Large-Scale Dynamics in the Canary Current EBUS

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IOCAG Instituto de Oceanografía y Cambio Global

North Atlantic Ocean

Thermocline circulation (0-1000 m depth)

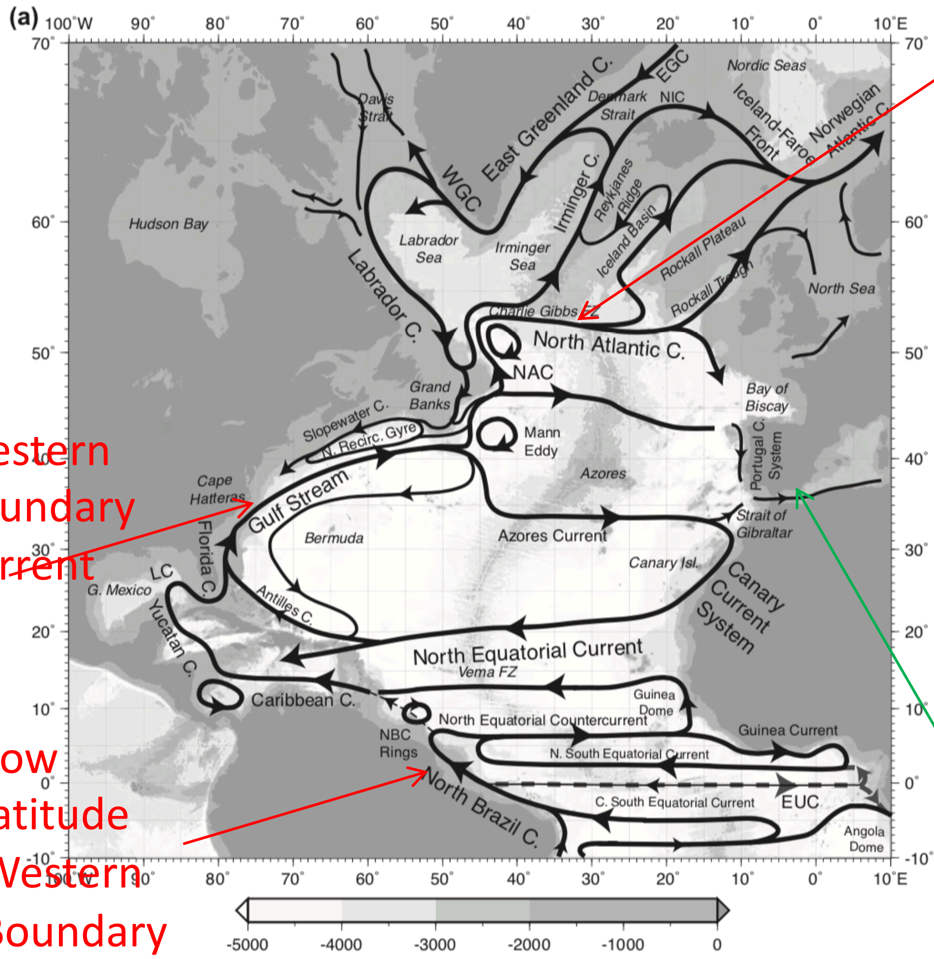


FIGURE 9.1. Atlantic Ocean surface circulation schematics. (a) North Atlantic and (b) South Atlantic; the eastward EUC along the equator just below the surface layer is also shown (gray dashed).

North Atlantic Current

Cyclonic subpolar gyre:

- Norwegian Atlantic Current
- East Greenland Current
- Labrador Current

Wind-driven subtropical gyre

Eastern Boundary Current Upwelling Systems

- The Canary Current System

Wind-driven tropical circulation

Predominantly zonal:

