Interannual Variability of the AMOC and Ocean Heat Transport at 26.5°N observed by RAPID-MOCHA Array

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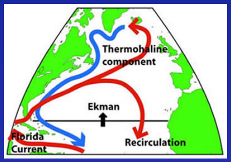
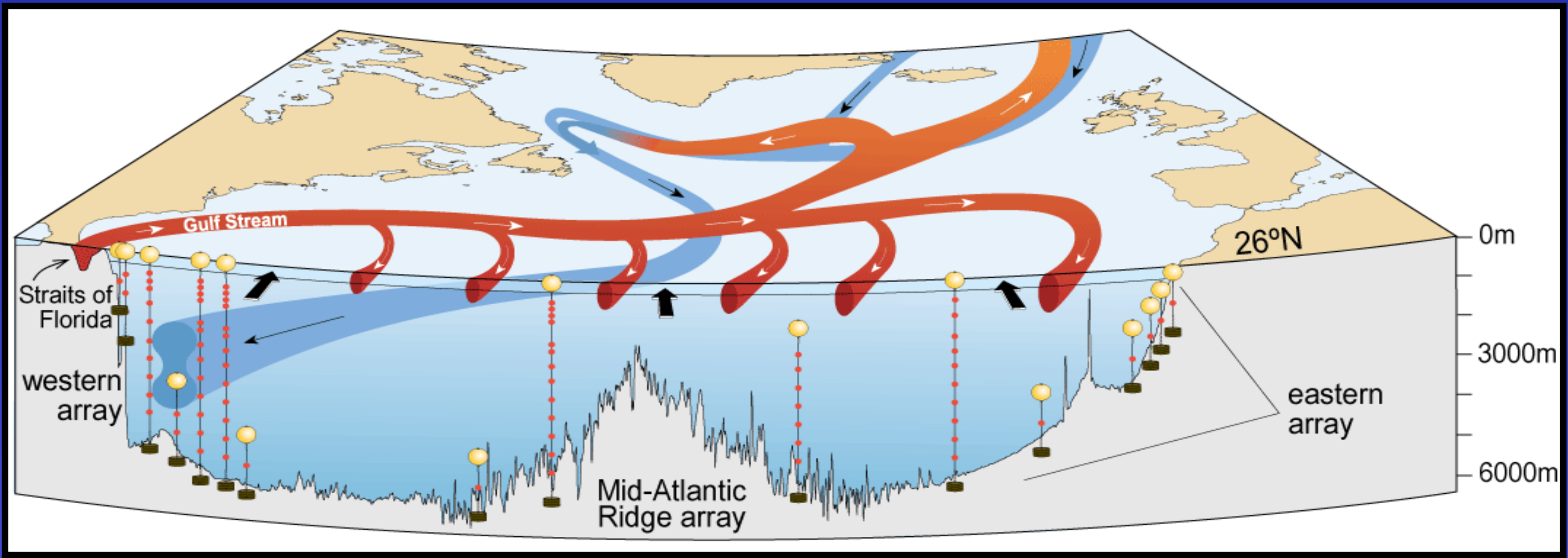
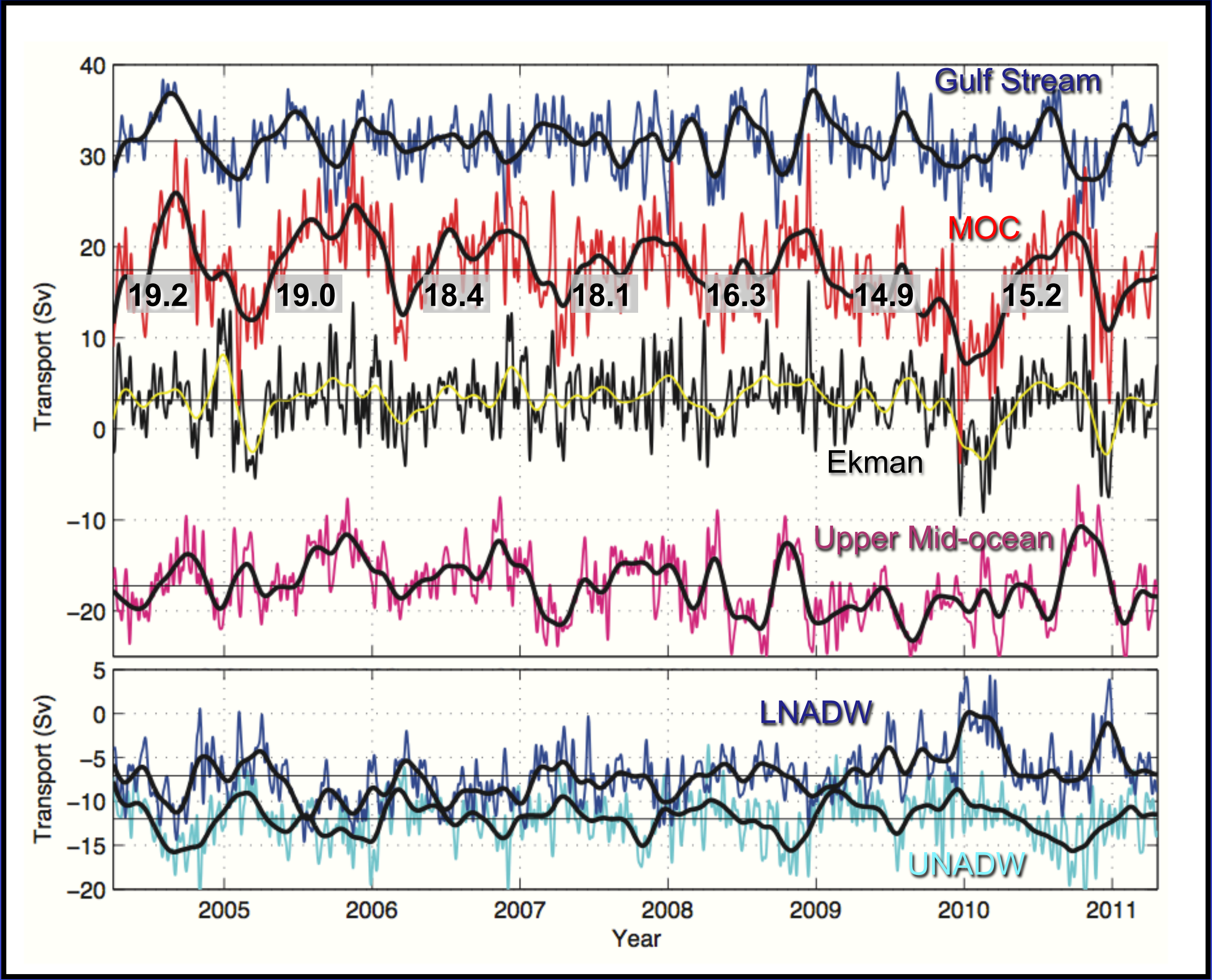




