Response of the South and Tropical Atlantic to changes in the Meridional Overturning Circulation in numerical experiments with the SPEEDO (MICOM-SPEEDY) coupled model

E. Campos[1], R. Haarsma[2], W. Hazeleger[2],

C. Severijns[2] and S. Drijfout[2]

[1]Oceanographic Institute of the University of São Paulo – Brazil

[2]Royal Netherlands Meteorological Institute (KNMI) – Netherlands

Outline

- Motivation
- Modes of Variability of the Tropical Atlantic
- The “Cold” and “Warm” paths in the South Atlantic
- The Agulhas “Leakage”
- Experiments with MICOM-SPEEDY
  - NO-MOC
  - NO-AGU
- Conclusions

Motivation

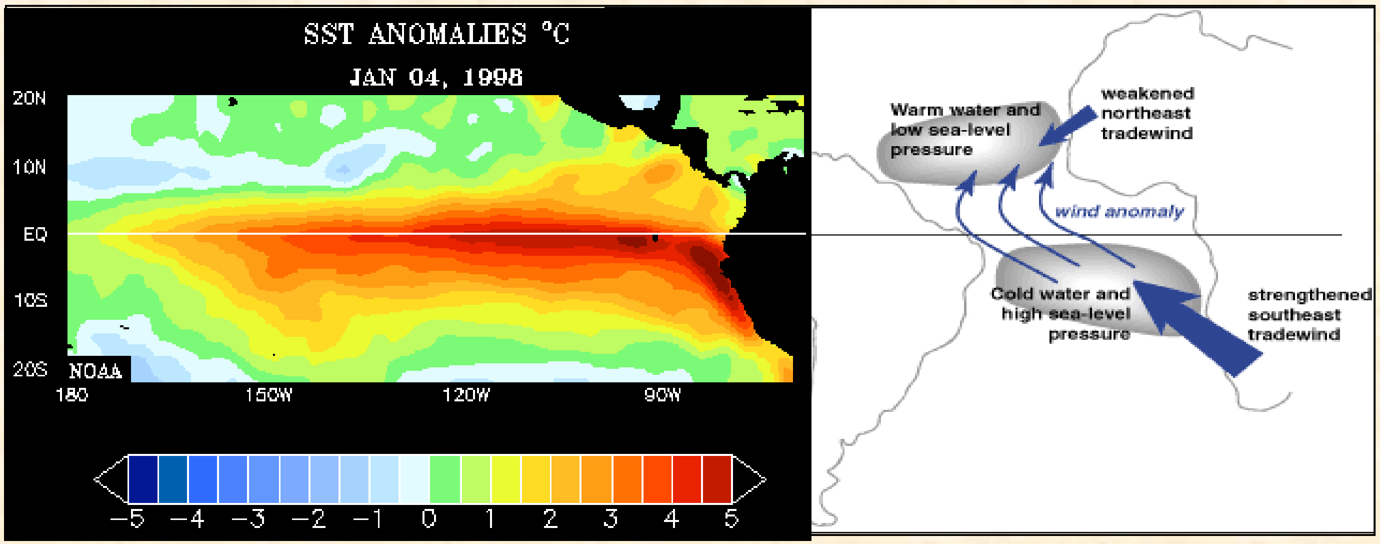
Modelling studies with coupled climate models suggest that major changes in the strength of the THC significantly affect the atmospheric and oceanic circulation on a global scale.

A common picture is that a weakened THC results in a dipole response, with cooling in the North Atlantic and warming in the South Atlantic (e.g: Vellinga and Wood, 2002; Dahl et al., 2005; Zhang and Delworth, 2005).

Because the seasonal cycle and interannual variability are strongly linked to the climatological mean state, it is expected that they also be affected by a weakened THC.

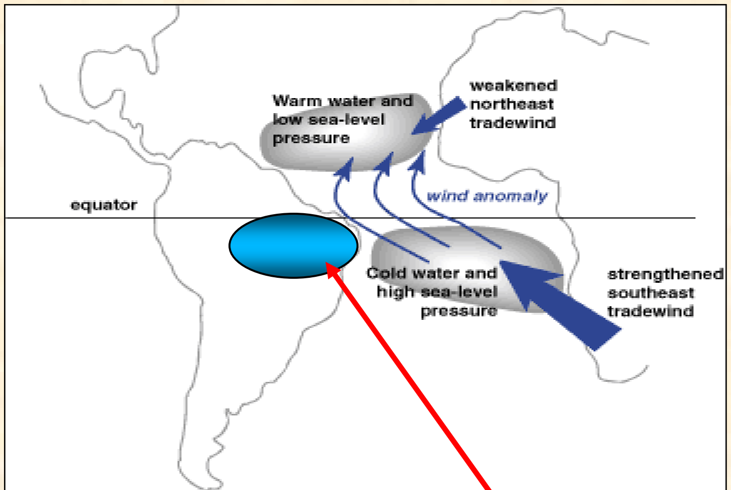
Motivation

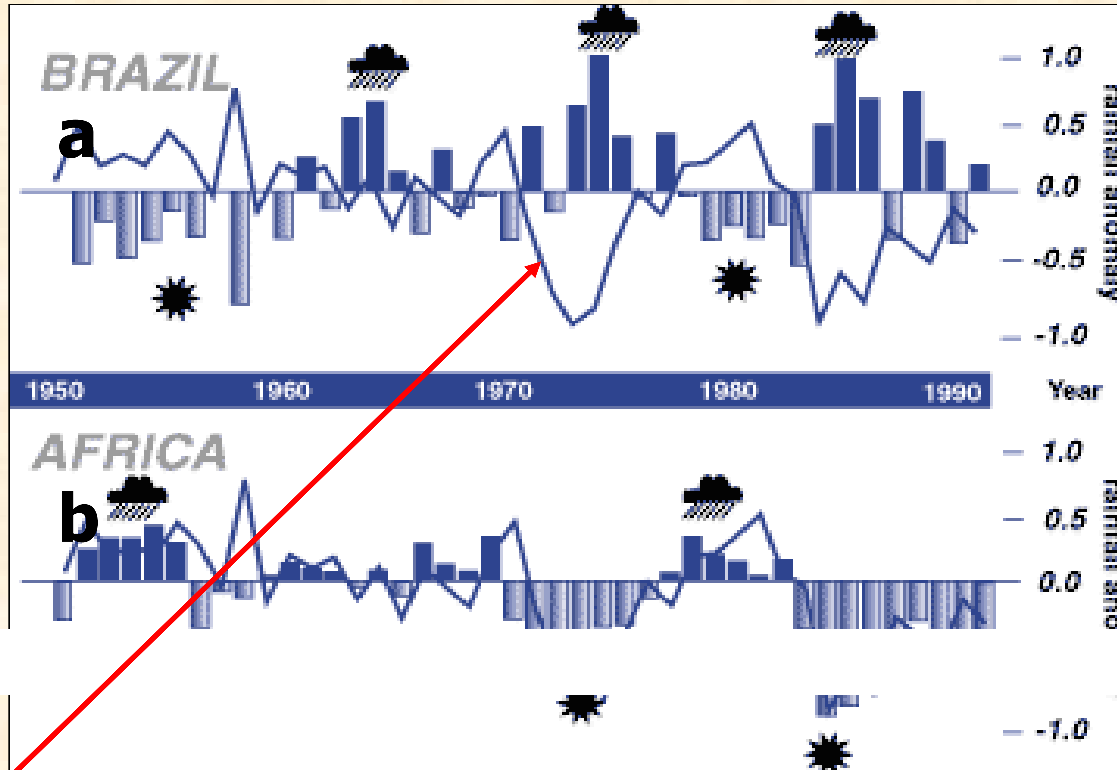
The climate in the east Amazon and NE Brazil is strongly affected by the combined effect of both the Pacific ENSO and the **Atlantic interhemispheric SST gradient mode.**



The Atlantic Gradient Mode is a decadal mode of variability, in which the equatorial North Atlantic is warmer (positive phase) or cooler (negative phase) than the average.

Motivation





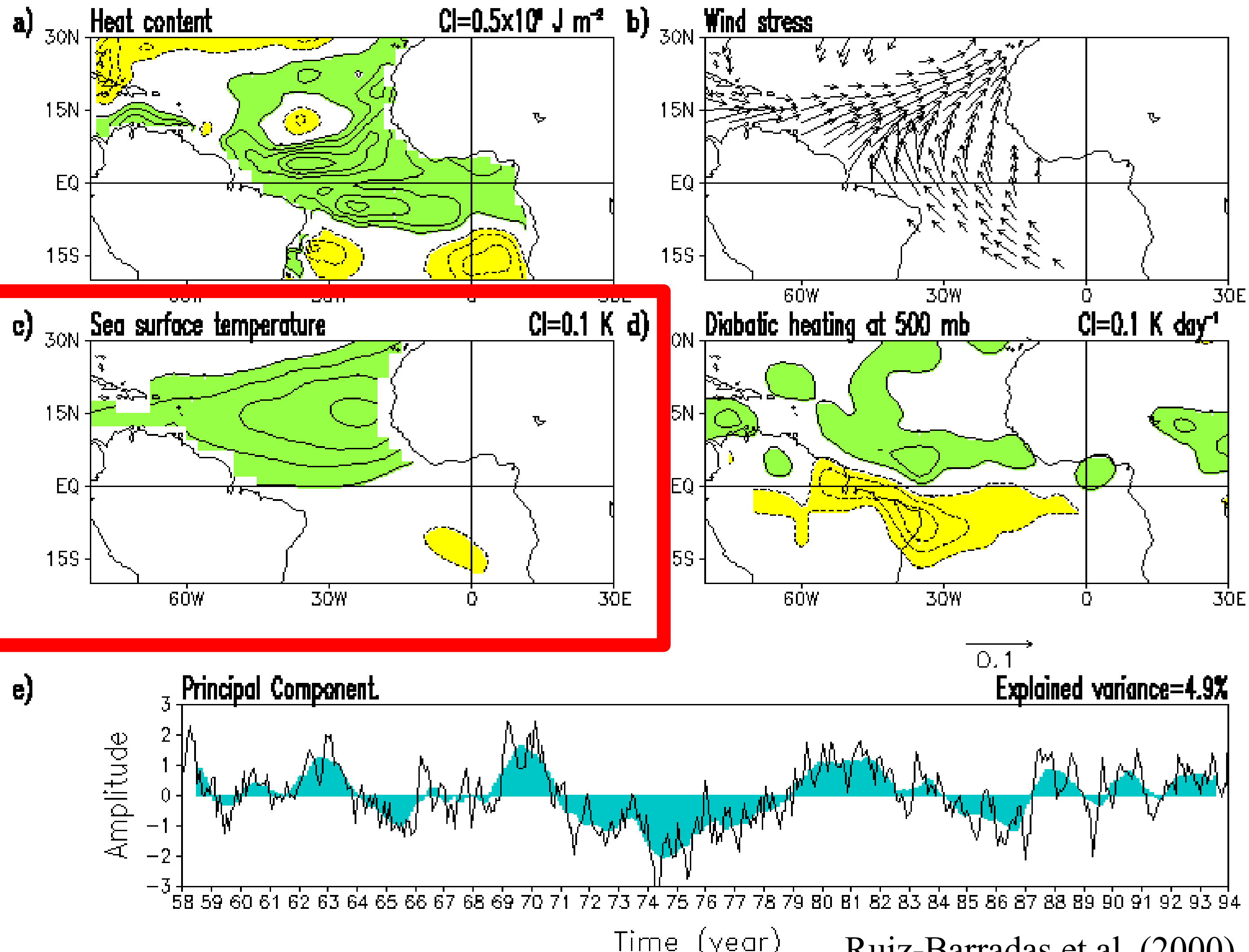
Precipitation in the EA and NE Brazil is anti-correlated to the meridional mode index, also called dipole index

Question:

Would changes in the THC affect the climate and variability in the Tropical Atlantic?

