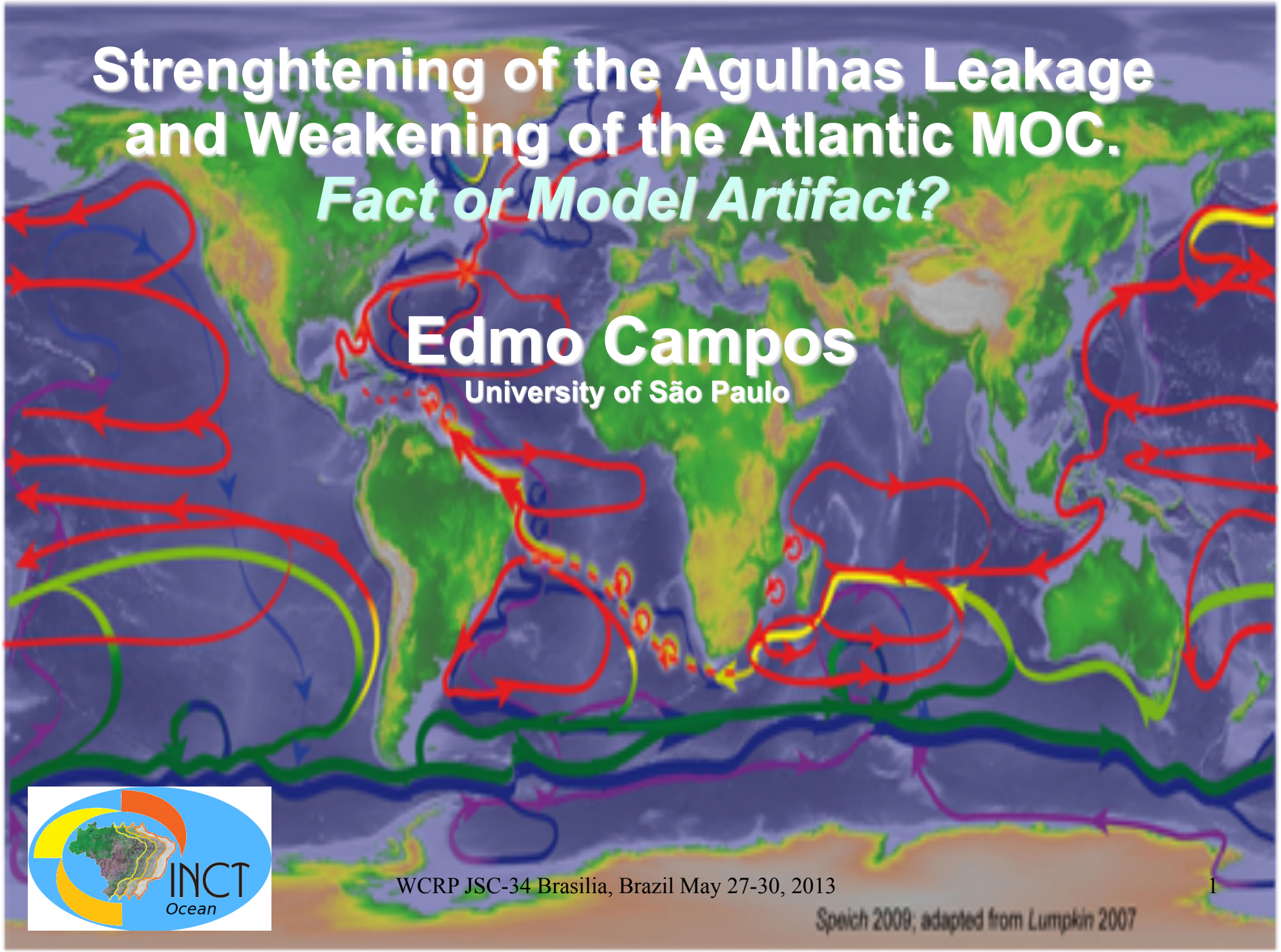
Strenghtening of the Agulhas Leakage and Weakening of the Atlantic MOC.

Fact or Model Artifact?

Edmo Campos
University of São Paulo



INCT Ocean

OUTLINE

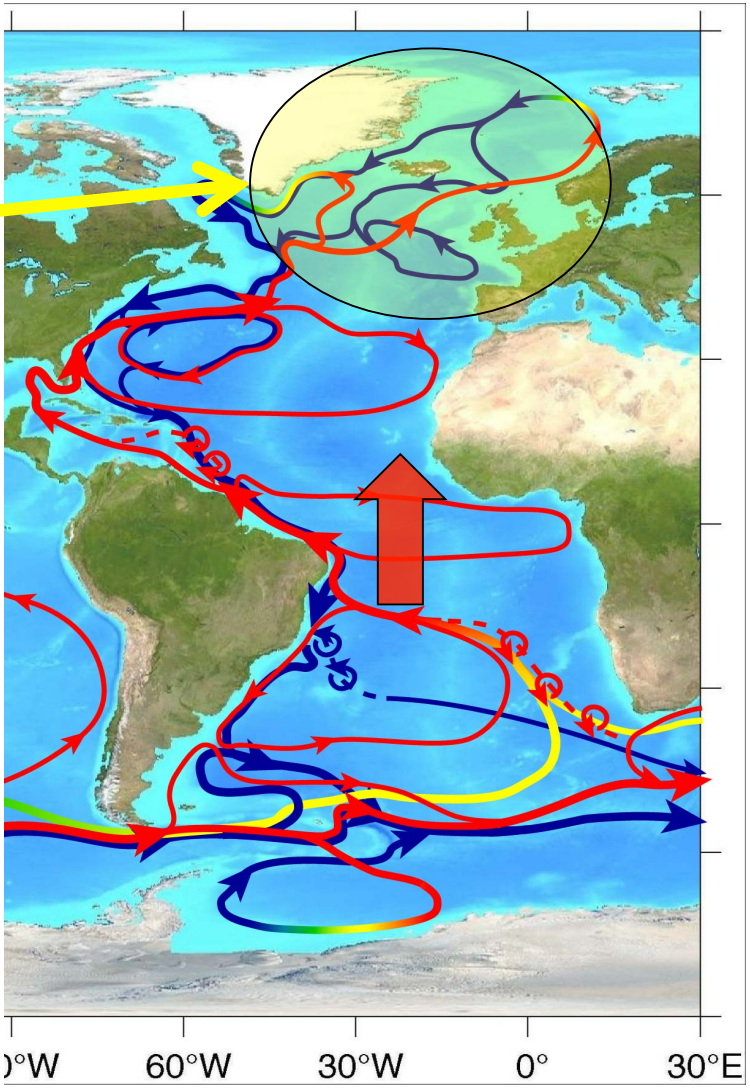
- ✧The Atlantic Meridional Overturning Circulation
- ✧The South Atlantic and the Agulhas Leakage
- ✧Signs of Increasing Agulhas Leakage
- ✧A Numerical Experiment
- ✧Variability of the AMOC: Model & Observations
- ✧Some Brazilian Efforts in the South Atlantic

AMOC: An important mechanism in the Climate System

The deep water formation by convection in the higher latitudes of the North Atlantic is crucial mechanism for the maintenance of the Global Thermohaline Circulation.

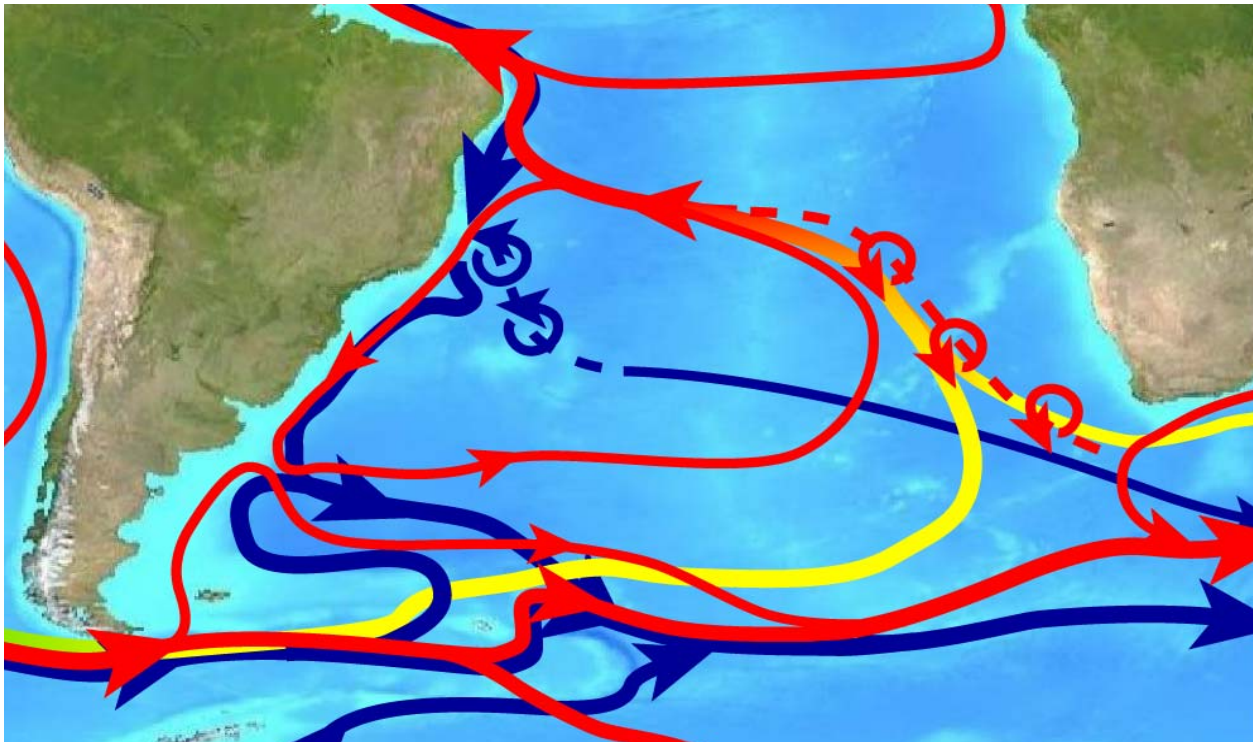
The southward flow of the cold North Atlantic Deep Water requires a northward transport of warmer waters in the upper layers.

This Atlantic Meridional Overturning Circulation (AMOC) results in the northward heat transport of about 1.3 petawatts.



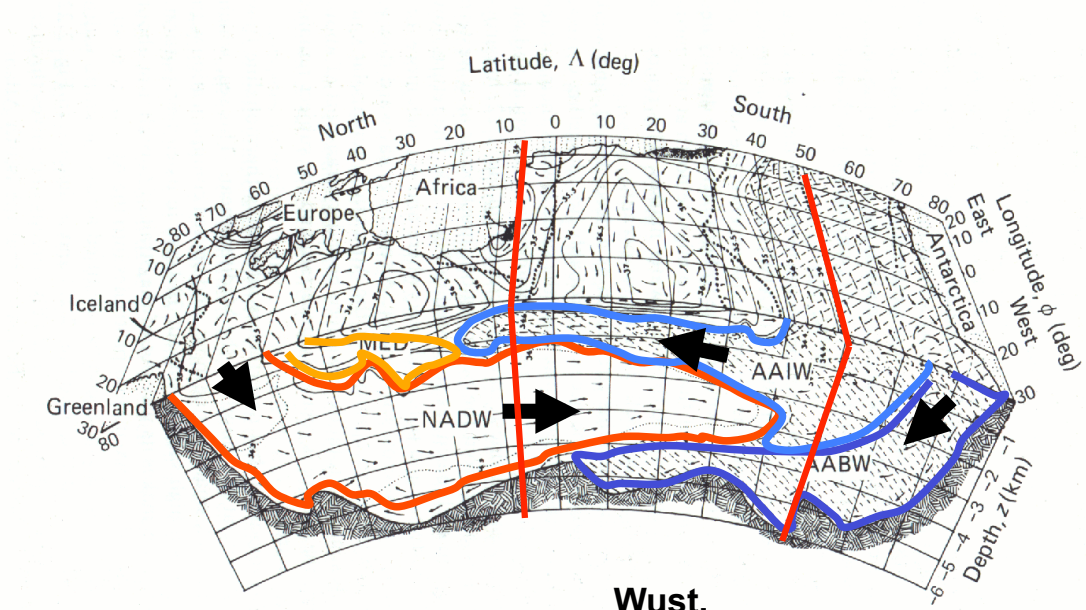
Small variations in the MOC strength may have serious consequences