- North Equatorial Countercurrent
- South Equatorial Current

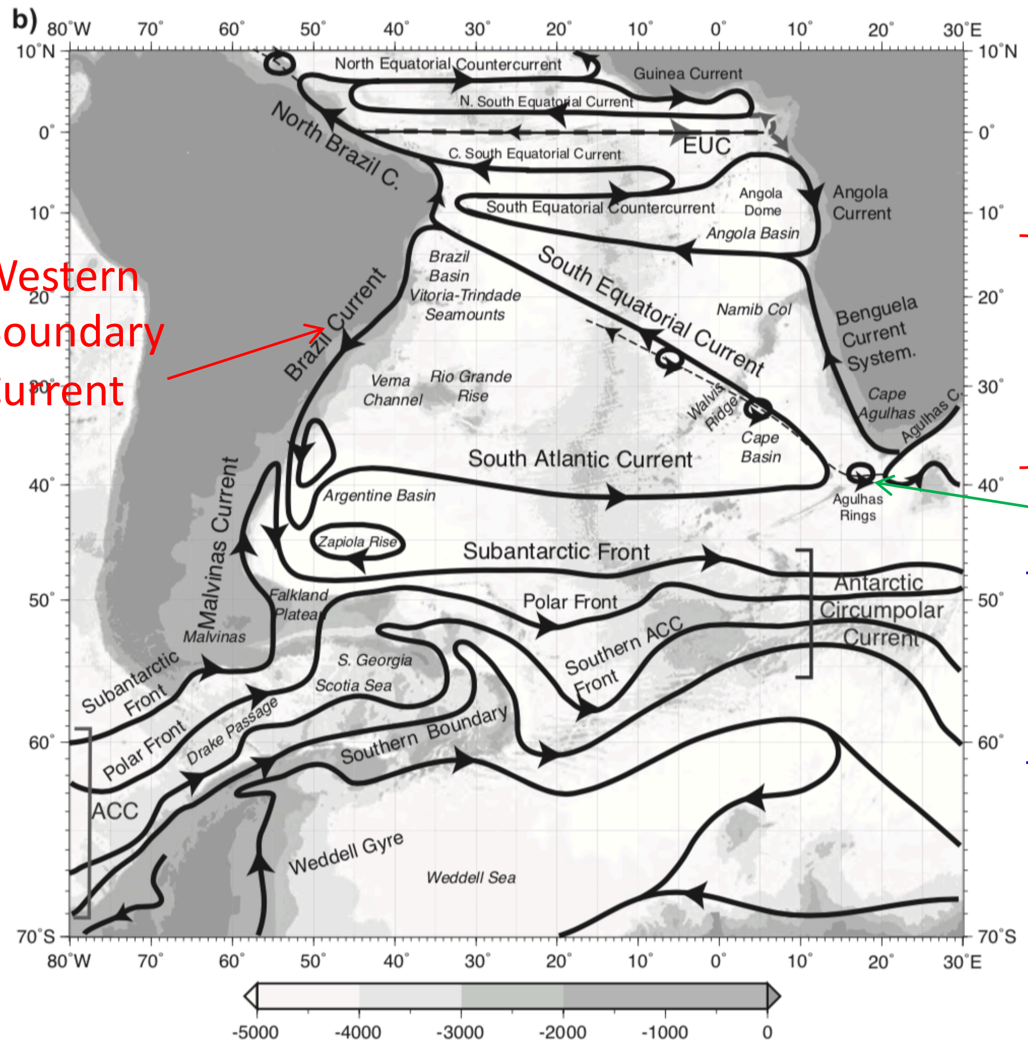
Mediterranean Sea

Western Boundary Current

Low latitude Western Boundary Current

South Atlantic Ocean

Thermocline circulation (0-1000 m depth)



Western Boundary Current

Wind-driven subtropical gyre

Eastern Boundary Current Upwelling Systems

- The Benguela Current System

Agulhas Rings

Southern Ocean

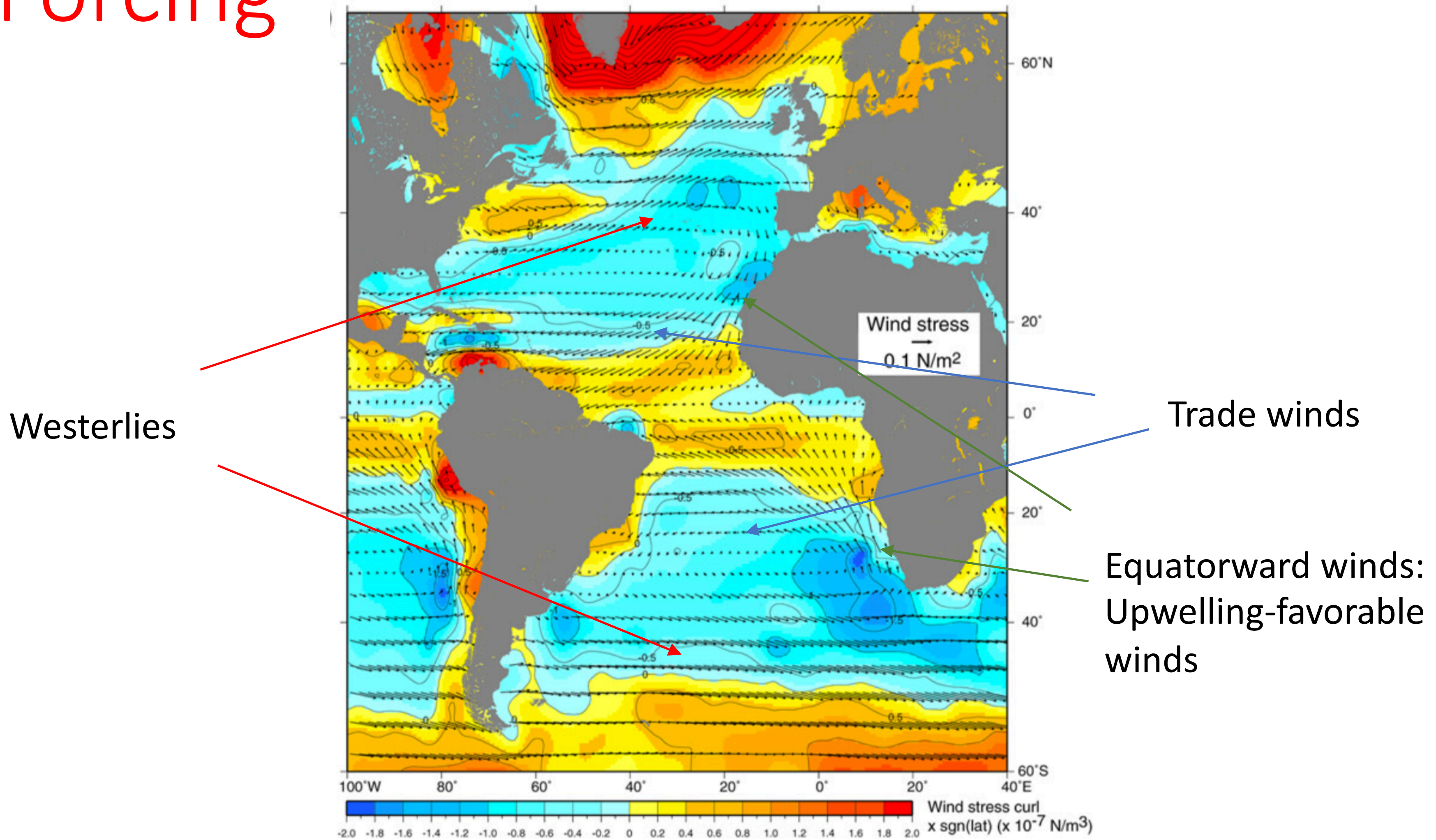
- It connects the Atlantic Ocean with the Indian and Pacific Oceans

Who drives these currents?
What is the forcing field driving these currents?

