The Atlantic Meridional Overturning Circulation and its Northward Heat Transport in the South Atlantic

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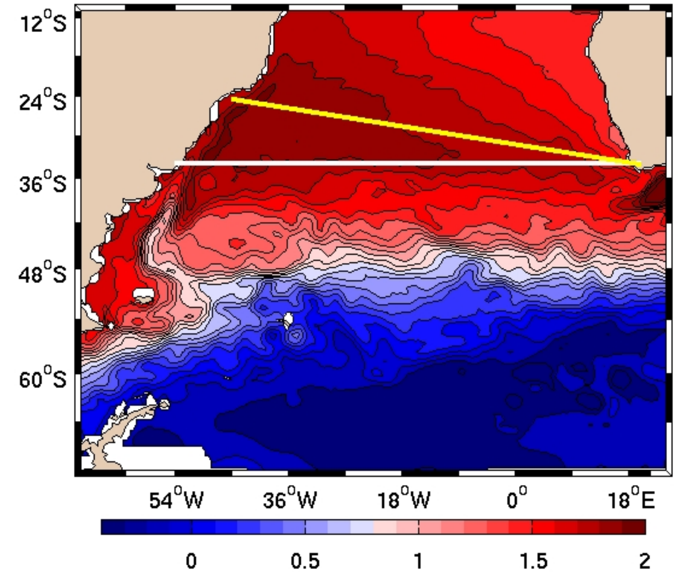
May 5, 2009

Objectives and Outline

Main objective: To examine the relationship between the strength of AMOC and the northward heat transport in the South Atlantic.

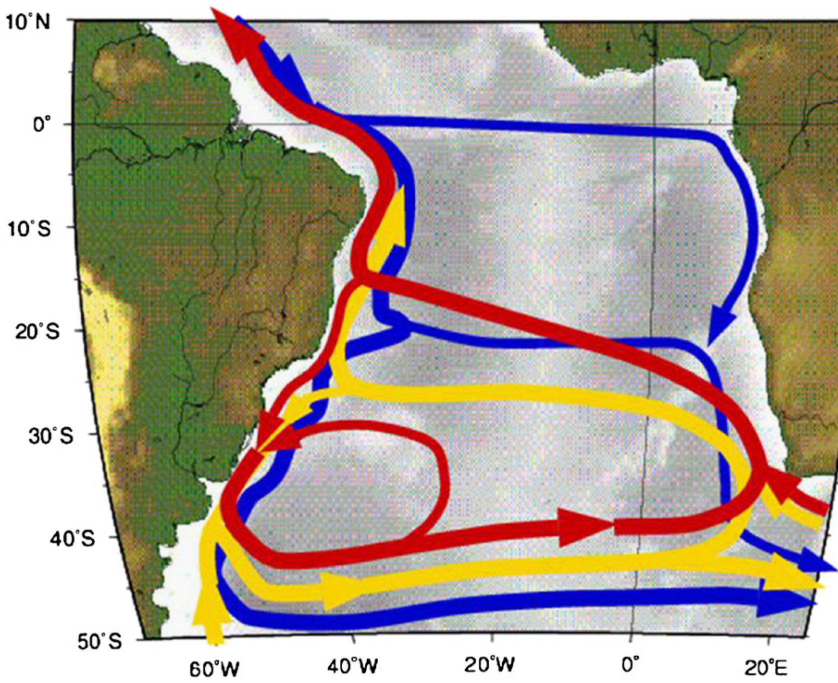
Northward heat transport and AMOC from high-density XBT line AX18 (2002 – 2008):

- Total northward heat transport, contributions from various components.
- The AMOC strength, its seasonal variability, and contributions from boundary currents and interior.
- Relationship between the strength of the AMOC and the total northward heat transport

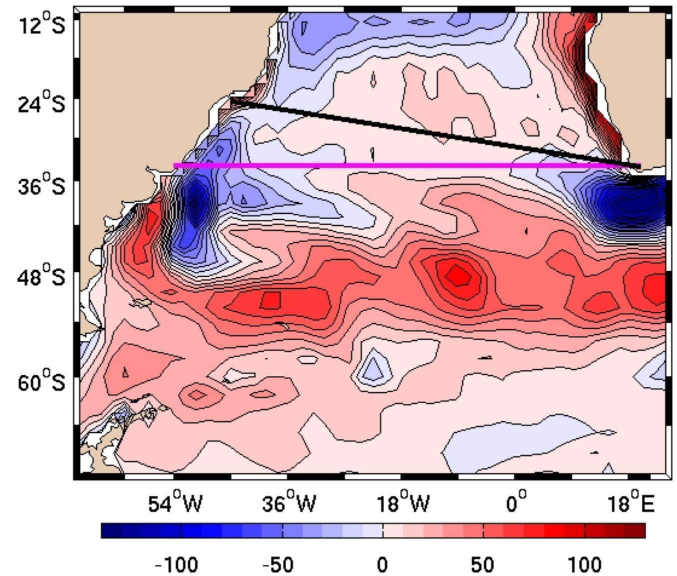


Mean Sea Surface Height (m)

