The Coherence and Impact of Meridional Heat Transport Anomalies in the Atlantic Ocean Inferred from Observations

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Box Model of Heat Budget

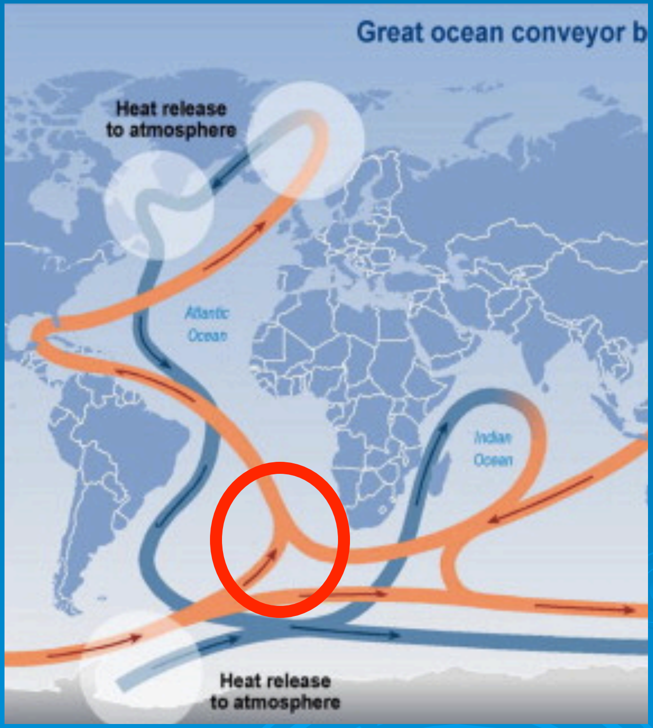
Goal: use observations to examine coherence and impact of meridional heat transport anomalies

- Heat budget with assimilation
- Infer heat transport
- Comparisons with RAPID/MOCHA
- Feedback onto air-sea fluxes

Conclusions

Heat budget from box model:

- MHT coherent from 30S-40N
- Model captures 2009-10 MHT anomaly from RAPID/MOCHA
- MHT anomalies “feed” subtropical heat losses
- MHT anomalies correlated with AAO => Southern Ocean origin



Model A: Equations

- Predict thermosteric sea level η_H
- Surface heat forcing Q_{net}
- Assimilation of thermosteric sea level TSL
- Heat transport convergence (HTC) as residual ("unknown control" version of Kalman filter)

Model A: Heat budget only (1993-2010)

$$\frac{\partial \eta_H}{\partial t} = \frac{\alpha Q_{net}}{\rho c_p} + HTC$$

$$\eta_H = TSL$$ (assimilation)

Model B Equations

- Add mass contribution to sea level η_M
- Surface freshwater fluxes P - E
- Assimilate SSH & equivalent water thickness EWT (GRACE, projected onto model EOFs, Chambers & Willis)
- Mass transport convergence (MTC) as residual

Model B: Add mass budget (2002-2010)

$$\frac{\partial \eta_M}{\partial t} = P - E + MTC$$

$$\eta_M = EWT$$

(assimilation)

$$\eta_M + \eta_H = SSH$$

Models A & B Comparison

- Model A: Heat budget only for 1993-2010
- Model B: Heat and mass budgets for 2002-2010

to get better temporal resolution

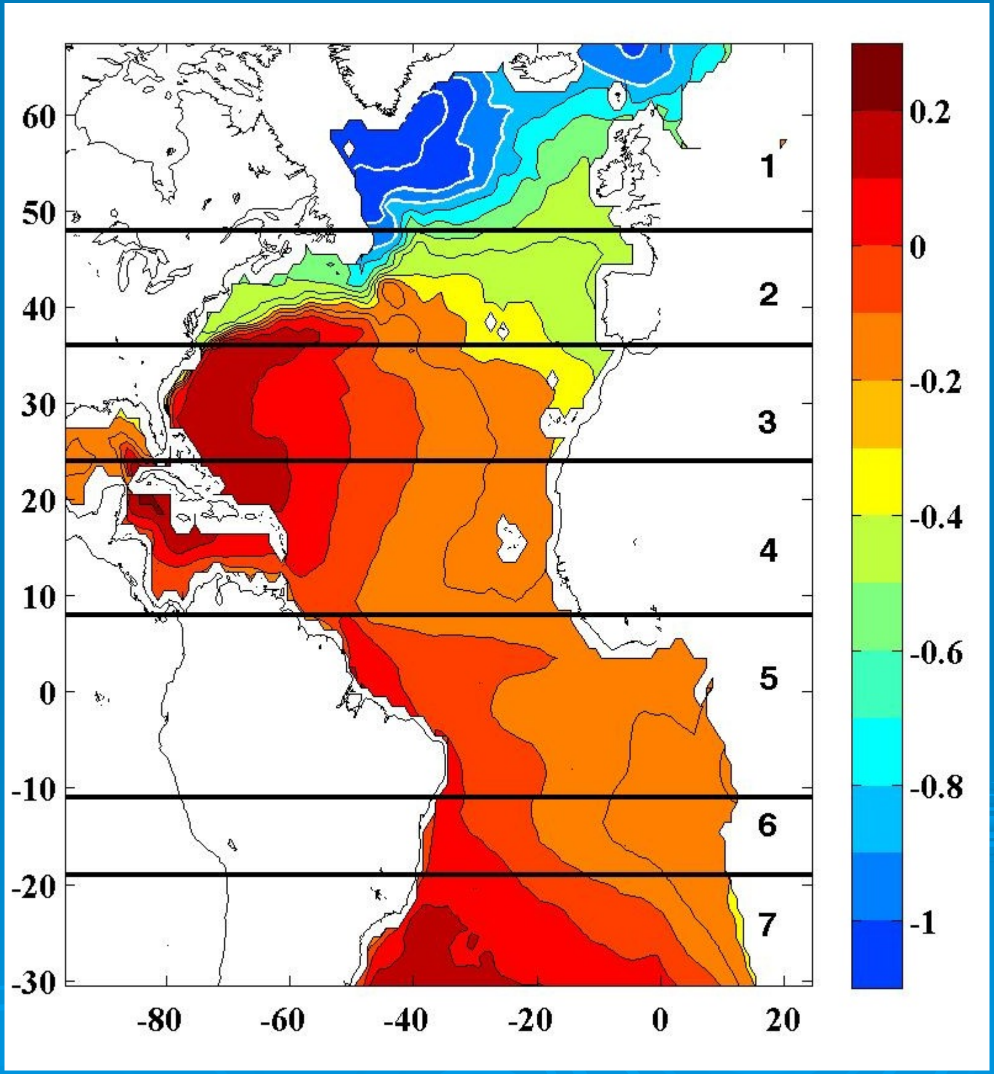
- Both models neglect salinity contributions to SSH

