Temporal and Spatial Changes in the Dominance of the Wind-driven and Density-driven processes in the South Atlantic MOC

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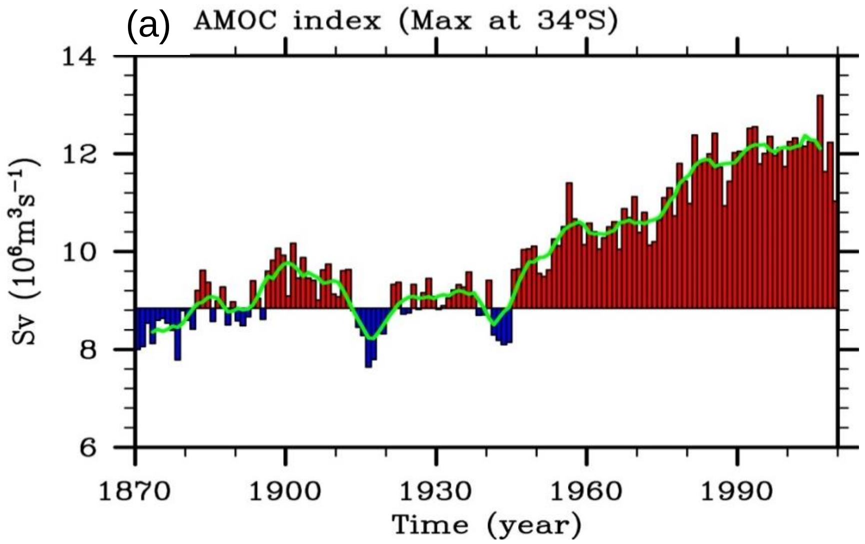
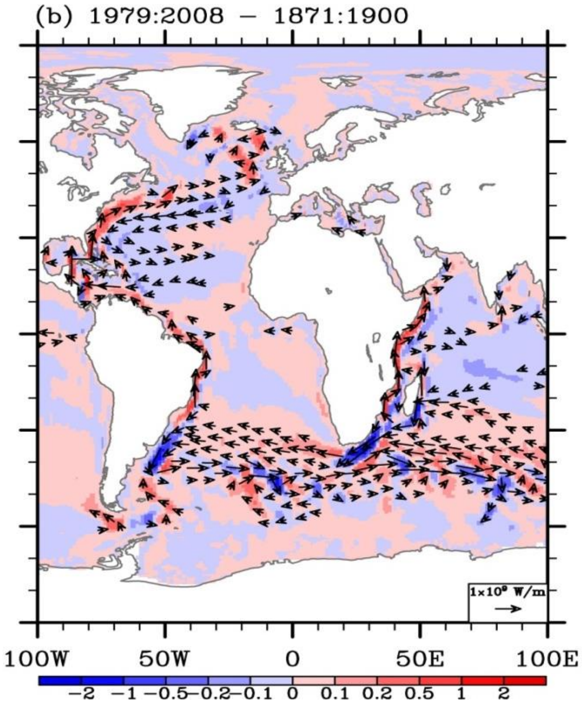
OSTST Meeting, October 23-27, 2017
Miami, FL

Research funded by NASA, NOAA CPO and AOML

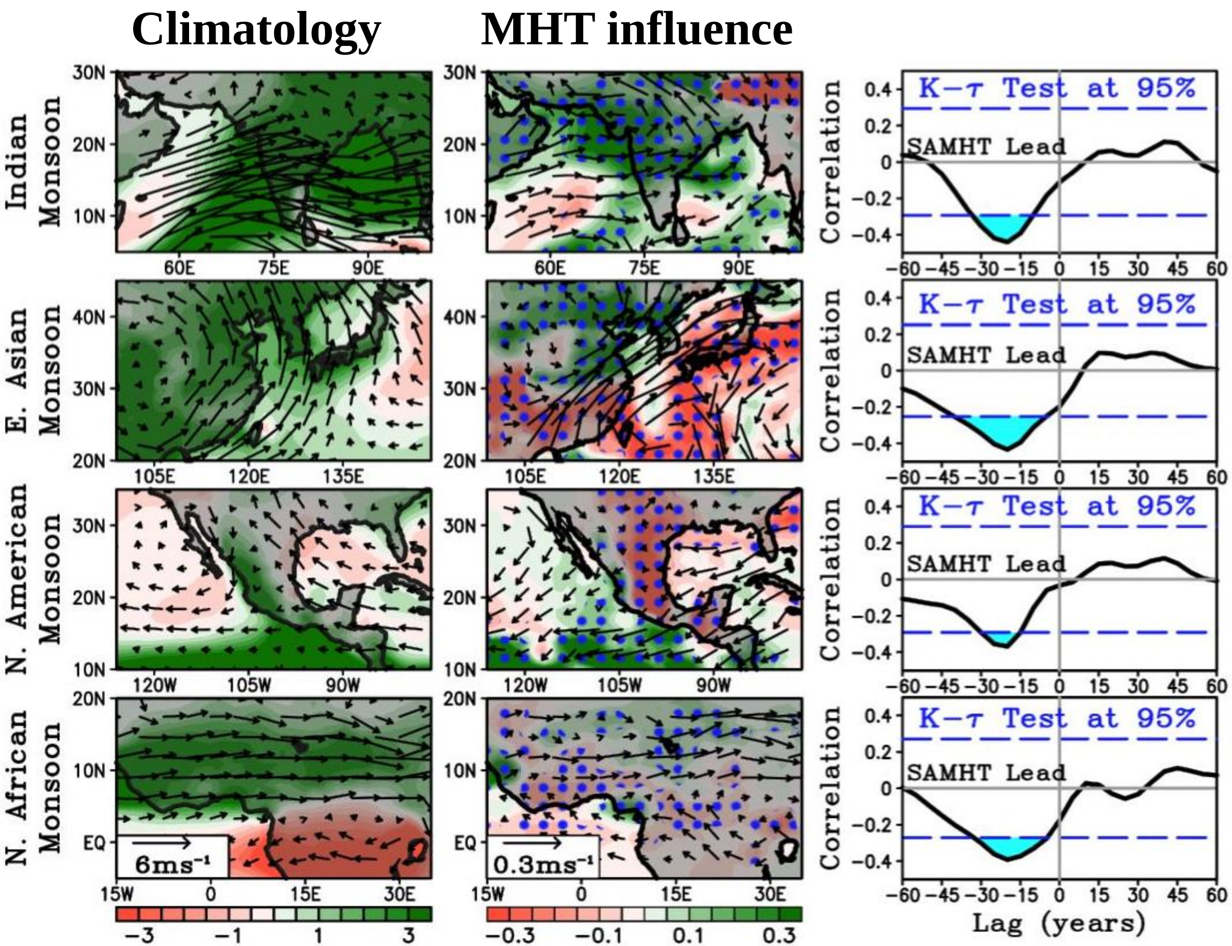
Motivation: Impact of SAMOC on Atlantic warming





- Lee et al. (2011): 20th century global ocean simulation shows that the rapid warming of the Atlantic Ocean since the 1950s is due to increase in the SAMOC.