Modes of Variability of the Tropical Atlantic

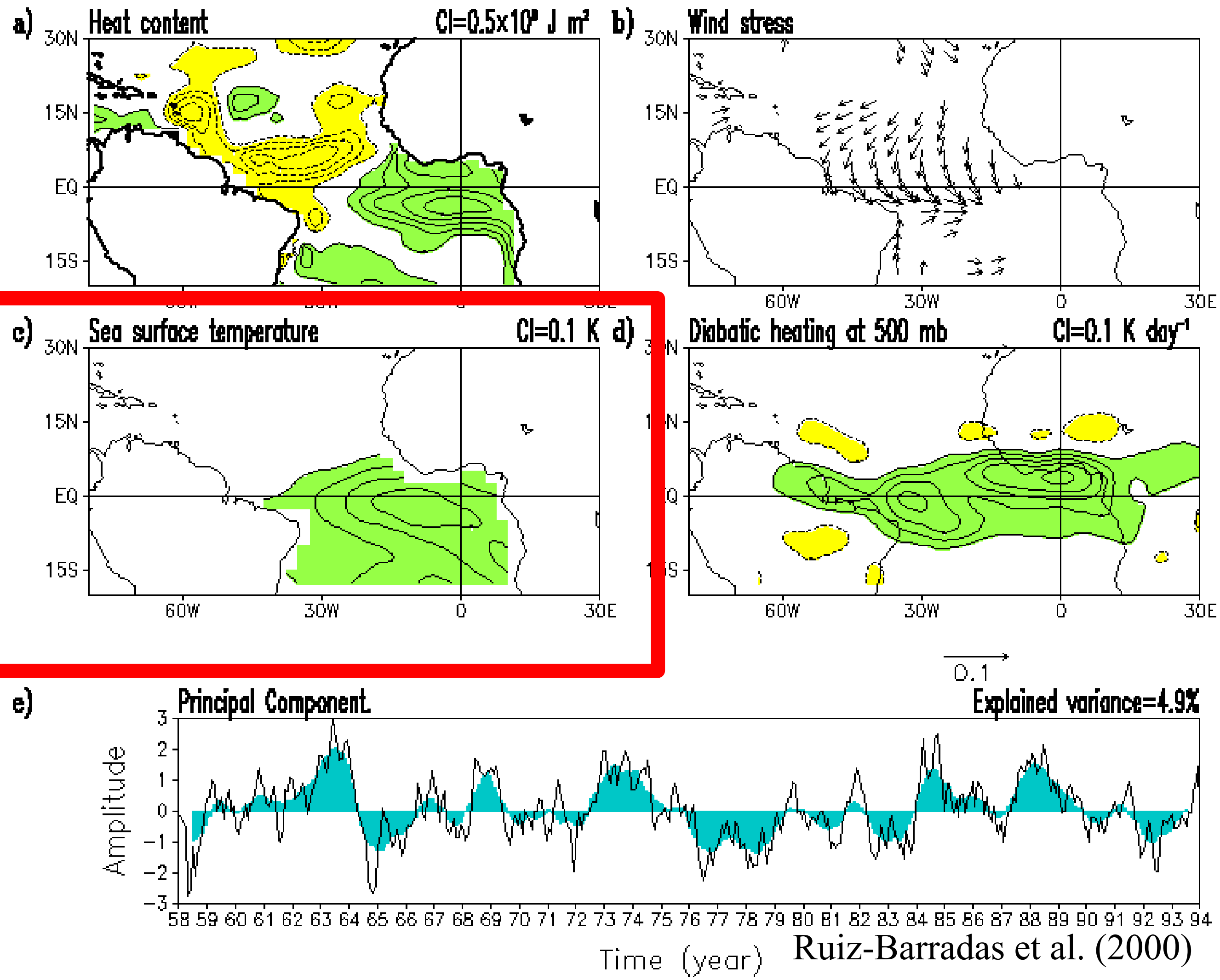
The Gradient Mode



Ruiz-Barradas et al. (2000)

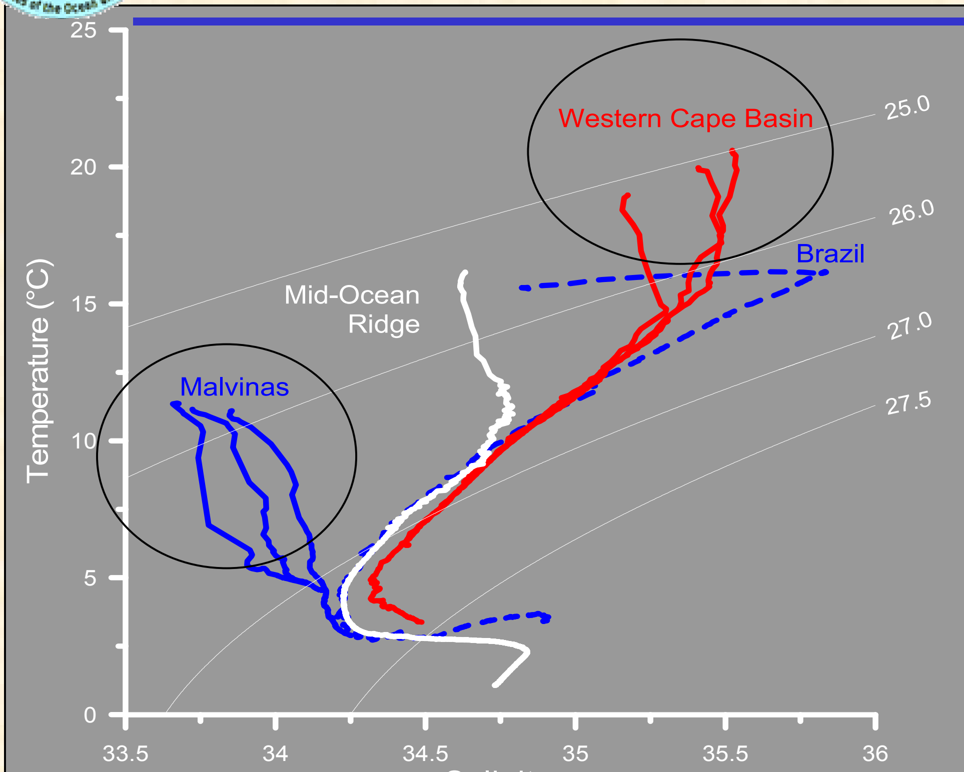
Modes of Variability of the Tropical Atlantic

The Equatorial or "Cold Tongue Mode" (El Nino type)

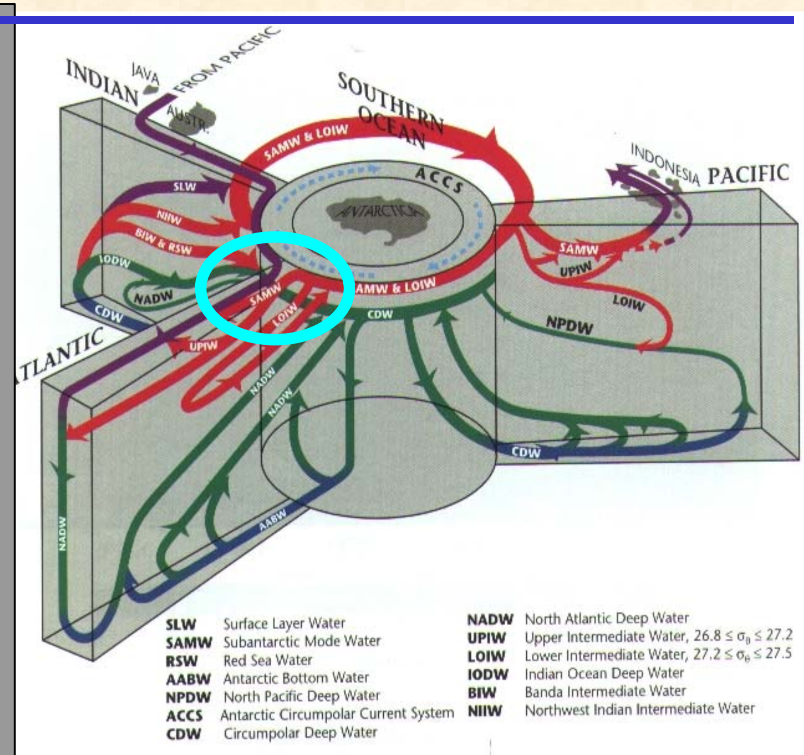


Ruiz-Barradas et al. (2000)

The “Cold” and “Warm” Paths



After Piola’s SACOS presentation

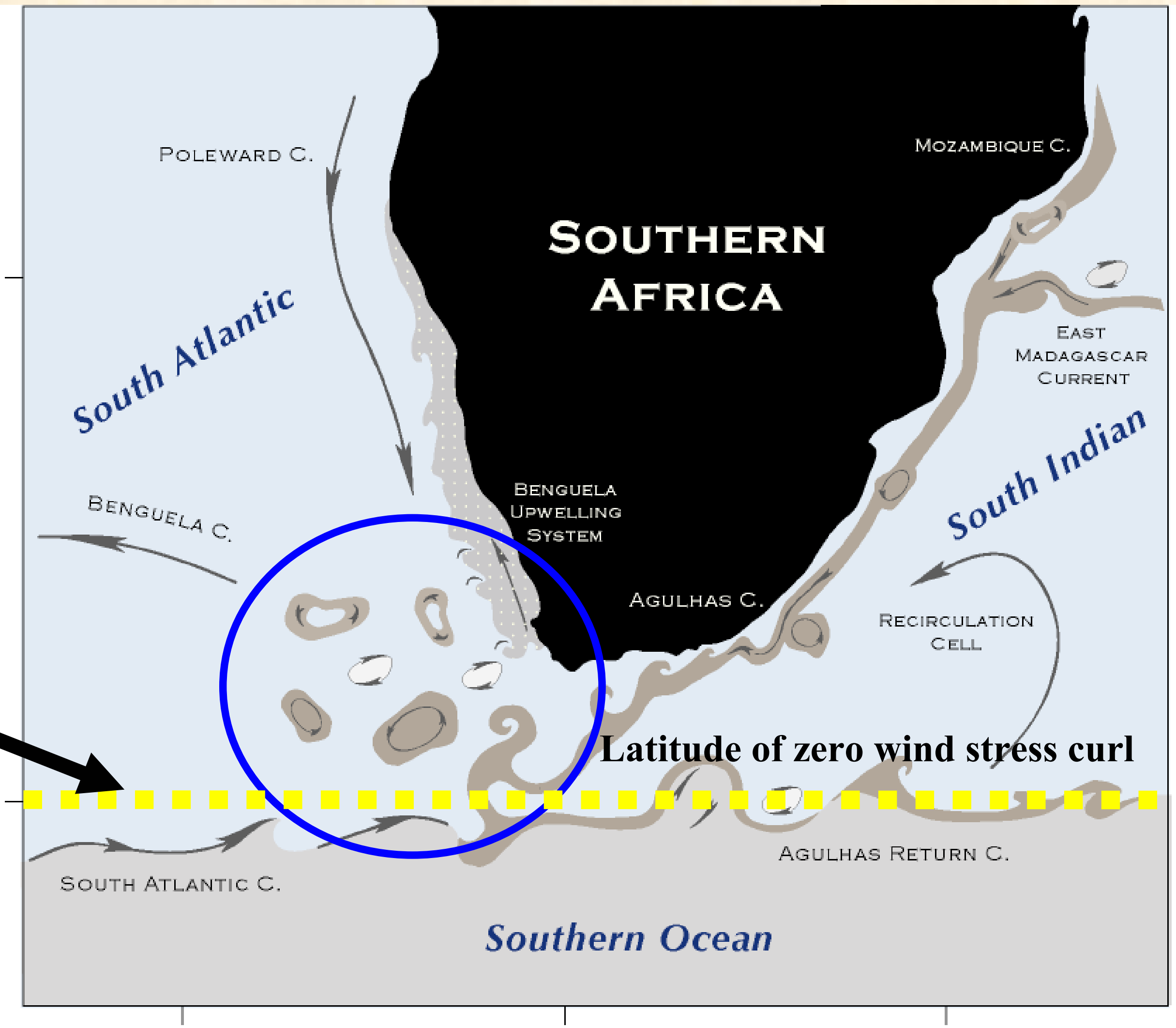


The MOC upper limb includes water masses coming from the Pacific, via AACC (the “cold path”), and by means of the water “leaked” from the Indian Ocean in the Agulhas Retroflection (the “warm path”)

The “Agulhas Leakage”

The Agulhas leakage is formed by an average number of 6 rings per year, each transporting between 0.5 and 1.5 Sv.