Surface forcing:

- OAFlux: turbulent and longwave fluxes
- ISCCP radiative fluxes
- GPCP precipitation & OAFlux evaporation

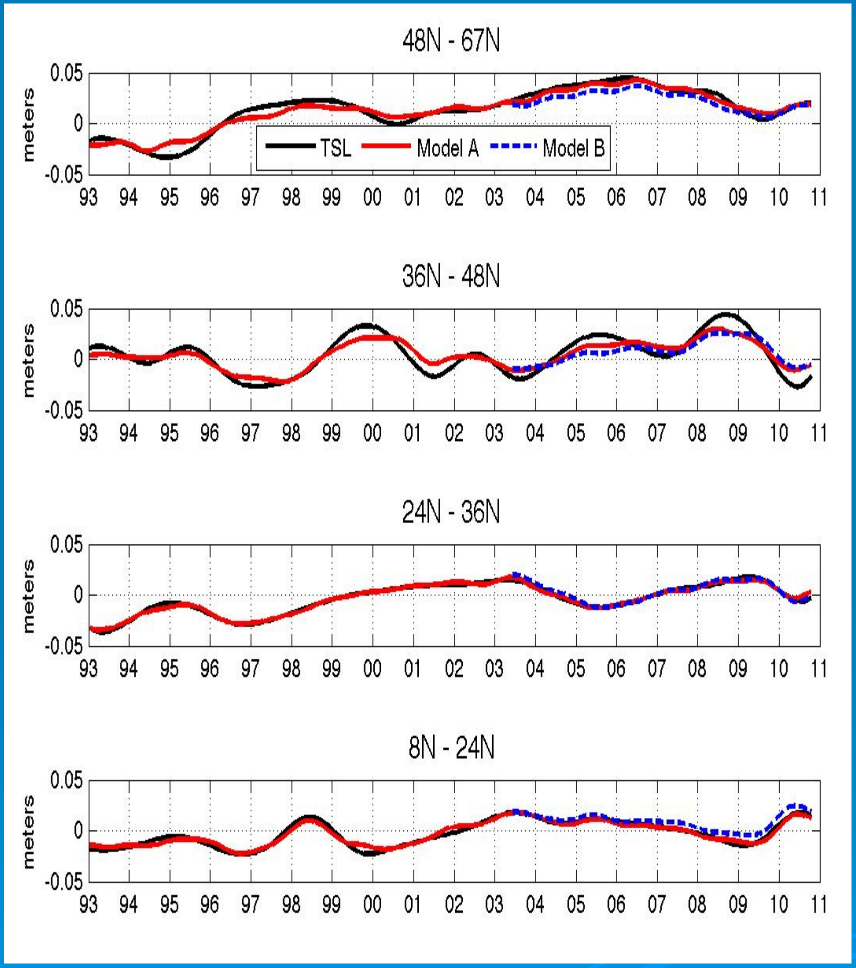
Regions for Box Model

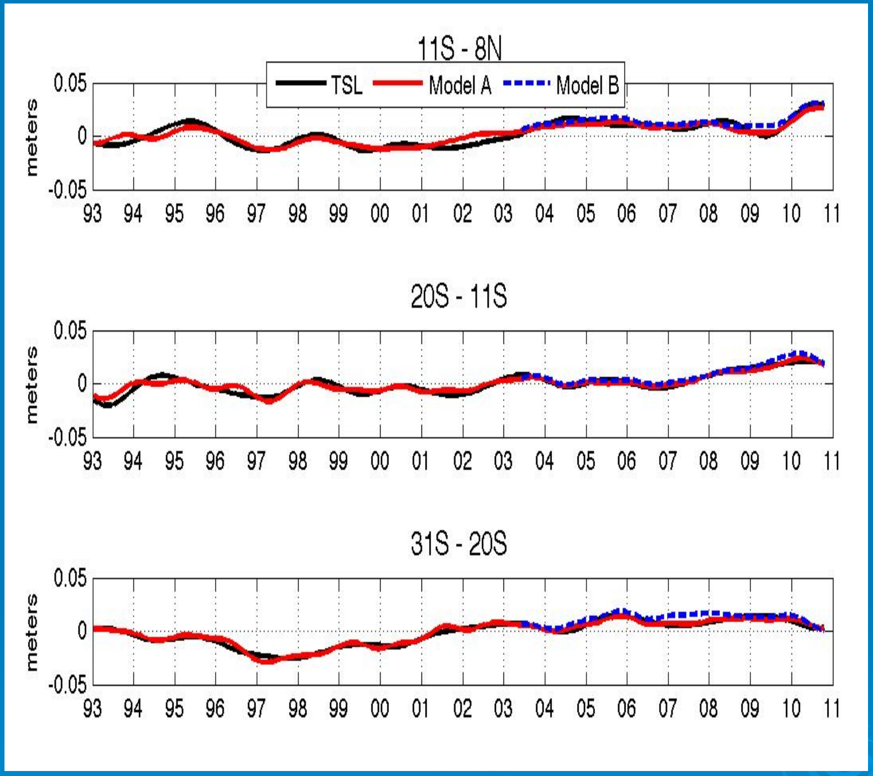
- Regions divided by WOCE lines
- Forcing & observations averaged over regions