Motivation: Impact of SAMHT on Monsoon



Weak SAMHT leads to stronger NH monsoons 20 years later.
(Lopez, Dong, Lee, and Goni, 2015)

Goal

- To test the ability of the altimeter SSH measurements (combined with *in situ* observations) in estimating the Meridional Overturning Circulation (MOC) and Meridional Heat Transport (MHT) in the South Atlantic.

- To investigate spatial (latitudinal) and temporal changes of the MOC and MHT in the South Atlantic.

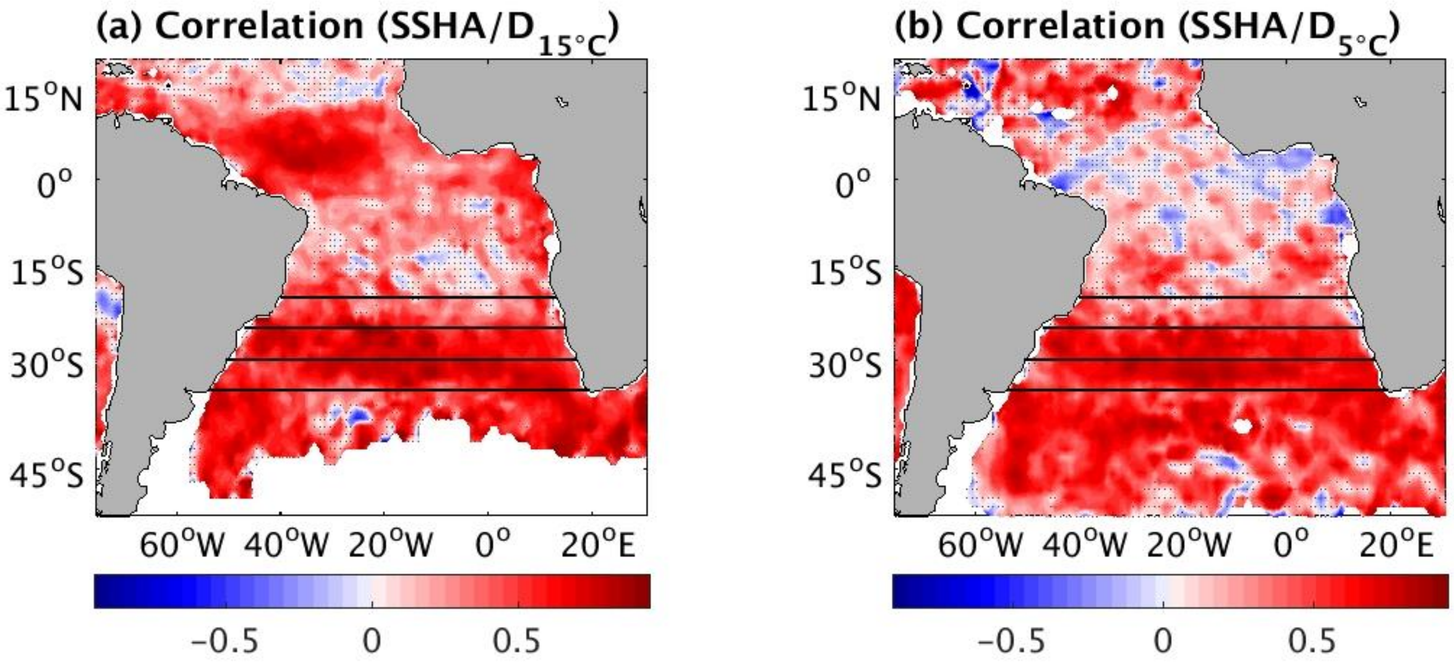
Outline

- Methodology using altimeter to estimate the MOC and MHT in the South Atlantic (20° S-35° S).
- Results of the MOC and MHT derived from Altimeter since 1993.
- Heat budget in the subtropical South Atlantic (20° S-35° S).
- Summary

Methodology

- Altimetry SSH observations as the main data set to derive geostrophic transport.
    - T(z) derived from satellite altimetry, T(0) by satellite-derived SSTs.
    - S(z) derived from T(z)-S(z) historical relationship built using profiles from all available hydrographic data.
    - T(z) and S(z) are used to compute the geostrophic transport with reference velocity from Argo drifter velocity at 1000 m depth.
- ERA-I Winds are used to compute the Ekman transport.
- XBT observations as the main complimentary data set (evaluation of the methodology).