Circulation and Forcing Structure in the South Atlantic



2002-2008 mean air-sea heat flux (NCEP)



Schematic diagram of the circulation in the South Atlantic:

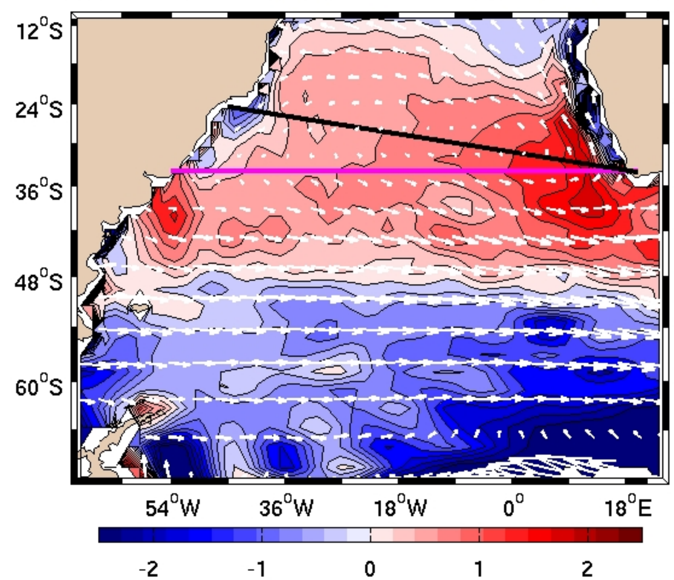
Red: upper layer

Orange: intermediate water layer

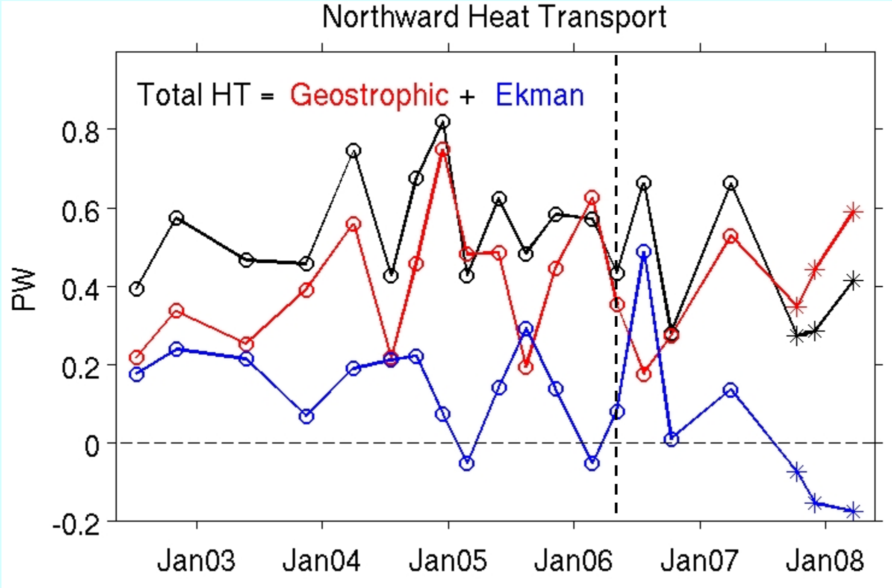
Blue: deep western boundary current

(***adapted from Stramma and England***)

Mean Wind (vector) and Wind Stress Curl (color)