MOC and Transport Components

Upper Limb



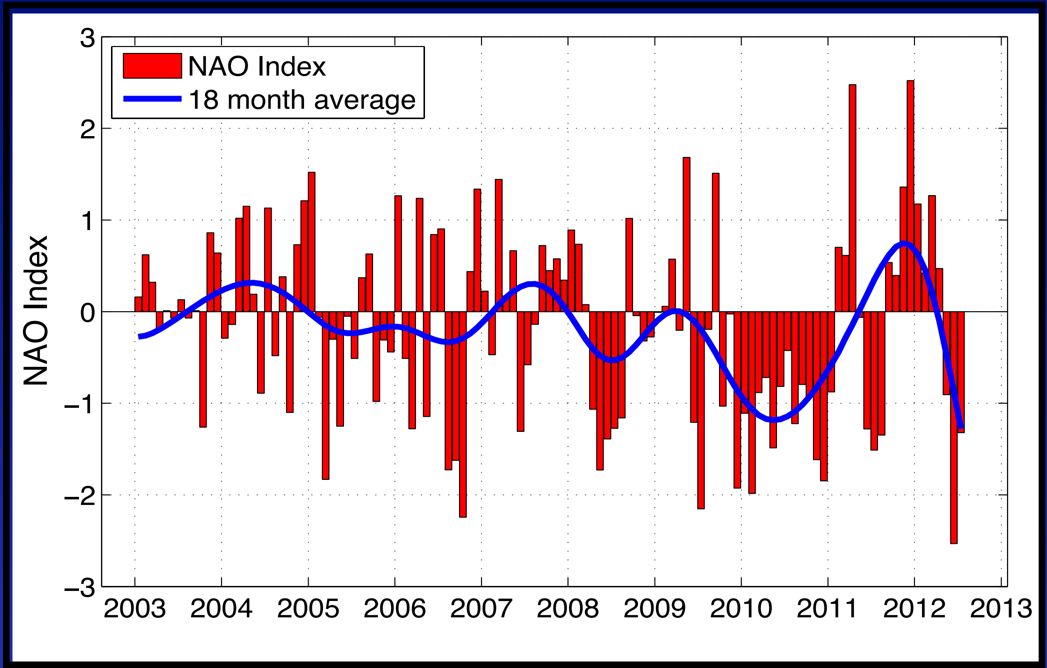
Lower Limb

2004-2011 mean MOC strength: 17.5 Sv

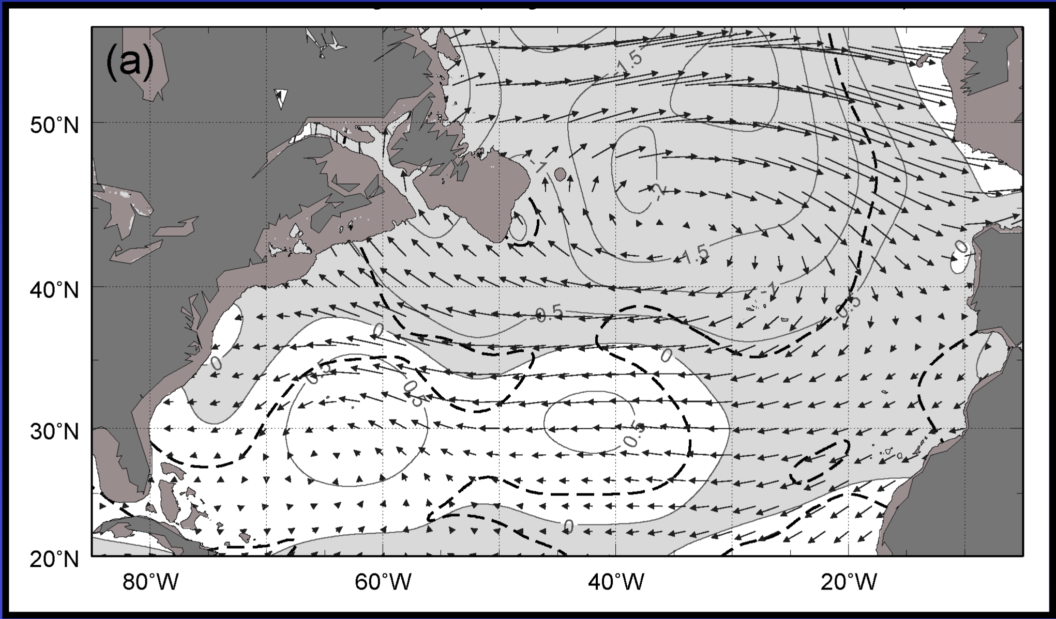
McCarthy et al. (2012), submitted to GRL

NAO Forcing

NAO Index shows a strong negative anomaly in 2009-2010



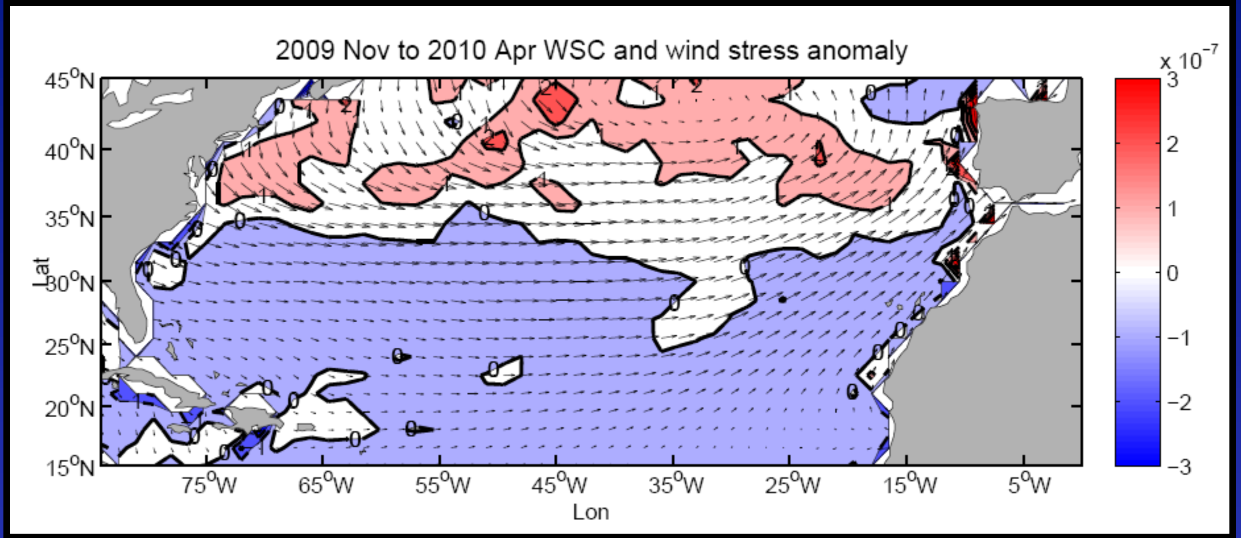
Regression of NCEP-NCAR winds onto a time series of the NAO index (DiNezio et al., 2009)



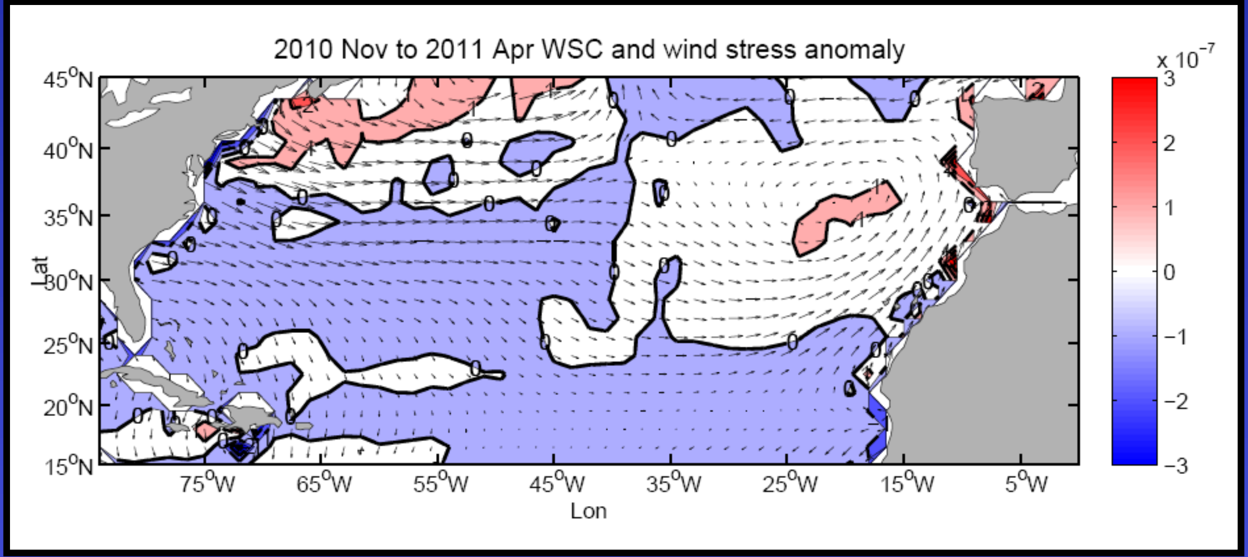
Wind stress anomalies in winter 2009-2010 and 2010-2011

