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 $\eta_H$
- 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)

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

\[
\eta_H = TSL \quad \text{(assimilation)}
\]
Model B Equations

- Add mass contribution to sea level $\eta_M$
- 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)

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

\[
\eta_M = EWT
\]

\[
\eta_M + \eta_H = SSH
\]

(assimilation)
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 $\eta_H$

models A & B and TSL
Contributions to SSH

- Model $\eta_H$ similar in A & B
- Trend in SSH $\eta$
- Heat $\eta_H$ dominates over mass $\eta_M$
- Model B $\eta_M$ anomalies much smaller than Model A residual
- Slight trend in $\eta_M$
Heat Transport Convergence (Petawatts)

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

Sum HTC to get MHT:

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

(a) MHT for North Atlantic

(b) MHT for South Atlantic

estimated errors
Coherence of Meridional Heat Transport

- High correlations with 24°N (RAPID at 26.5°N)
- 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
- 1999-2001 began in S Atlantic
- Maximum 2002-2005

(a) MHT for North Atlantic
- Recent drop in MHT

(b) MHT for South Atlantic
- Previous large drop in MHT
MHT and Surface Fluxes

- 0.2 PW increase in MHT => 10W/m² 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)

\[ \rho = -0.52 (0.40) \]
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