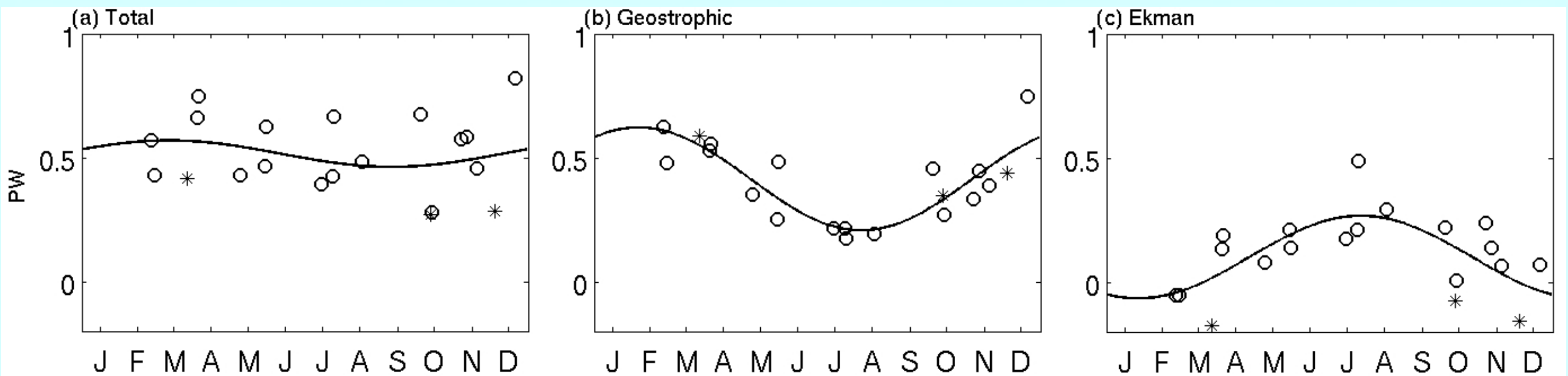


Northward Heat Transport



Total = 0.51 ± 0.15 PW
Geos. = 0.40 ± 0.16 PW
Ekman = 0.11 ± 0.16 PW

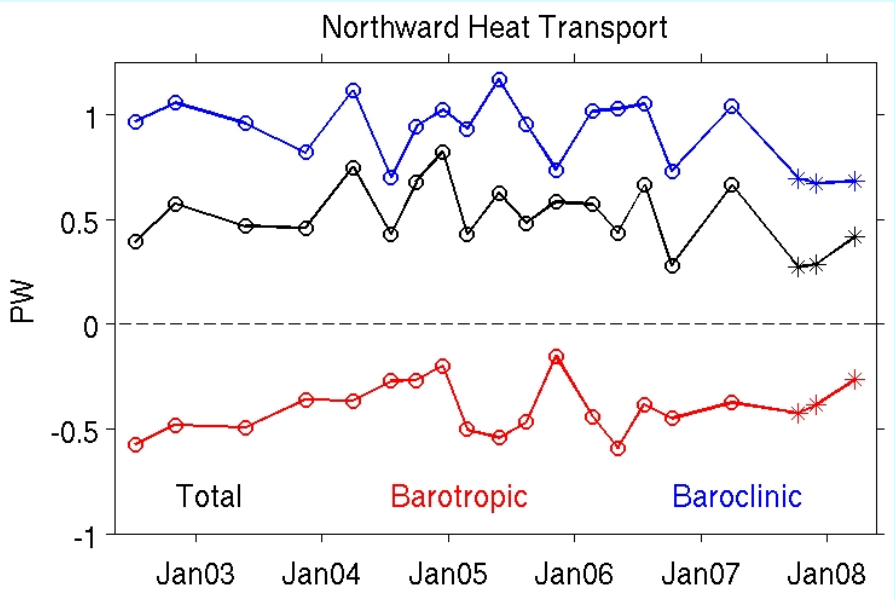
- Geostrophic transport controls the total northward heat transport.
- Geostrophic and Ekman transports experience comparable variability



Both geostrophic and Ekman transports experience annual cycles, but they are out of phase.

Garzoli and Baringer (2007)
Baringer and Garzoli (2007)