Thermosteric Sea Level η_H

models A & B and TSL





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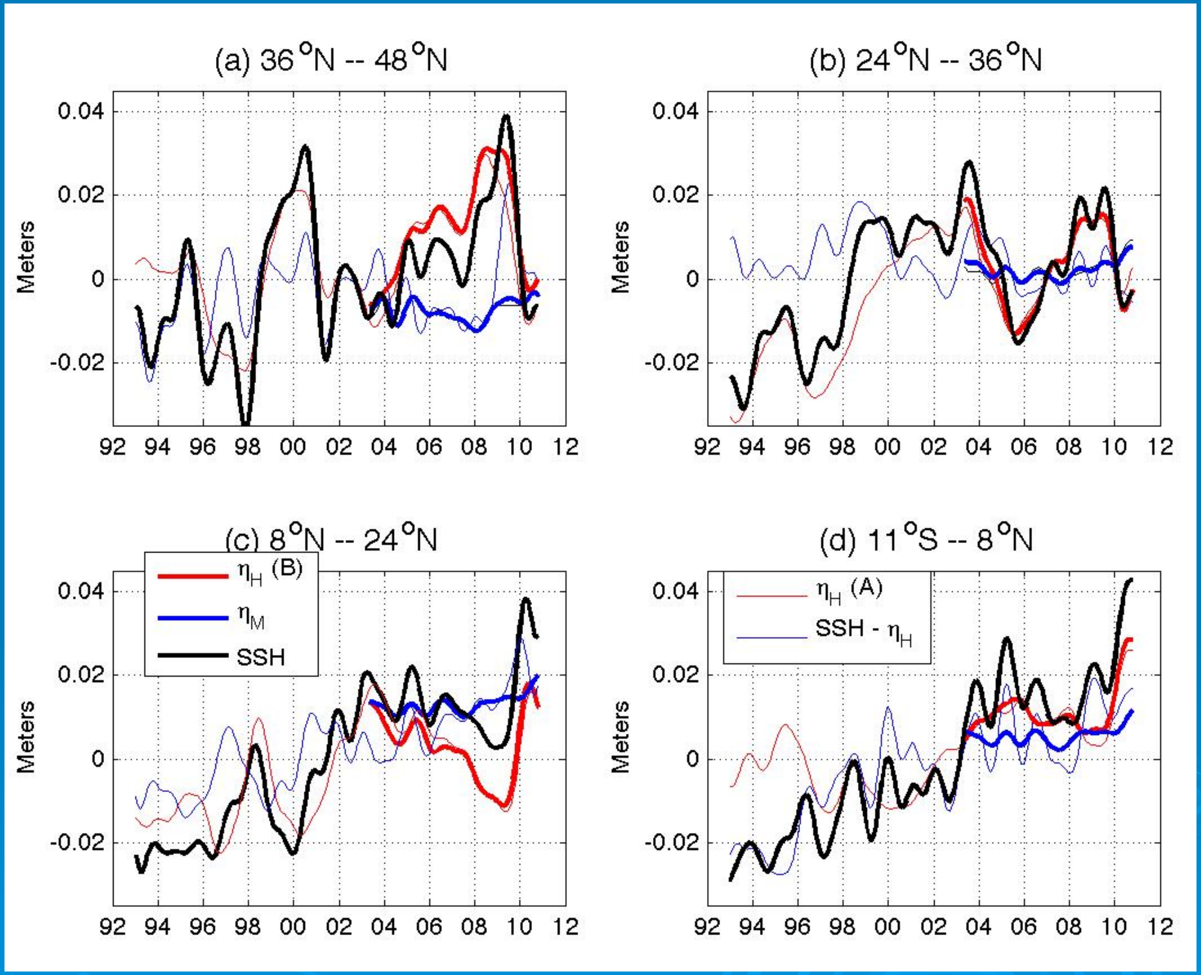
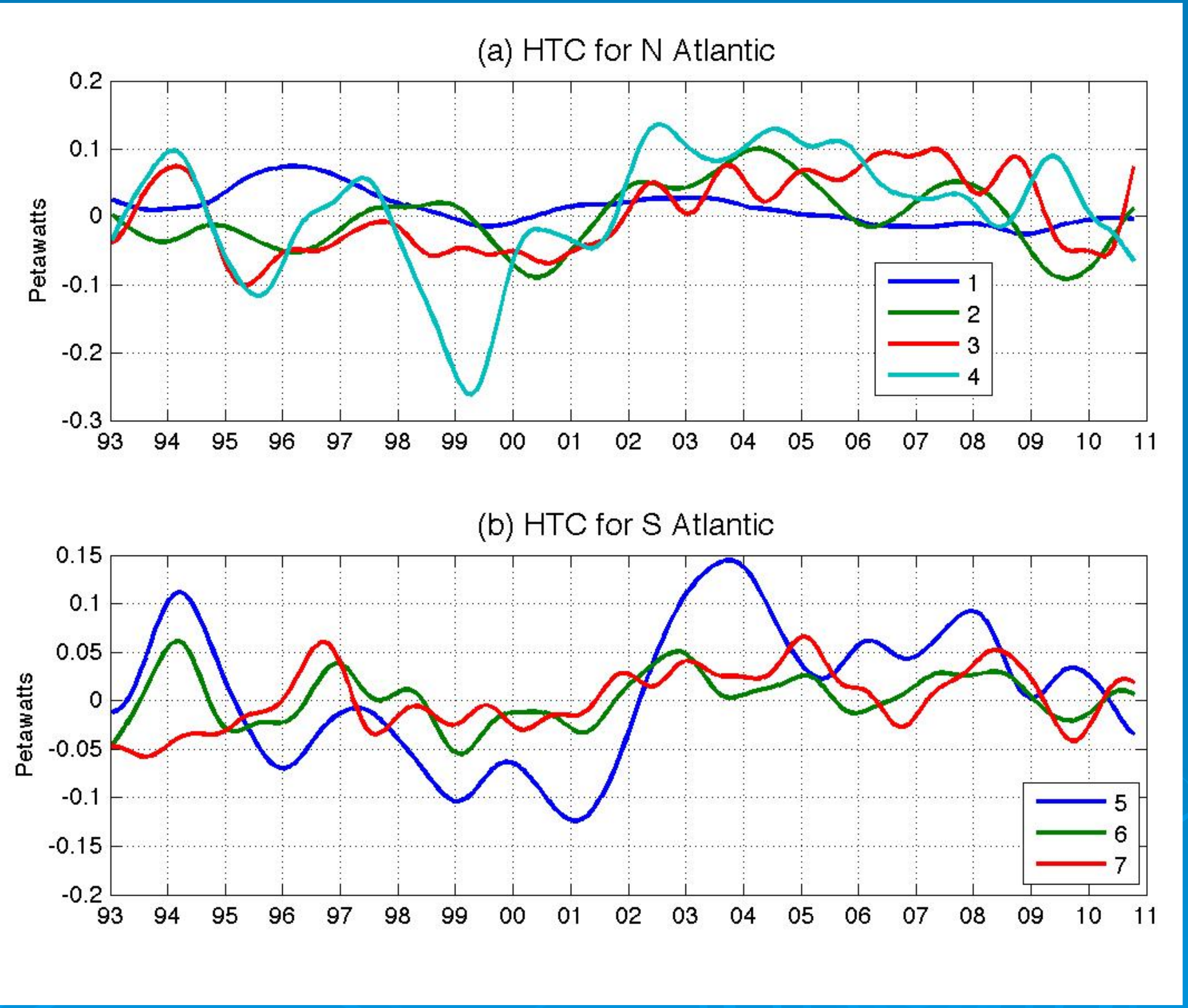
Contributions to SSH