Who drives these currents?
What is the forcing field driving these currents?

The wind

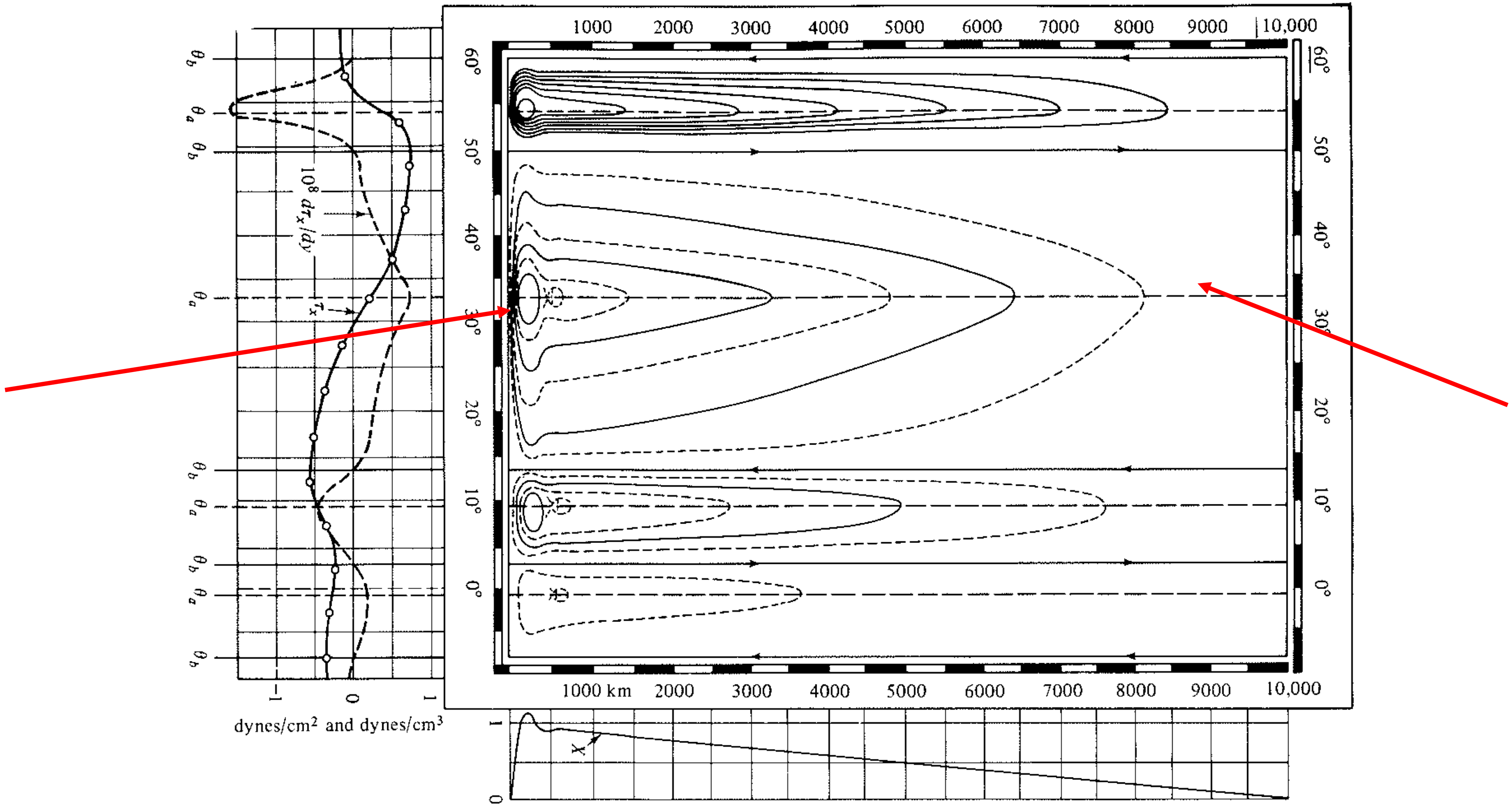
Atlantic Ocean
Wind Forcing



Wind-stress curl multiplied by -1 in the Southern hemisphere

Munk (1950):

Currents driven by the wind in baroclinic ocean



Munk (1950):
Currents driven by the wind in baroclinic ocean

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}-fv=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\frac{1}{\rho}\left[\frac{\partial}{\partial x}\left(A_H\frac{\partial u}{\partial x}\right)+\frac{\partial}{\partial y}\left(A_H\frac{\partial u}{\partial y}\right)+\frac{\partial}{\partial z}\left(A_V\frac{\partial u}{\partial z}\right)\right]$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}+fu=-\frac{1}{\rho}\frac{\partial p}{\partial y}+\frac{1}{\rho}\left[\frac{\partial}{\partial x}\left(A_H\frac{\partial v}{\partial x}\right)+\frac{\partial}{\partial y}\left(A_H\frac{\partial v}{\partial y}\right)+\frac{\partial}{\partial z}\left(A_V\frac{\partial v}{\partial z}\right)\right]$$