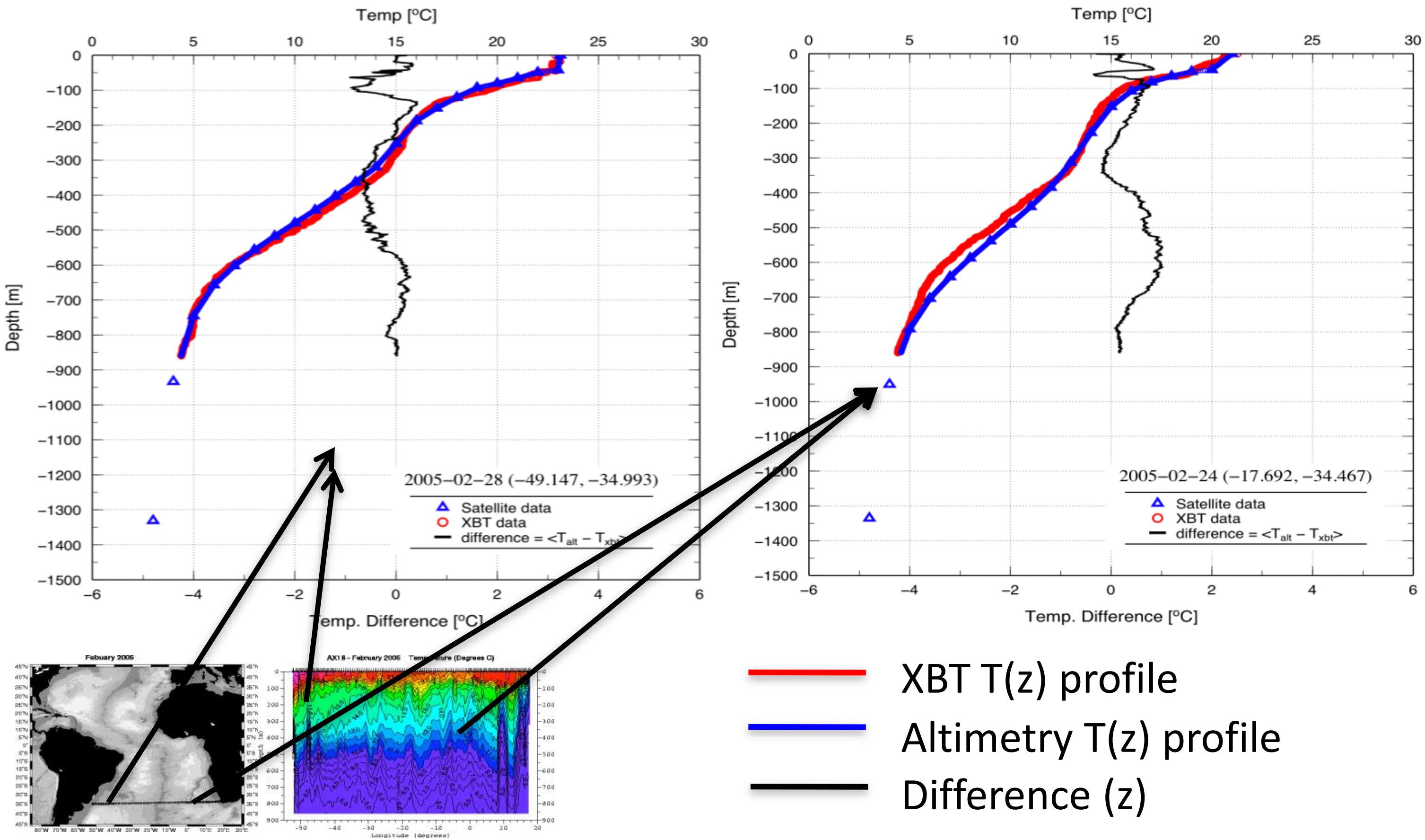
Sea Surface Height Anomalies and Isotherm Depths



Large correlation between SSHA and Isotherm depths (D_T) south of 20° S, which allows to derive temperature profiles from SSHA.

$D_T = \alpha + \beta \times SSHA$, T: 3°C to 28°C

Altimetry-derived temperature profiles



XBT T(z) profile

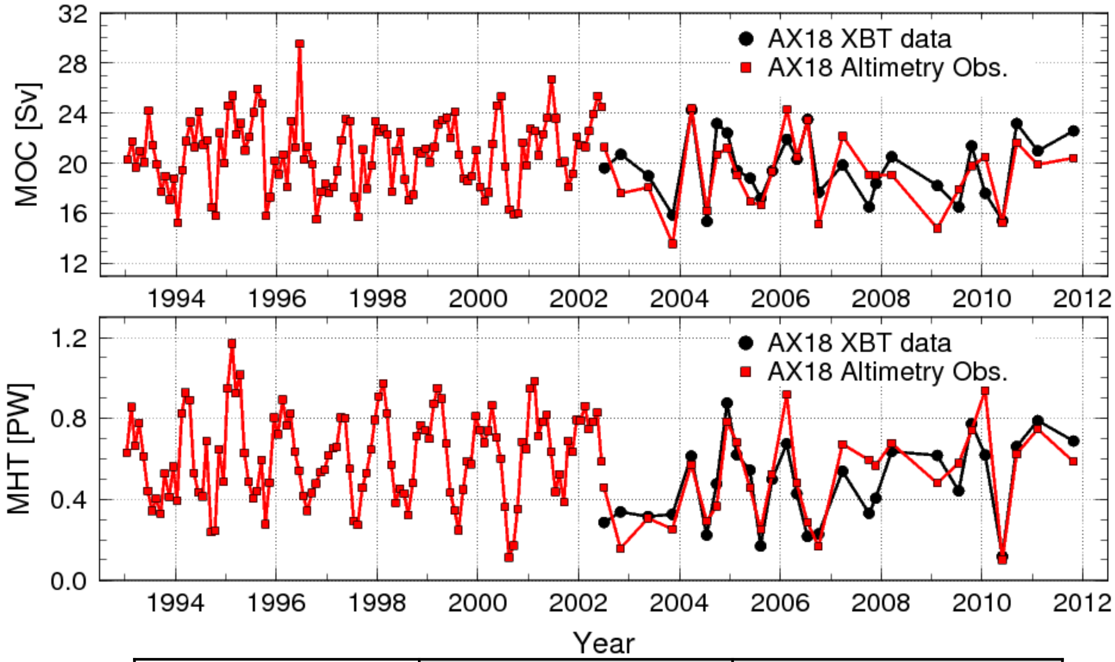
Altimetry T(z) profile

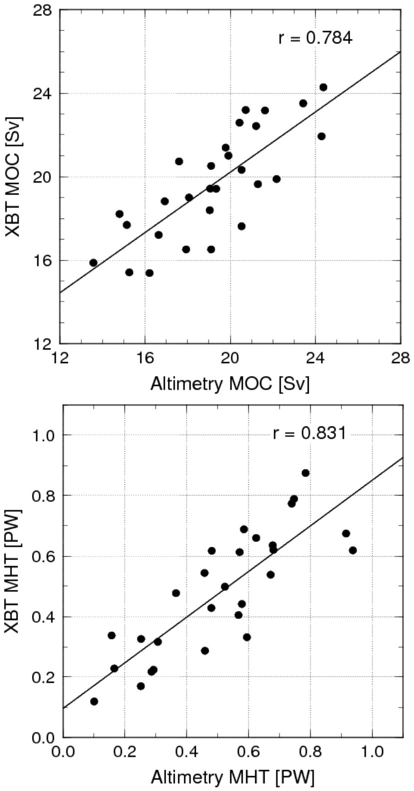
Difference (z)