The South Atlantic connects the North Atlantic to rest of the Ocean

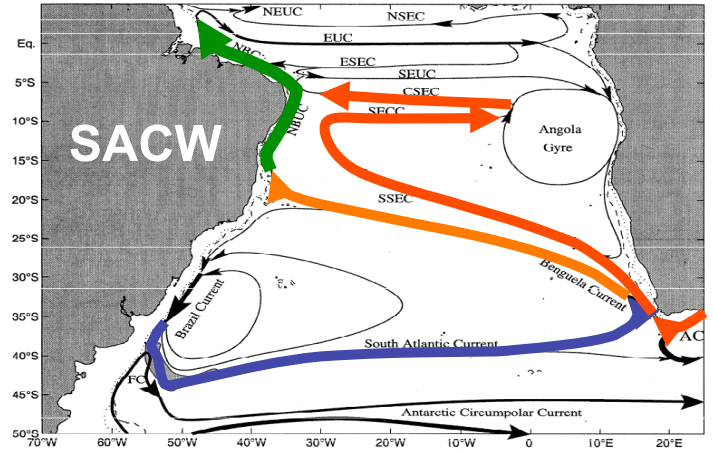


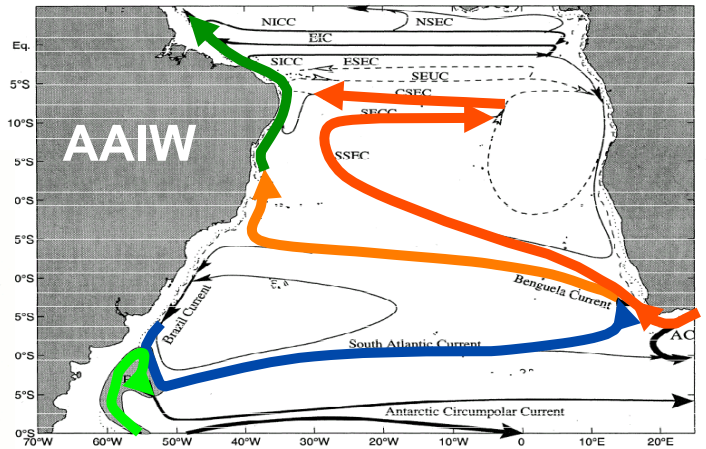
Components of the MOC in the South Atlantic

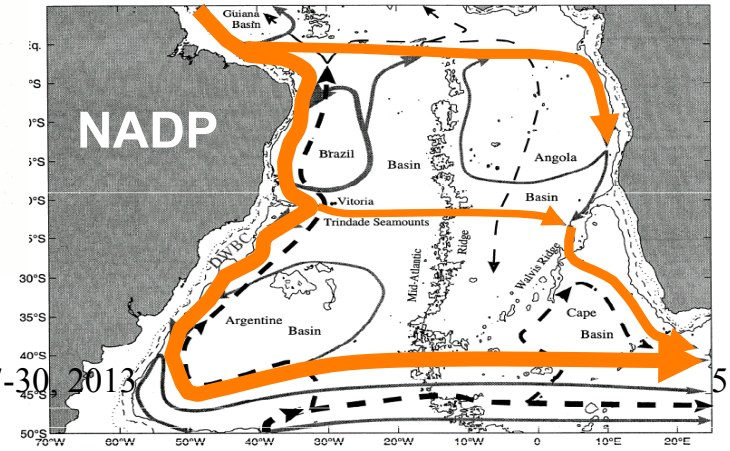
The Northward branch is formed by the South Atlantic Central Water (SACW) and the Antarctic Intermediate Water (AAIW). The southward deep flow carries North Atlantic Deep Water (NADP)



Wust, 1950

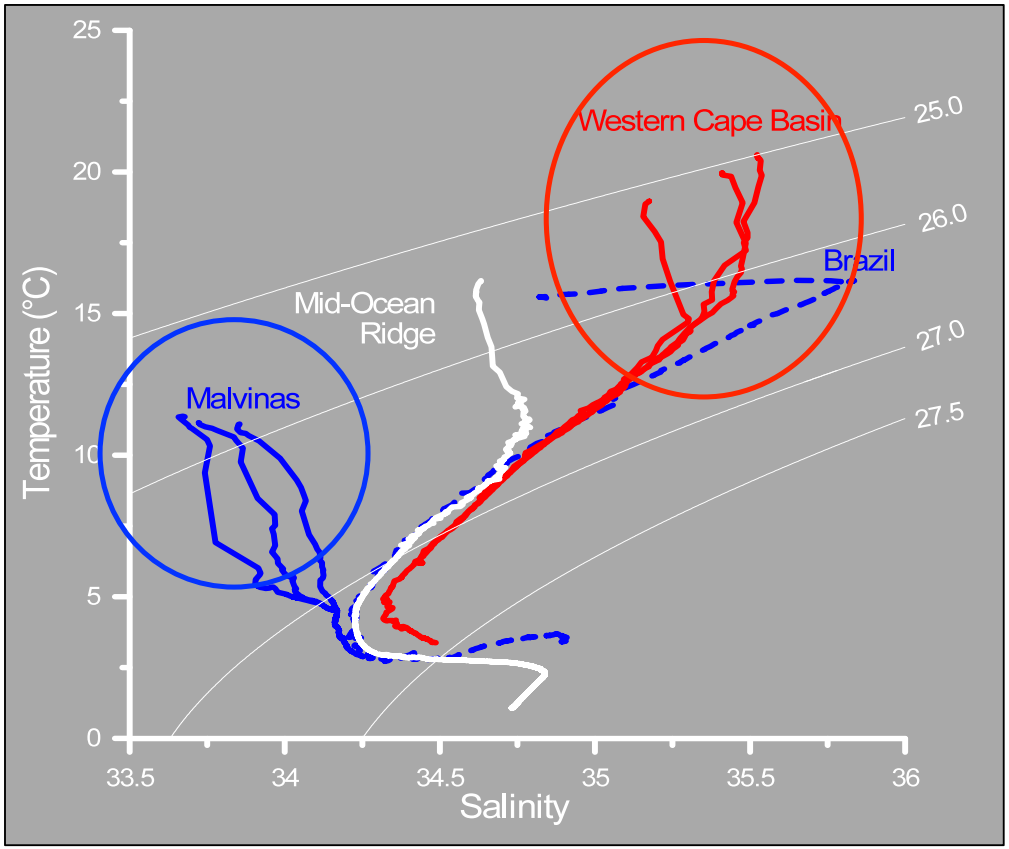






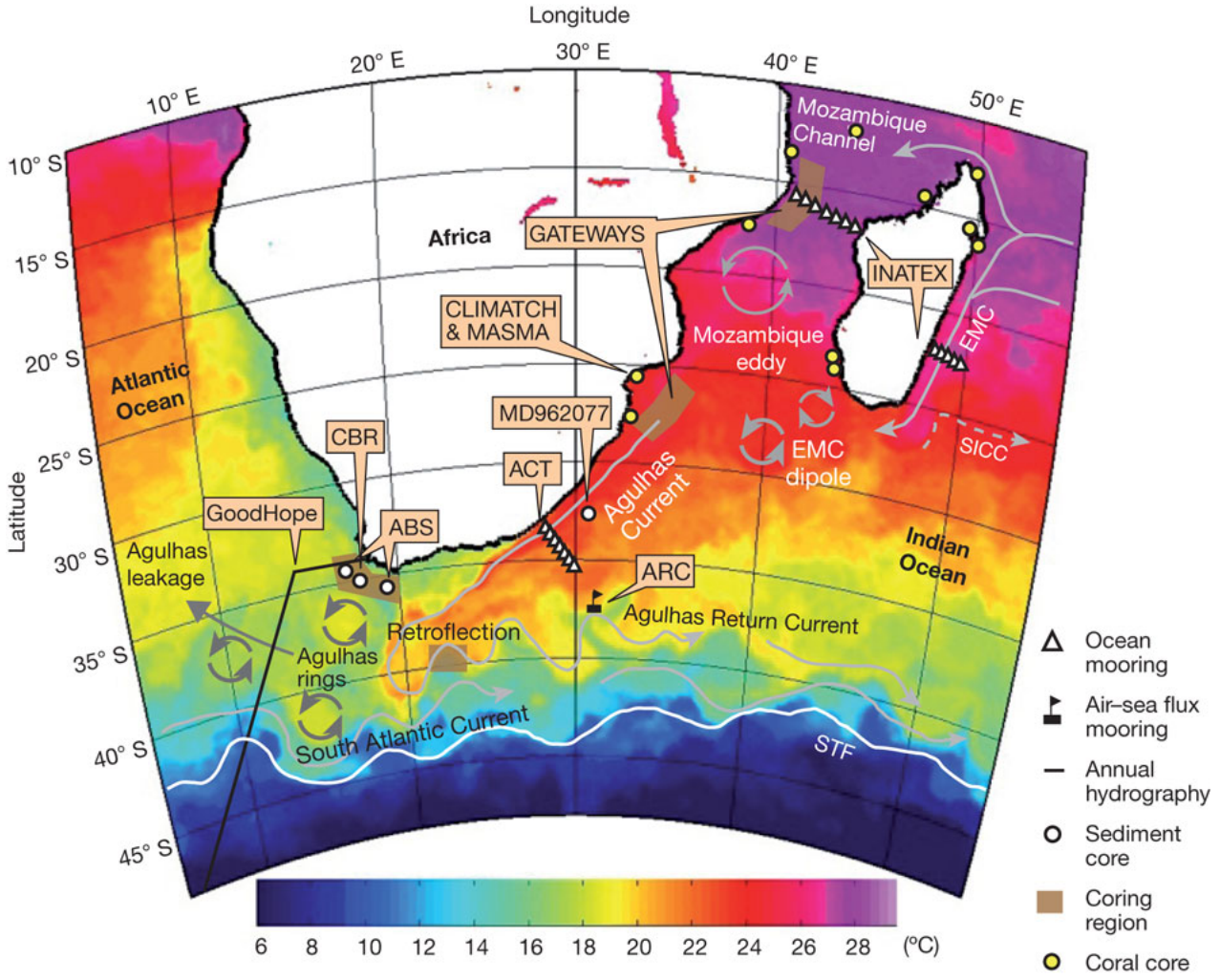
The upper limb of the AMOC in the South Atlantic is formed by waters from the Pacific and the Indian Oceans

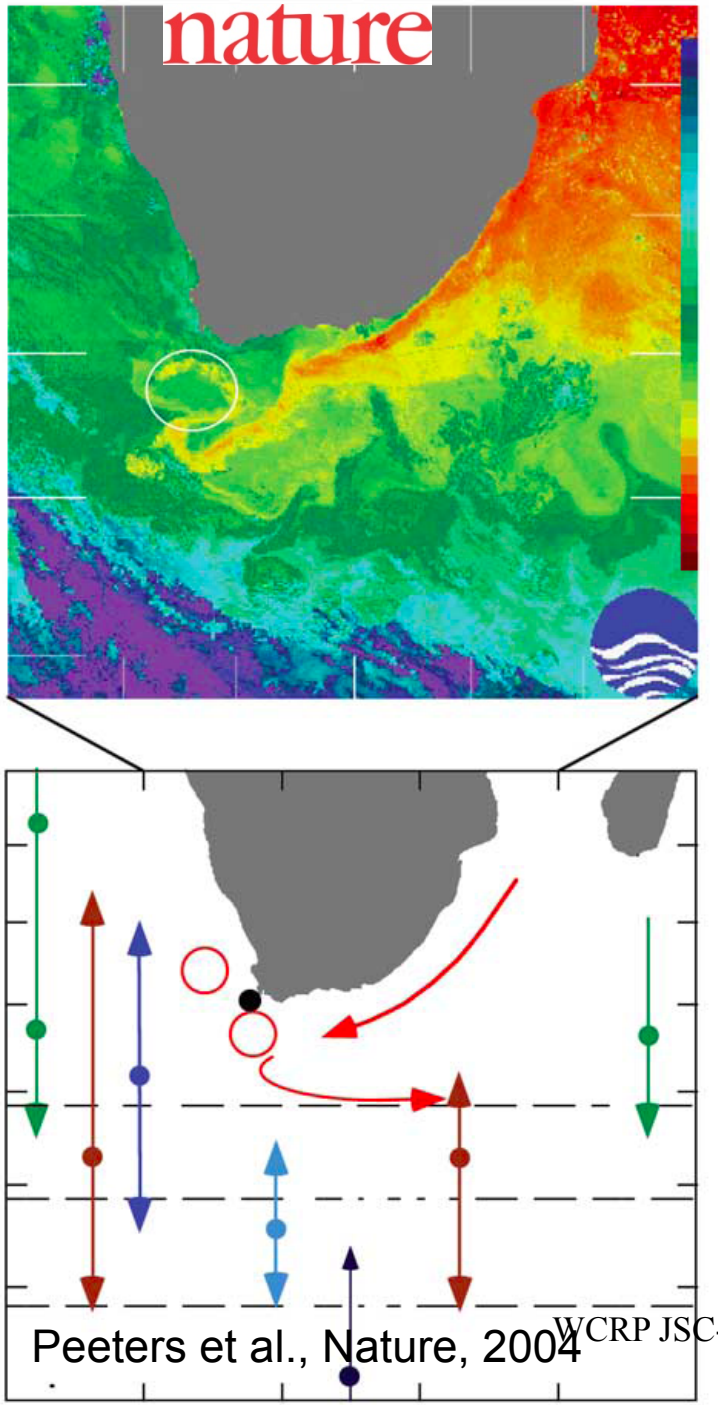
Changes in the relative contributions of these two water masses may have considerable impacts on the deep water formation in the North Atlantic.

