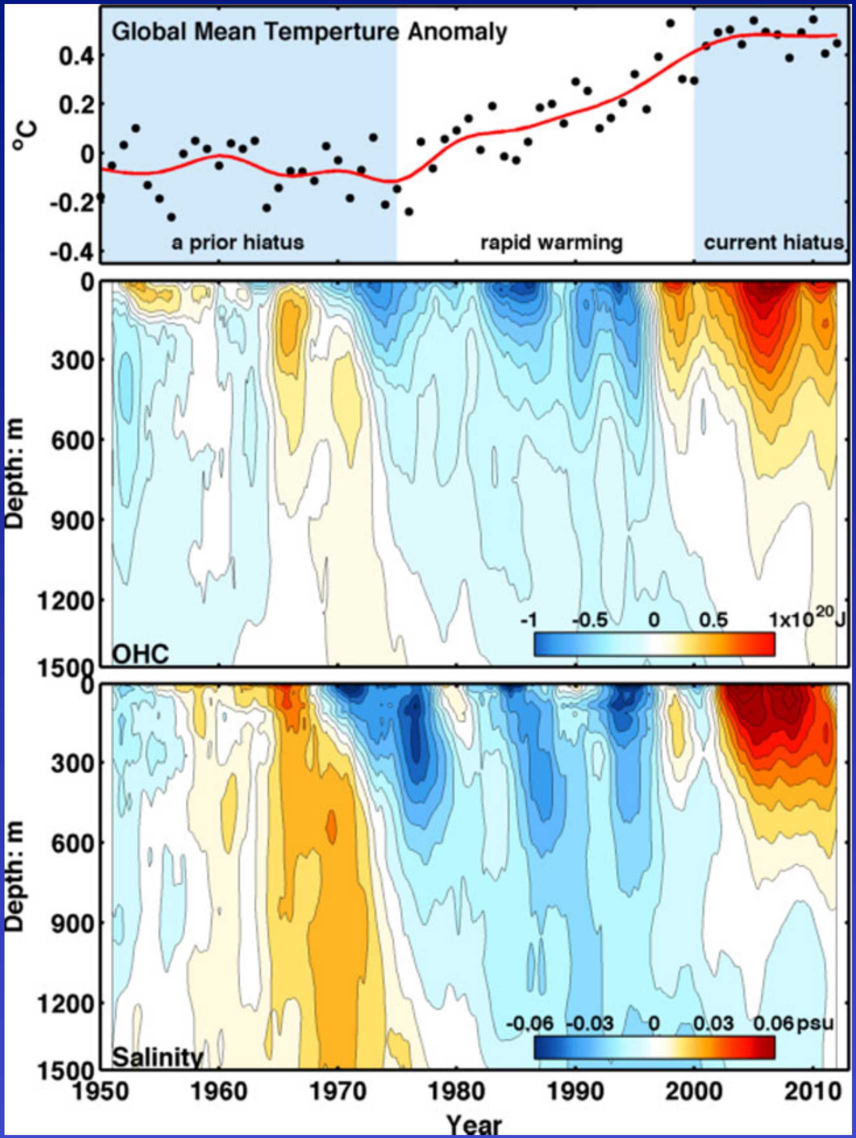
A longer term perspective on N. Atlantic heat storage

North Atlantic heat content (30-65°N; 0-700m)
http://www.nodc.noaa.gov



⇒ *Heat content in the N. Atlantic peaked during the first half of the RAPID period*

⇒ *The N. Atlantic may have contributed to net global ocean heat storage during the initial phase of the global warming "hiatus" (Chen and Tung, 2014)*



Chen and Tung (2014)

Summary

- The northward heat transport across 26.5°N has decreased during the RAPID-MOCHA observation period. The last 5 years show a reduction of 0.2 PW from the first 5 years.
- Interannual HT variability is dominated by the geostrophic circulation, and mostly by the mid-ocean HT. Both Ekman and Gulf Stream variability contribute to "extreme" events (including short-term HT reversals).
- Ocean heat content in the N. Atlantic has decreased since 2008, coinciding with the drop in HT across 26.5°N. The magnitude and timing of the OHC change is consistent with the observed HT reduction, suggesting surface cooling is playing a lesser (but possibly complementary) role.
- Key questions:

  - How do these heat transport anomalies move/spread into the N. Atlantic?
  - On what time scale?
  - What are the associated OHC tendencies resulting from ocean heat advection/divergence?
  - What OHC patterns are set up?

-> Data is available online! *http://www.rsmas.miami.edu/users/mocha/*