February 2005

Altimetry-derived MOC and MHT at 34.5° S

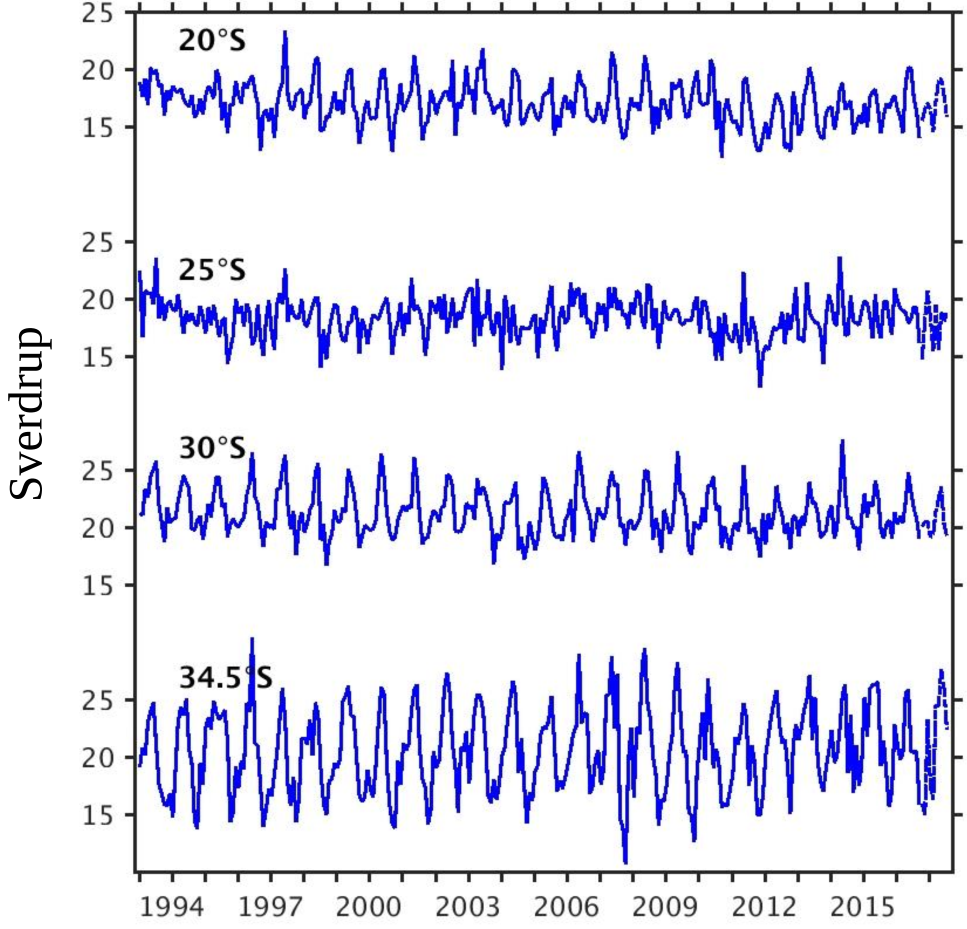
Altimetry-XBT comparison



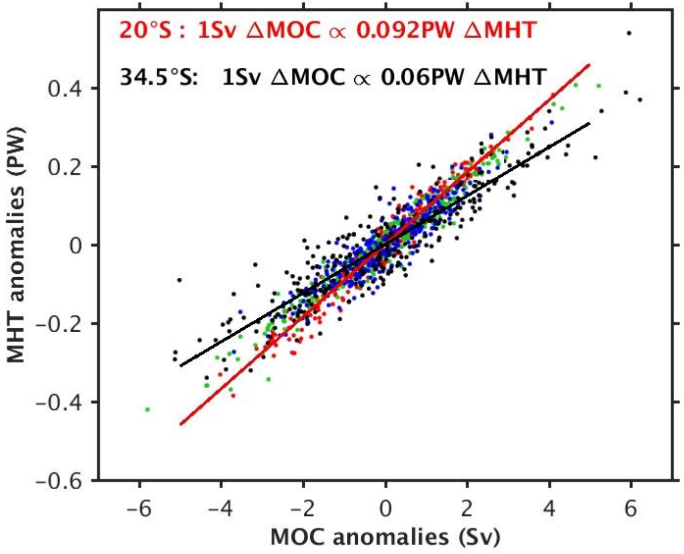


	MOC (Sv)	MHT (PW)
XBT AX18	**19.6±2.6**	**0.48±0.20**
Altimetry	**19.2±2.8**	**0.51±0.22**
RMS difference	**1.8**	**0.13**