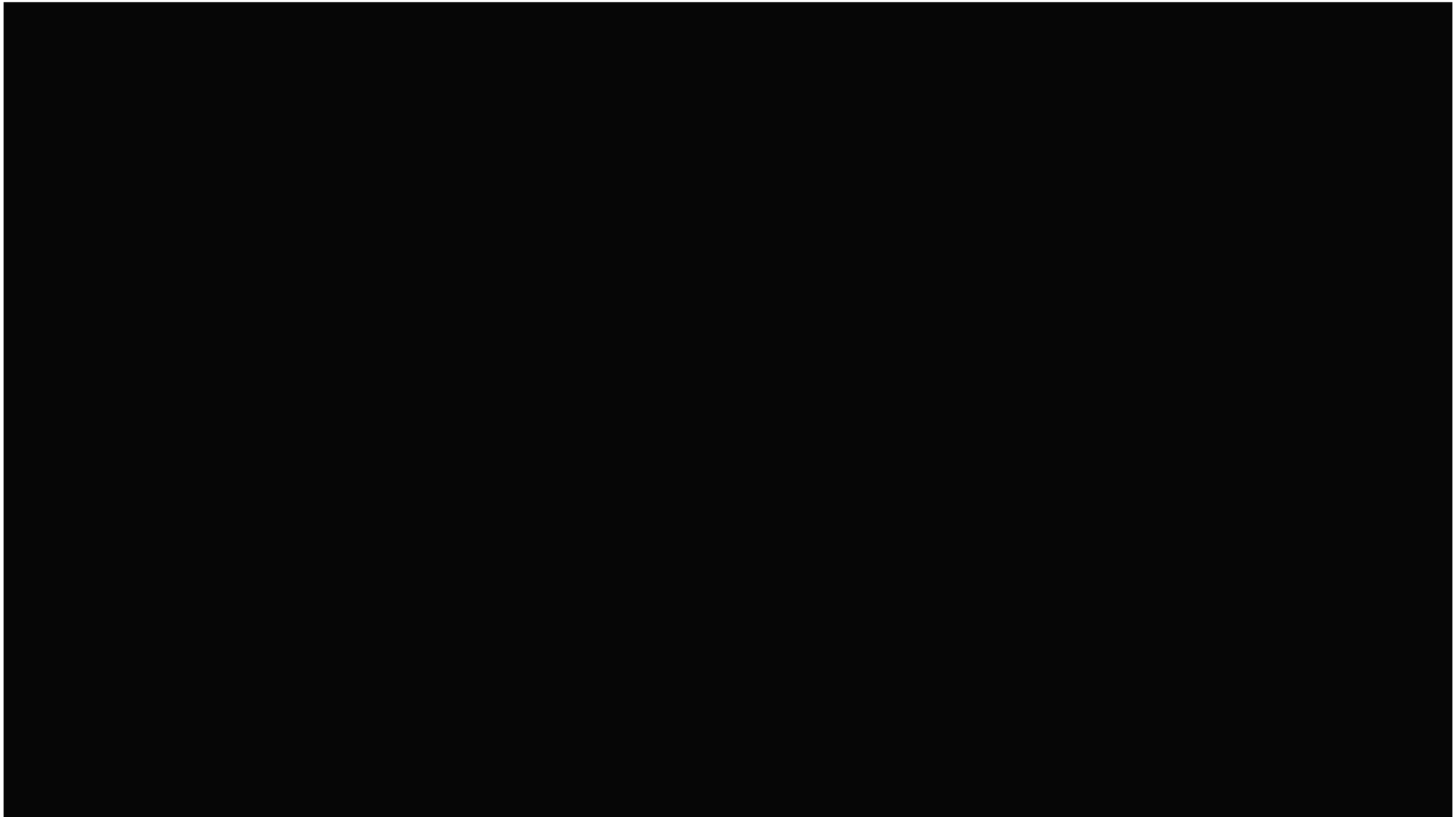
$$0=-\frac{\partial p}{\partial z}-\rho g$$

$$\frac{\partial \rho}{\partial t}+\vec{\nabla}\cdot\rho\vec{v}=0(estadoestacionario)\vec{\nabla}\cdot\rho\vec{v}=0$$

Aproximaciones:

1. R_{oT}=0, estado estacionario
2. R_o<<1, términos no lineales despreciables
3. Fricción lateral **NO** despreciable

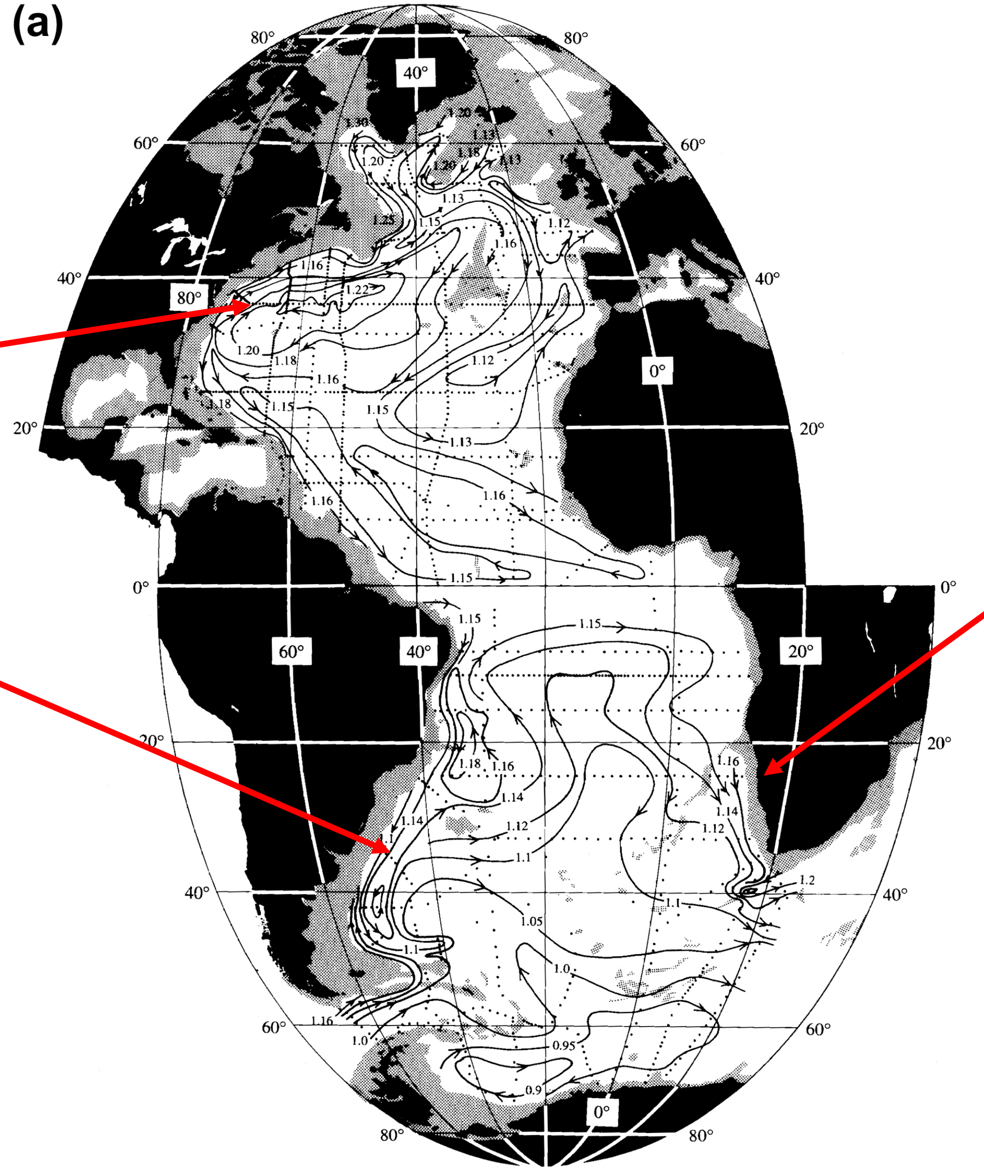
Ocean Circulation-Thermocline layers



Deep-layers (2000-4000 m depth)

Deep-layers (2000-4000 m depth)

(a)



DWBC

What is the forcing field for the Deep circulation?

What is the forcing field for the Deep circulation?