A northward shift of the zero wind stress curl line could interrupt the Agulhas leakage

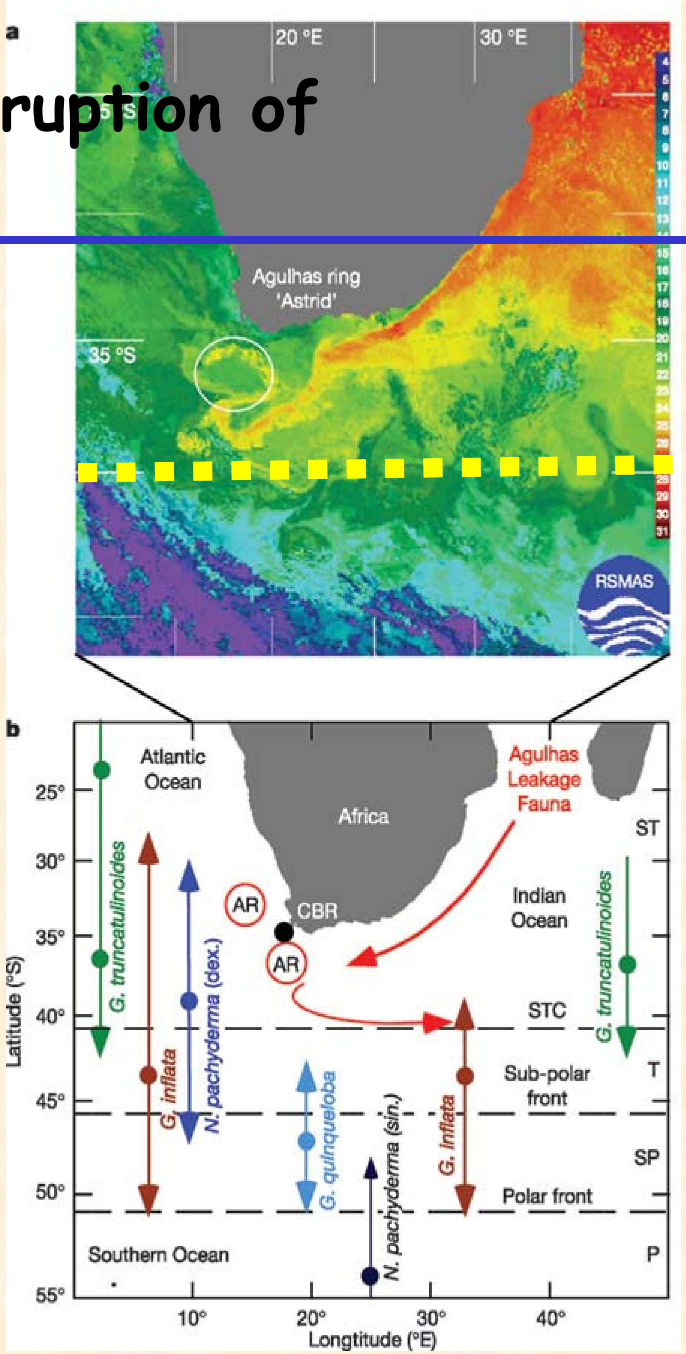


After J. Lutjeharms

Past evidences of interruption of the Agulhas Leakage

Paleoceanographic records indicate that the Agulhas leakage might have been interrupted during the last glacial period.

Events of extinction and reappearance of foraminifera species in the S. Atlantic seems to be associated with the closing and reopening of the Agulhas connexion



Peeters et al., Nature 430, 661-665 (2004)

Experiments with MICOM-SPEED

We used the SpeedO coupled model to study the impacts of changes in the MOC on the Climate and Modes of variability of the Tropical Atlantic

NOMOC

Influence of the Meridional Overturning Circulation on Tropical Atlantic Climate and Variability

Reindert Haarsma[1], Edmo Campos[2], Wilco Hazeleger[1], Camiel Severijns[1]

Submitted to J. of Climate, in review

NOAGU

Impacts of shutting off the Agulhas leakage on the tropical Atlantic in a coupled ocean-atmosphere model

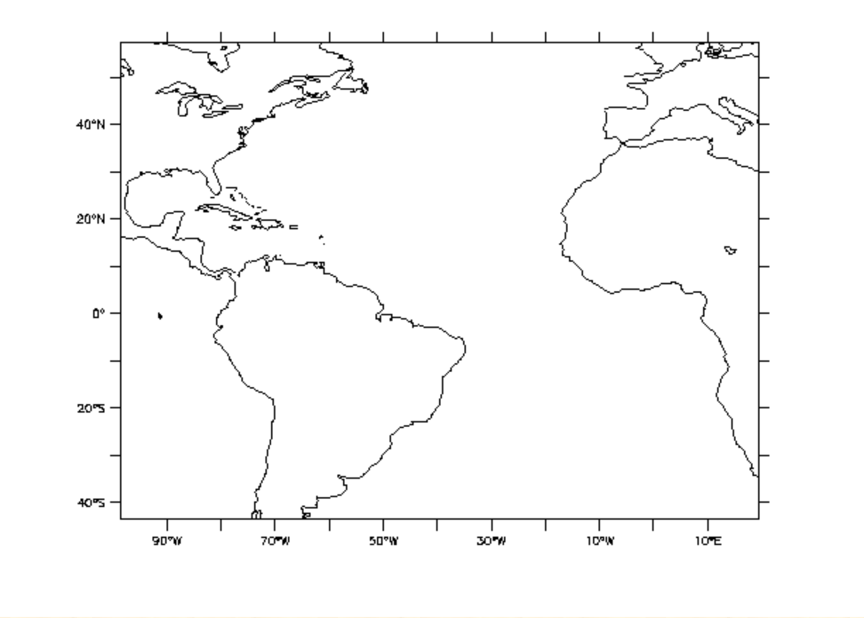
Edmo J. D. Campos[1], Reindert J. Haarsma[2], Wilco Hazeleger[2], Camiel Severijns[2] and Sybren Drijfhout[2]

In preparation. To be submitted to J. of Climate.

SpeedO-Atlantic

Atmosphere (Speedy, global):

T30 (3.5 degree) primitive equations
7 layers
Simplified parameterizations



Ocean (MICOM-Atlantic: 45S – 55N):

Isopycnic coordinate primitive equation model (MICOM

22 layers

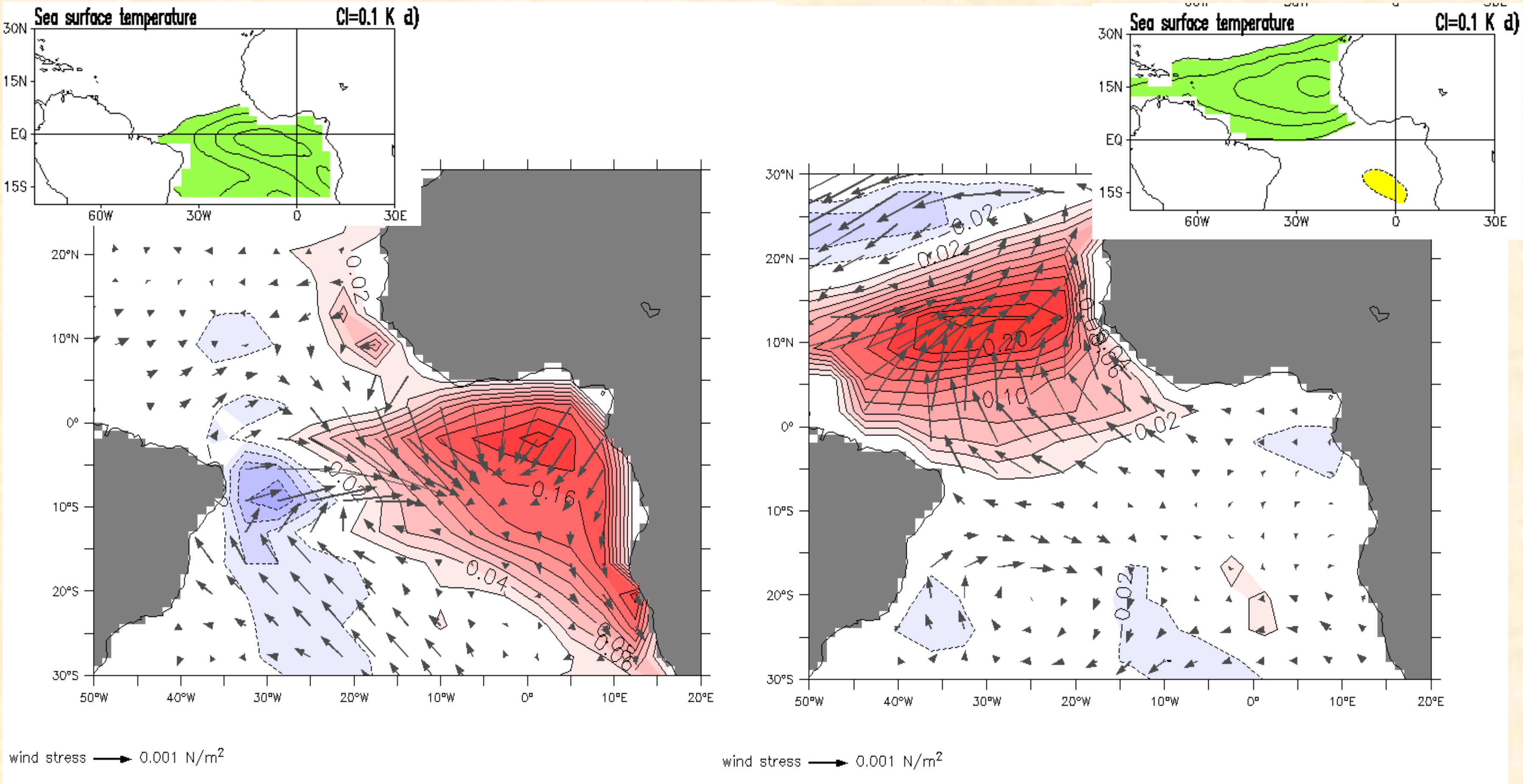
1 degree horizontal resolution

SST prescribed outside the Atlantic and nudging at lateral boundaries

See Hazeleger et al (2006) for more information.

Land:
Prescribed

The CONTROL Experiment



The CONTROL run simulates realistically the tropical Atlantic variability including the gradient mode and the cold tongue mode.