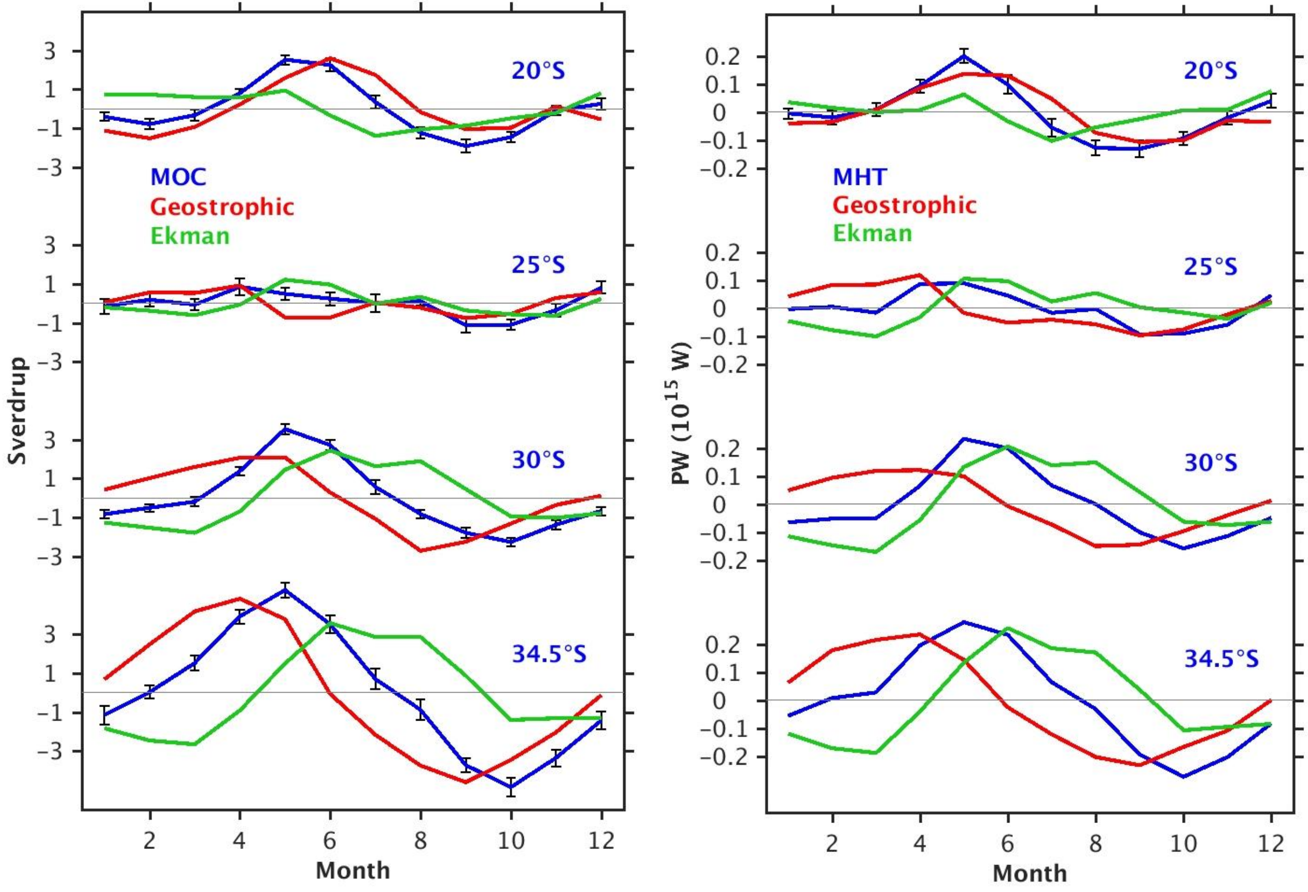
Altimetry-derived MOC



- Maximum variability at 34.5° S, twice as large as that at 20° S.
- Strong seasonal variations at 34.5° S and 30° S.
- Linear relationship between MOC and MHT, response of MHT to MOC strengthens northward.

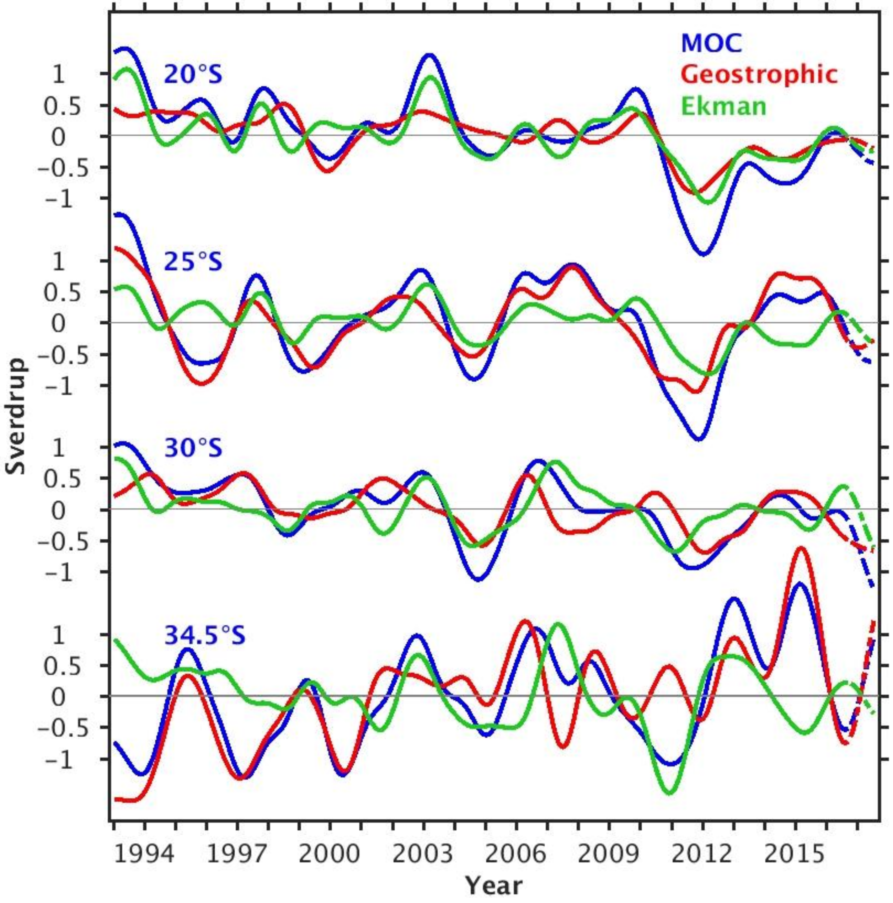


Altimetry-derived MOC: Seasonal Variability



- The amplitude of seasonal cycle in the MOC decreases toward the north.
- Both the Geostrophic and Ekman components contribute equally to the MOC seasonal variation.