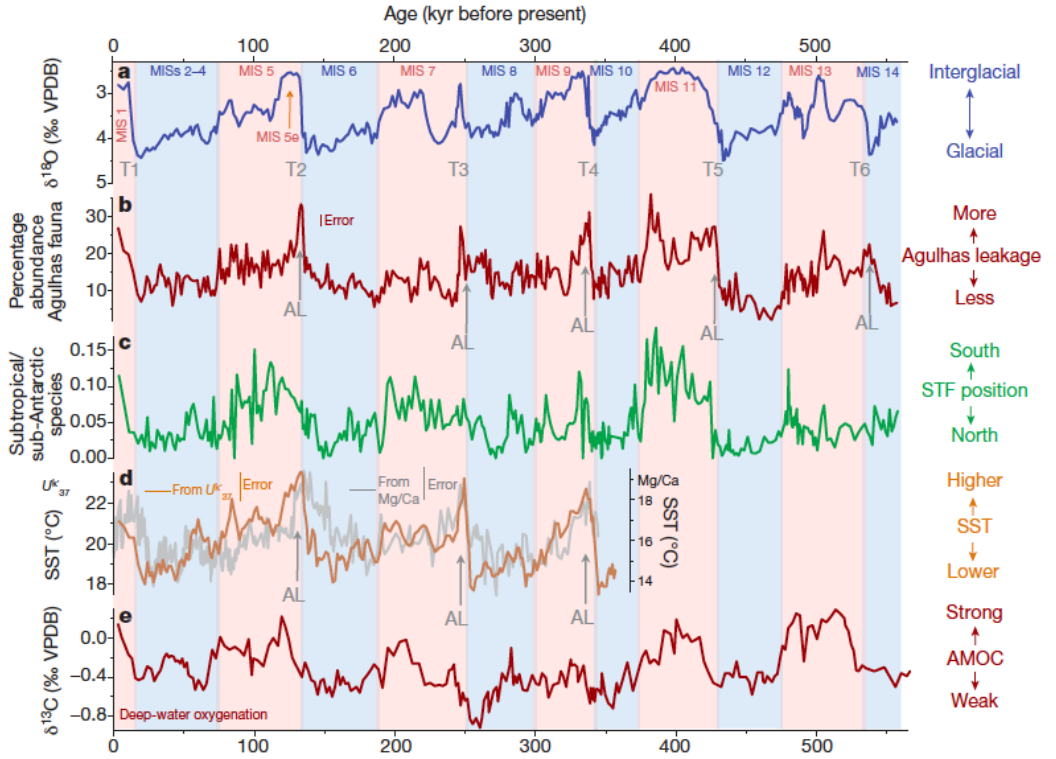


The Agulhas Leakage

The “Agulhas Leakage” is the export of Indian Ocean waters into the South Atlantic by rings and filaments at the Agulhas Current Retroflection region.



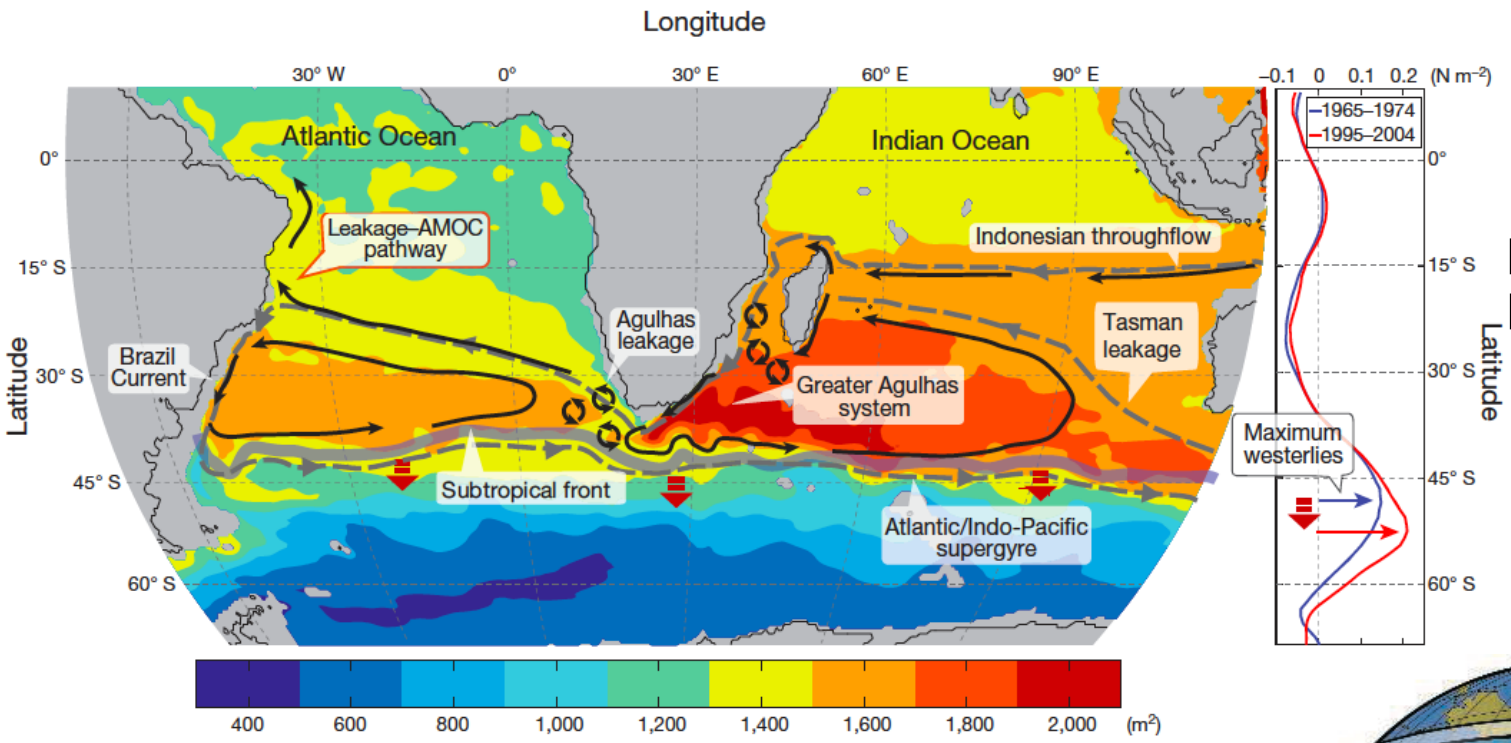




Beal et al, 2011 Nature

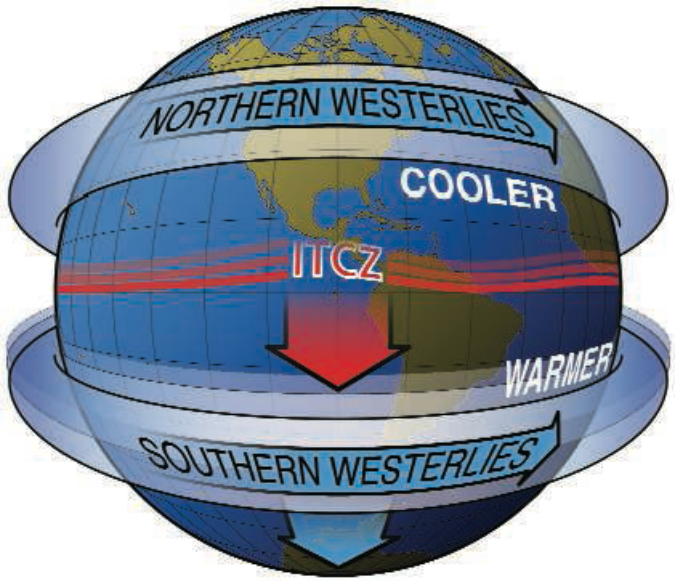
Paleo records indicate that the strength of the Agulhas Leakage has changed in the past.

Interruption of the Agulhas Leakage might have caused the weakening of the THC prior the last glaciation.



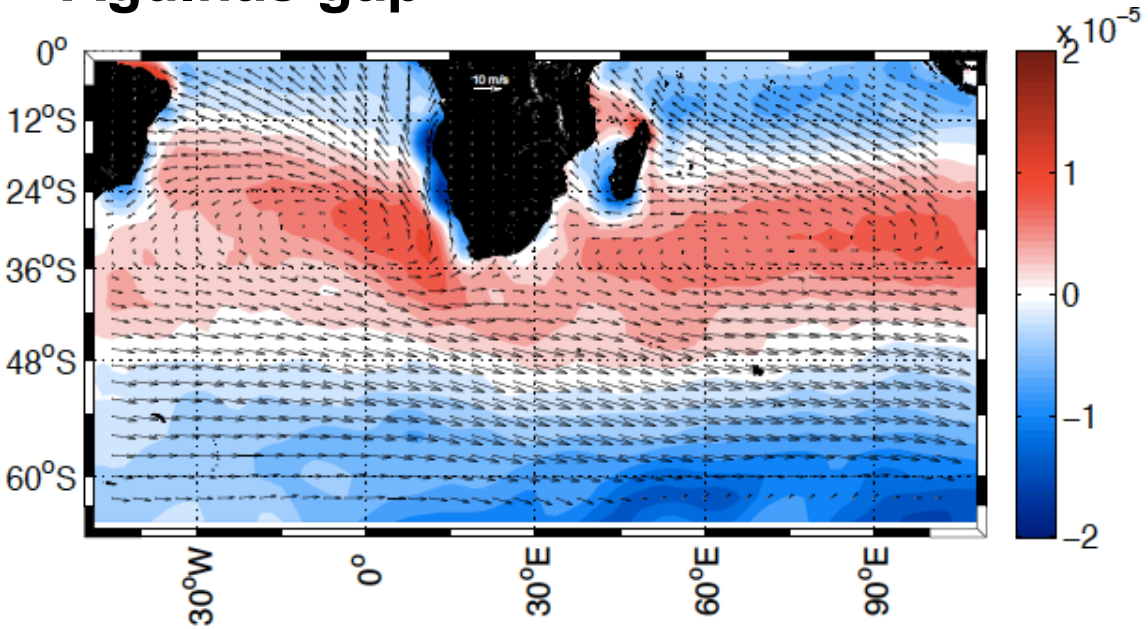
Beal et al, 2011 Nature

Models suggest that the "Agulhas Leakage" is increasing in response to changes in the winds.



Shifting Westerlies
J. R. Toggweiler, Science, 2009

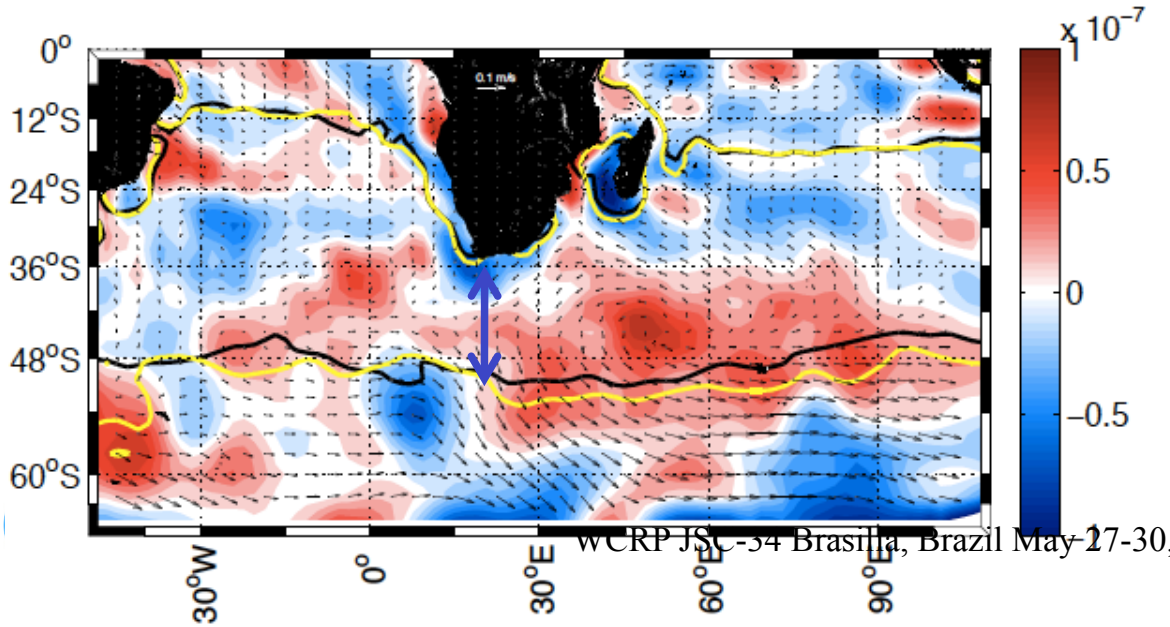
Strengthening of the wind-stress curl and widening of the "Agulhas gap"