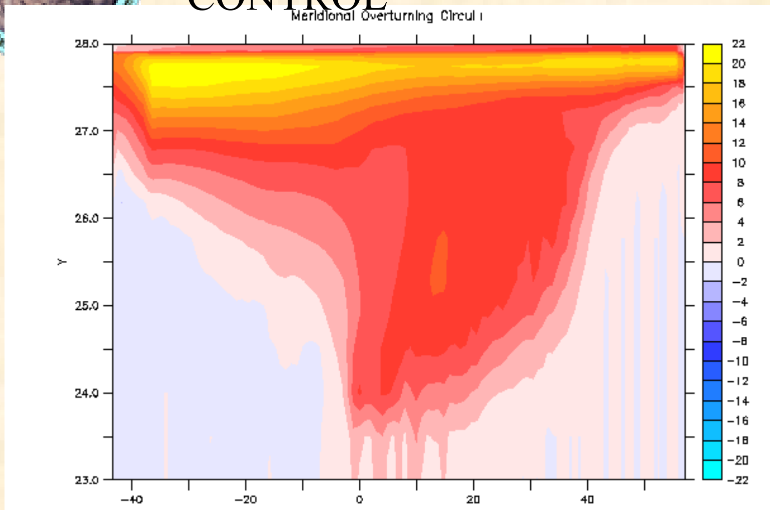
Experiment 1 (NO-MOC)

Total collapse of MOC

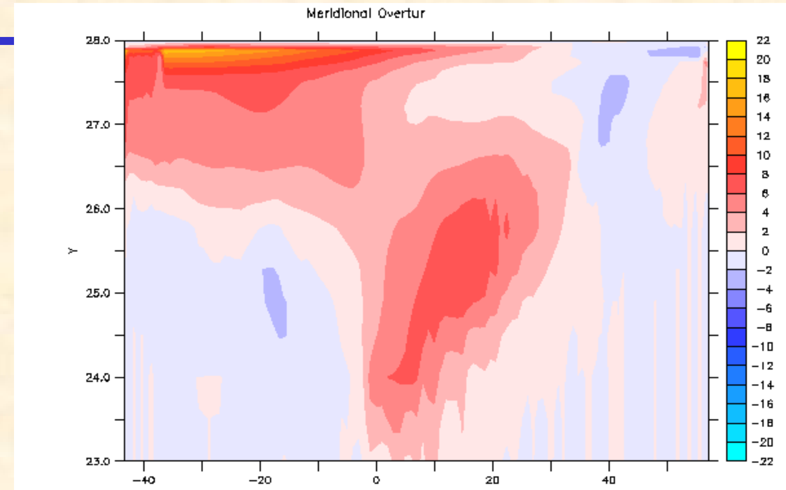
Ocean open boundary conditions are taken from global run without MOC.

Overturning (Sv)

CONTROL



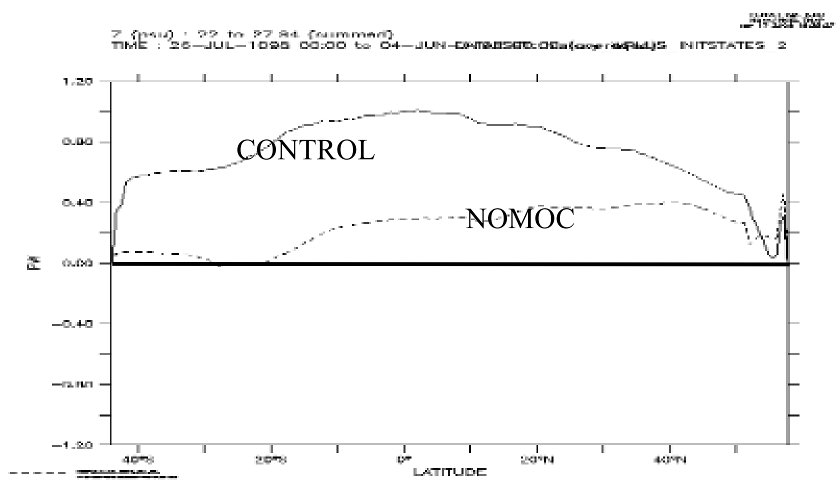
NO-MOC



In CONTROL (left), the MOC is about 18 Sv. The meridional heat transport is about 1 Pw. These values are approximately in agreement with the observations.

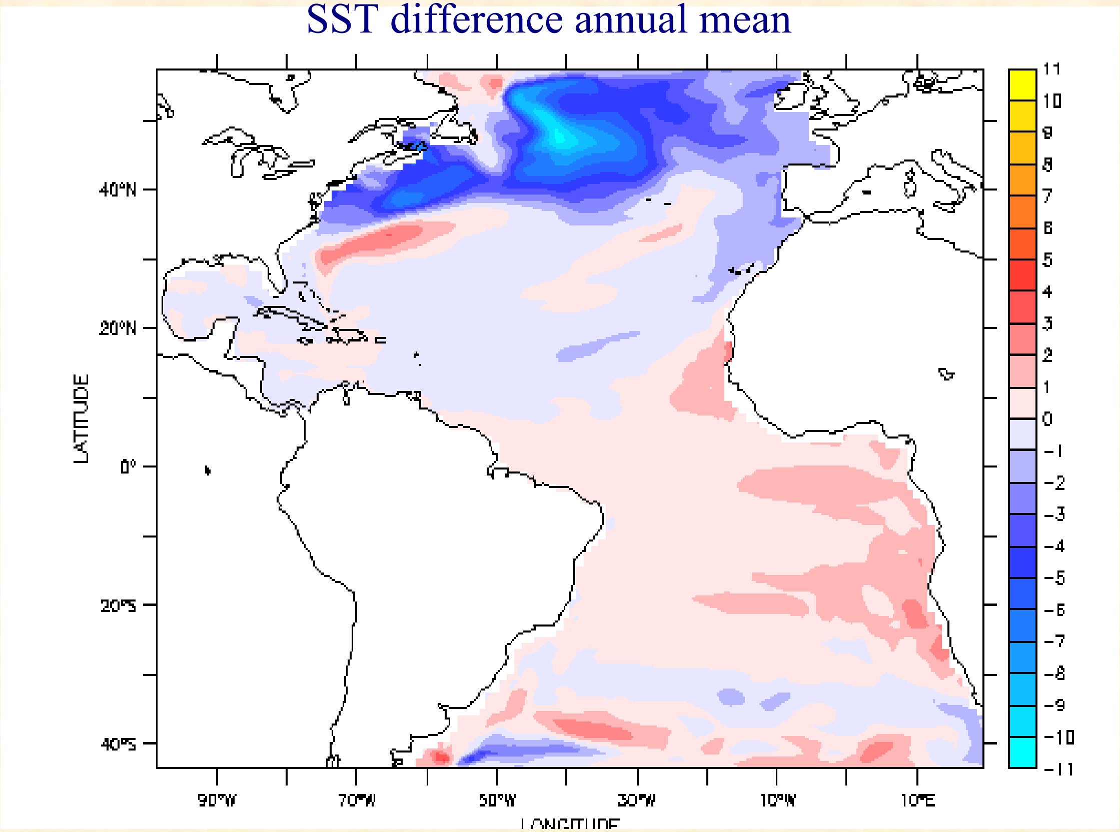
In NO-MOC, the MOC is collapses and the circulation is dominated by two STCs of 4 and 6 Sv in the South and North Atlantic respectively (top, right).

The meridional heat transport is reduced to 0.3 Pw, implying that about 70% of the ocean heat transport is due to the MOC.

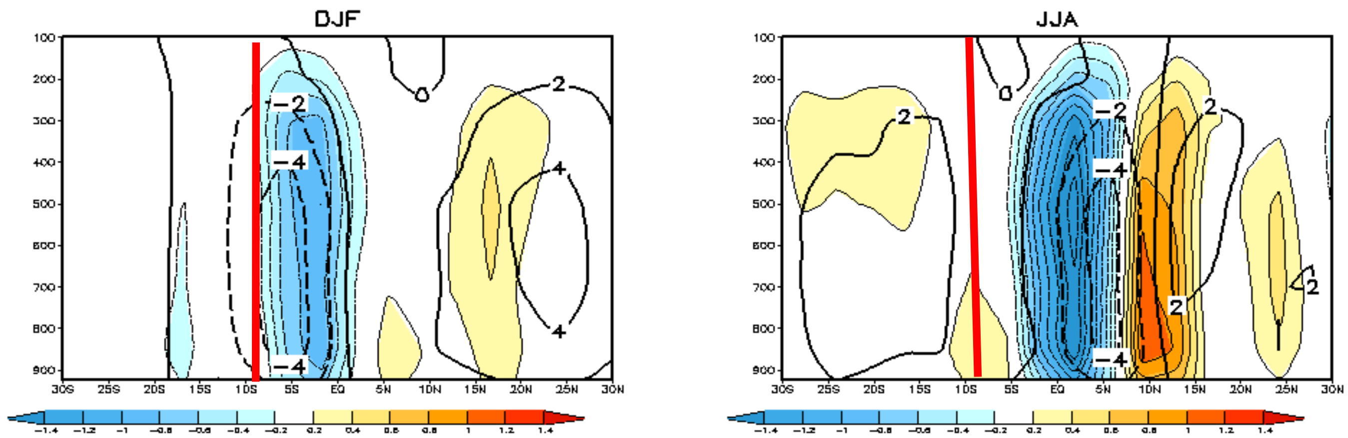


Meridional heat transport (Pw)

NO-MOC minus CONTROL

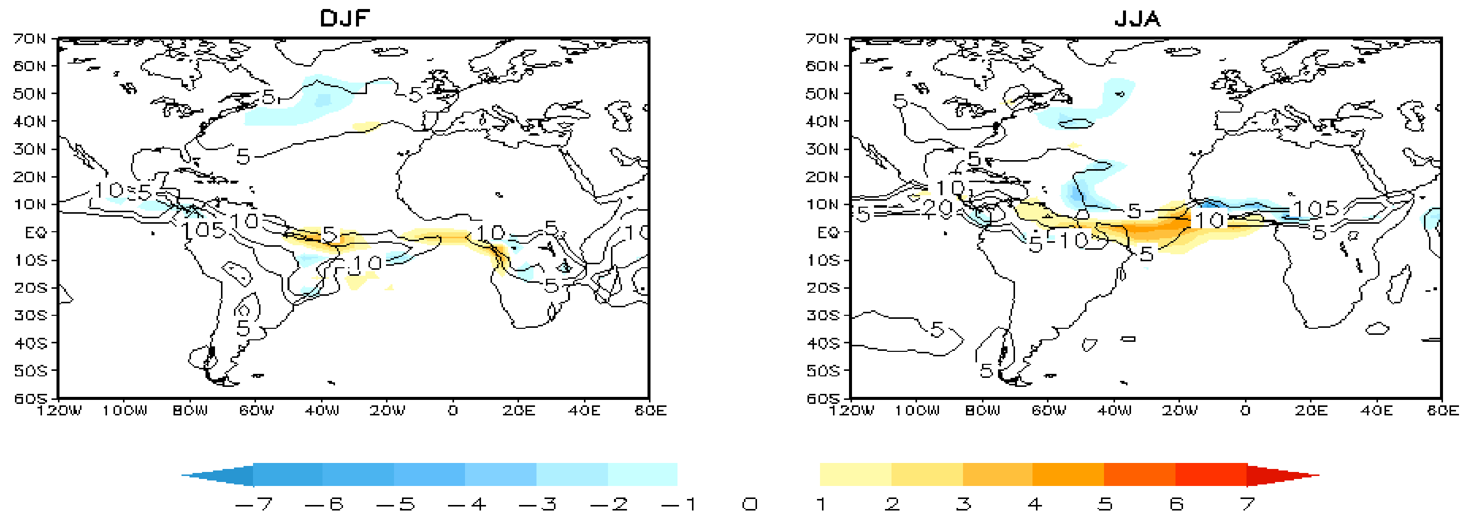


NOMOC leads to cooler North Atlantic and Warmer Topical and South Atlantic



Omega [hPa/s] for DJF e JJA. Contour lines: CONTROL run. Dashed lines indicate negative values (upward motion); Shaded: Difference between NO-THC and CONTROL run.