Contributions of Barotropic and Baroclinic Components



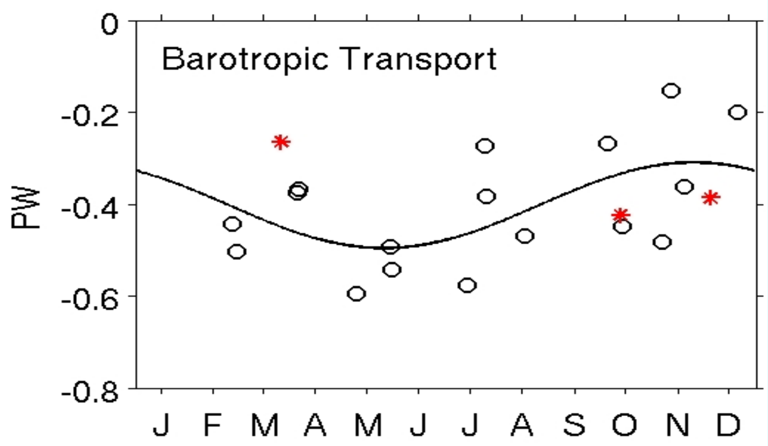
Total = 0.51 ± 0.15 PW

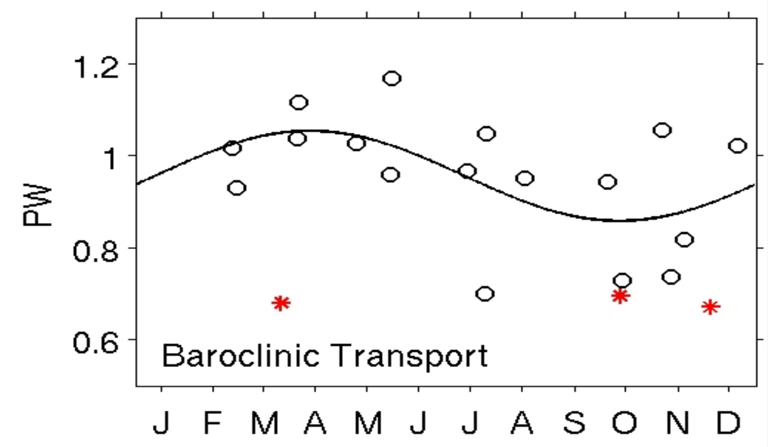
Barotropic = -0.40 ± 0.12 PW

Baroclinic = 0.91 ± 0.16 PW

$$\text{Barotropic} \propto \overline{V(z)} \times T(z)$$

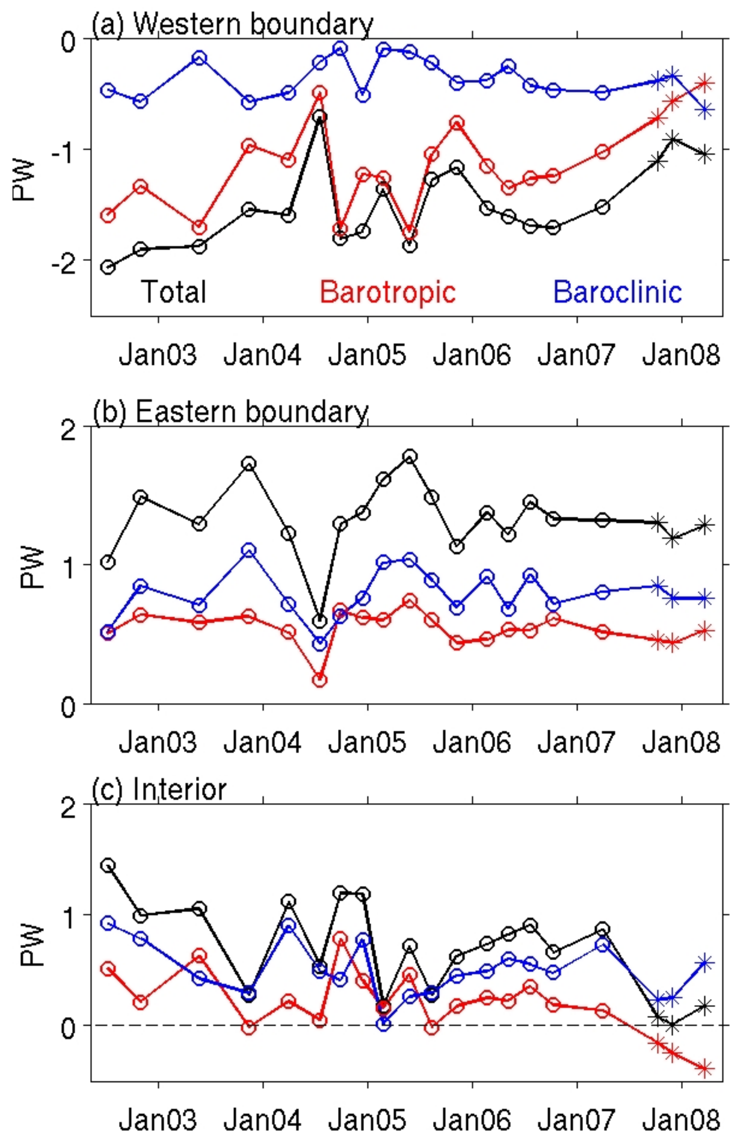
$$\text{Baroclinic} \propto (V(z) - \overline{V(z)}) \times T(z)$$