Wind Stress Curl - NCEP

Colors: Strength of the wind stress curl averaged from 1960 to 2010

Vectors: mean wind velocity

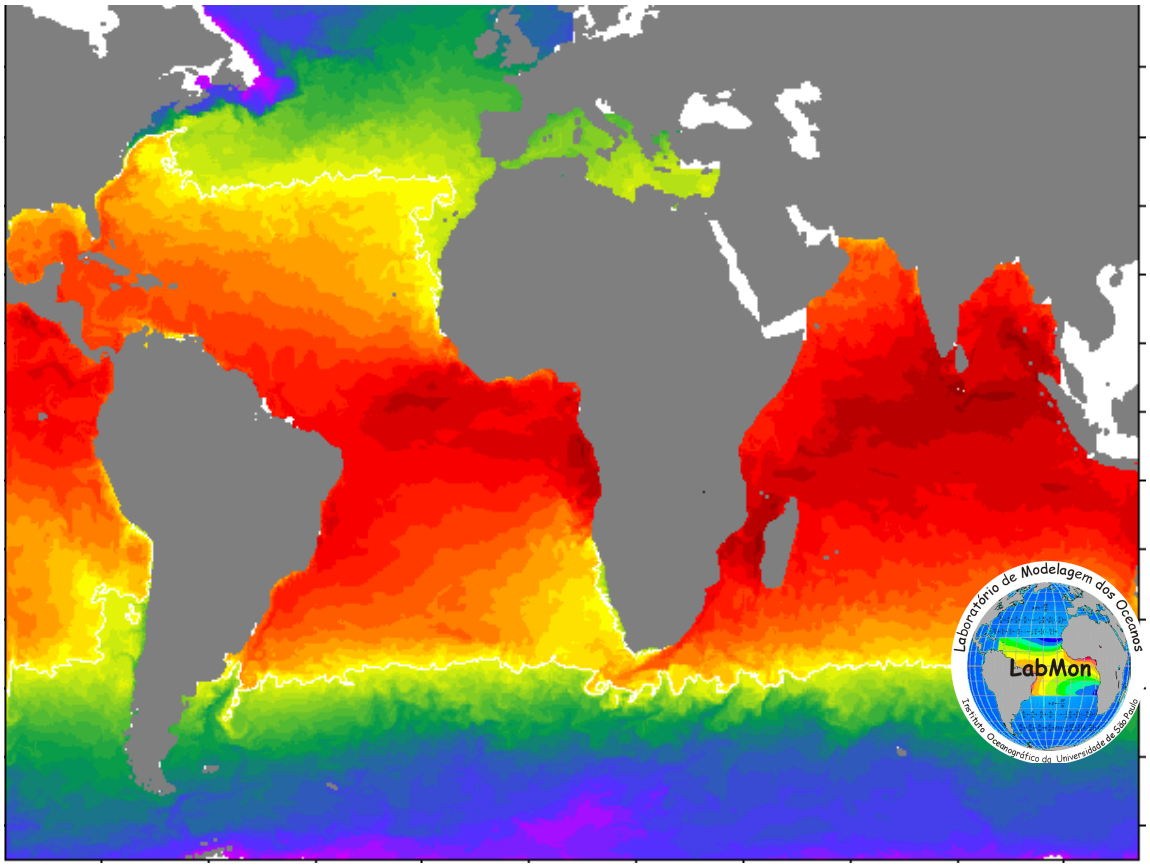


Colors: Linear trend of the wind stress curl. The black and yellow lines indicate zero curl line, before and after the trend.

Vectors: Linear trend of the wind velocity

A Numerical Experiment for testing the hypothesis:

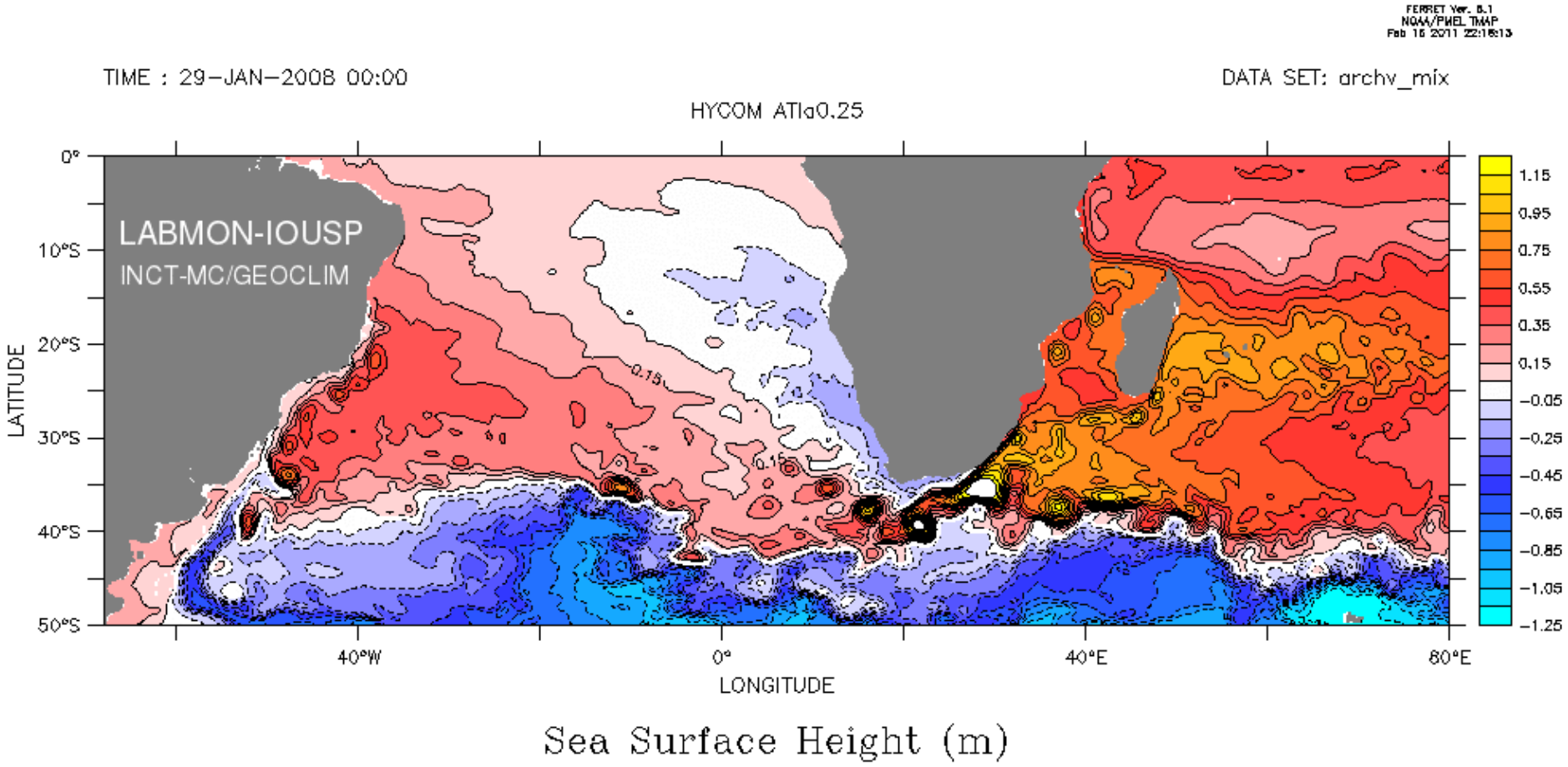
Wider "Agulhas gap" → Increased "Agulhas Leakage" → Stronger AMOC

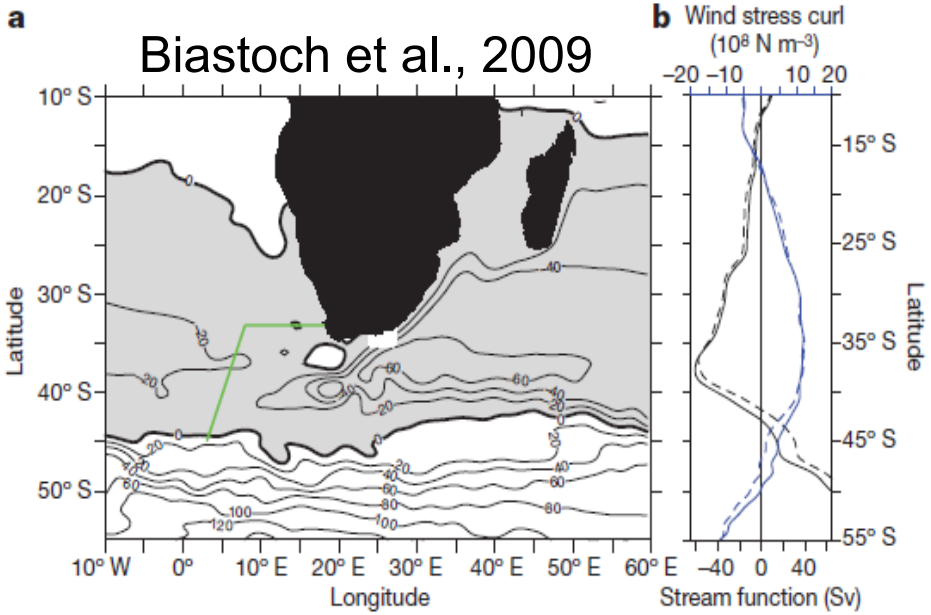


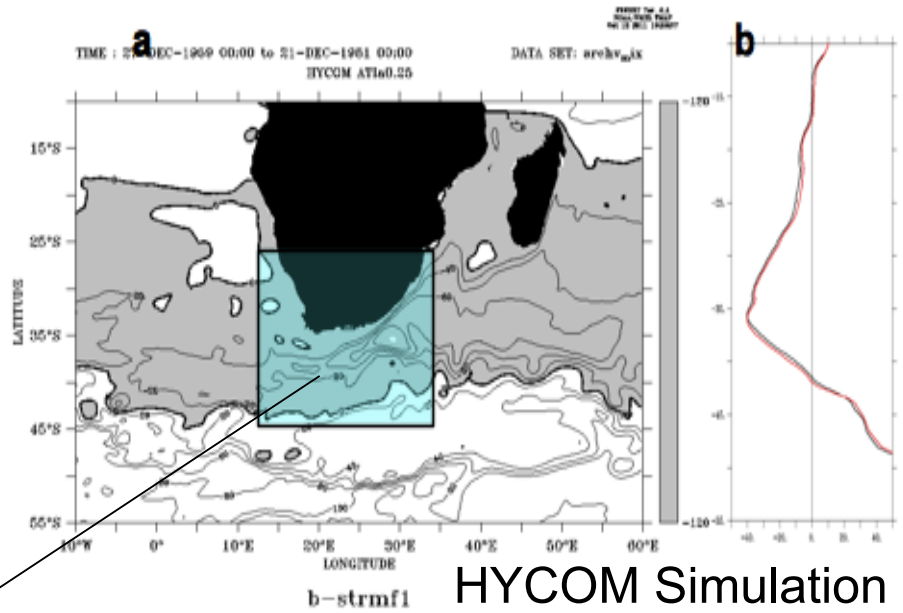
Forced with NCEP reanalysis products, from 1948 to 2012 to Investigate the ocean response to varying winds.

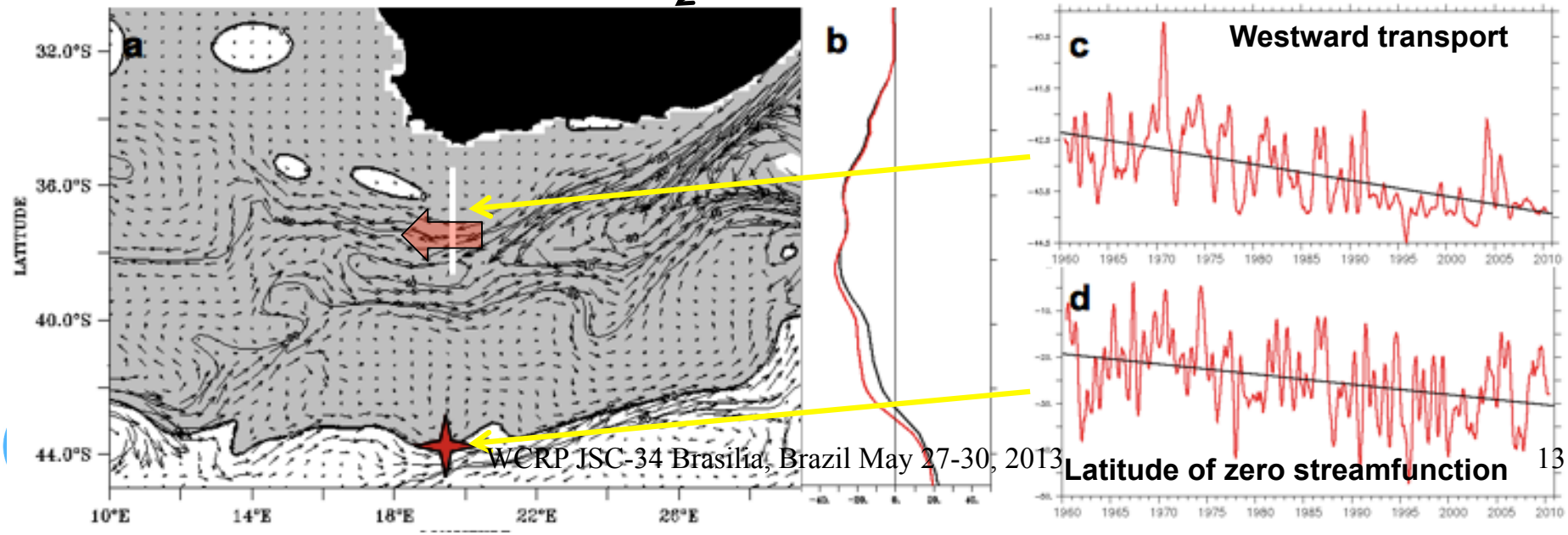
HYCOM, 1/4-degree,
22 hybrid layers
98W – 114E
65S – 60N