NCEP wind stress and wind stress curl anomalies

Nov. 2009 – Apr. 2010



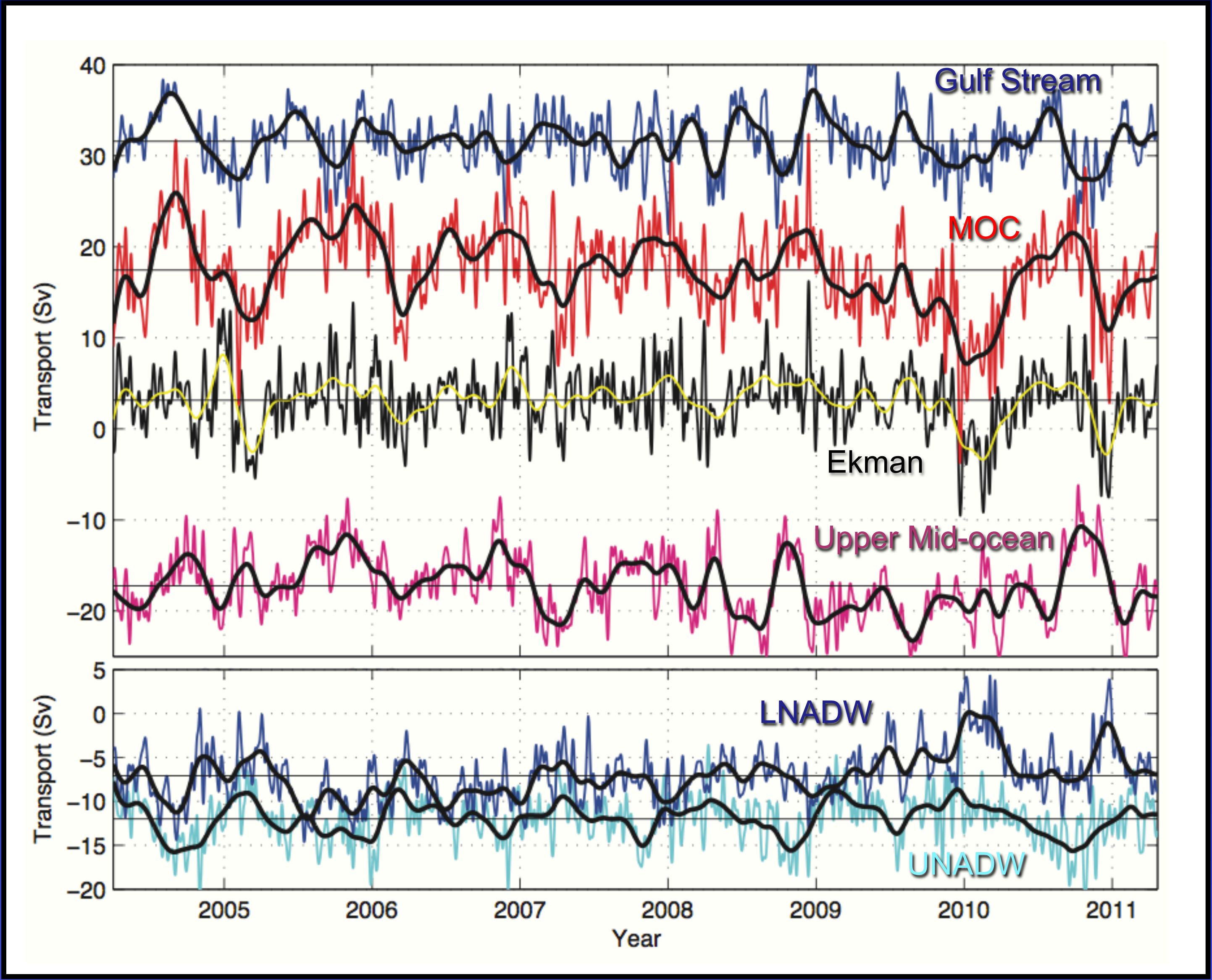
Nov. 2010 – Apr. 2011



MOC and Transport Components

Upper Limb

Lower Limb



2004-2011 mean MOC strength: 17.5 Sv

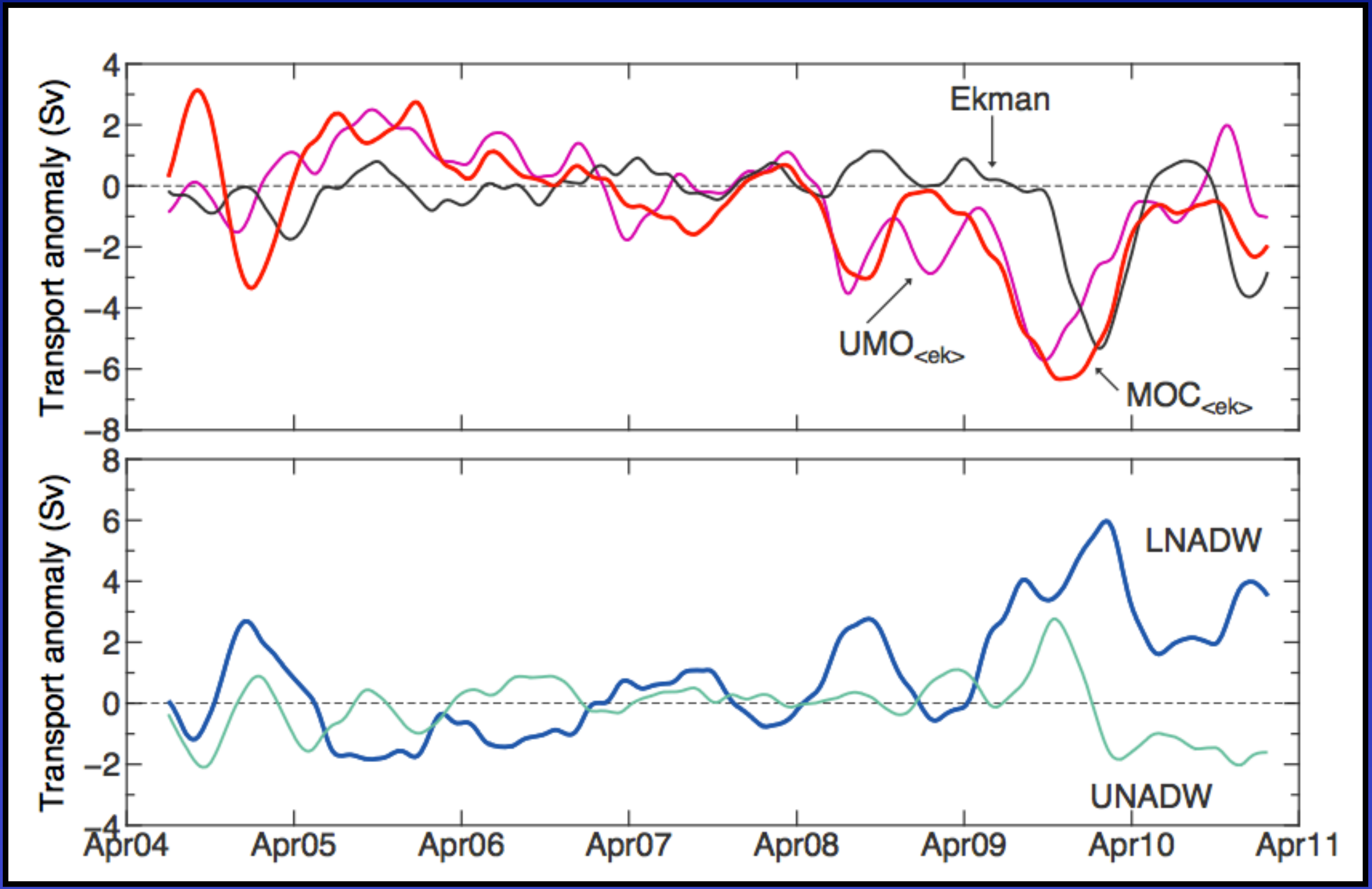
McCarthy et al. (2012), submitted to GRL