Altimetry-derived MOC: Interannual Variability



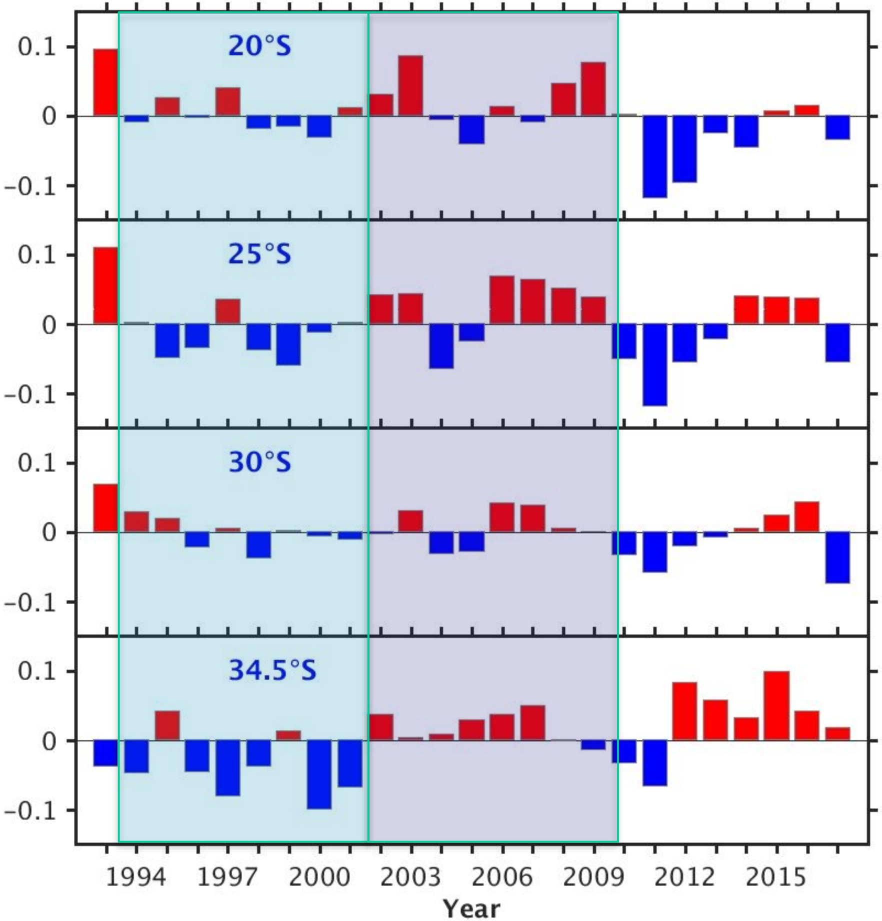
Dominance of the Geostrophic and Ekman components in the MOC and MHT varies with time and latitude.

- At 35° S, MOC variations are dominated by geostrophic component, except during 2002-2005 and 2010-2012 when the Ekman transport plays a large role.
- At 25° S, geostrophic component dominates throughout the study period.
- At 20° S and 30° S, both components are important.

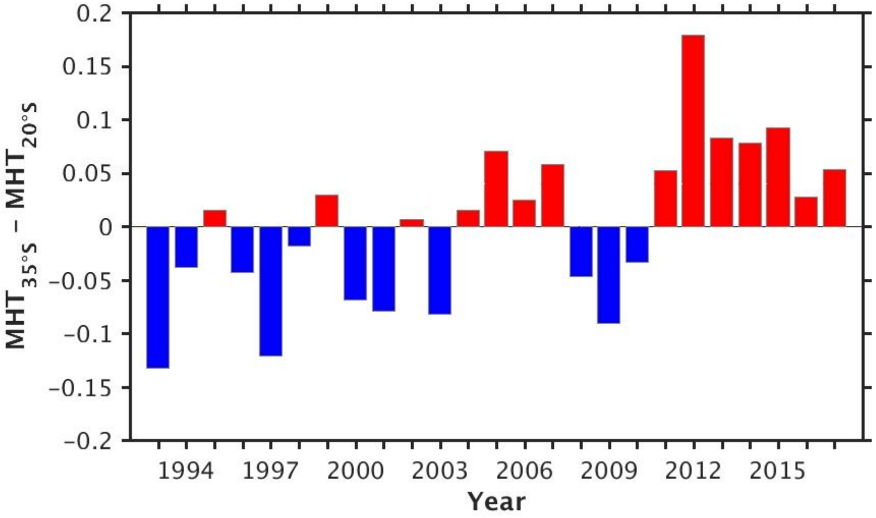
High correlations of the MOC between 20° S-30° S.

Altimetry-derived MHT: Yearly Anomalies

MHT Yearly Anomalies (PW)

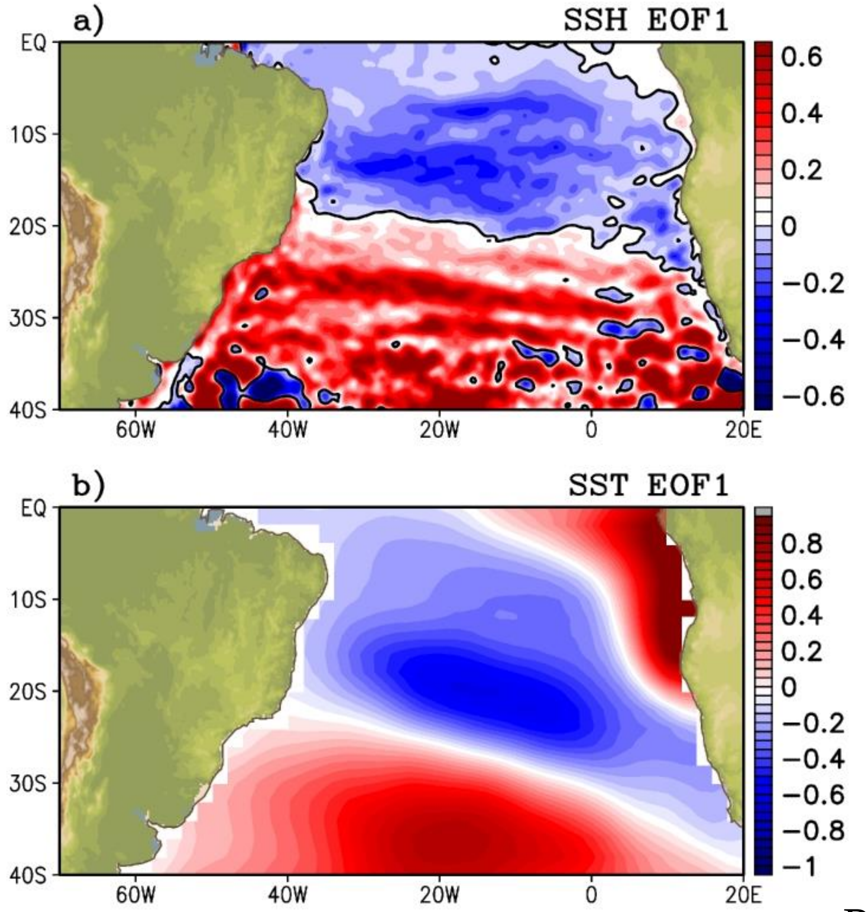


Convergence of oceanic heat transport between 20°S and 35°S



- In 1990s, oceanic heat transport between 20°S-35°S show divergence anomalies.
- In the recent decade (2010s), more heat converged into the subtropical South Atlantic.