- The warming of the tropical Atlantic enhances the Hadley circulation, mainly in JJA.
- In addition to the strengthening there is a southward shift of a few degrees during the boreal summer, when the ITCZ is at its northernmost position.

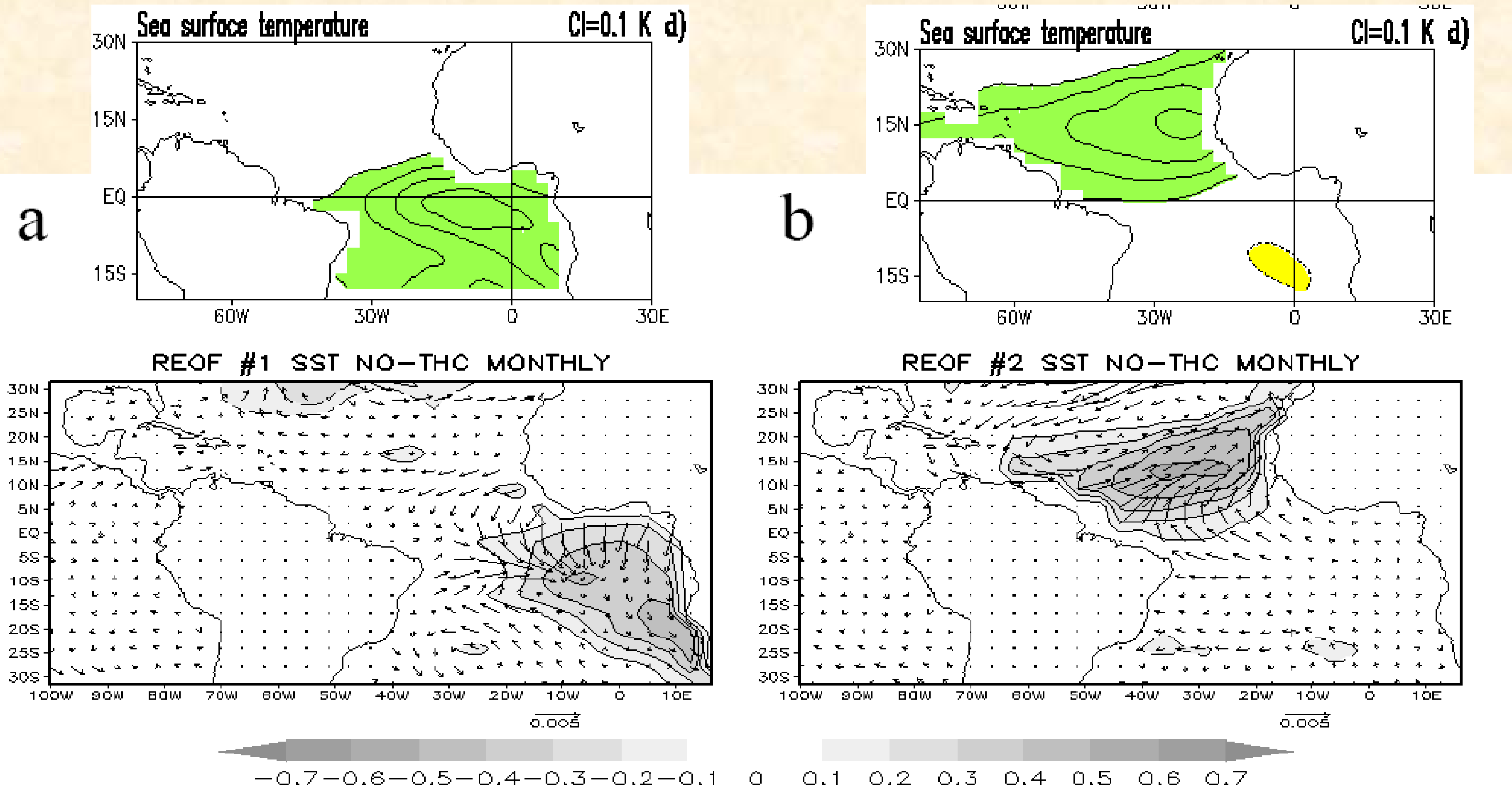


Rain fall in mm/day for DJF e JJA. Contour lines: CONTROL run. Shaded: Difference between NOMOC and CONTROL run.

The largest changes in rainfall occur during JJA and are in the order of 5 mm/day. During this season the ITCZ is shifted southward, whereas it is shifted northward during DJF

Increased precipitation in NE Brazil in the dryer season !

Impacts on the TA Modes



The Cold Tongue mode weakens and the dominant variability shifts to the Benguela region.

Conclusions NO-MOC

- Equatorial thermocline becomes warmer and more saline

- Large impact on equatorial climatology

- Disappearance of cold-tongue mode

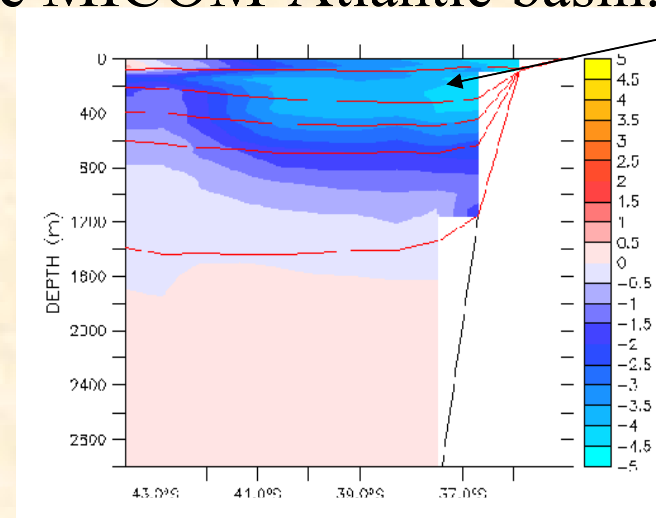
- Enhancement and southward shift of tropospheric jet in the N. Atlantic

Experiment NO-AGU

The No Agulhas Leakage Experiment

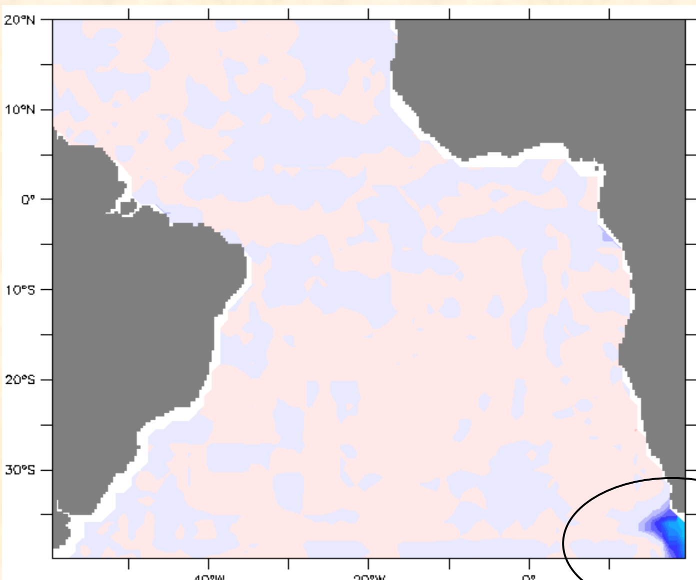
The “Closing of Agulhas leakage” experiment

Change only the boundary conditions in the South Eastern corner of the MICOM-Atlantic basin.

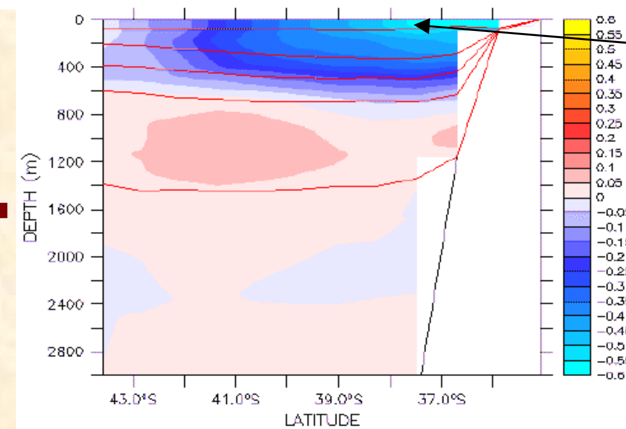


~ -3º to -5º C

Temperature



NOAGU minus CONTROL, for salinity, one month after start-up.