Interannual "Geostrophic" MOC variability

(Ekman transport response and mean seasonal cycle removed)

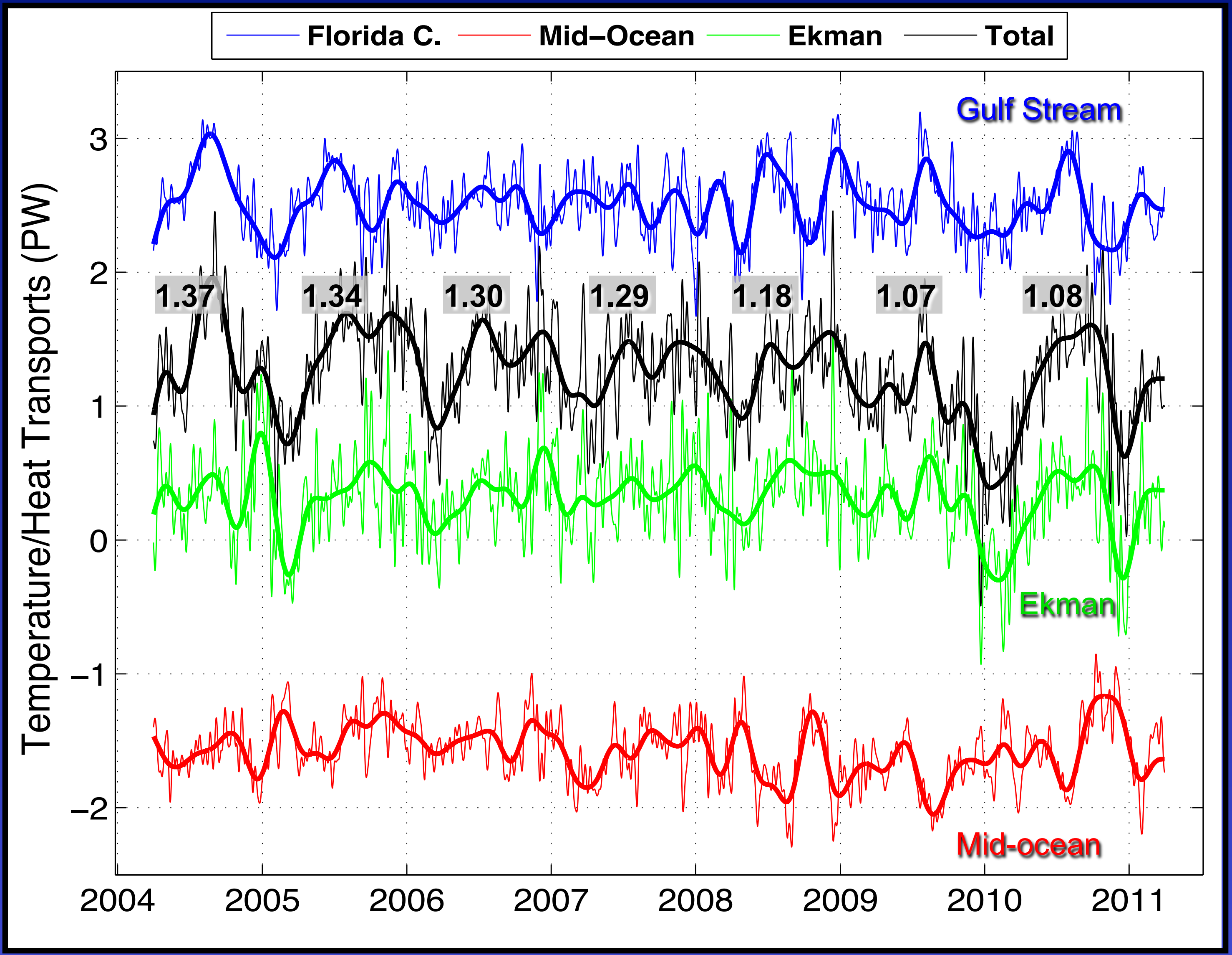
Upper Limb

Lower Limb



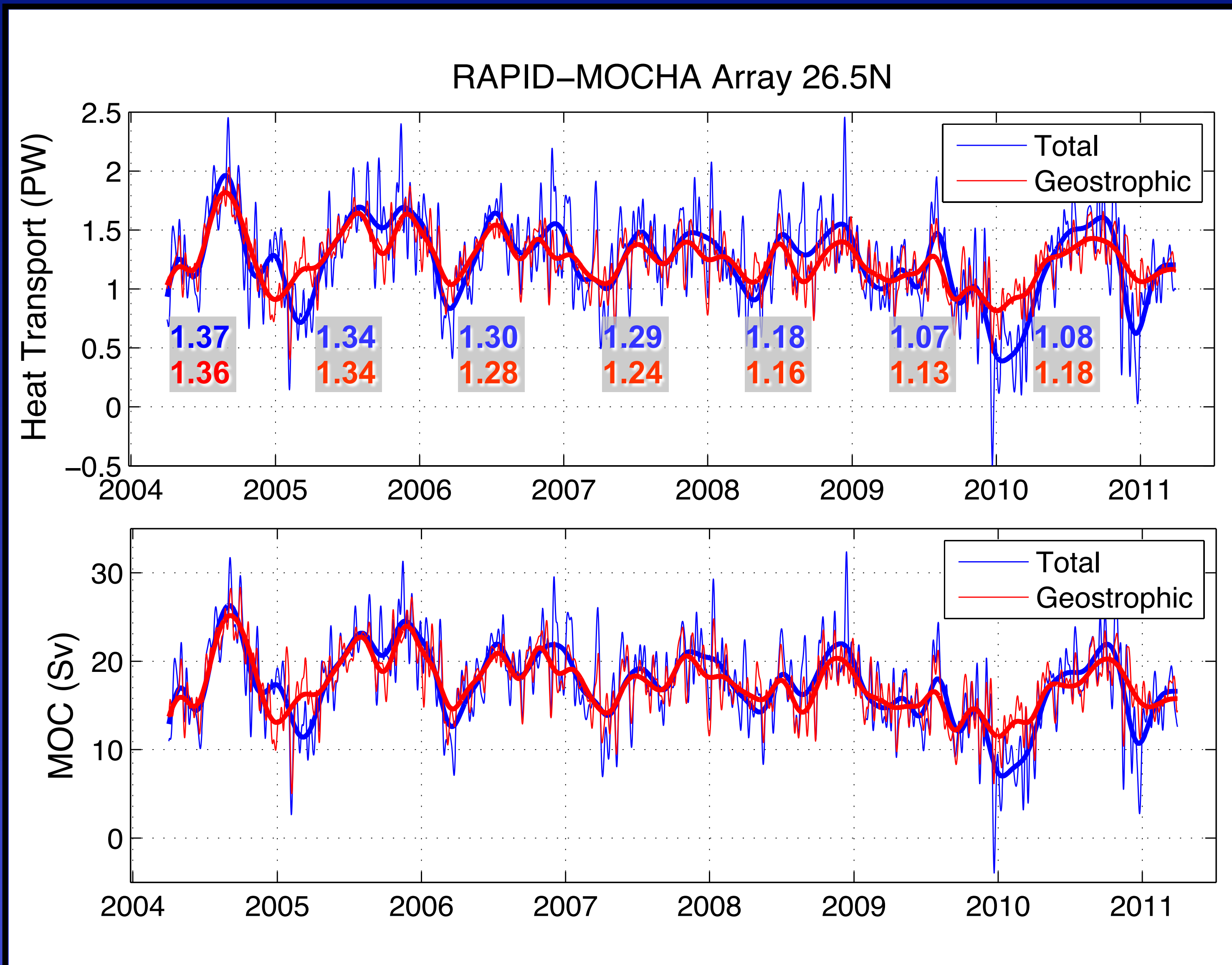
McCarthy et al. (2012), submitted to GRL