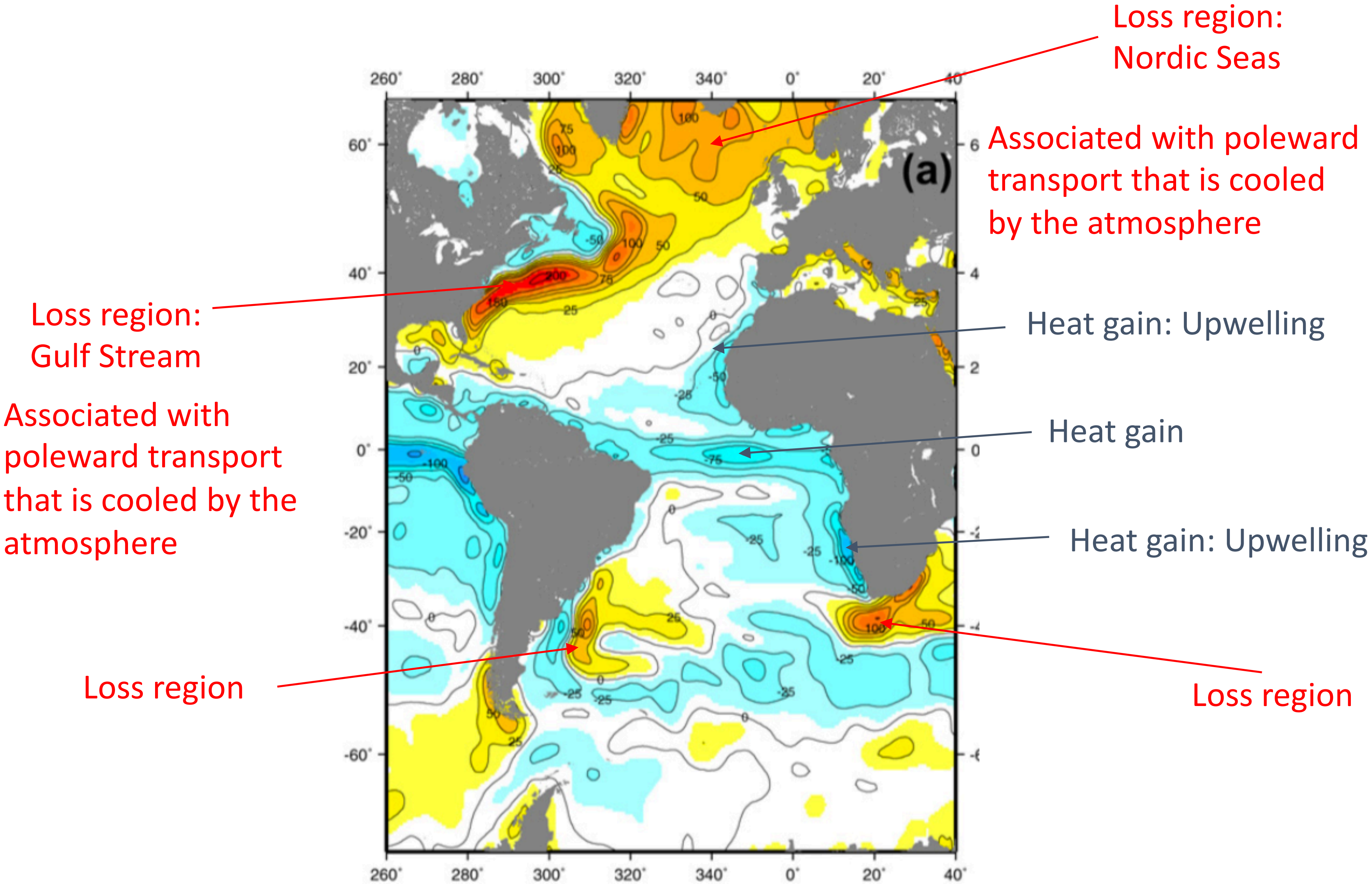
The buoyancy

Atlantic Ocean
Buoyancy Forcing

Buoyancy forcing = Heat flux + freshwater flux

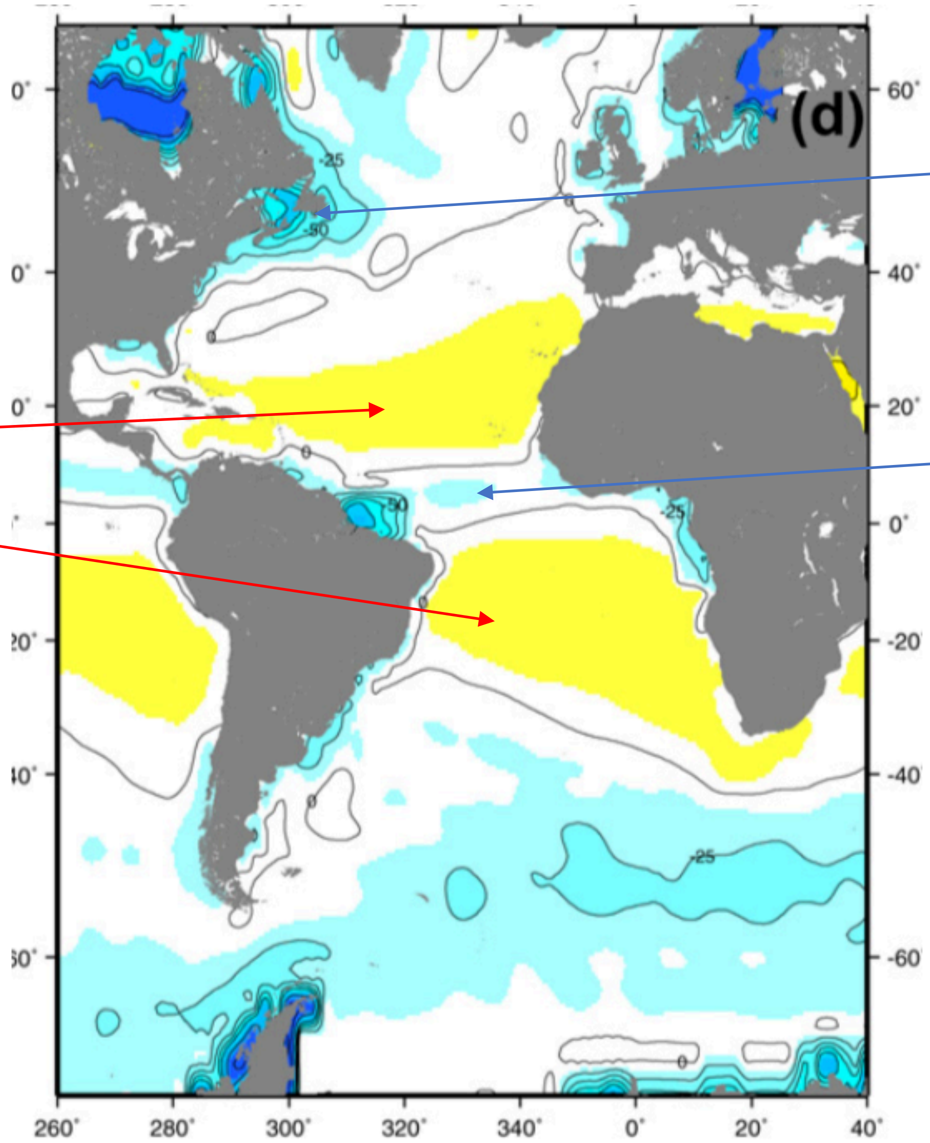
freshwater flux = Evaporation – (Precipitation + river runoff)

Atlantic Ocean
Heat Flux



Atlantic Ocean

Freshwater Flux (E-P-runoff)