The Agulhas Leakage in the Numerical Experiment



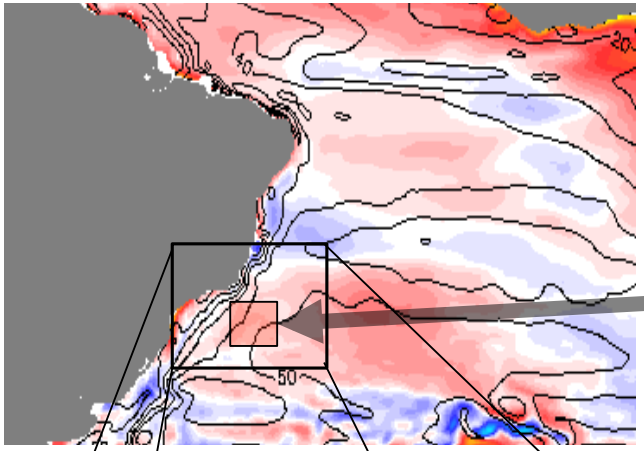

a
Biastoch et al., 2009
b Wind stress curl
(10⁸ N m⁻³)
Latitude
Longitude
Stream function (Sv)

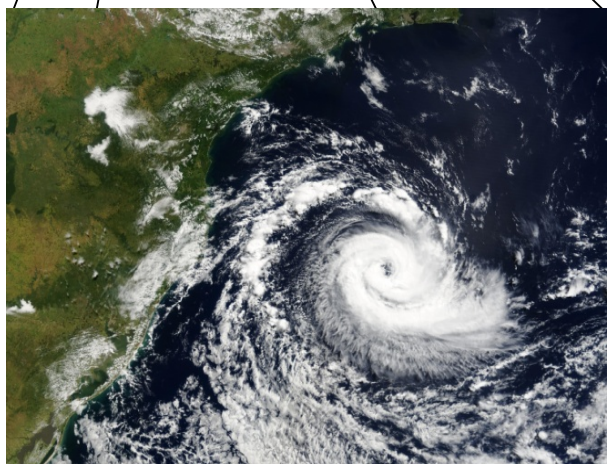

a
b
HYCOM Simulation
b−strmf1

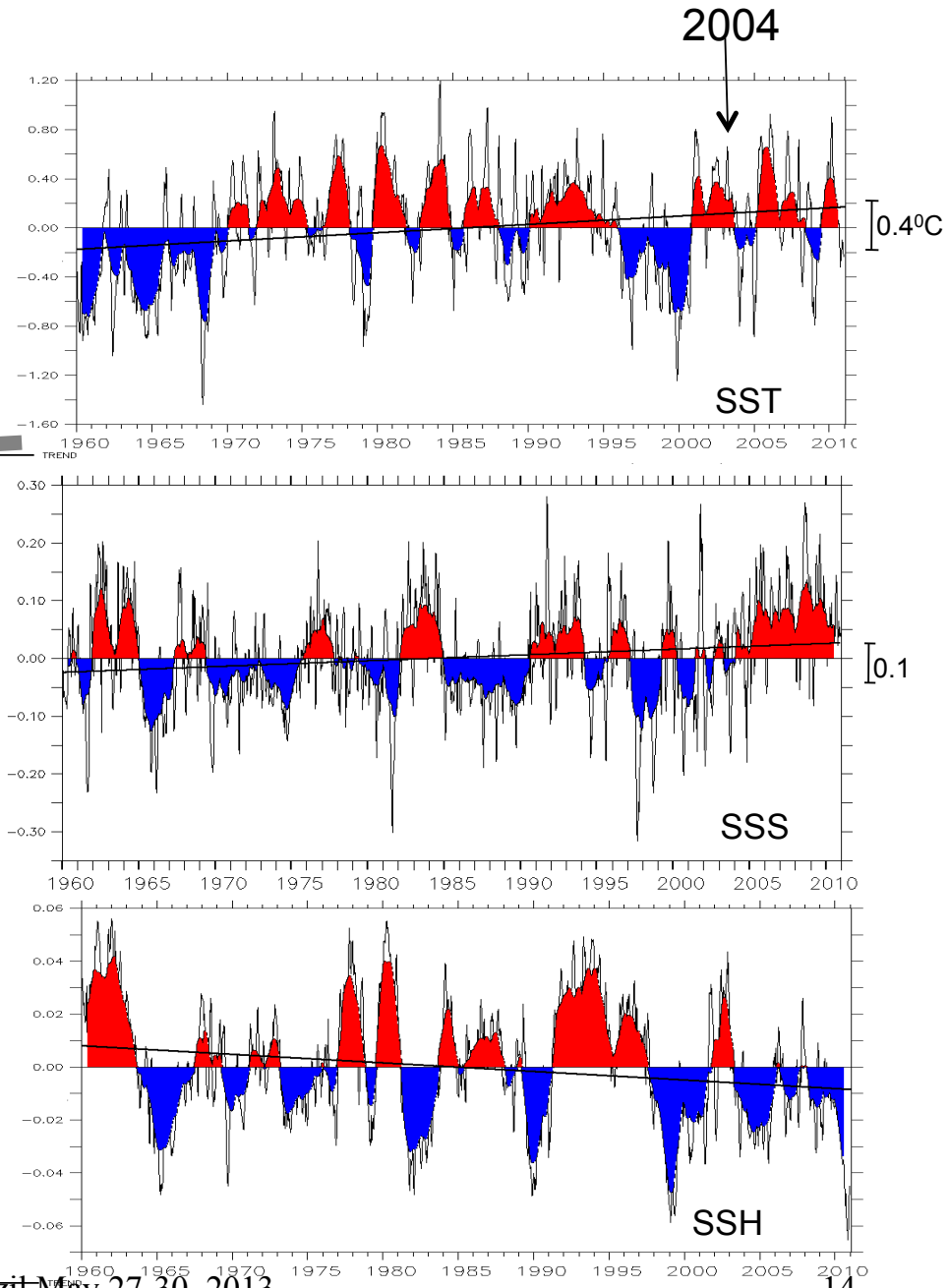

a
b
c
Westward transport
d
Latitude of zero streamfunction

Regional Relevance

Other “Catarinas”?

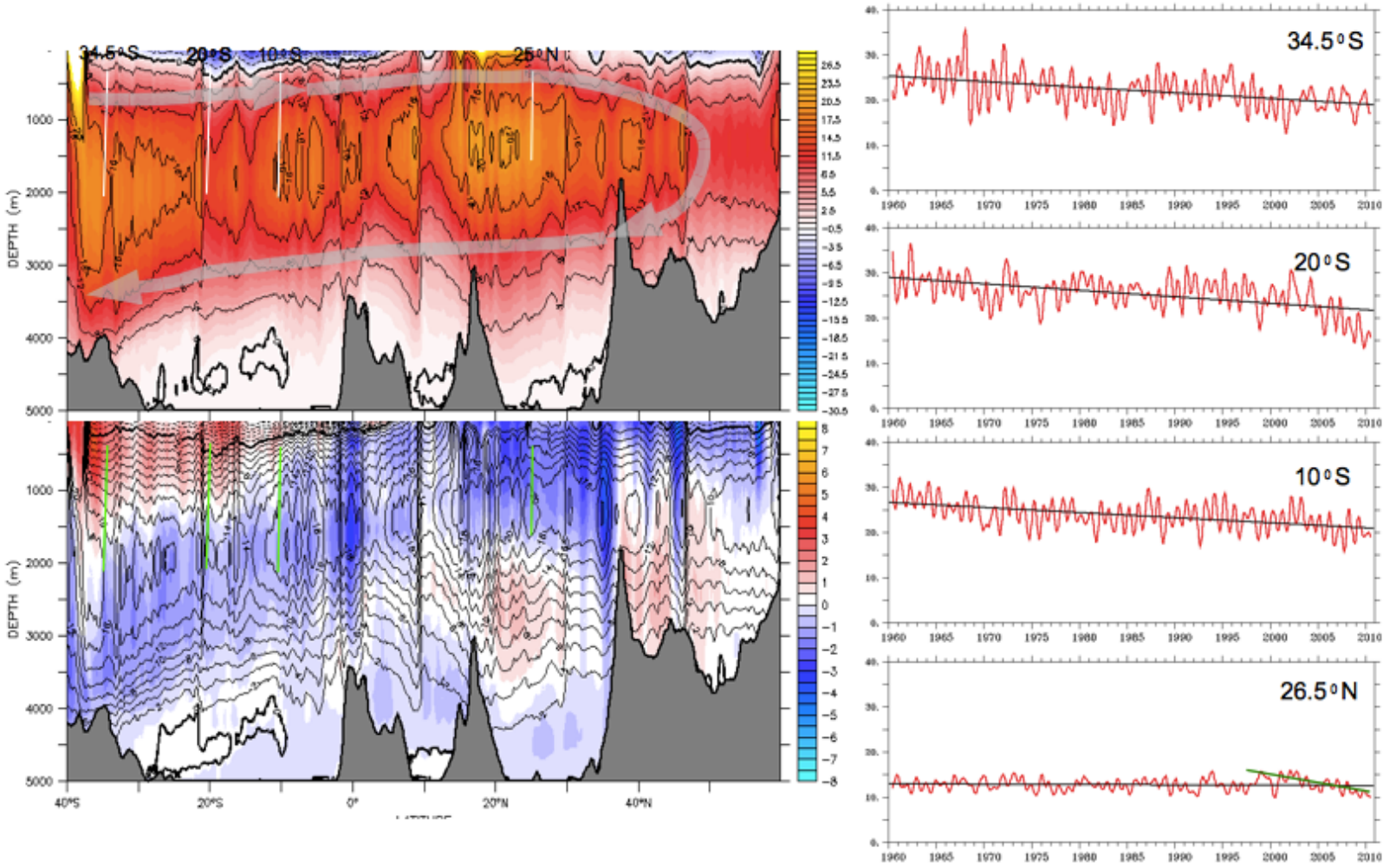






Catarina, the 1st Hurricane in the South Atlantic – Mar 2004

Model results show an increase in the Agulhas Leakage. However, the preliminary analyses showed a weakening of the AMOC



Need to compare with observations

NATURE, vol 497, 9 May 2013

IN FOCUS NEWS

OCEANOGRAPHY

Oceans under surveillance

Three projects seek to track changes in Atlantic overturning circulation currents.

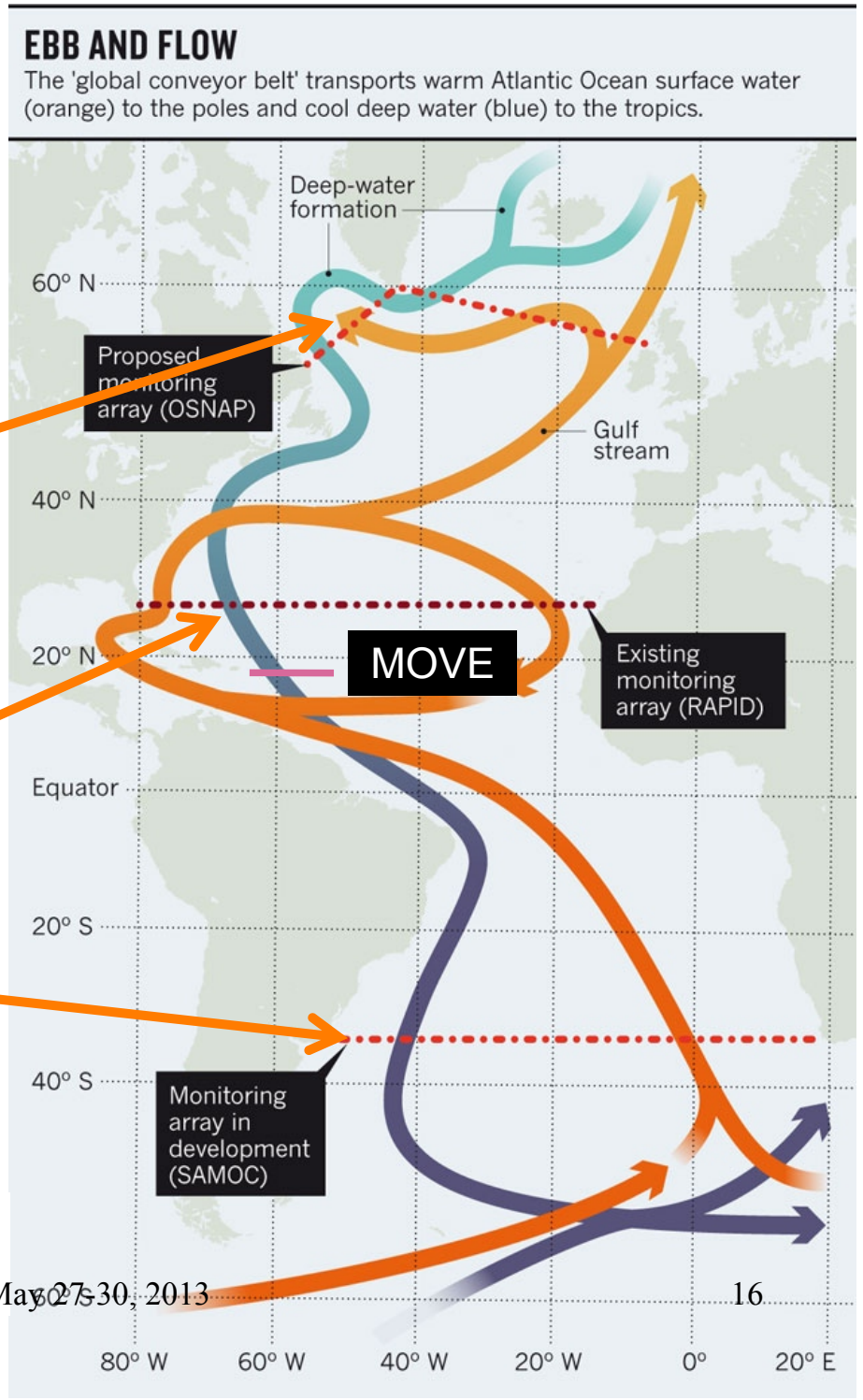
The AMOC will be monitored on three arrays across the Atlantic:

OSNAP, surface-to-bottom monitoring array between Canada and Scotland, proposed to US and British funding agencies.