Meridional Heat Transport and Components

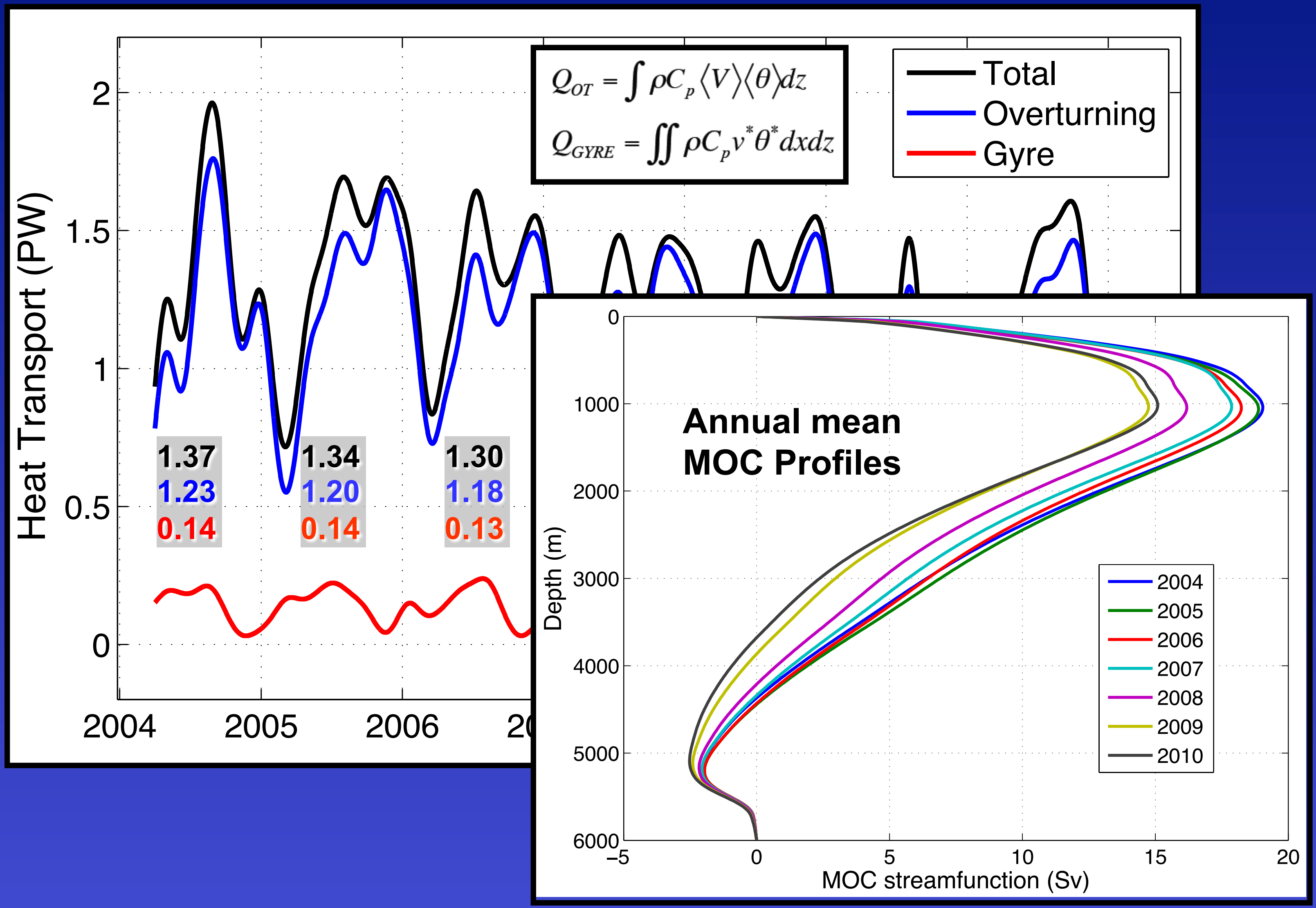


2004-2011 mean heat transport: 1.25 PW

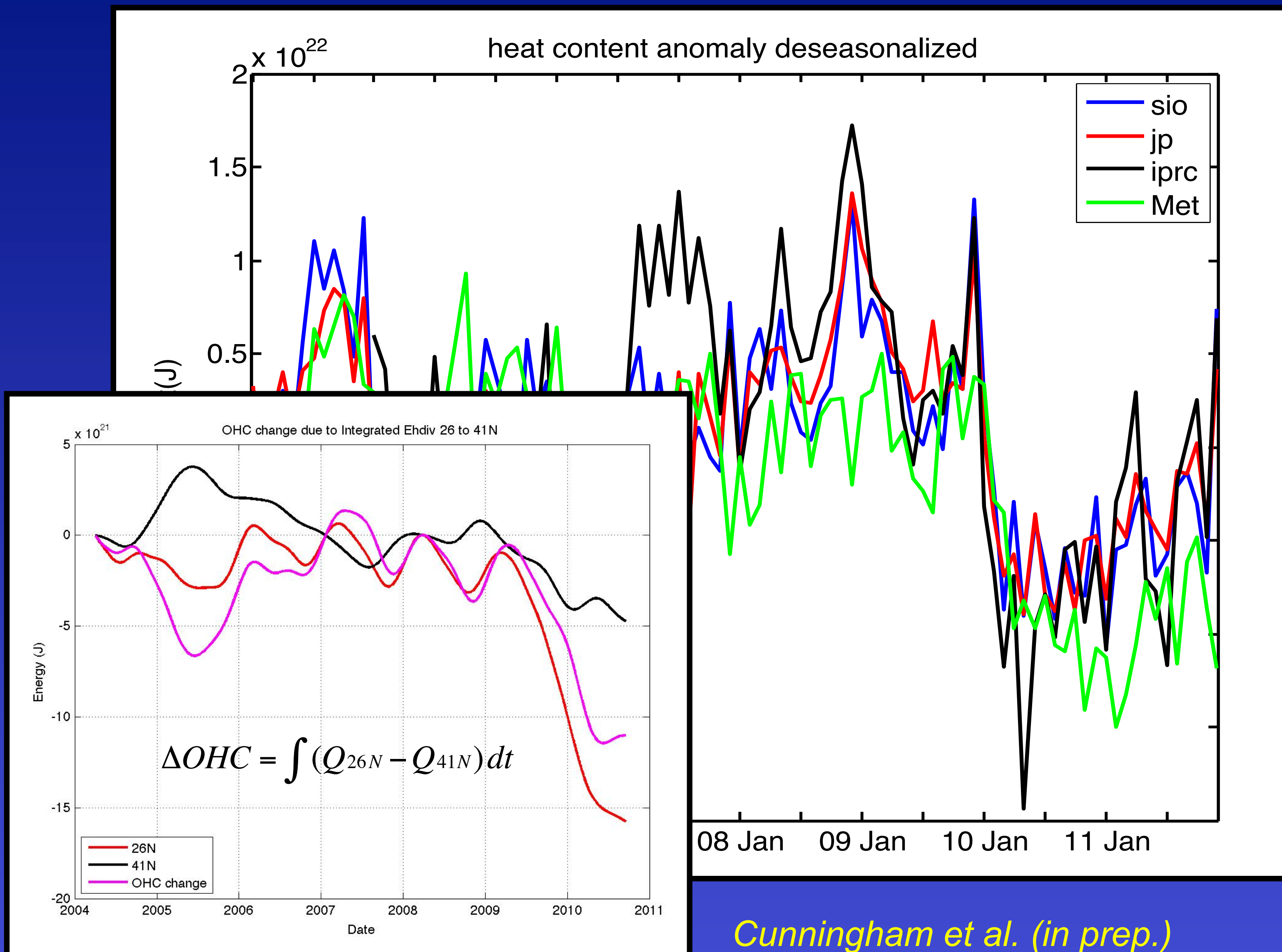
MOC and Heat Transport Variability



Overturning and Gyre Heat Transports



Ocean heat content changes in northern subtropics (26°N - 41°N)