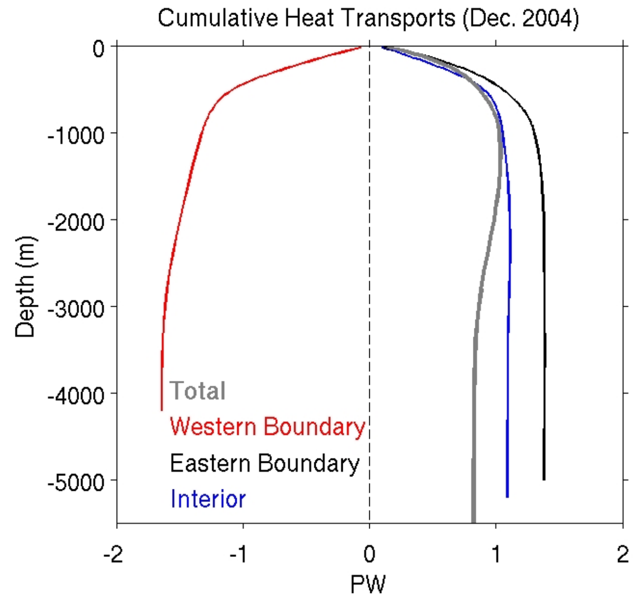




Annual cycle explains 31% of the total variance

Contributions from Boundary Currents and Interior

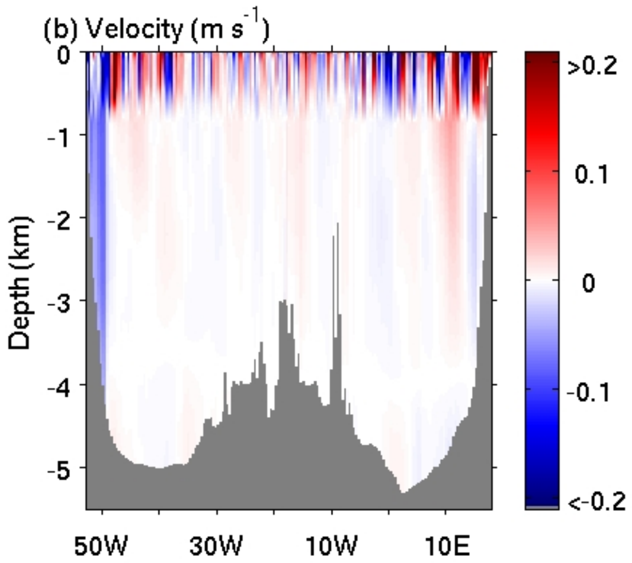




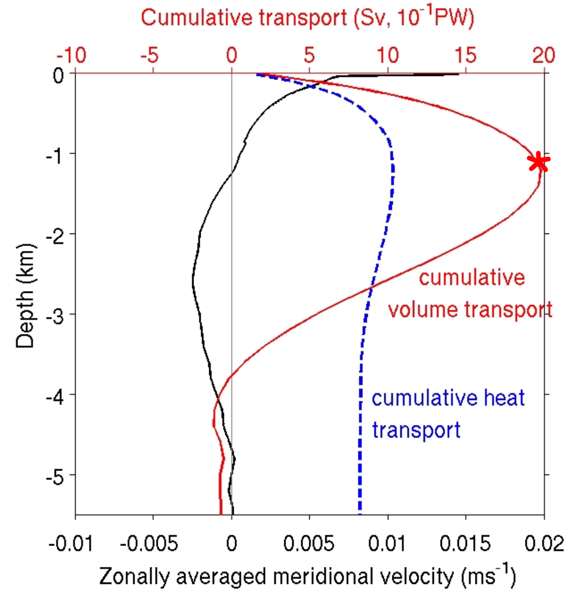
(PW)	Western	Eastern	Interior
Total	−1.50±0.36	1.32±0.25	0.69±0.42
Barotropic	−1.13±0.40	0.53±0.12	0.20±0.29
Baroclinic	−0.37±0.17	0.79±0.17	0.49± 0.24

Barotropic component dominates in the western boundary, baroclinic transport plays a relatively large role in the interior and eastern boundary

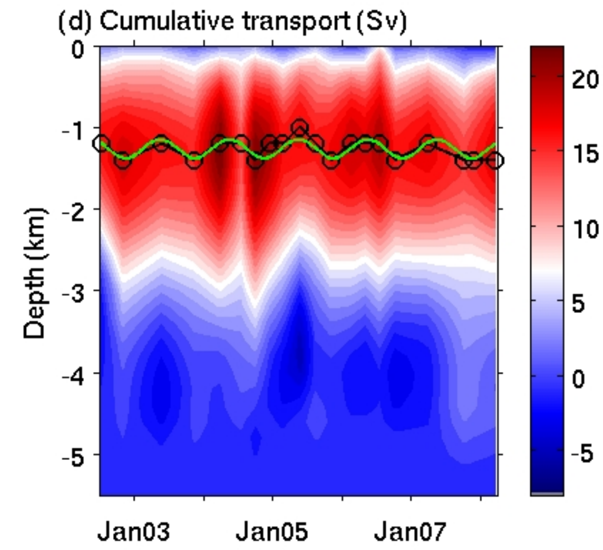
Meridional Velocity and Transport Across AX18



Meridional velocity distribution for December 2004 transect.