South Atlantic Subtropical Dipole



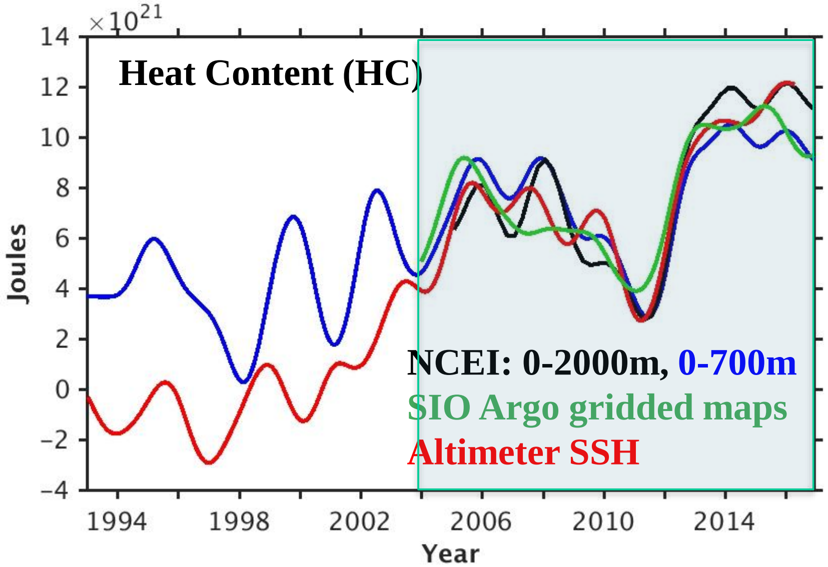
South Atlantic Subtropical Dipole (SASD), the dominant mode of coupled ocean-atmosphere variability, plays an important role for:

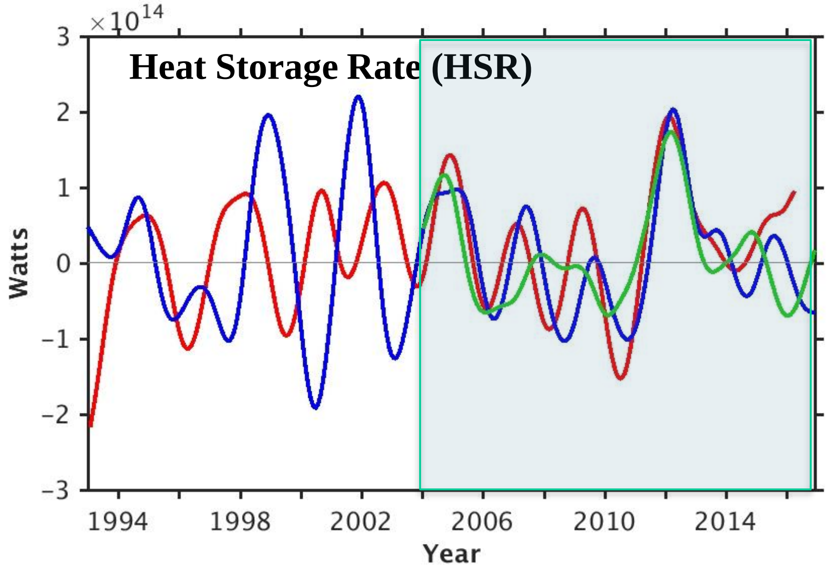
- South America Monsoon
- South Atlantic convergence zone

SAMOC and SASD are highly correlated. (***For detail please see poster # SC2_009)***

Provided by Hosmay Lopez

Heat Content in the Subtropical South Atlantic (20°S-35°S)





- Regression between HC and SSH:

  $HC_{NCEI,0\text{-}2000m} = \alpha+\beta\times SSH$ (2005-present)

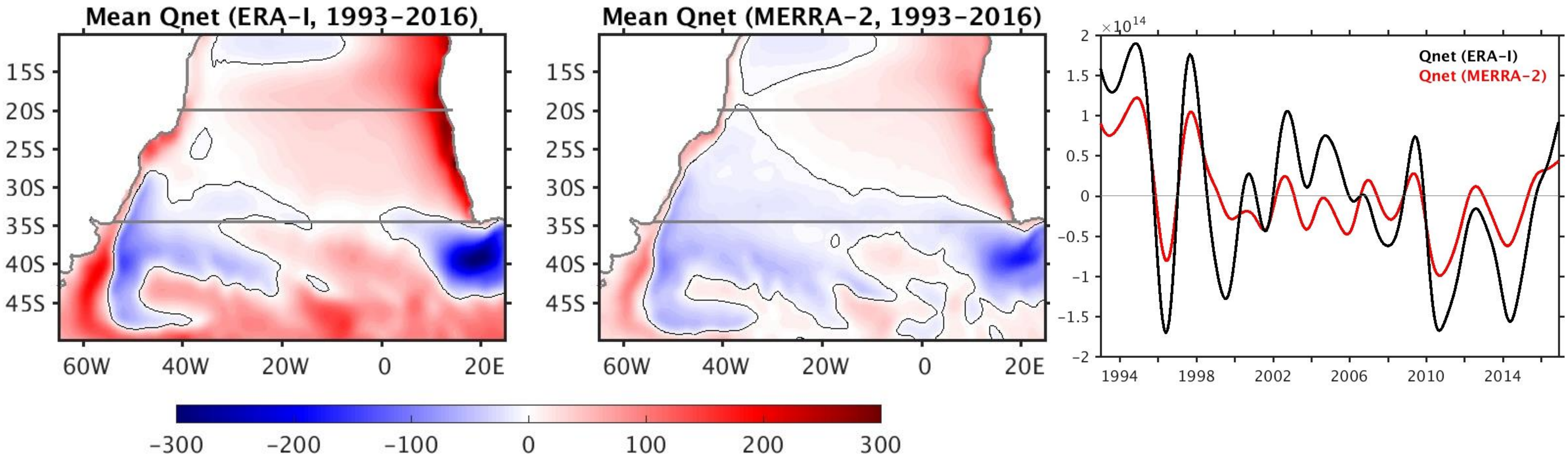
  $HC_{altimeter} = \alpha+\beta\times SSH$ (1993-present)

- Good agreement among various products during Argo period since 2004.
- Large differences between HC from NCEI and regressed from SSH during pre-Argo period.

- Good agreement in HSR as well during Argo period since 2004.
- Large differences in HSR during pre-Argo period.