RAPID-MOCHA, from the Florida to Africa across 26.5N, which has been in place since 2004

SAMOC, a multinational effort in the South Atlantic from Brazil to South Africa, along 34.5S. The Brazil-US-Argentina component is in place.

There is a 4th system, the MOVE array, which monitors the deep flow on 16N.



Variability of the AMOC: Model X Observations

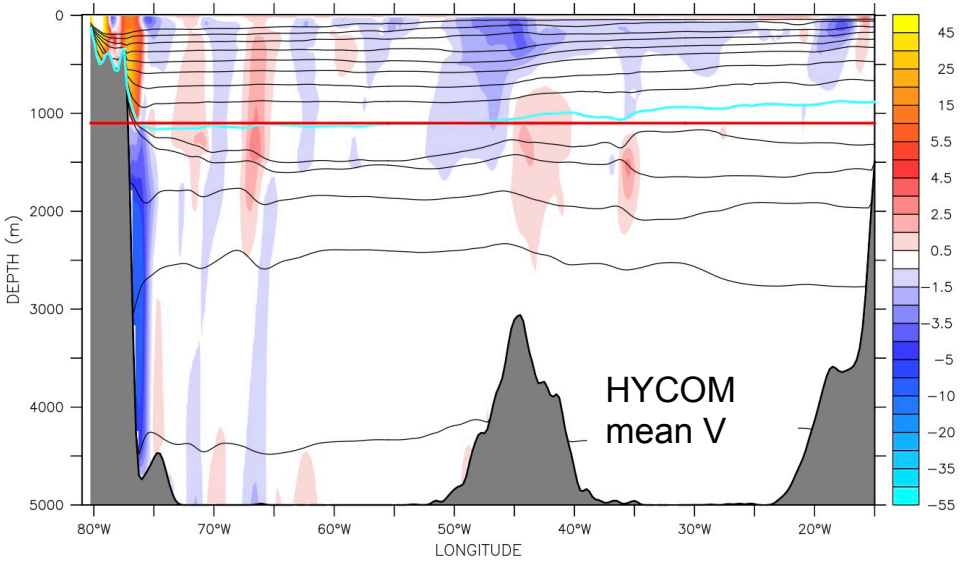
GEOPHYSICAL RESEARCH LETTERS, VOL. ???, XXXX, DOI:10.1029/,

Weakening of the Atlantic Meridional Overturning Circulation in the North Atlantic from 1960 to 2010

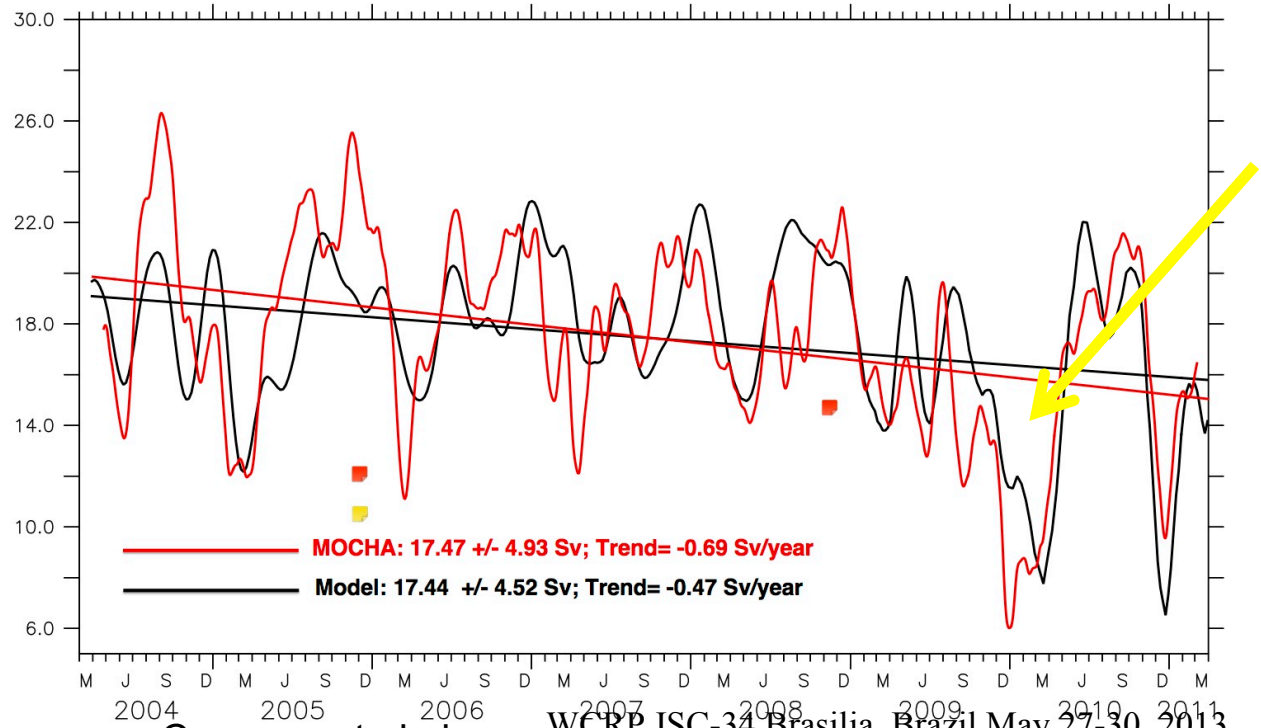
Edmo J. D. Campos,[1] William E. Johns,[2] Christopher S. Meinen,[3], Silvia L. Garzoli[3,4] and Uwe Send[5]

Output from a numerical experiment with the Hybrid Coordinate Ocean Model (HYCOM), forced with NCEP/Reanalysis, was used to calculate heat and volume transports by the Meridional Overturning Circulation (MOC) in the North Atlantic. The results are compared with estimates from the RAPID-MOCHA-WBTS and the MOVE arrays. It is found that the mean values, the interannual variability and trends computed from the model are in remarkably good agreement with the estimates from the

show that a weakened AMOC, resulting from changes in the South Atlantic inter-ocean exchanges, can induce a dipole response over the Atlantic, with a cooling in the North Atlantic and a warming in the tropical and South Atlantic. These modeling results appear to be supported by paleo-records [*Caley et al., 2012; Peeters, 2004; Stott et al. 2002; Peterson et al. 2000*]. The IPCC 4th Assessment Report [*IPCC-AR4*], based on the analyses of a suite of climate models, reports a weakening of the AMOC at 30N during the 20st Century.



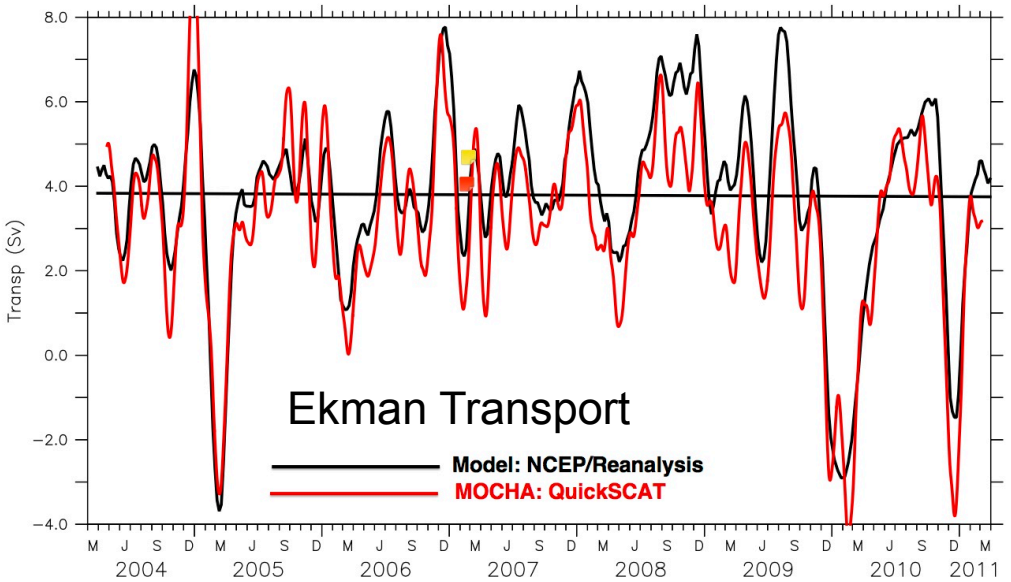
Estimates of the AMOC across 26.5N, from 0 to 1100 meters, from RAPID/MOCHA Array and from a model simulation forced with NCEP products show negative trends from 2004 to 2011.

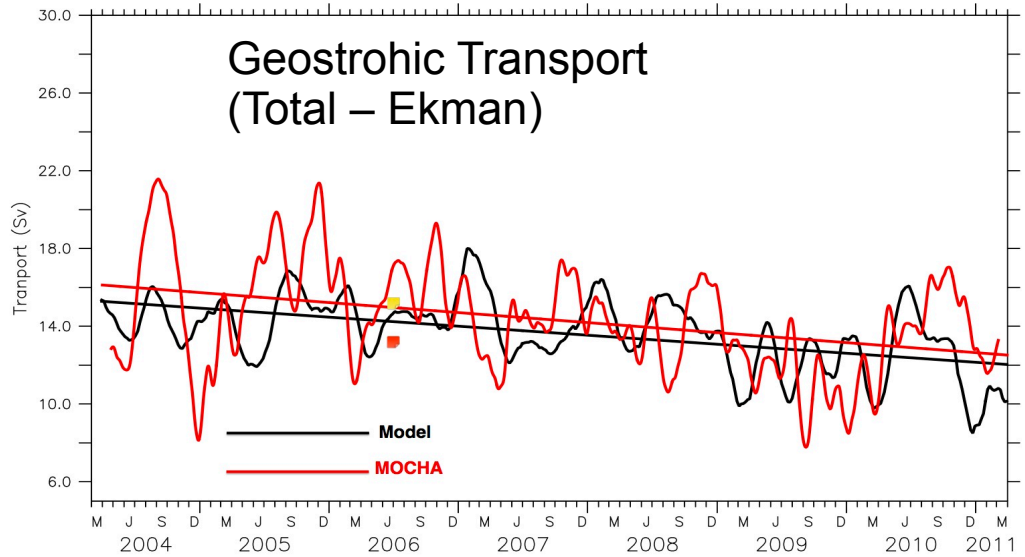


Both, model and data show a drop in the northward transport in 2009-2010.

This drop in the flow reduced the northward heat transport by almost 200 trillion watts.

Campos, et al., in prep.