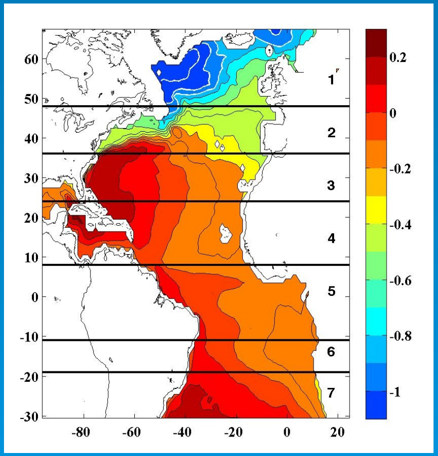
- Model η_H similar in A & B
- Trend in SSH η
- Heat η_H dominates over mass η_M
- Model B η_M anomalies much smaller than Model A residual
- Slight trend in η_M



Heat Transport Convergence (Petawatts)

- HTC (advection) summed over region
- HTC anomalies <0.3 PW
- largest anomaly in Region 4 (8-24N)





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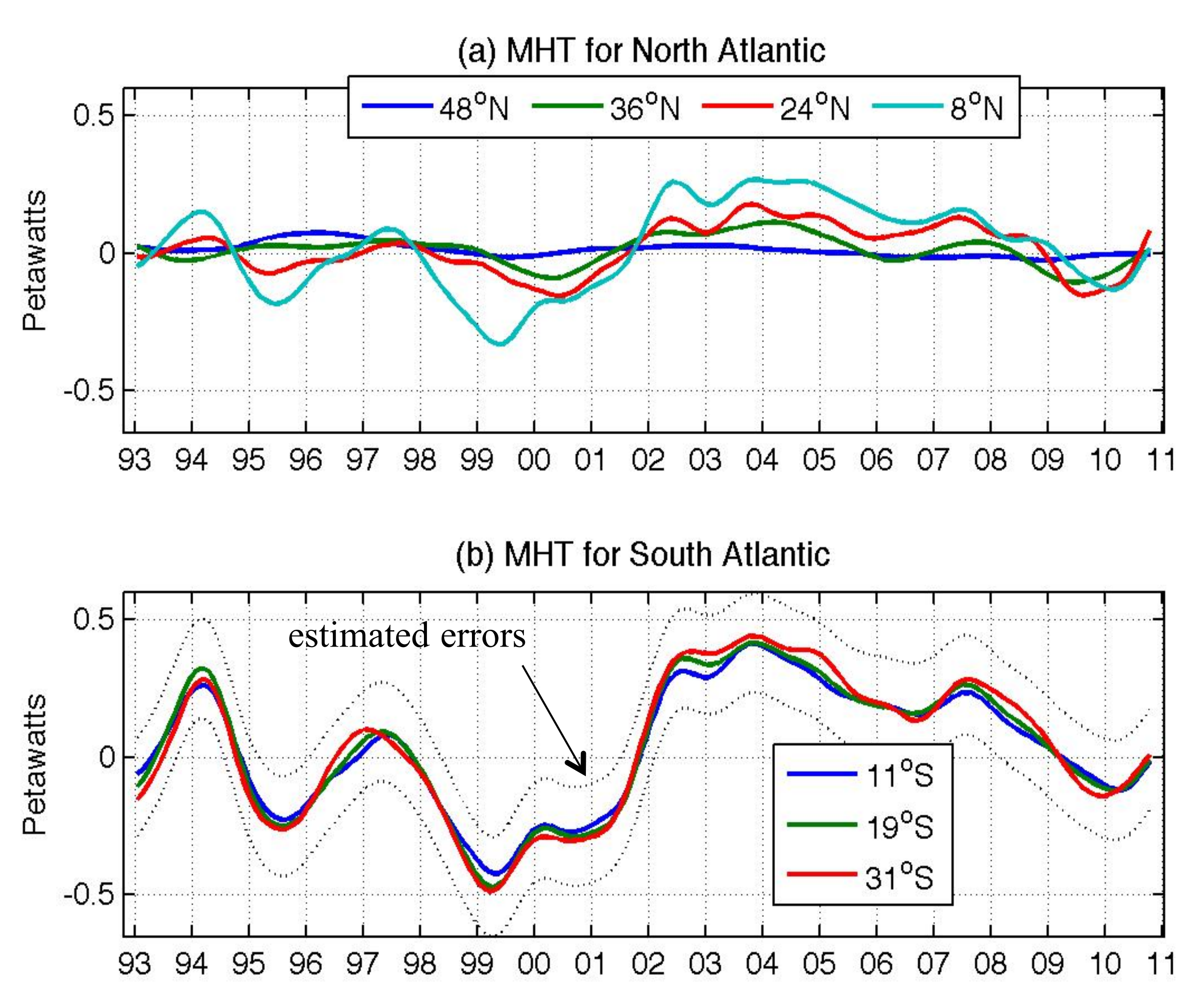
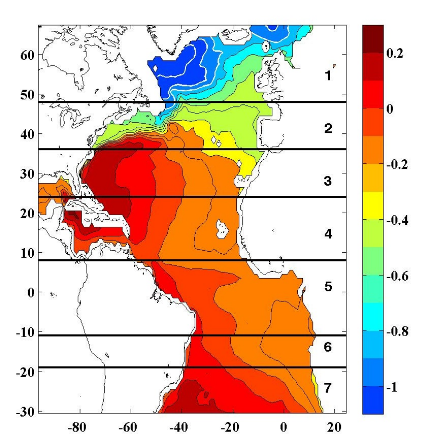
Meridional Heat Transport

Sum HTC to get MHT:

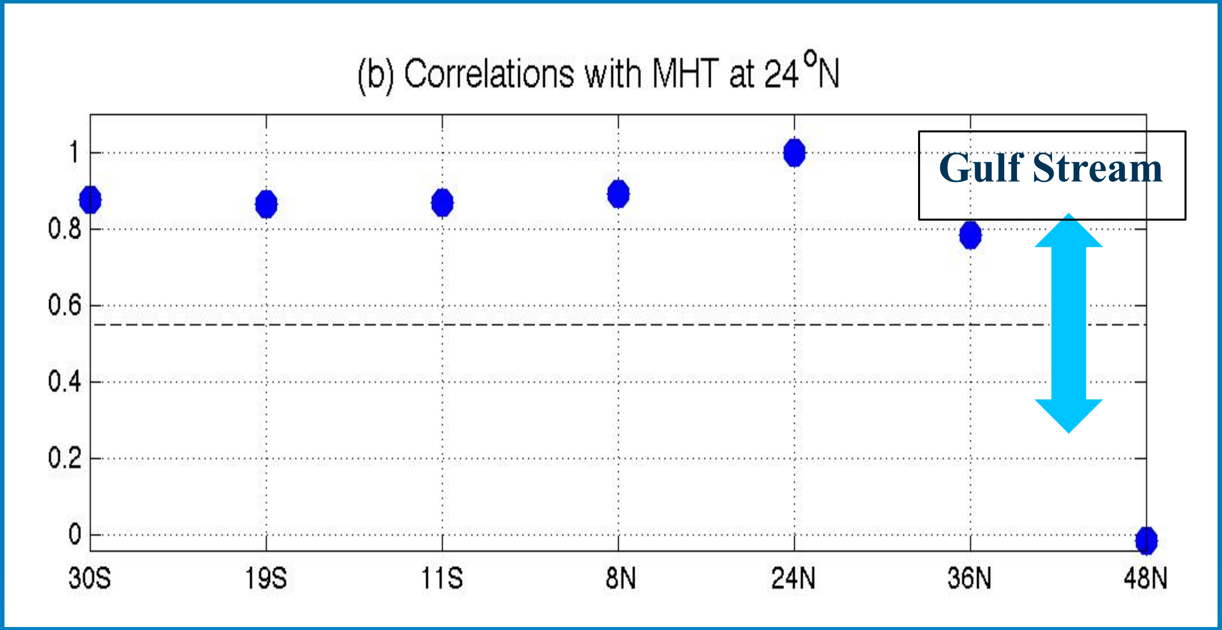
- MHT anomalies less than 0.5 PW
- anomalies coherent & larger in South Atlantic