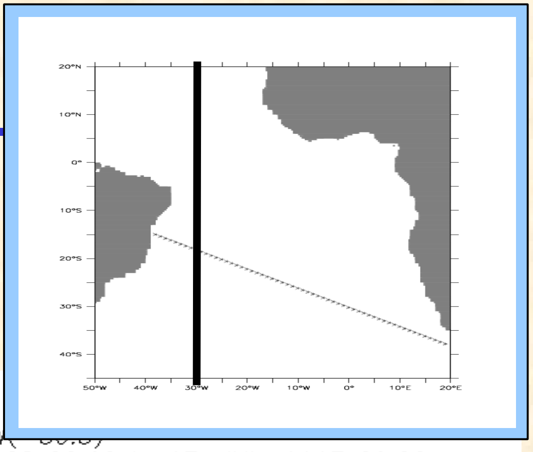


~ -.4 to -.6

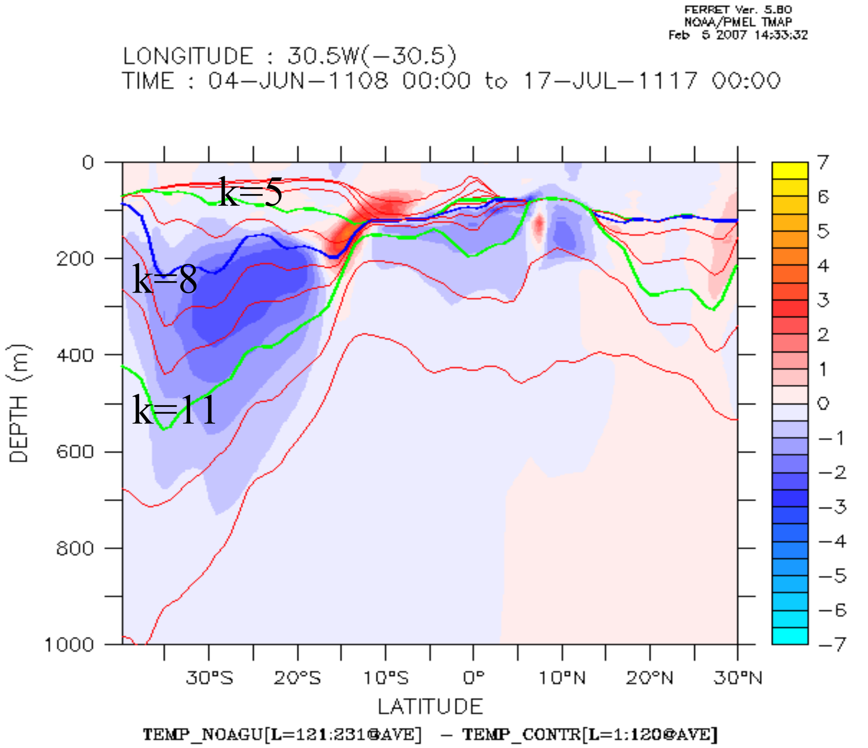
Salinit
y

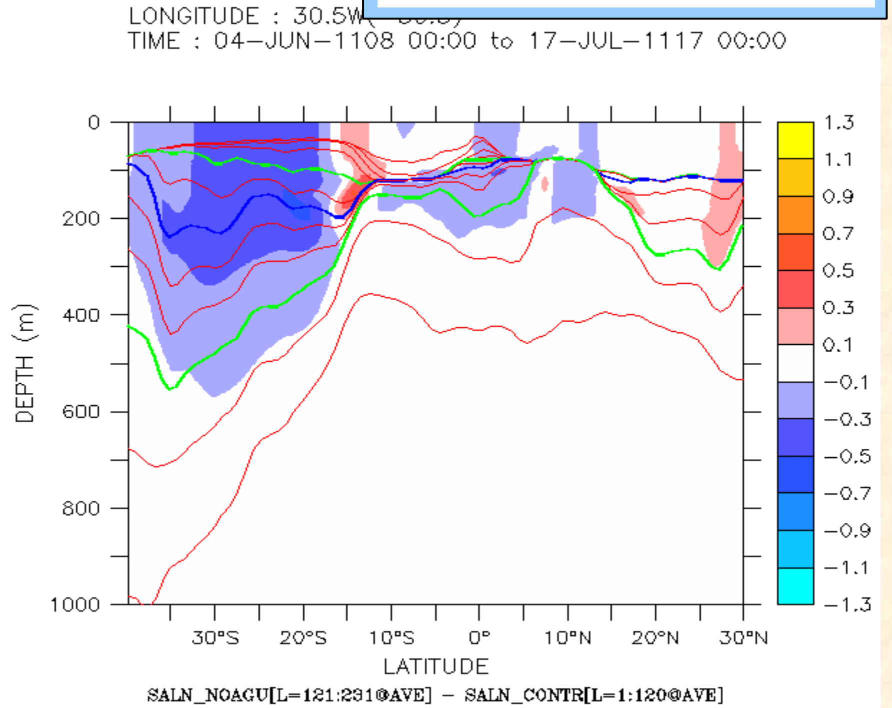
Differences between mean values of NOAGU and CONTROL

Results:



NO_AGULHAS minus CONTROL:
Difference of averaged temperature and salinity profiles along 30W



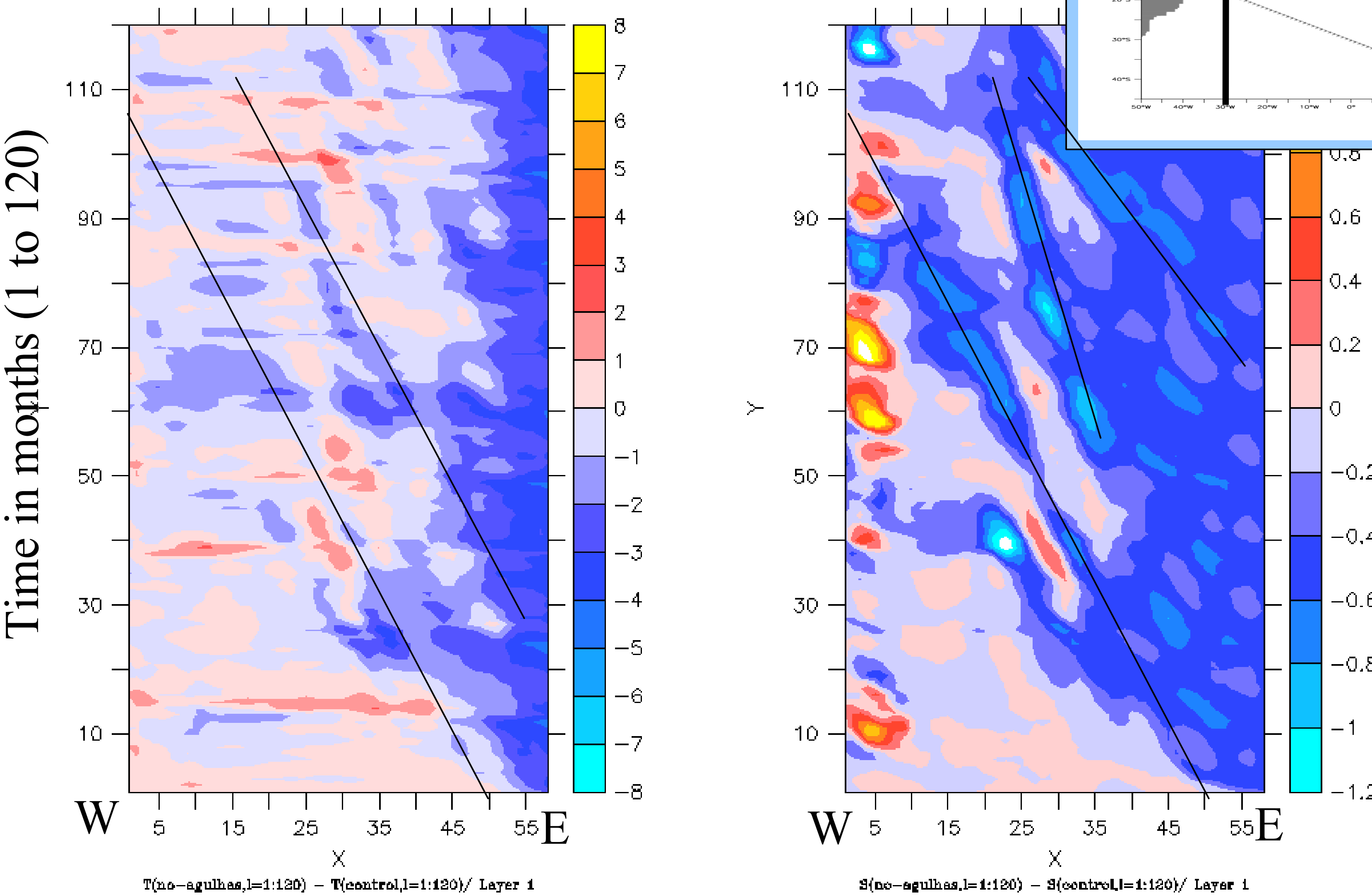


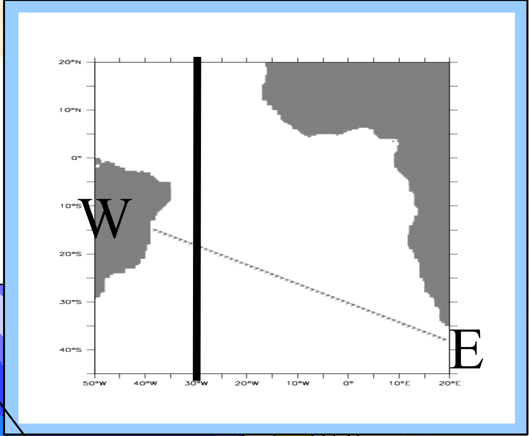
Across 30˚W, only the salinity anomalies appear in the mixed layer. This is because the temperature signal is damped out more quickly by exchanges with the atmosphere.