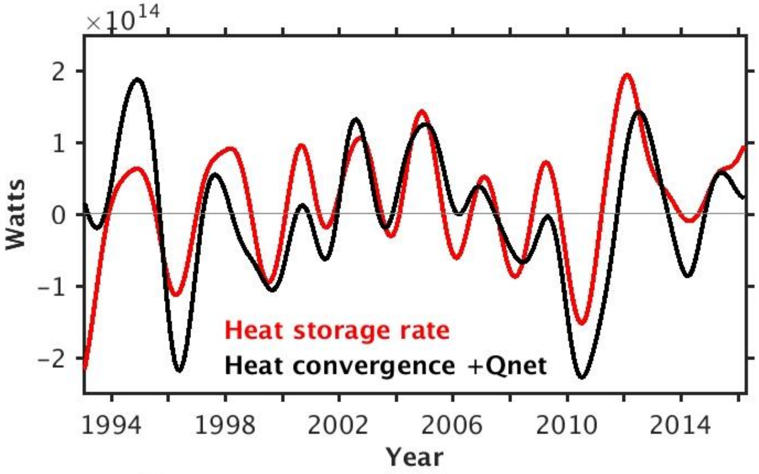
$HSR = Q_{net}+(MHT_{35°S}-MHT_{20°S})$

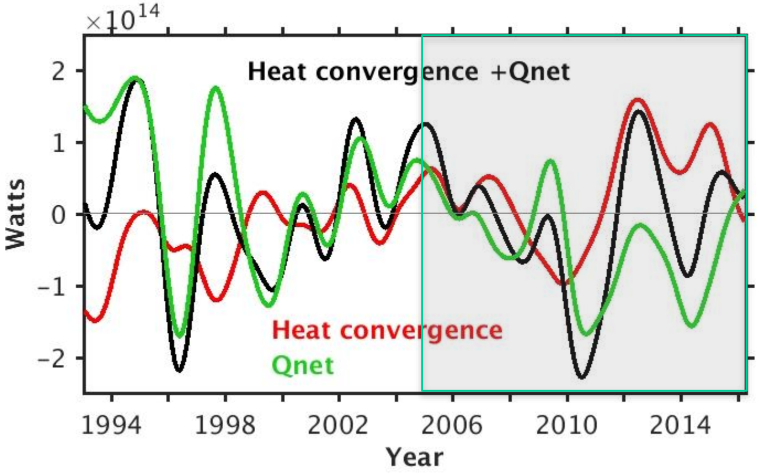
Air-Sea Heat Fluxes (Q_{net})



- Q_{net} from MERRA-2 is much weaker than that from ERA-I in the South Atlantic, for both the mean values and interannual variations.

Heat Budget in the South Atlantic (20° S-35° S)





HSR from $HC_{altimeter}$: $\partial HC/\partial t$

Heat convergence: $MHT_{35°S}$-$MHT_{20°S}$

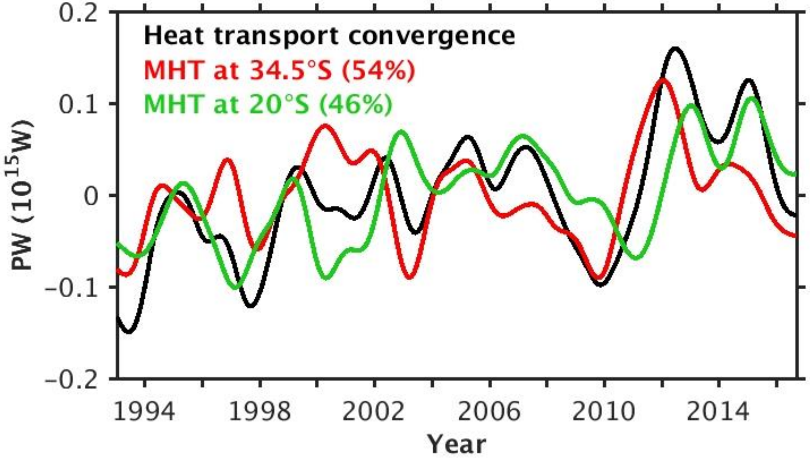
Q_{net}: ERA-I

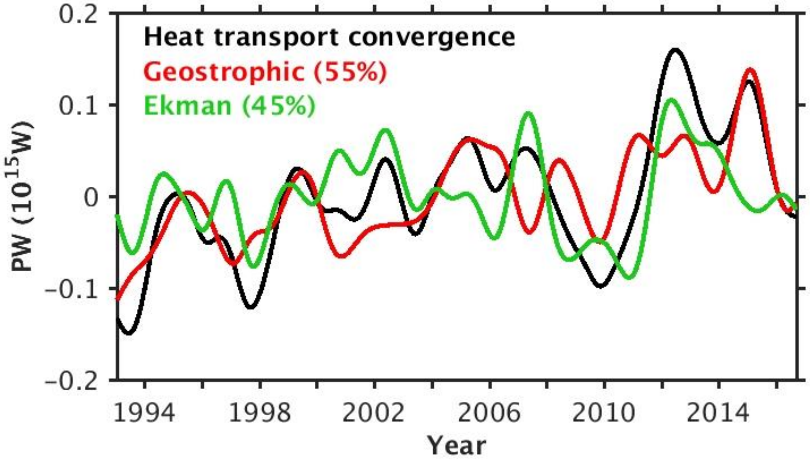
- Good agreement between HSR and the sum of the oceanic heat convergence and air-sea heat fluxes on interannual time scales.
- Air-sea heat fluxes dominate before 2005, whereas oceanic heat transport convergence plays a larger role after 2005.

Potential reasons:

- Regime shifts
- Errors in the data

Heat Transport Convergence (20° S-35° S)





- Transports at both boundaries contribute to the oceanic heat transport convergence in the region, with the southern boundary (35° S) plays a slightly larger role.
- Both the Ekman transport and geostrophic transport are important for total heat transport convergence, although the geostrophic transport contributes more than half of the variance in the oceanic heat transport convergence.

Conclusions

- Satellite altimetry allows to obtain an extended time series of MOC and MHT back to 1993.
- MOC variability decreases toward north from 34.5° S to 20° S.
- Dominance of the Geostrophic and Ekman components in the MOC and MHT varies with time and latitude.
- In 1990s, oceanic heat transports advect heat out of the subtropical South Atlantic, whereas in the recent decades, large amount of heat converged into the region.
- Air-sea heat fluxes dominate heat storage rate before 2005, whereas oceanic heat transport convergence plays a larger role after 2005.

Thank You!