Coherence of Meridional Heat Transport

- High correlations with 24N (RAPID at 26.5N)
- EXCEPT north of Gulf Stream



MHT Comparison with RAPID/MOCHA

MHT MOCHA:

2009-10 - 2004-2008:

0.24PW for MOCHA

(Johns et al, 2011, WCRP)

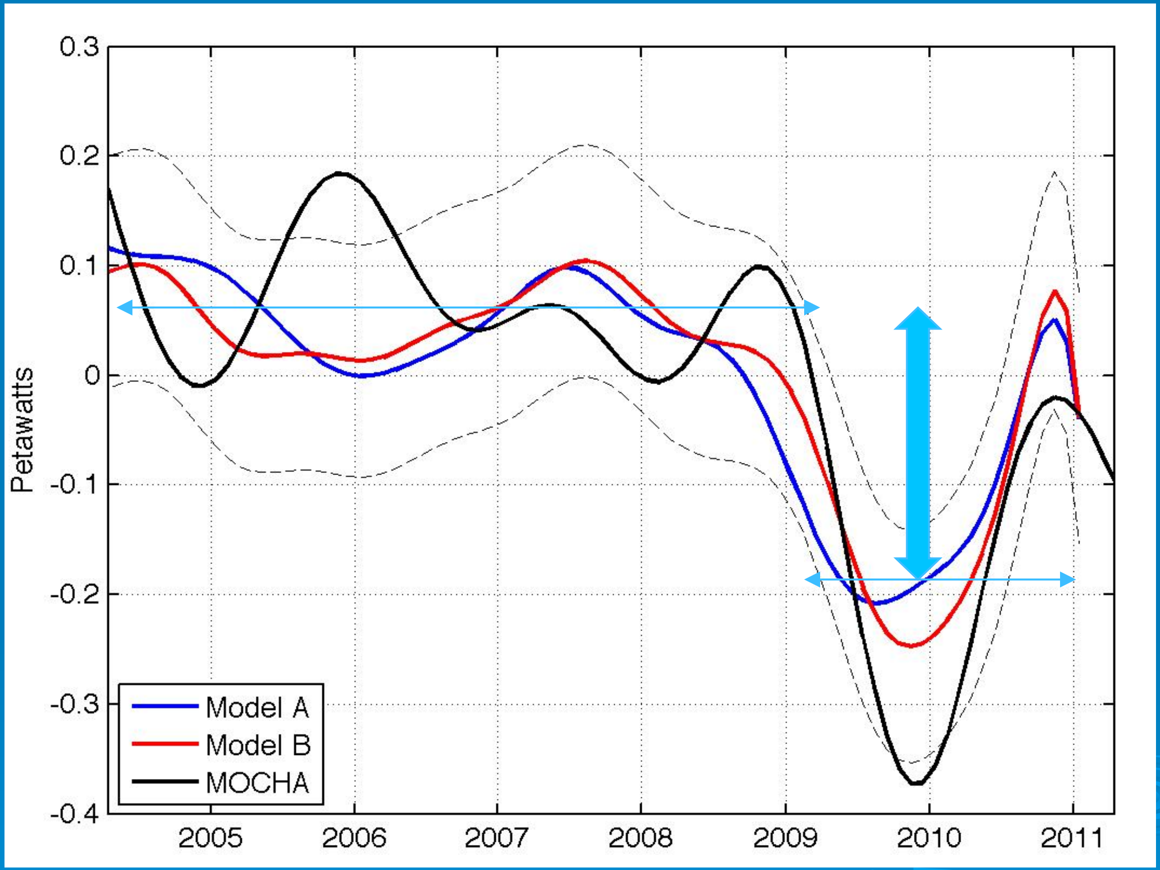
Box model:

2009-10 - 2005-2008:

0.16-0.17PW

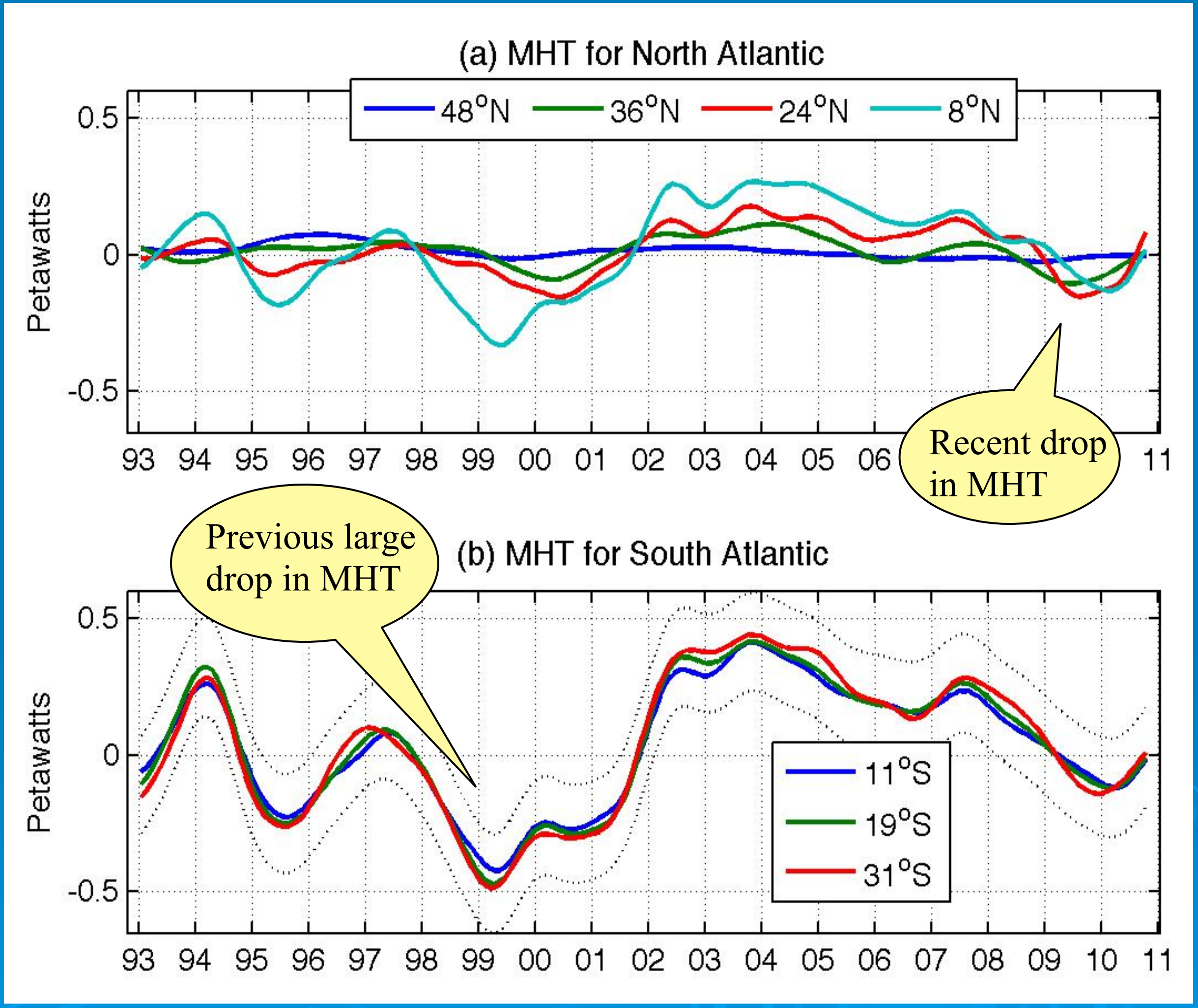
RAPID/MOC:

(Srokosz et al, 2012, BAMS)