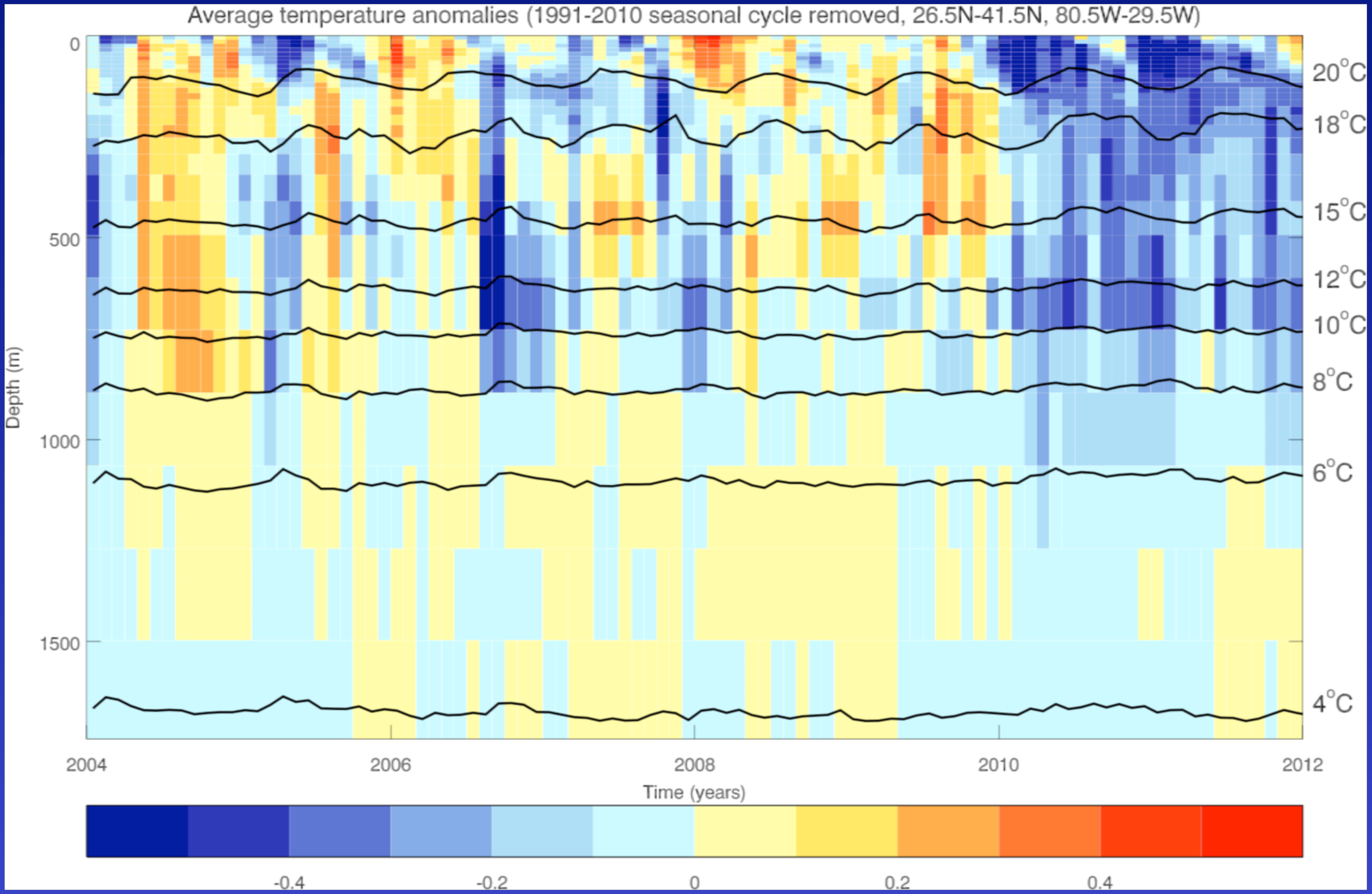
Cunningham et al. (in prep.)

Conclusions

- The 2004-2010 mean AMOC strength from the RAPID-MOCHA array is 17.5 Sv. The first four years (2004-2007) showed stable annual means of 18.7 ± 0.5 Sv while 2009-2010 show lower values of ~15.0 Sv.
- Reductions in Ekman transport associated with the extreme low NAO phase over the North Atlantic in 2009-2010 contribute to the weaker AMOC, but do not account for all of it. Changes in mid-ocean geostrophic transport also contribute significantly and actually precede the downturn in Ekman transports.
- The meridional heat transport shows a similar decline, from 1.33 ± 0.04 PW in 2004-2007 to approx. 1.1 PW in 2009-2010. Essentially all of this interannual variability is contained in the overturning heat transport component.
- Ocean heat content in the subtropical gyre north of the RAPID line shows a marked decrease in late 2009, coincident with the downturn in heat transport across 26.5°N. The heat transport divergence between 26.5°N and 41°N can approximately explain the magnitude and timing of this event.

-> Data is available online! MOC: *http://www.noc.soton.ac.uk/rapidmoc/*
Heat transport: *http://www.rsmas.miami.edu/users/mocha/*

Ocean Heat Content anomalies (26°N – 41°N)



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} → Cable transport • Seasonally varying flow-weighted FC temperature, (Shoosmith et al., 2005)

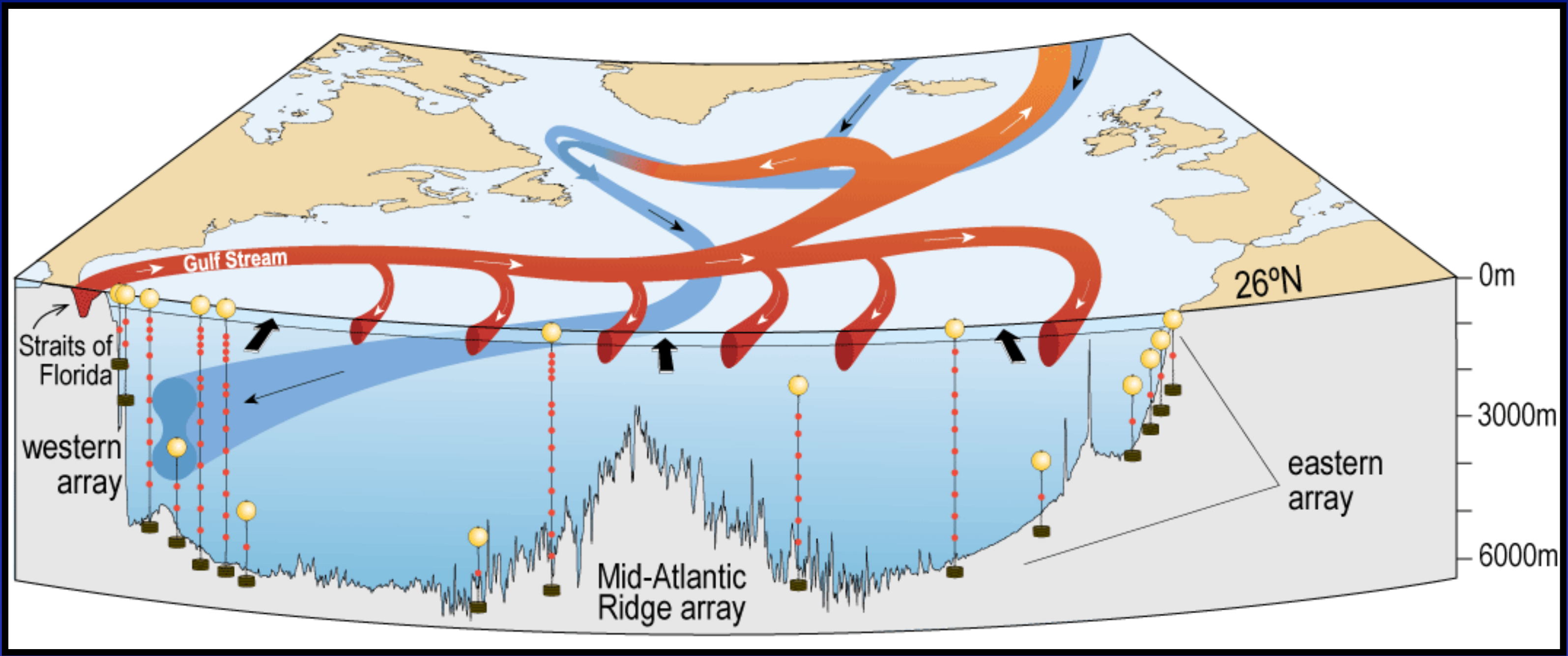
Q_{EK} → CCMP wind stresses • ARGO Ekman layer temperature