Timescale

FERRET Ver. 5.80
NOAA/PMEL TMAP
Feb 5 2007 15:24:57

Surface Layer

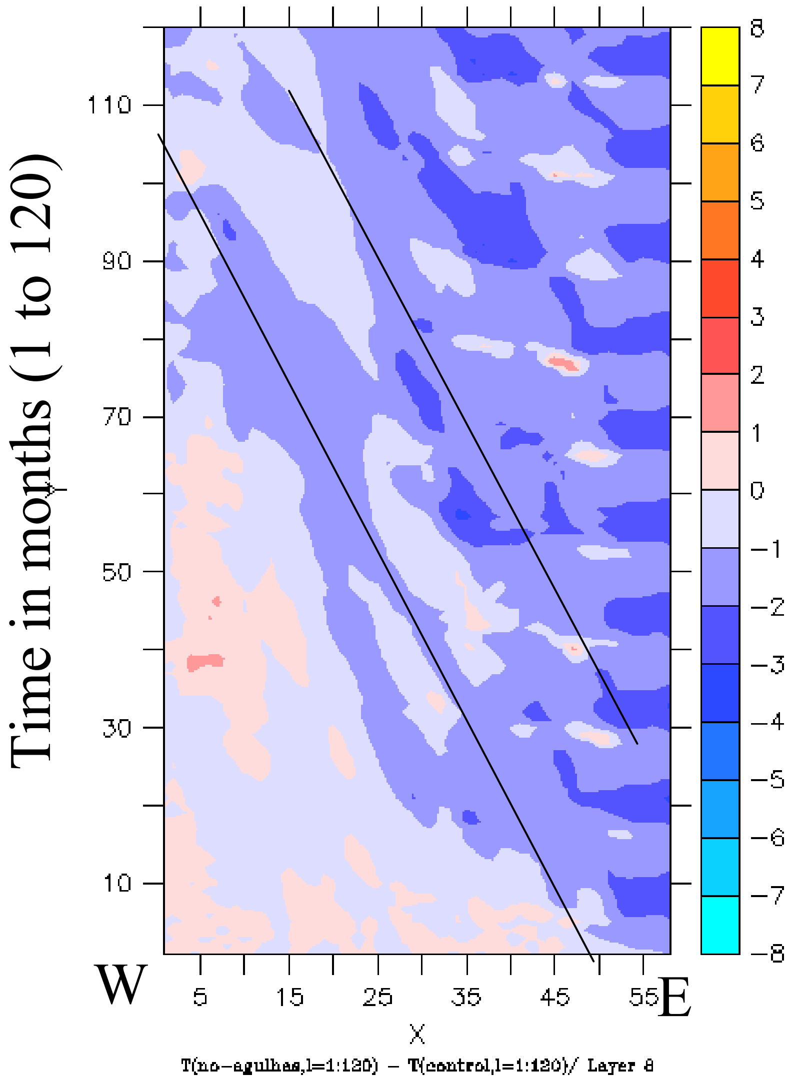


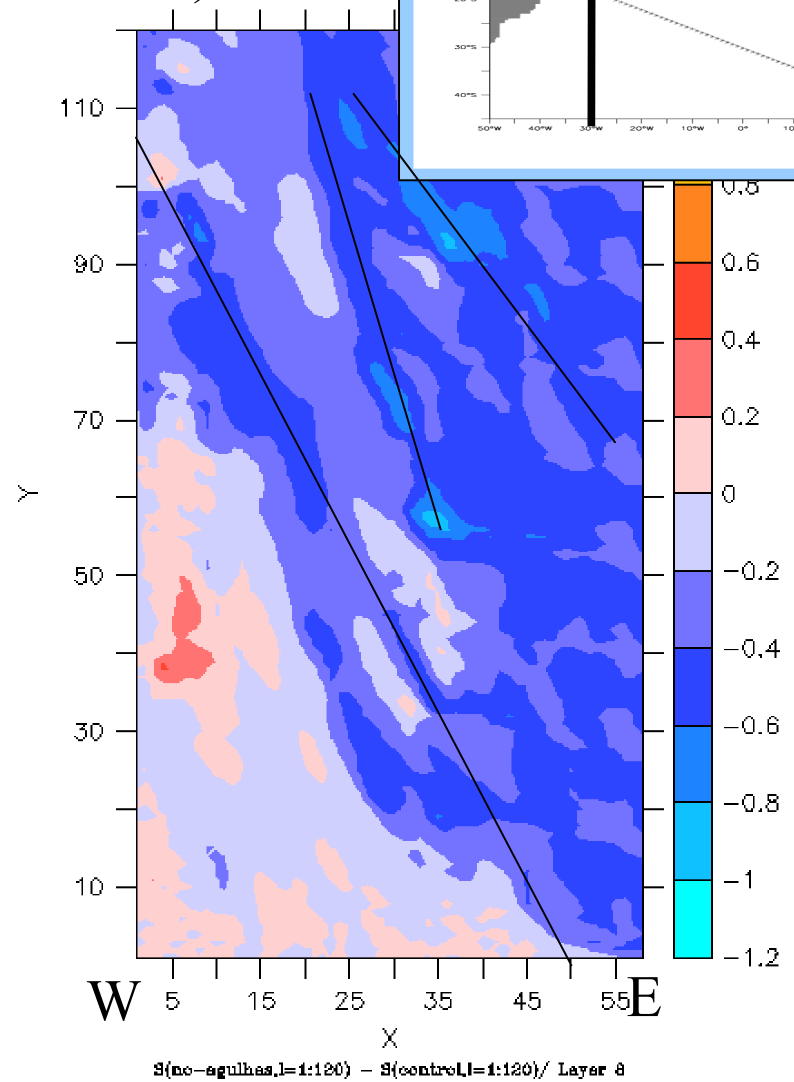


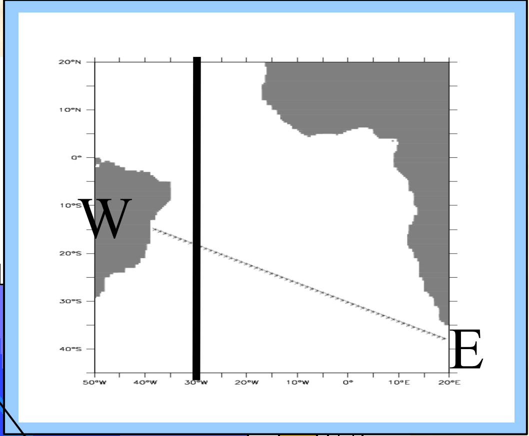
Points along line from Brazilian Coast (W) to Agulhas (E)

FERRET Ver. 5.60
NOAA/PMEL TMAP
Feb 5 2007 15:23:16

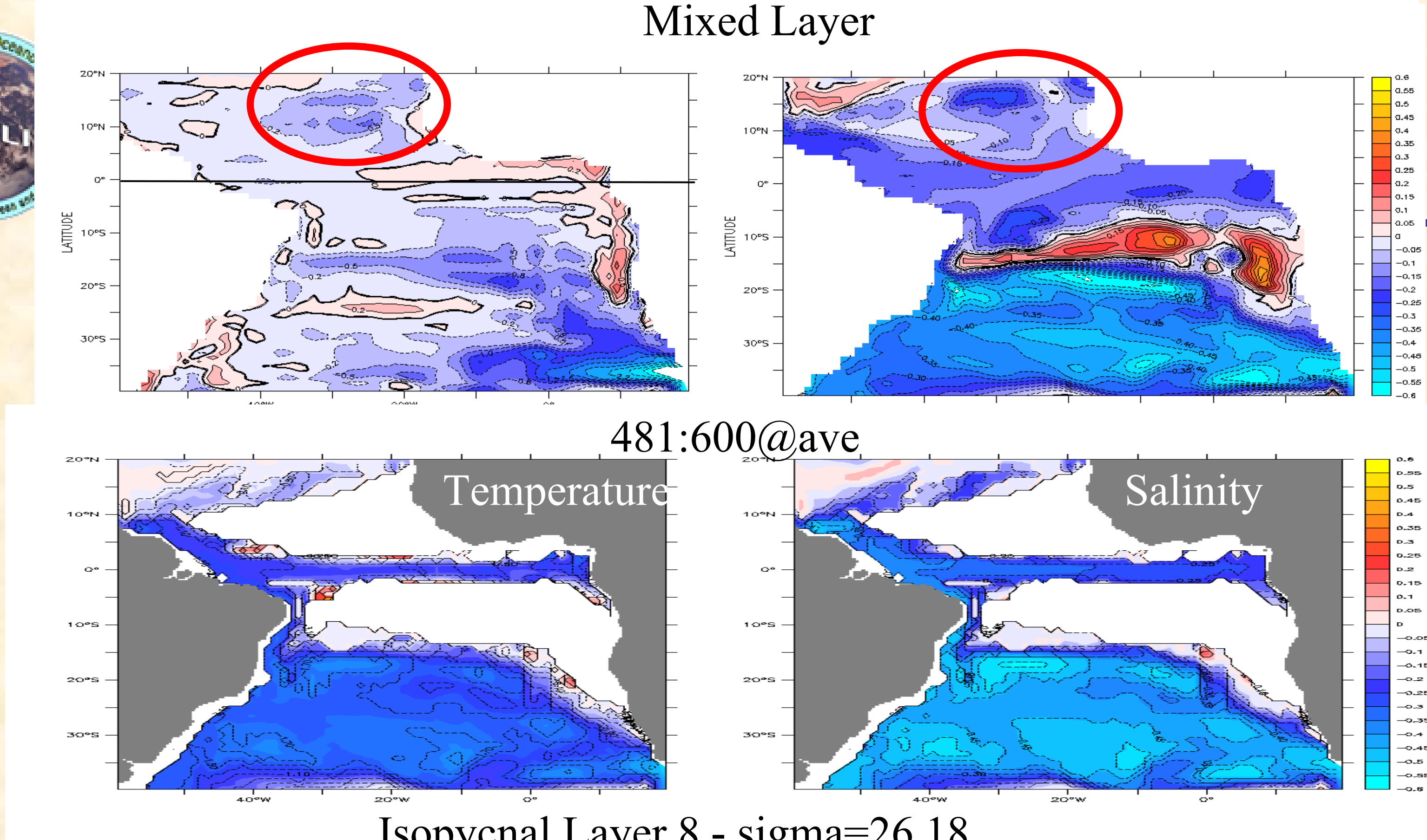
K=8 (thermocline)





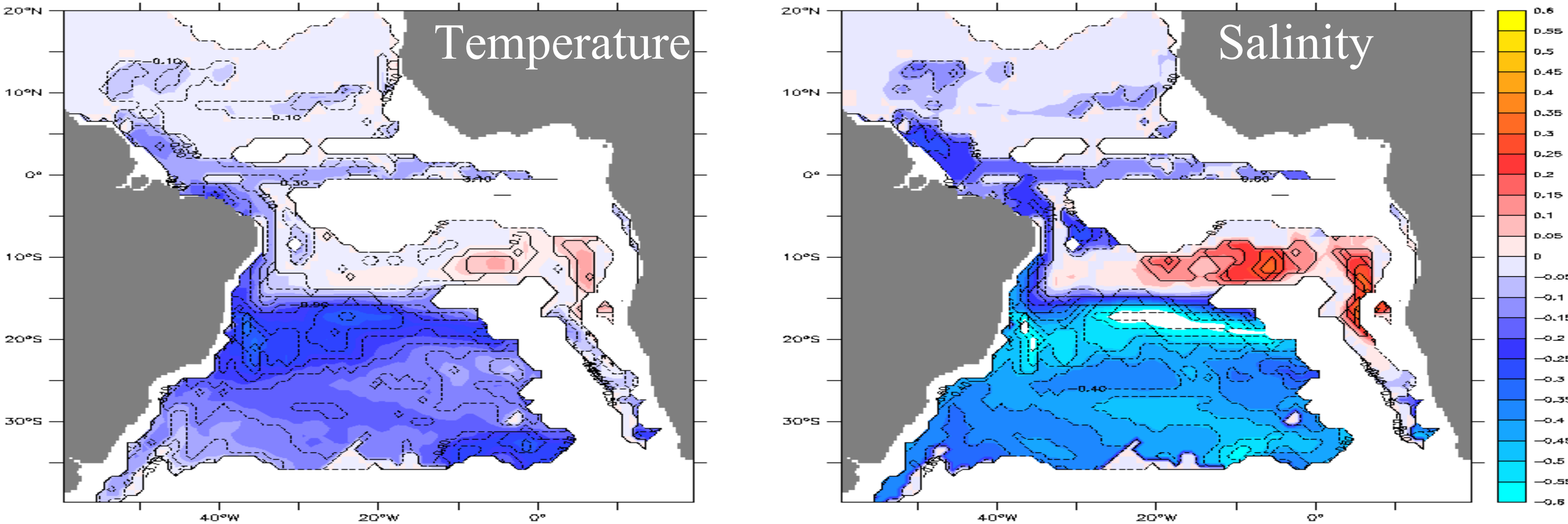


Points along line from Brazilian Coast (W) to Agulhas (E)

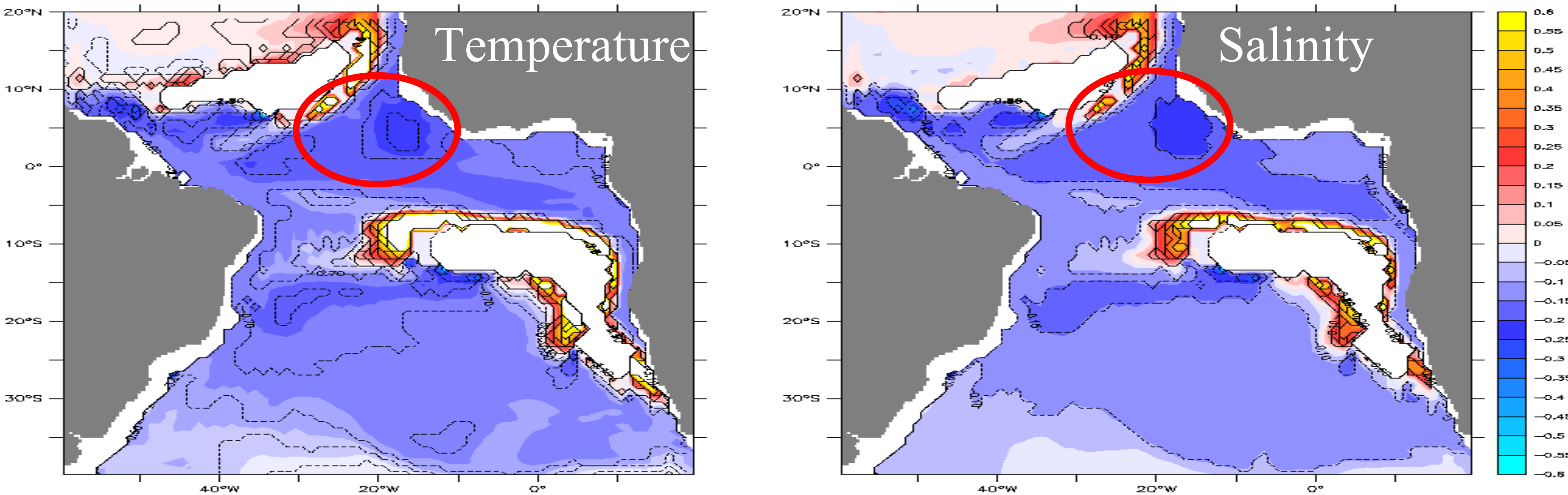


At the surface (top panels), the temperature anomaly does not reach the equatorial region, which shows a sligh warming up in the eastern side of the basin. There is, however, a freshening of the equatorial mixed layer.

Within the thermocline (lower panels), both T and S signals reach the EUC and are advected eastward.