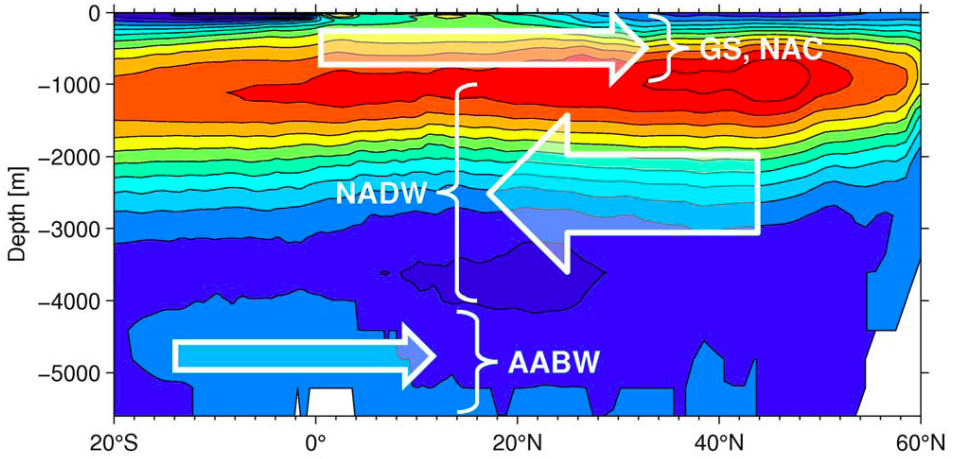


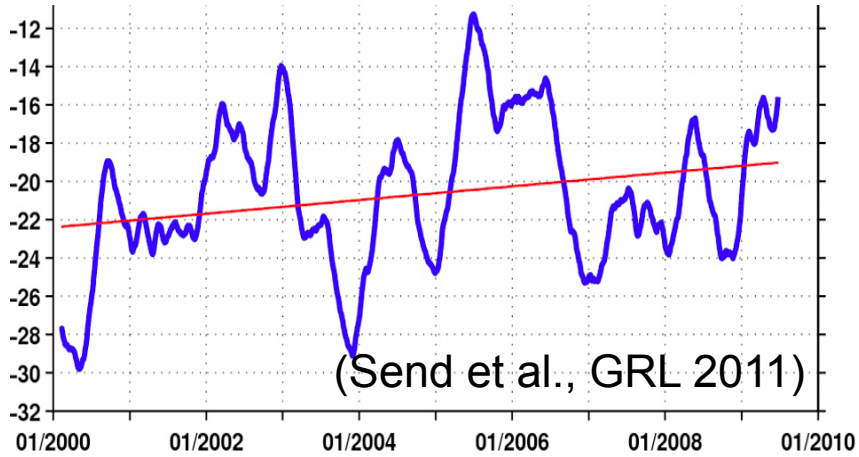


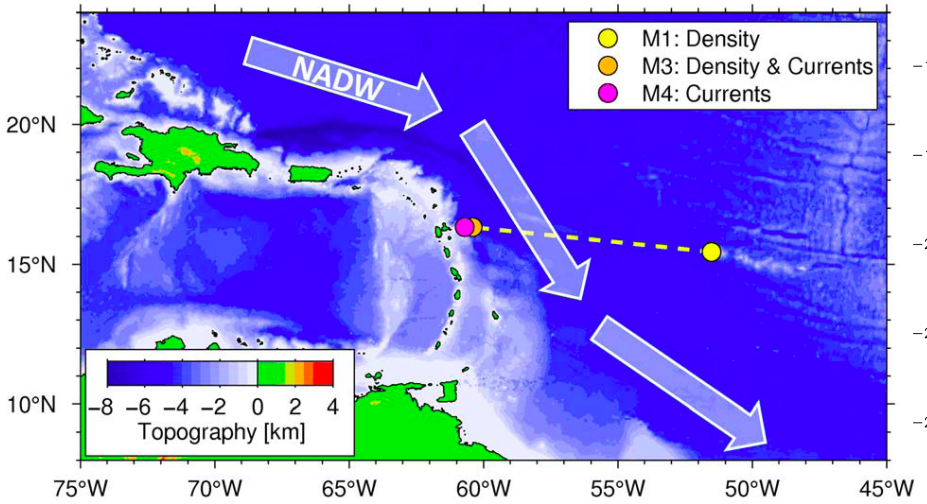
Calculations from model and observations show that the abrupt decrease in the MOC strenght in 2009 was due to wind anomaly.

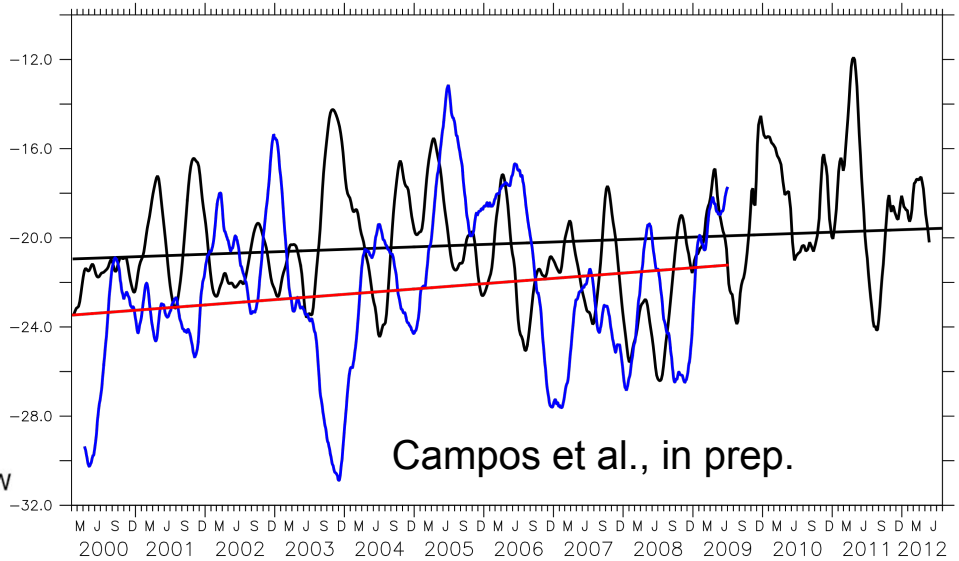
The long term trend, however, seems to be associated with the geostrophic component

Campos et al., in prep.

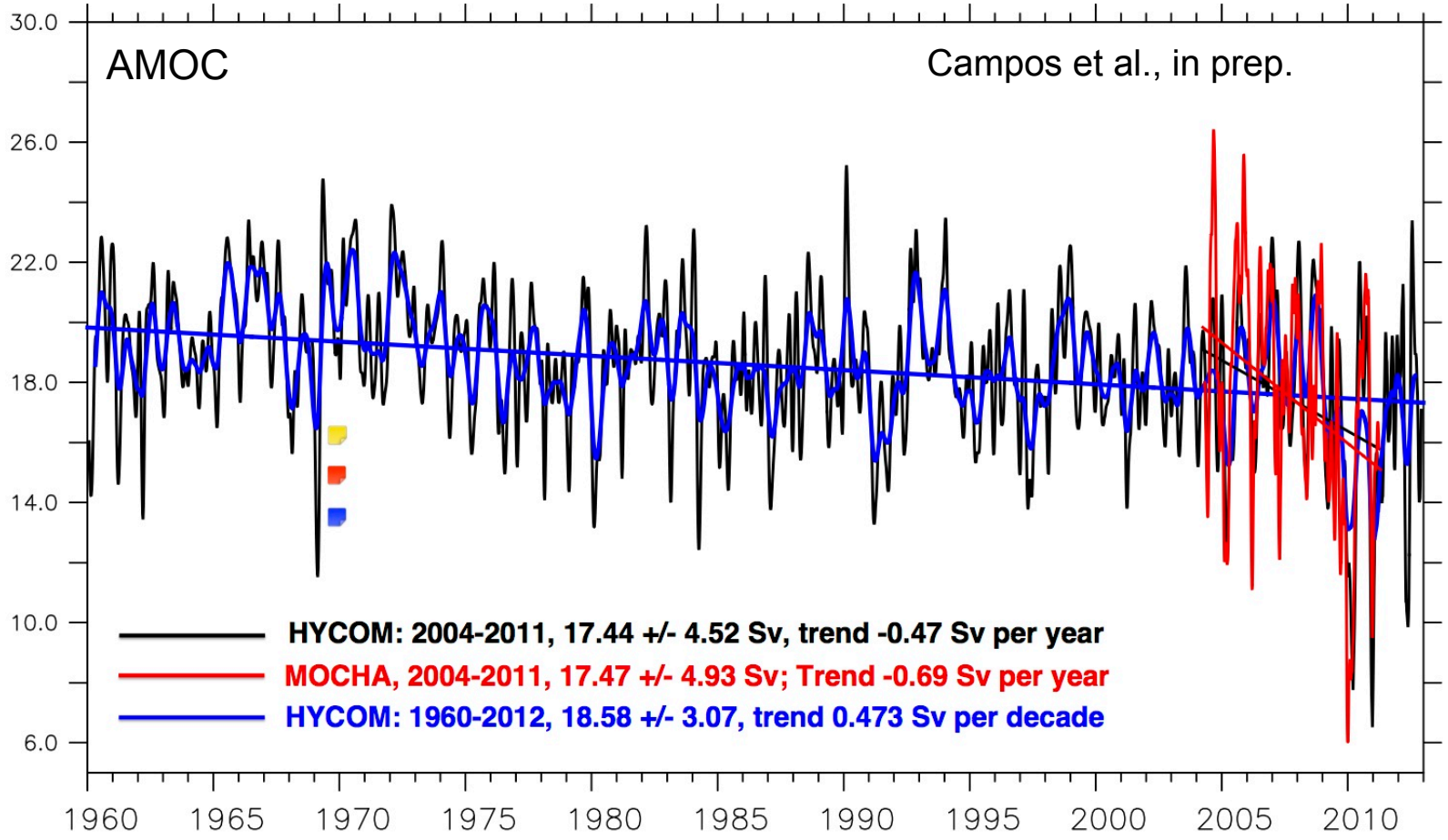








Calculations with the almost 10-year long MOVE time-series show that the deep flow of the NADW across 16N decreased at a rate of 0.3 Sv per year.



The numerical experiment show a negative trend of the AMOC across 26.5N, at a rate of 0.473 Sv per decade.

Conclusions(?)

- ✧ Agulhas Leakage has been increasing sine 1960
- ✧ Increase is larger in the past two decades
- ✧ The AMOC strength at 26.5N show a negative trend since 2004, both in data and model results
- ✧ The model shows that the AMOC is weakening since 1960

Most Importantly:

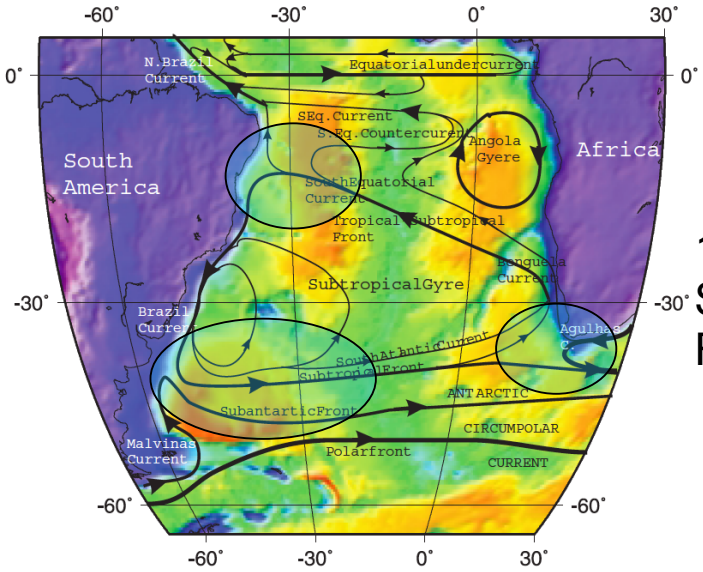
NEEDS LONGER, SUSTAINED OBSERVATIONS!

Brazilian Efforts in the South Atlantic

Oceanobs99:

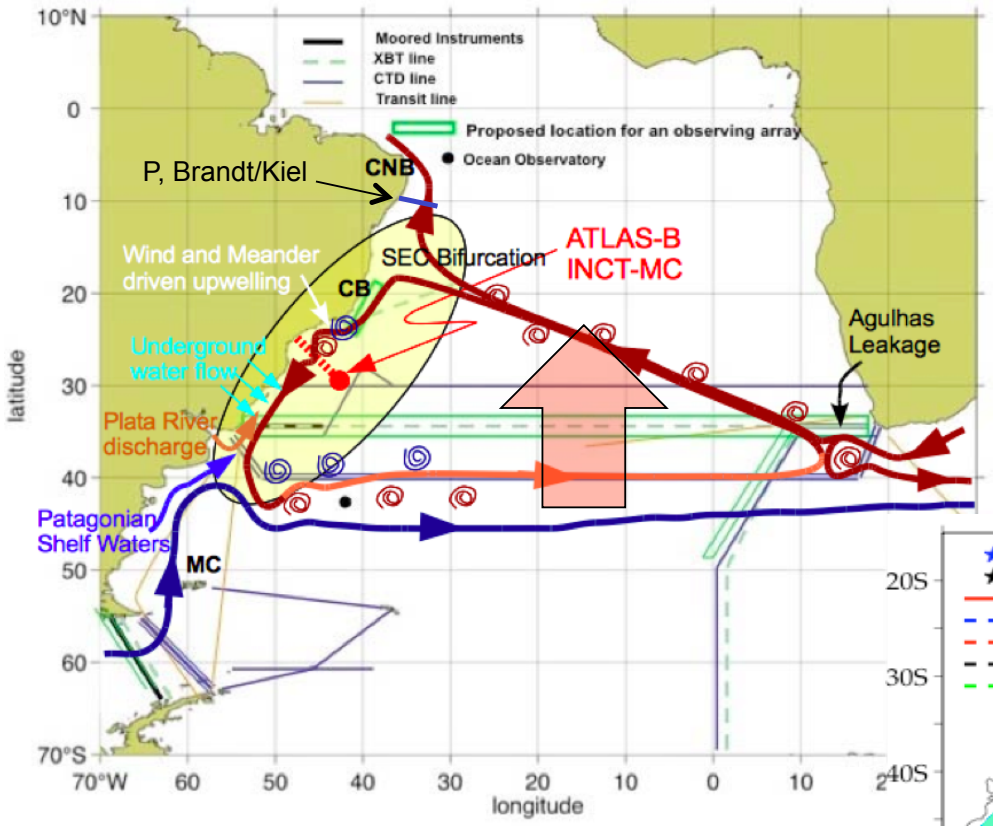
Important Aspects of the South Atlantic to the Understanding of the Global Climate