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

Q_{INT} → Zonally-averaged interior transport profile from endpoint geostrophic moorings • zonally averaged interior ocean temperature (ARGO in top 2000m merged with seasonal Hydrobase climatology below 2000 m)

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

The RAPID / MOCHA* Array



How it works:

- Gulf Stream : telephone cable
- Ekman : scatterometer
- Mid-ocean : density, current meters

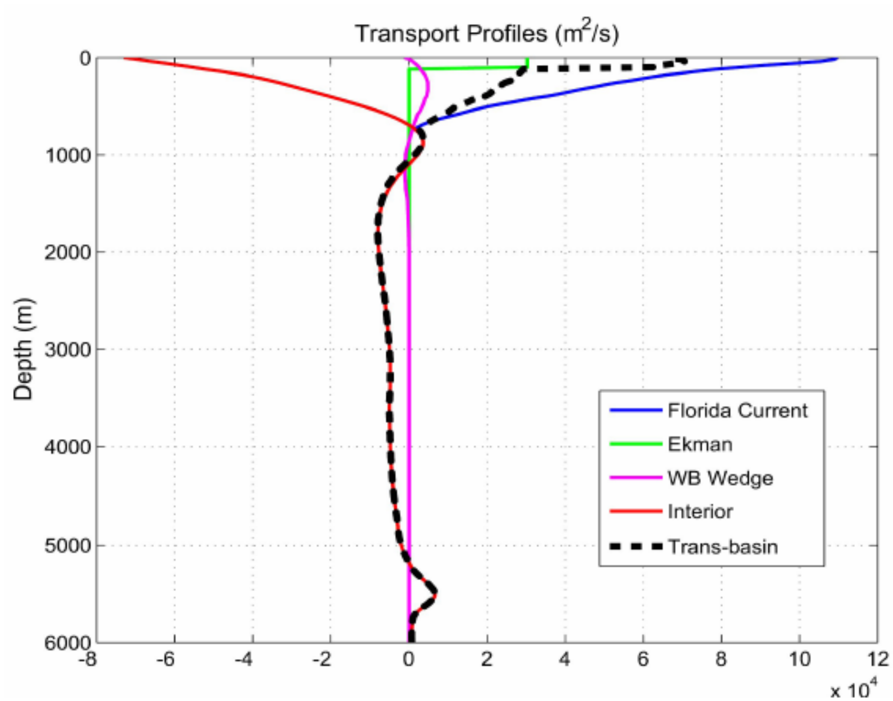
Why 26.5°N?

- Maximum heat transport
- History of measurements:
  - Florida Current
  - repeat hydro-sections

→ Funded through 2014 - will provide a 10 year time series (2004-2014)

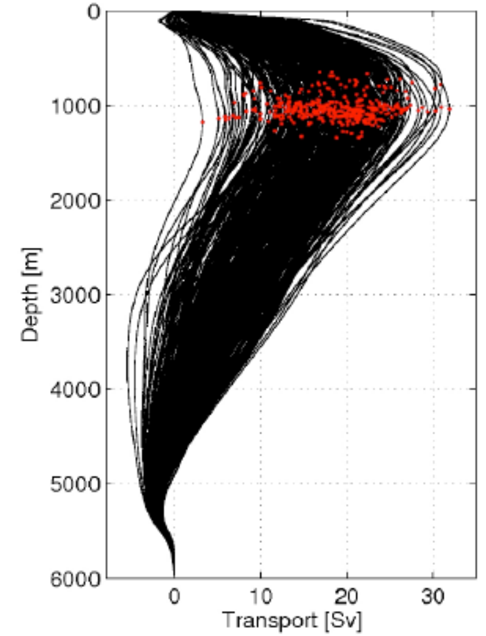
* NERC / UK RAPID Climate Change Programme
NSF / US Meridional Overturning Circulation and HeatFlux Array

Overturning stream function



$$T_{AMOC}(z) = T_{GS}(z) + T_{Ek}(z) + \left[T_{INT}(z) + T_{WBW}(z)\right] + T_{comp}(z)$$

$h_{\varphi_{MAX}} = 1025 \pm 125m$ red dots



$$\varphi_{MAX}(t) = \int_{h_{\varphi_{MAX}}}^{0} T_{AMOC}(z,t)\,dz$$

Methods: Cunningham et al. (2007)
Kanzow et al. (2007, 2010)