Net precipitation

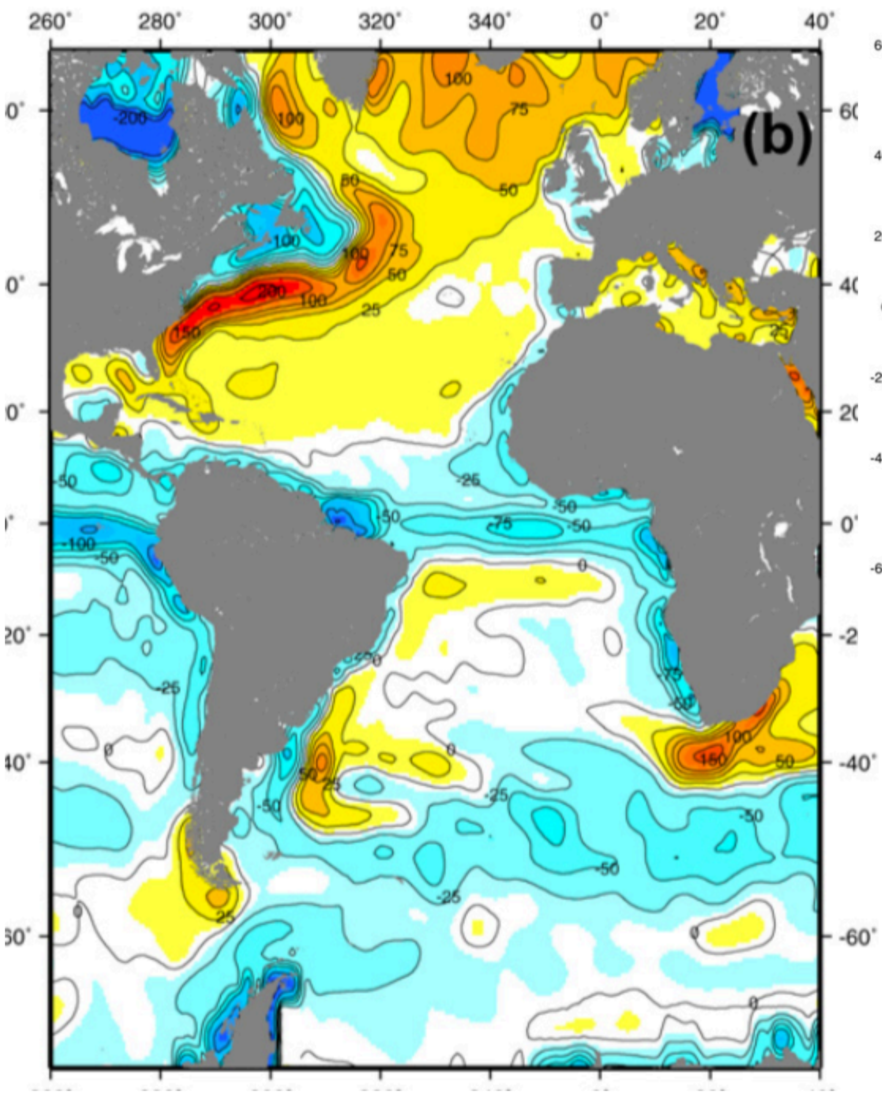
Net Evaporation in the subtropics

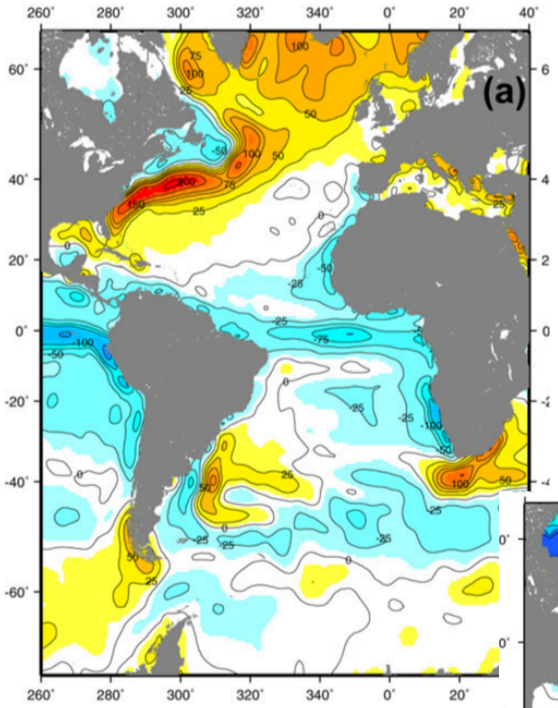
Net Precipitation associated with Intertropical Convergence Zone (ITCZ)

In the Atlantic Ocean, E>P compared to the Pacific Ocean. Then, the salinity in the Atlantic is higher than in the Pacific.