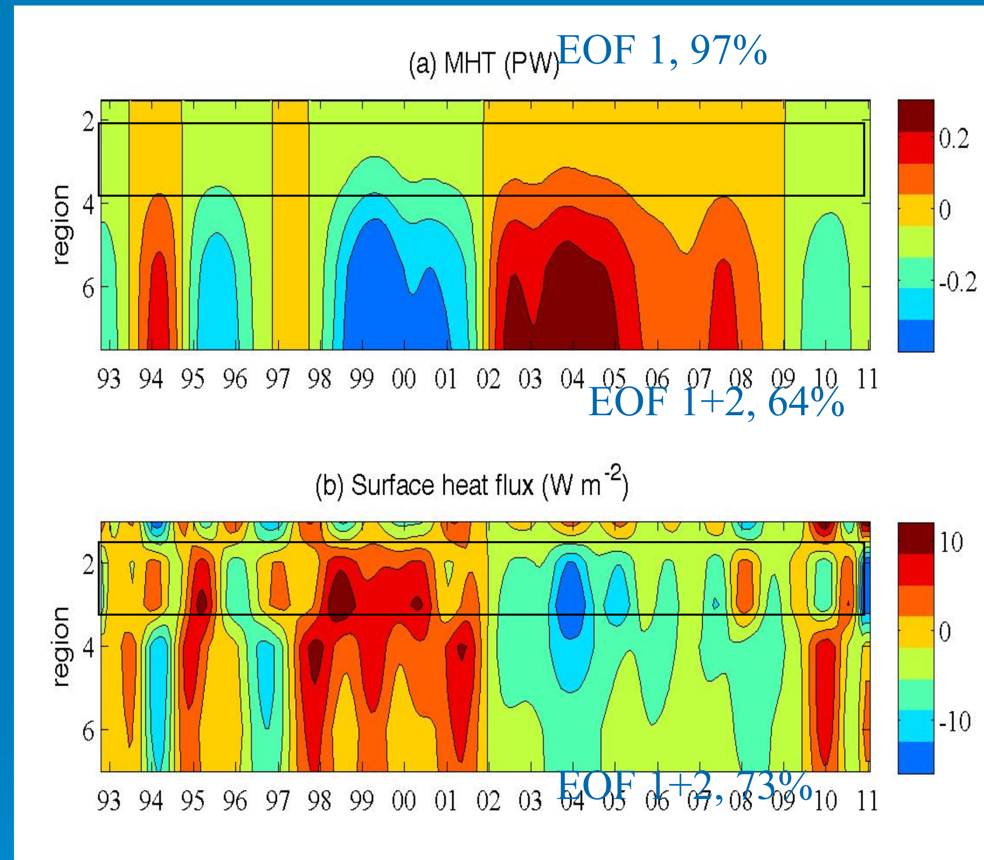
MHT Anomalies over 18 years

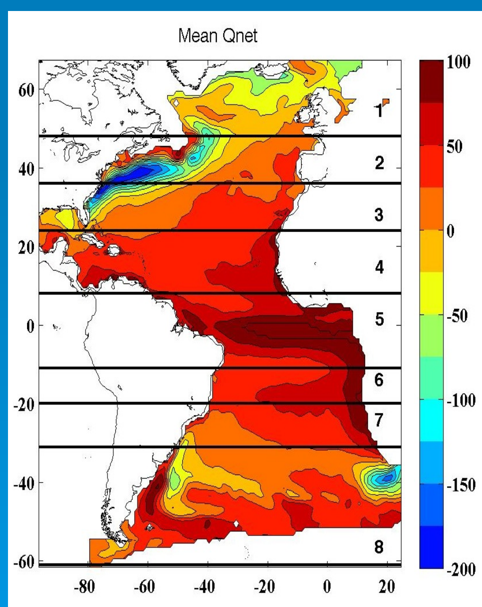
- Coherent MHT anomalies over periods of 1-6 years
- Minima in 1995-96, 1999-2001 and 2009
- 1999-2001 began in S Atlantic
- Maximum 2002-2005



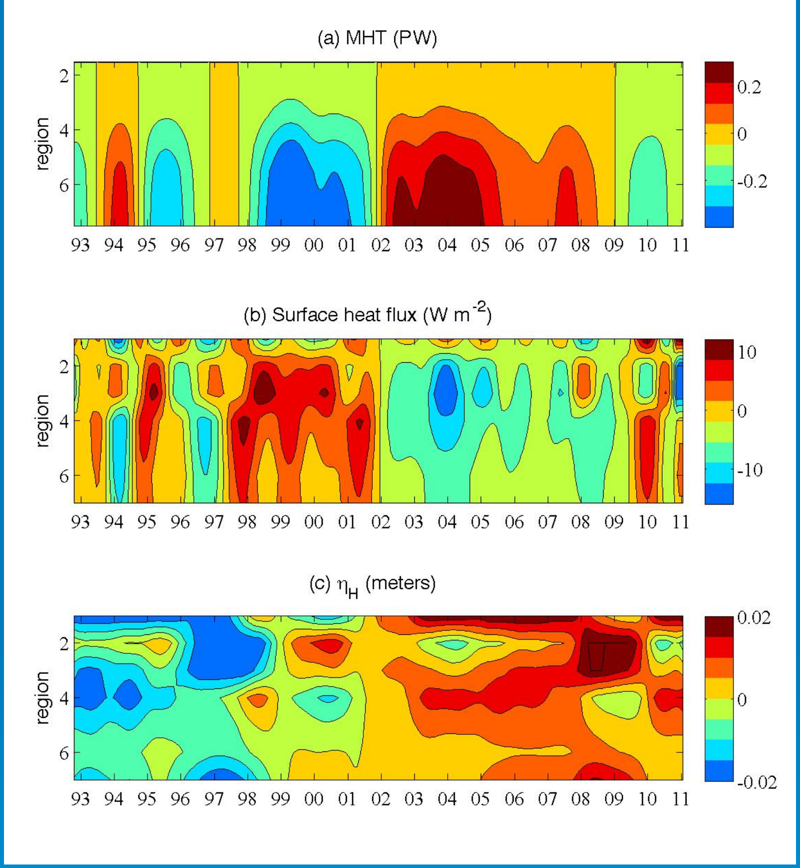
MHT and Surface Fluxes

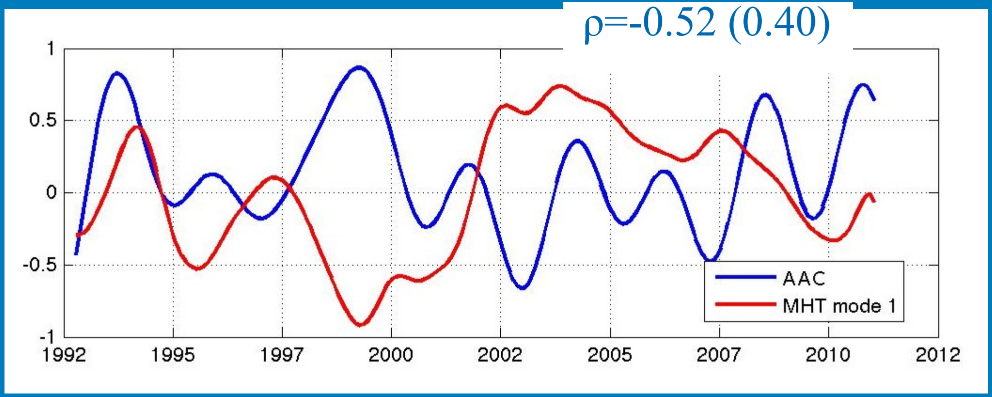
- 0.2 PW increase in MHT => $10 W/m^2$ loss in subtropics
- GS region forces air-sea fluxes (*Kelly et al 2010, Zhai & Sheldon 2012)*





MHT Anomalies and Climate Indices





- No correlations with NAO or AMO
- Significant lag-correlation with AAO: AAO leads by 1.5 yr
- Increase in AAO (winds) => increase in poleward eddy heat fluxes from wind forcing (*Spence et al, 2010*)

Conclusions

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