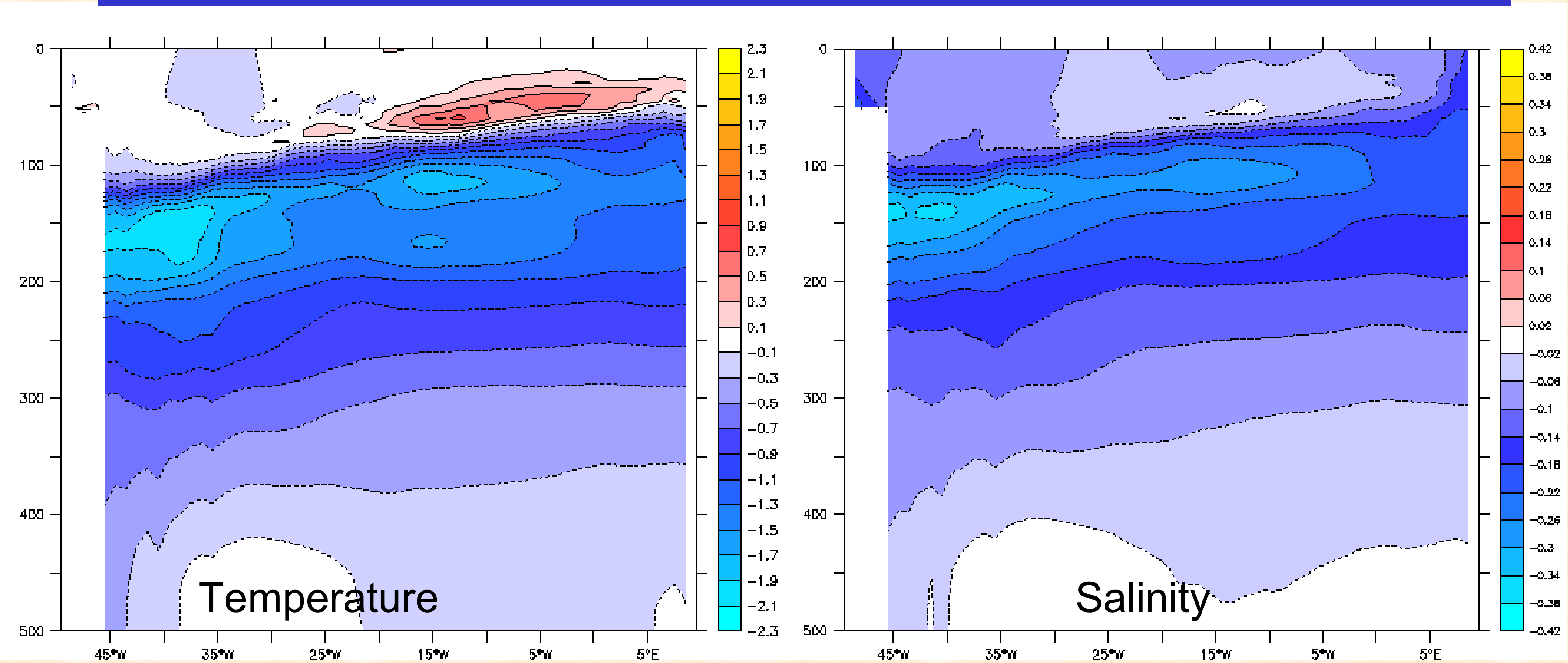


Isopycnal Layer 5 - sigma=24.9



Isopycnal Layer 11 - sigma=24.9

EQUATOR



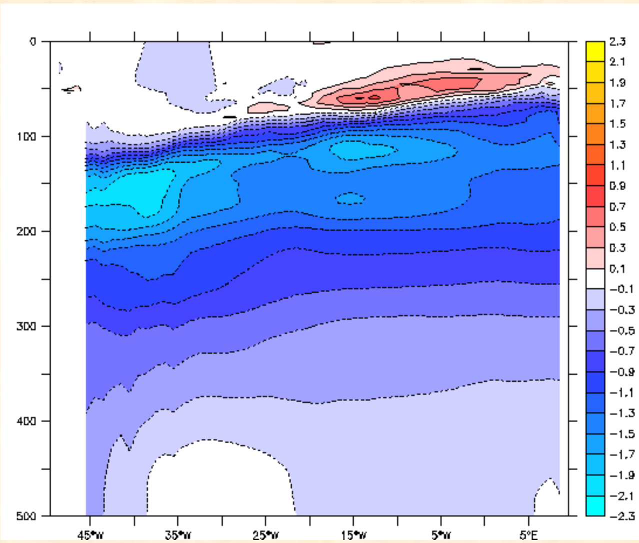
Along the Equator, the thermocline gets cooler and fresher. The mixed layer is also freshened in the NOAGU experiment. However, the temperature the mixed layer hardly changes.

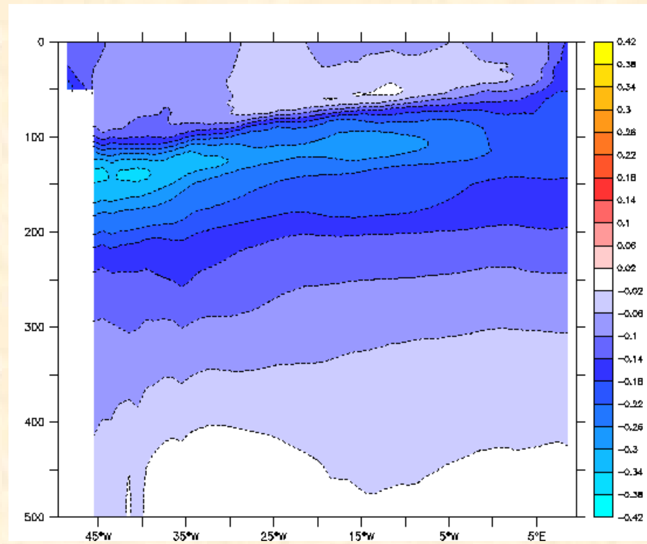
A slight warming up is observed in the bottom of the mixed layer in the eastern Atlantic.

Eliminate atmospheric response of wind stress:

NO-AGU experiment with wind stress from CONTROL run

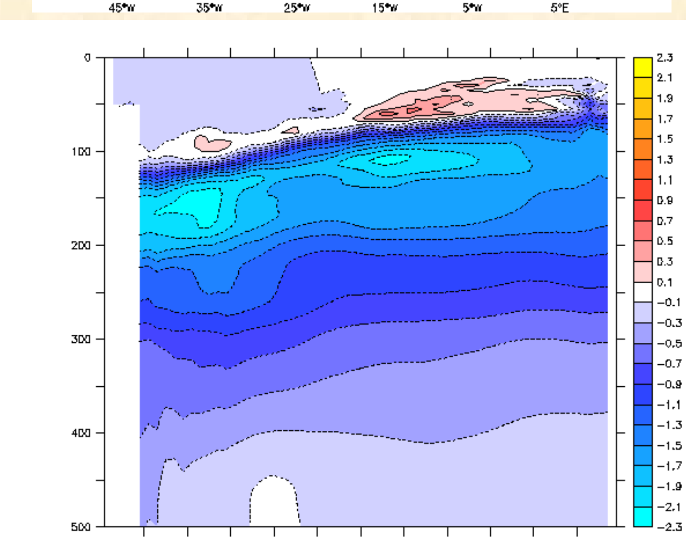
Temperature EQ. Salinity

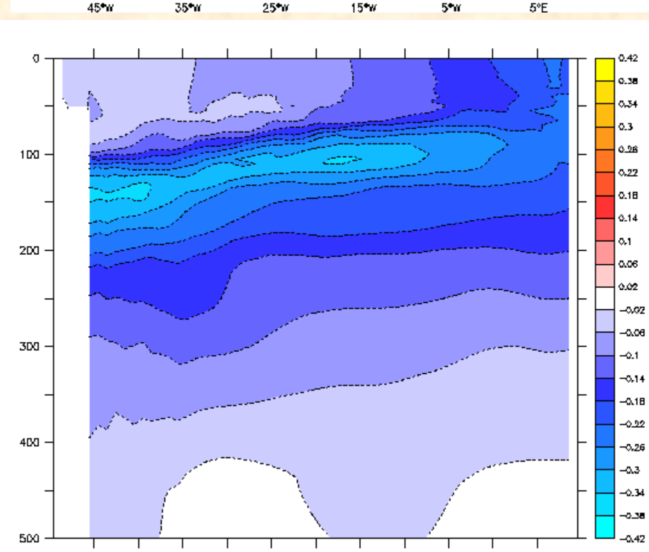




NOAGU-CONTROL

Atmospheric response reduces upwelling in mixed layer

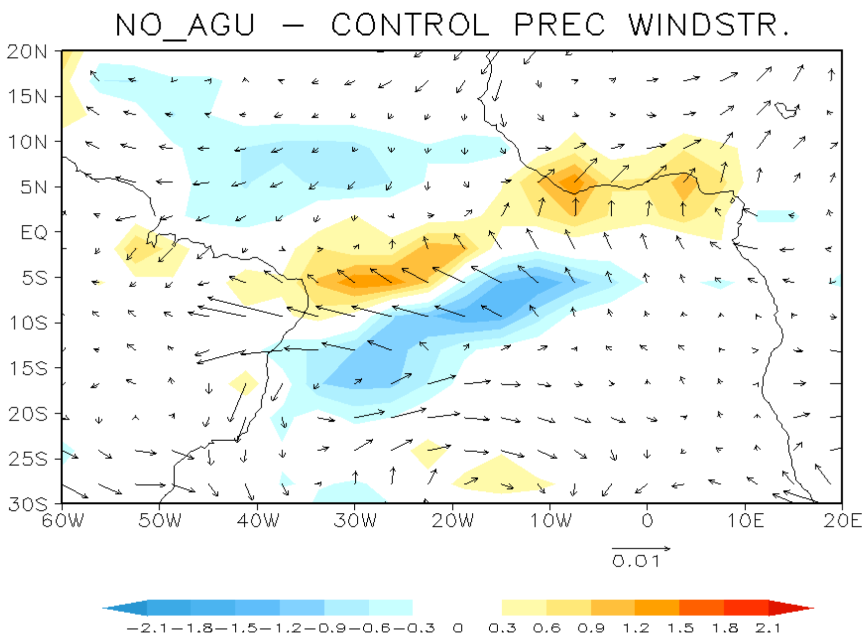


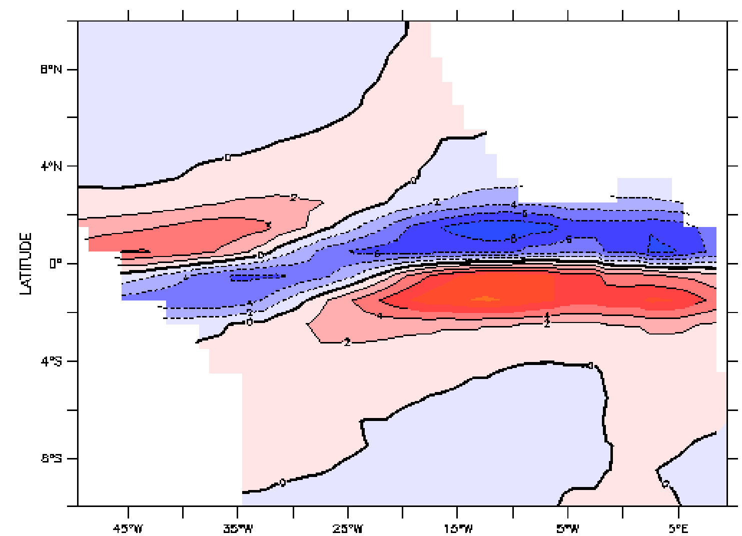


NOAGU-CONTROL

Wind stress in NOAGU run is from CONTROL run

Atmosphere response





Northward shift of ITCZ

Explains salinity maximum at the surface

Estimated change in Ekman divergence

Conclusions NO-AGU

- Impact on tropical Atlantic after about 10 years
- Cooling and freshening of South Atlantic
- Limited impact on equatorial climatology and variability
- Northward shift of ITCZ.
- Change in trade winds and Ekman pumping
- Anomalies advected by the EUC reach and affect the Guinea Dome region