Zonally averaged meridional velocity, and cumulative volume transport from sea surface to ocean floor.

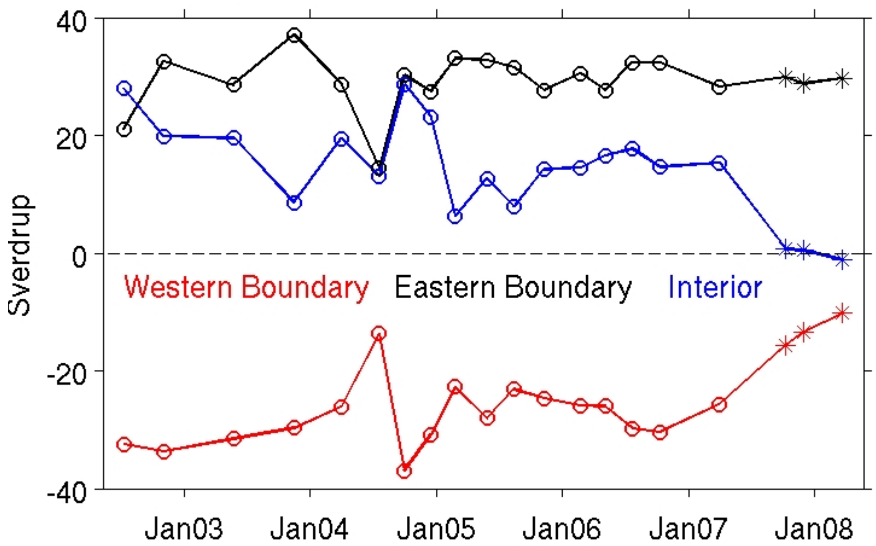


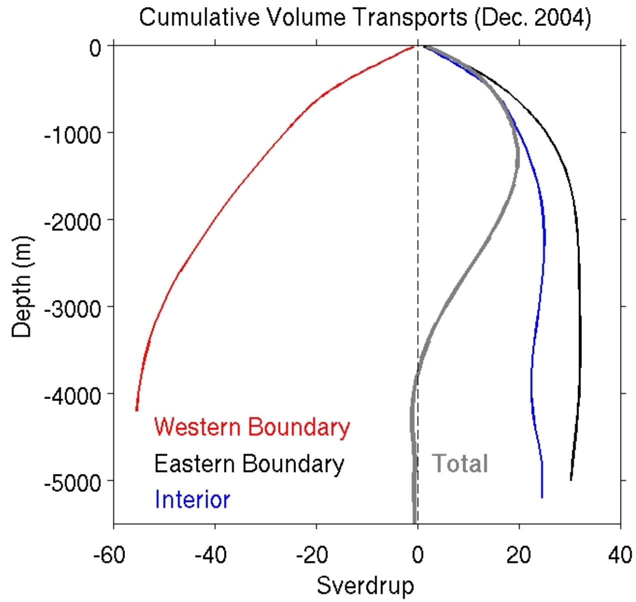
Cumulative volume transport (color), which reaches its maximum at 1300 m depth (black).

$$AMOC = \max\left(\int_0^Z \left[\int_{X_w}^{X_e} v(x,z)dx\right] dz\right)$$

Strength of AMOC: the maximum cumulative transport (trans-basin integrated) from the sea surface to the ocean bottom, represents the total northward transport in upper water column.