Remote effects from NAO-related buoyancy forcing in the subpolar gyre

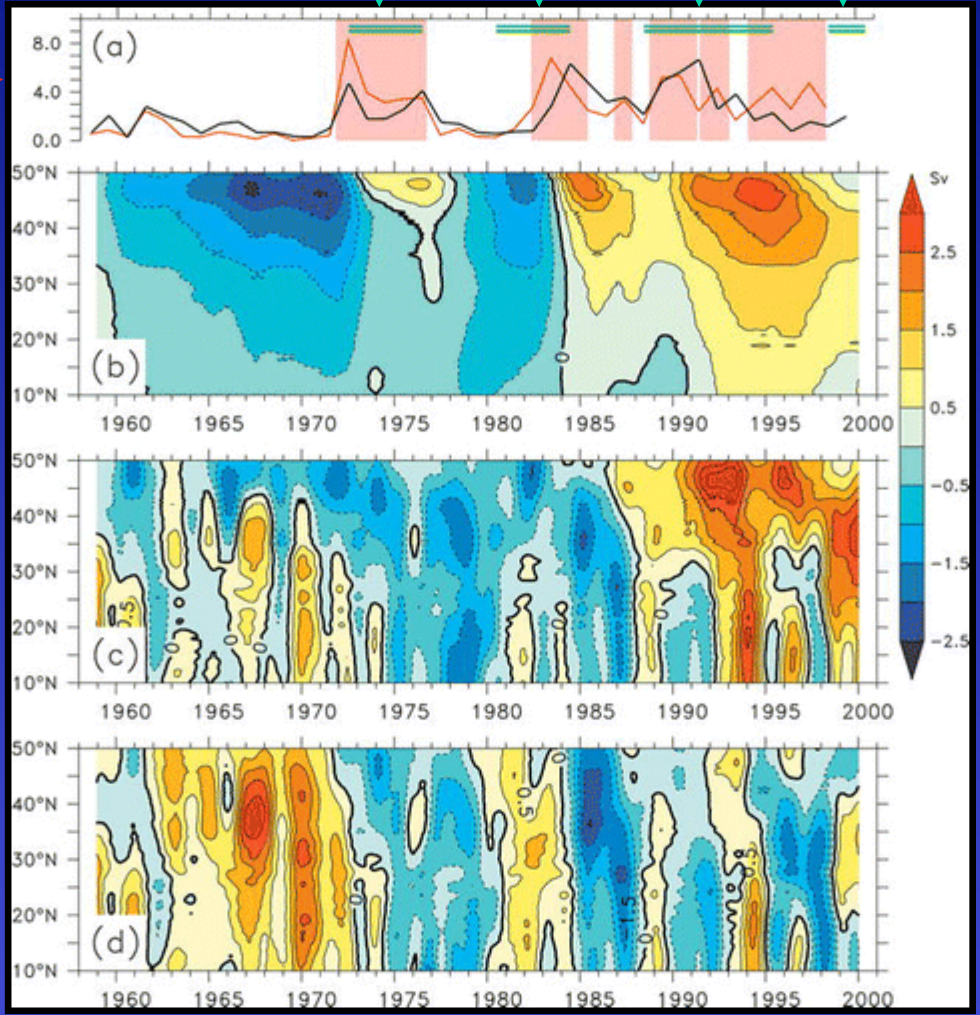
High NAO periods

Labrador Sea Water formation rate (black = wind and heat flux forcing; red = heat flux forcing only)

AMOC anomalies vs. latitude (heat flux forcing only)

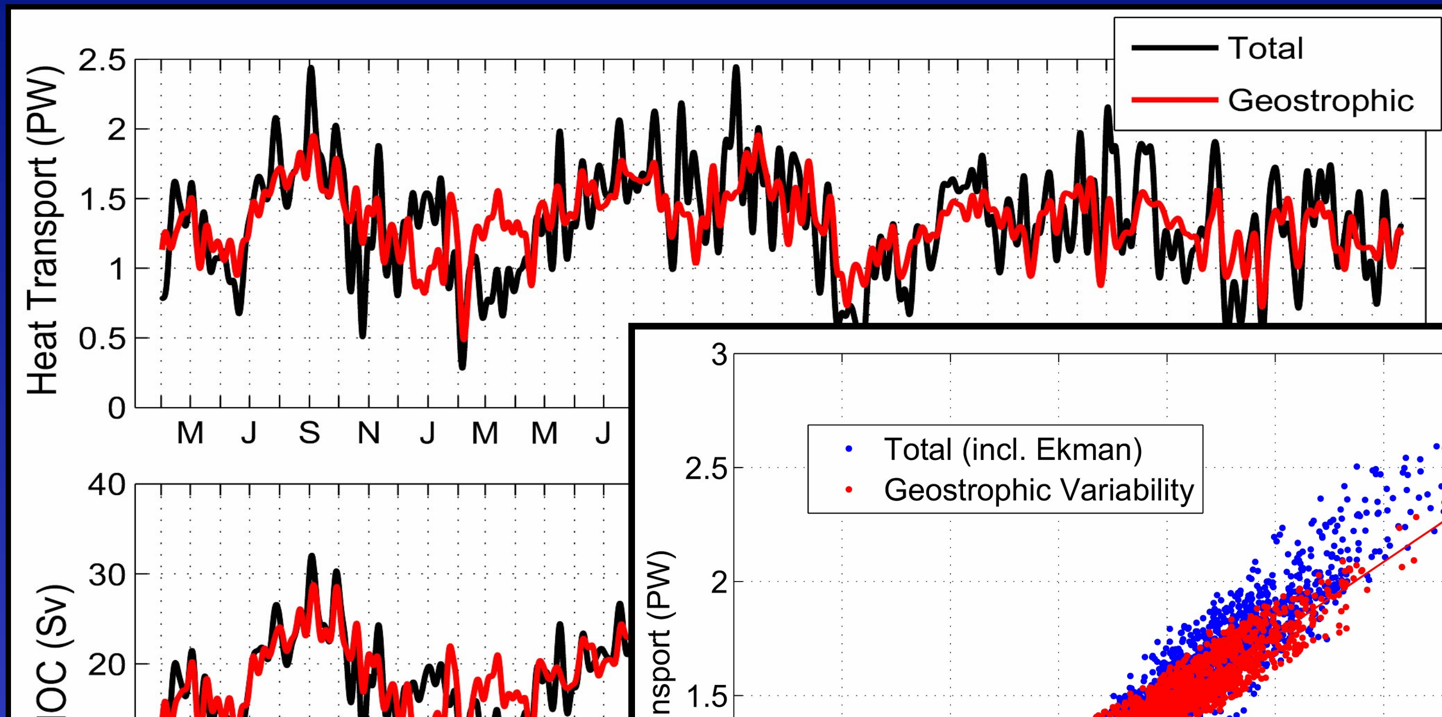
AMOC anomalies vs. latitude (wind and heat flux forcing)

Inferred AMOC variability due to wind stress forcing

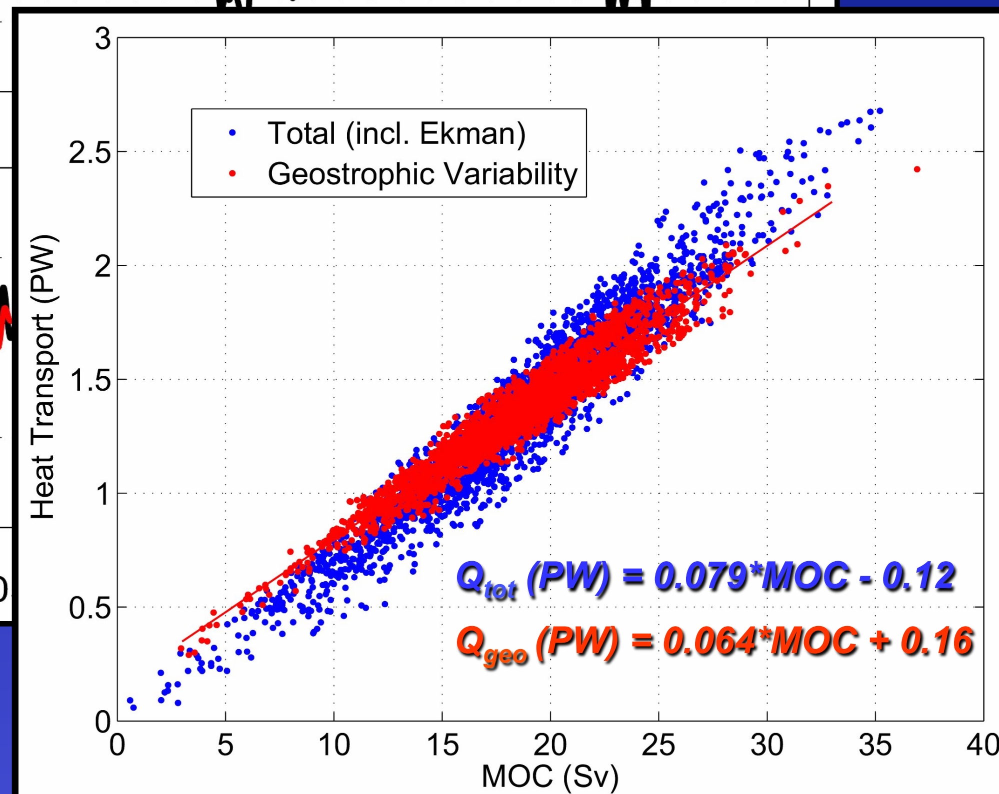


Biastoch et al. (2008)

Heat Transport and MOC Variability



Johns et al. (2011) J. Clim.



w/ Ekman