E. Campos, A. Busalachi, S. Garzoli, J. Lutjeharms, R. Matano, P. Nobre, D. Olson, A. Piola, C. Tanajura and I Wainer



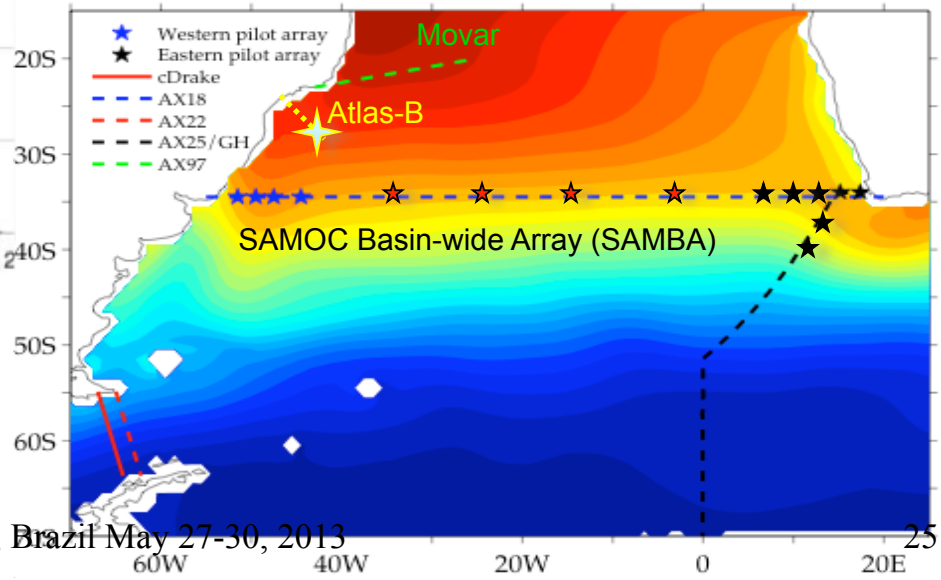
1999
St-Raphael
France

The SAMOC-BR, the Atlas-B and the MOVAR Programs



Components of the INCT-MC and INCT-Mar-COI for monitoring the South Atlantic

Brazilian contributions to the International Research Program SAMOC



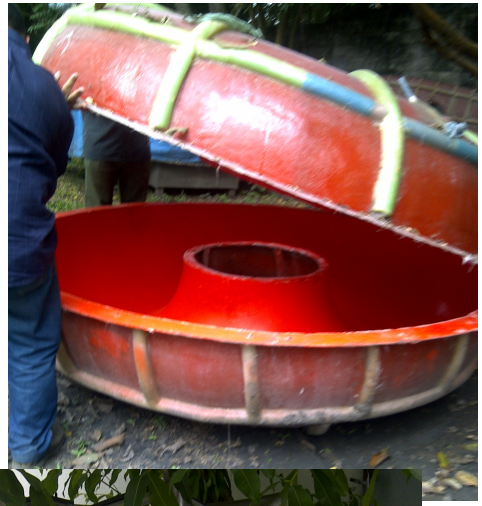
Current meter moorings across BC (Atlas-B) and NBC (P. Brandt/Kiel), to monitor south and northward fluxes

The Atlas-B "Guariroba"

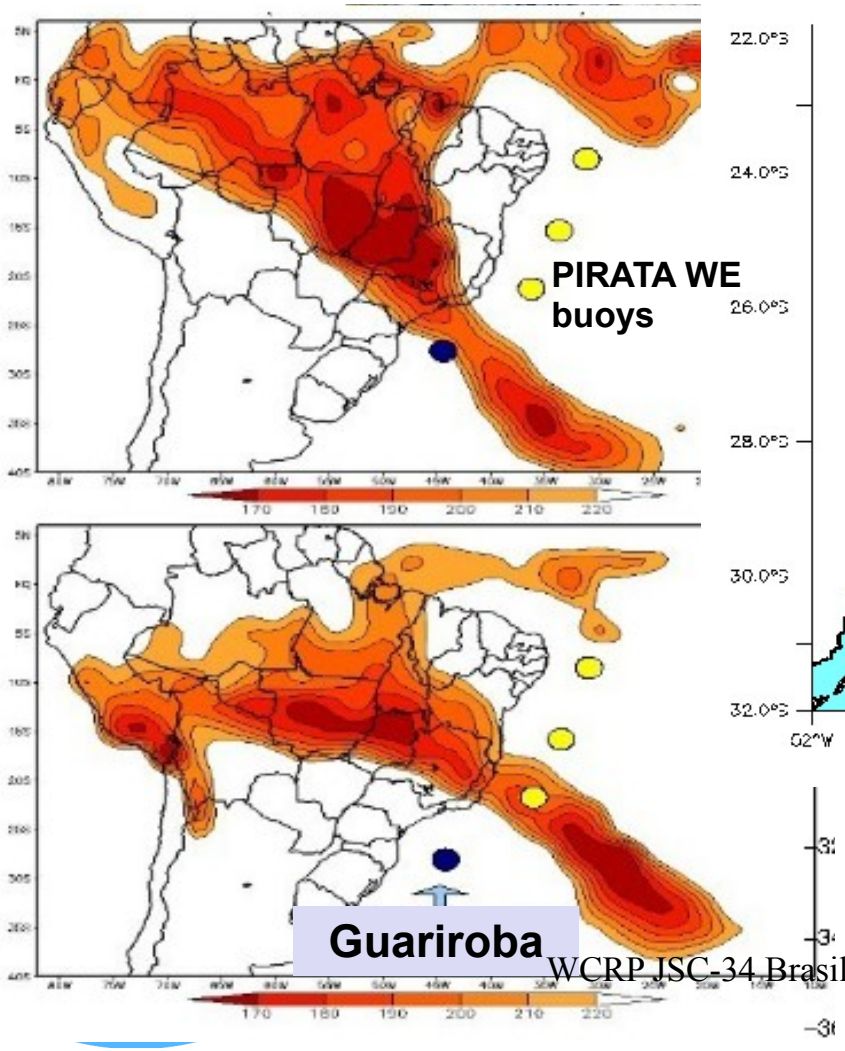
A monitoring system for the South Atlantic

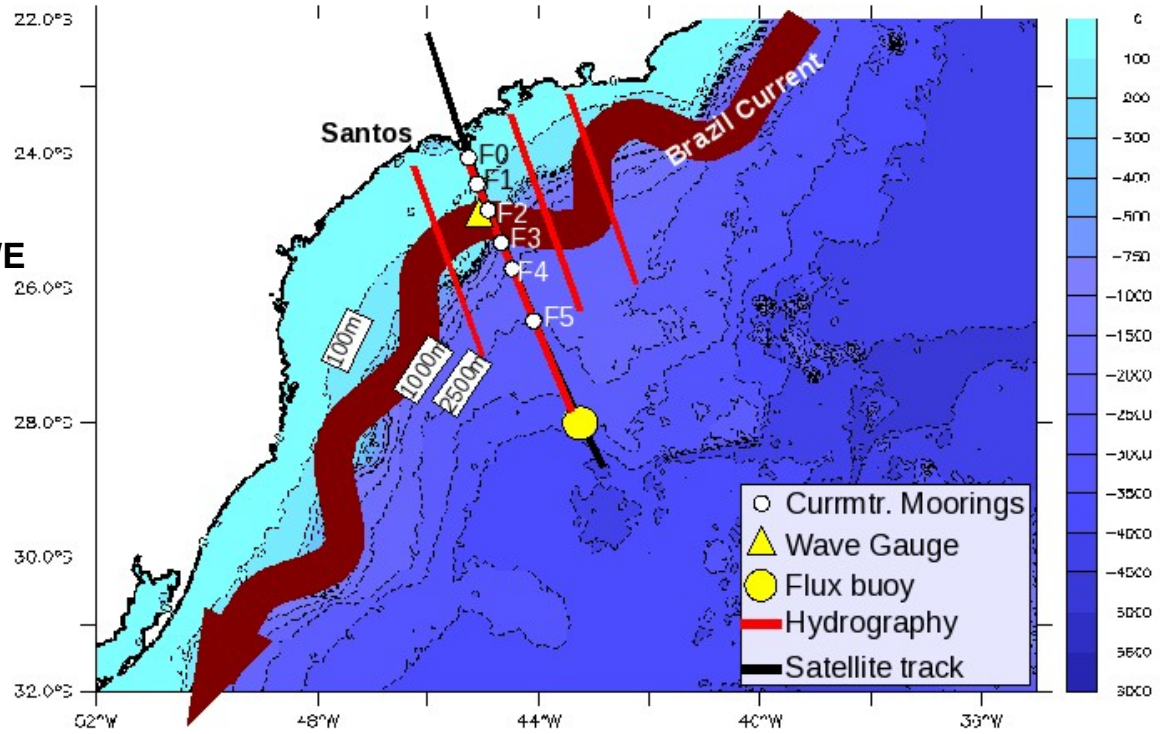
An Initiative of the
Instituto Nacional de Ciências e Tecnologia para Mudanças Climáticas – INCT-MC

Guariroba is an Atlas-like boy completely constructed and instrumented in Brazil

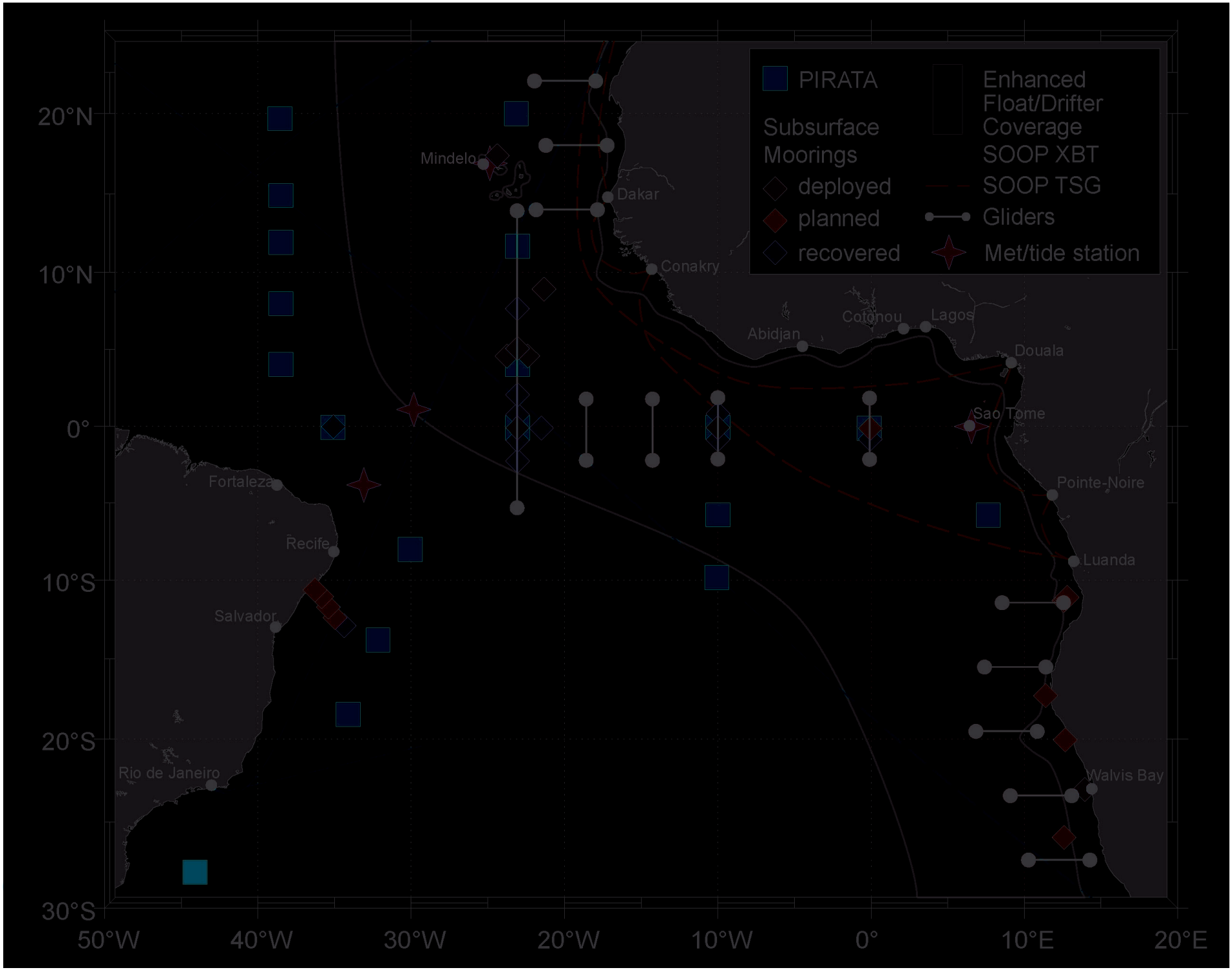


Guariroba will contribute to PIRATA in the understanding of the SACZ.





Guariroba is part of a larger effort for monitoring the Brazil Current.


PIRATA
Enhanced Float/Drifter Coverage
Subsurface Moorings
deployed
planned
recovered
SOOP XBT
SOOP TSG
Gliders
Met/tide station
Mindelo
Dakar
Conakry
Abidjan
Cotonou
Lagos
Douala
Sao Tome
Pointe-Noire
Luanda
Walvis Bay
Fortaleza
Recife
Salvador
Rio de Janeiro
20°N
10°N
0°
10°S
20°S
30°S
50°W
40°W
30°W
20°W
10°W
0°
10°E
20°E