Contributions of Boundary Currents and Interior to AMOC



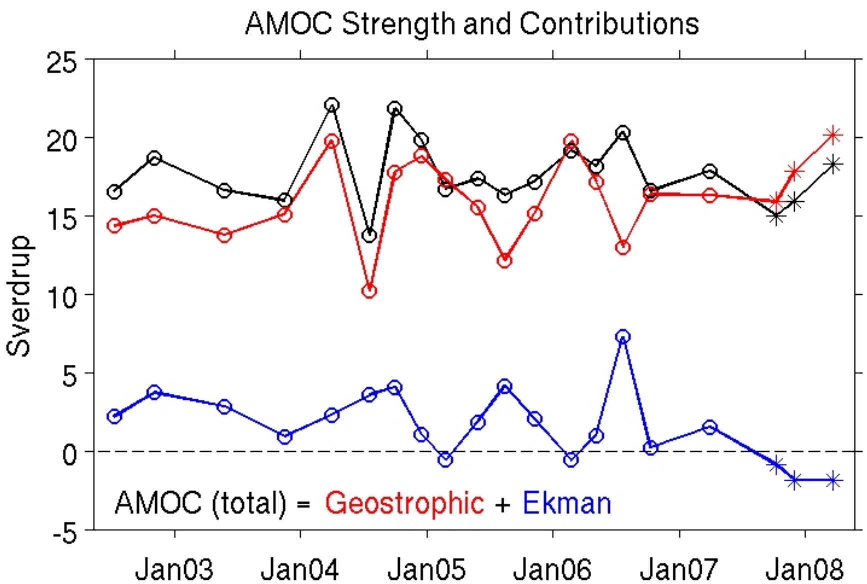


West = -25.5 ± 7.3 Sv, [27.7 ± 5.3]
East = 29.2 ± 4.7 Sv, [29.2 ± 5.2]
Inerior = 14.0 ± 8.4 Sv, [16.5 ± 6.3]

Cumulative volume transport from sea surface to ocean floor in boundary currents and interior.

To quantify the AMOC variability, it is critical to measure all three regions: the western boundary, eastern boundary, and interior.

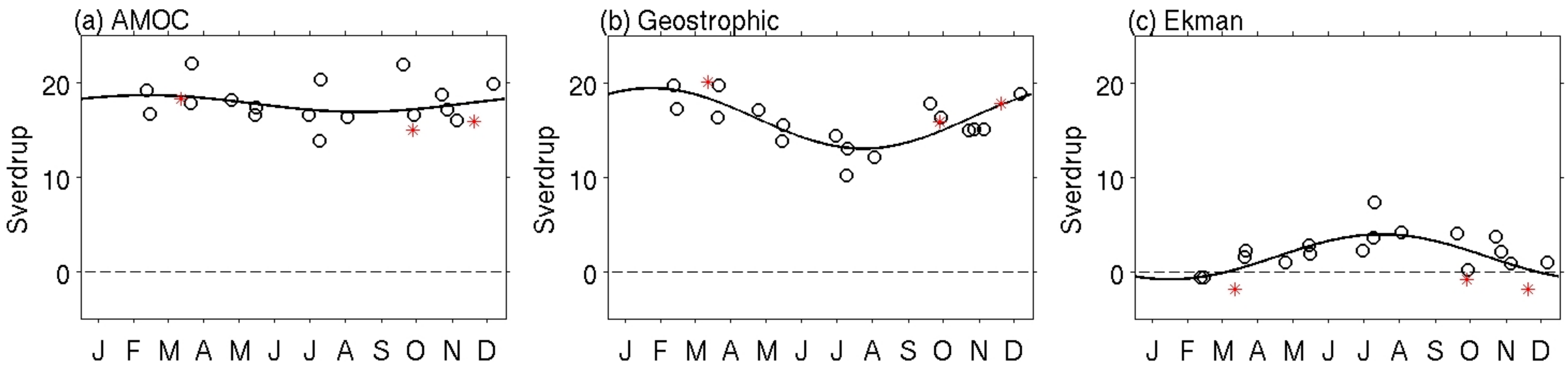
Ekman and Geostrophic Contributions to AMOC



AMOC = 17.7 ± 2.1 Sv, [17.9 ± 2.2]
Geos. = 16.1 ± 2.6 Sv, [15.7 ± 2.6]
Ekman = 1.6 ± 2.3 Sv, [2.2 ± 2.0]

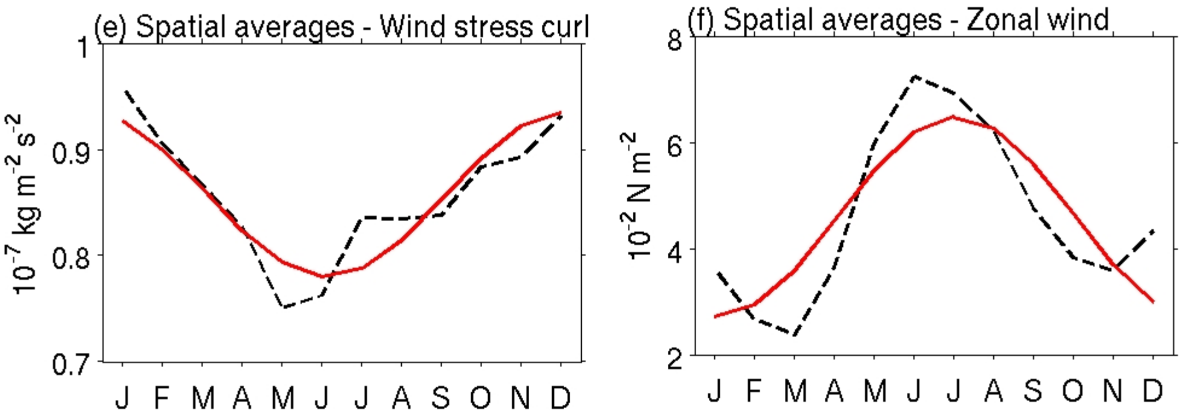
- Time-mean AMOC is dominated by geostrophic component.
- Both geostrophic and Ekman components are important in explaining the AMOC variability.

Seasonal Variability

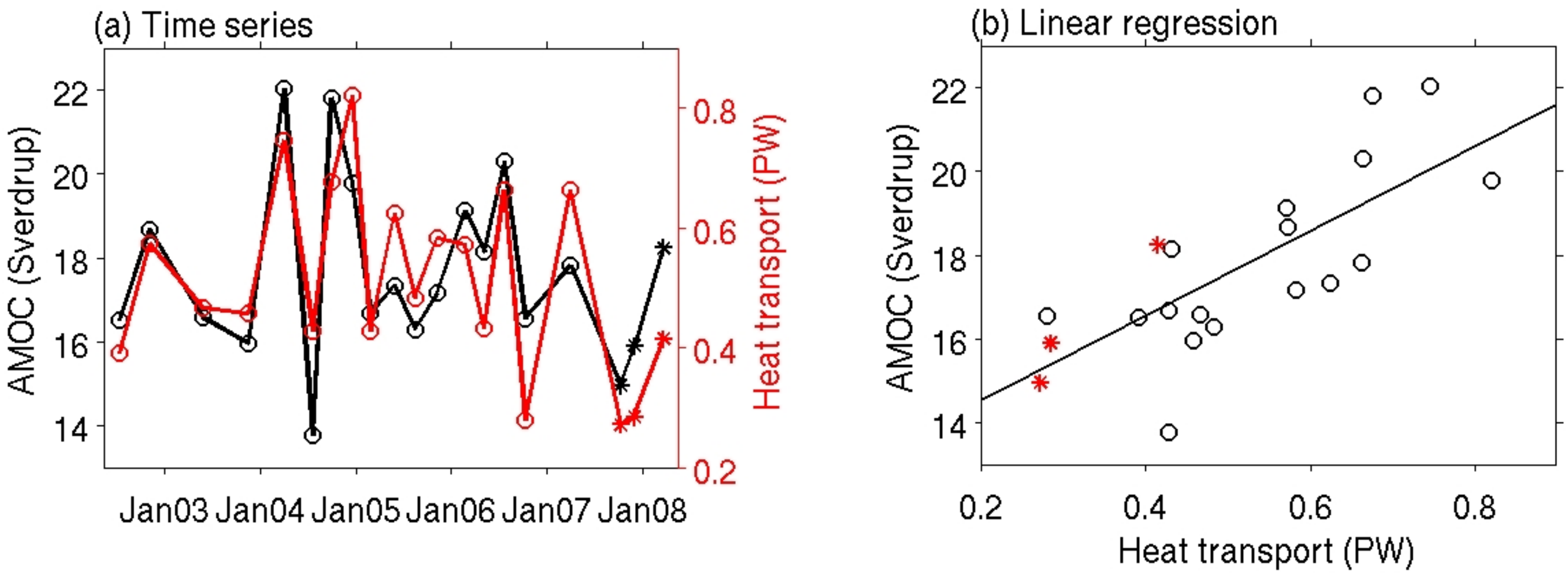


Both geostrophic and Ekman contributions to the AMOC experience annual cycles, but they are out of phase.

Seasonal cycles in geostrophic and Ekman components are consistent with the seasonal variations in wind stress curl and zonal wind stress, respectively.



AMOC Strength and Northward Heat Transport



Well correspondence between AMOC strength and the northward heat transport across AX18.

A one Sverdrup increase in the AMOC would give a 0.06 PW increase in the northward heat transport.

Conclusions

- The strength of the AMOC is significantly correlated with the northward heat transport across AX18 (~35S).
- It is important to measure boundary currents as well as interior regions in order to quantify the AMOC variability.
- Ekman and Geostrophic transports experience seasonal cycle, but they are out of phase in the South Atlantic, contrary to the North Atlantic where they are in phase.
- Ekman transport (1.6 Sv) contributes only 9% of the AMOC (17.7 Sv) on average. However, it accounts for 22% (0.11 PW) of the total northward heat transport (0.51 PW).
- The variability in Ekman transport (both volume and heat) is similar to that in geostrophic transport.