Atlantic Ocean

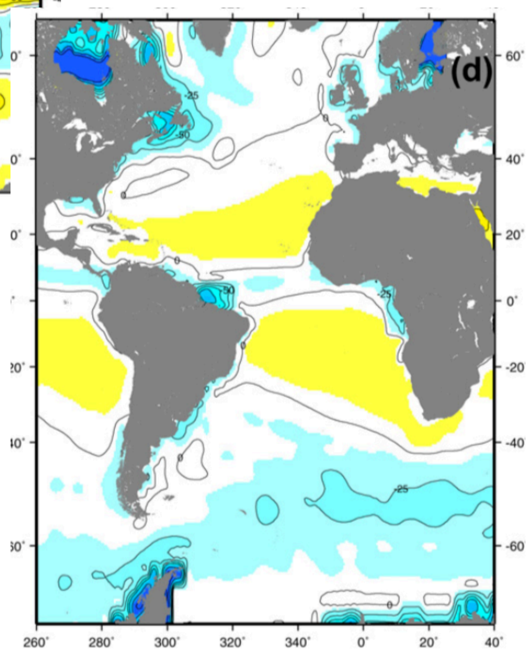
Buoyancy flux



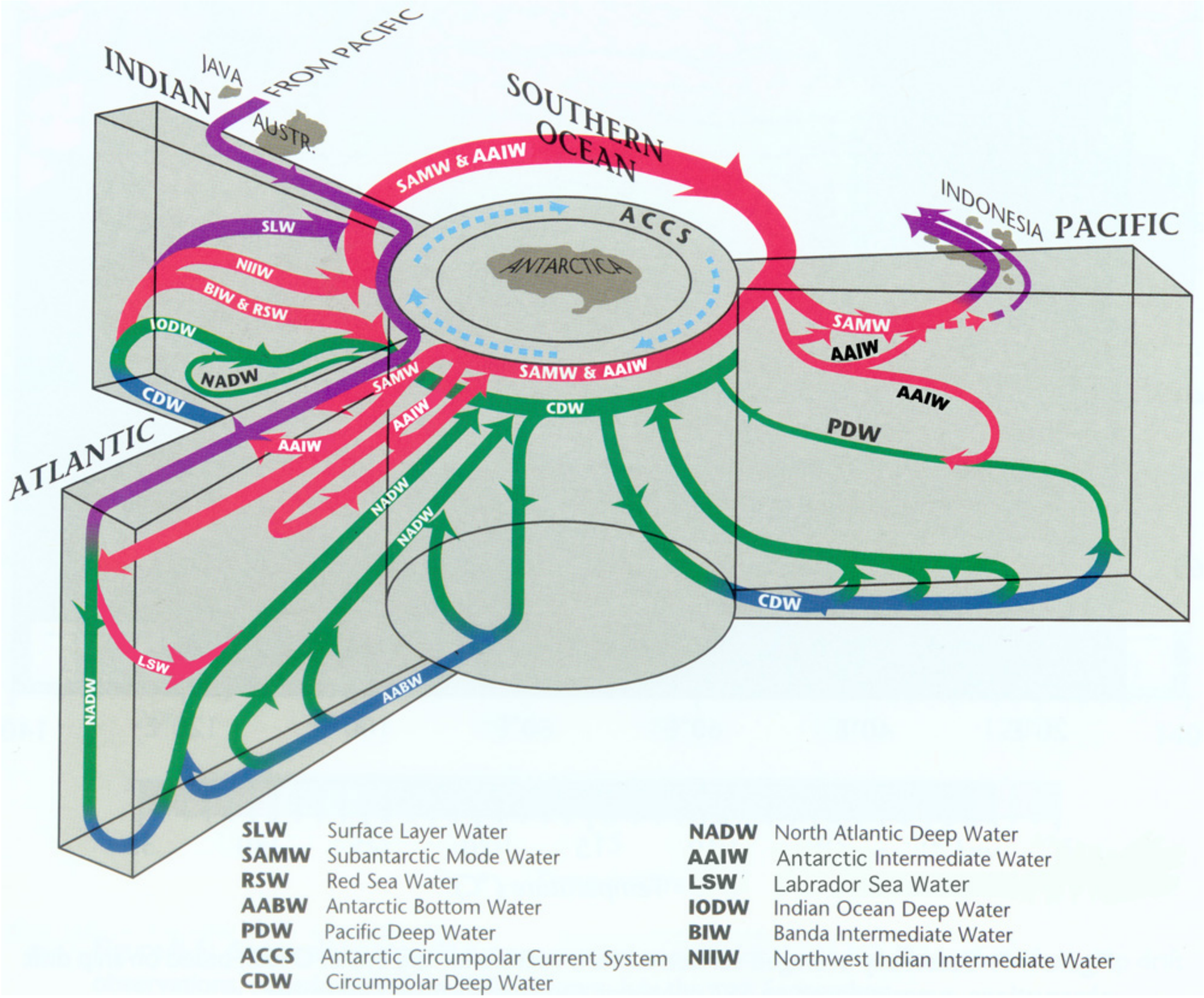


Heat Flux

Freshwater flux

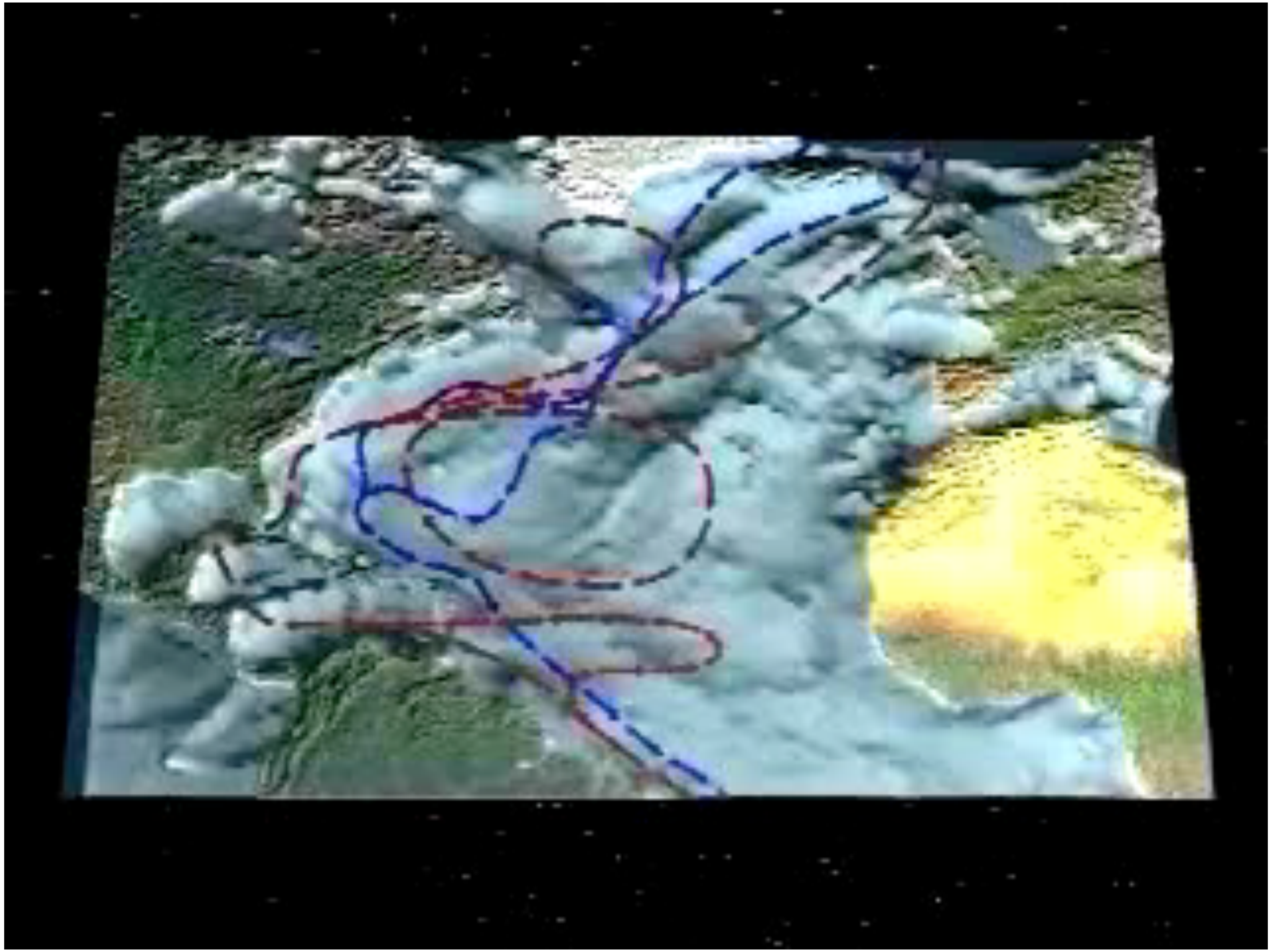


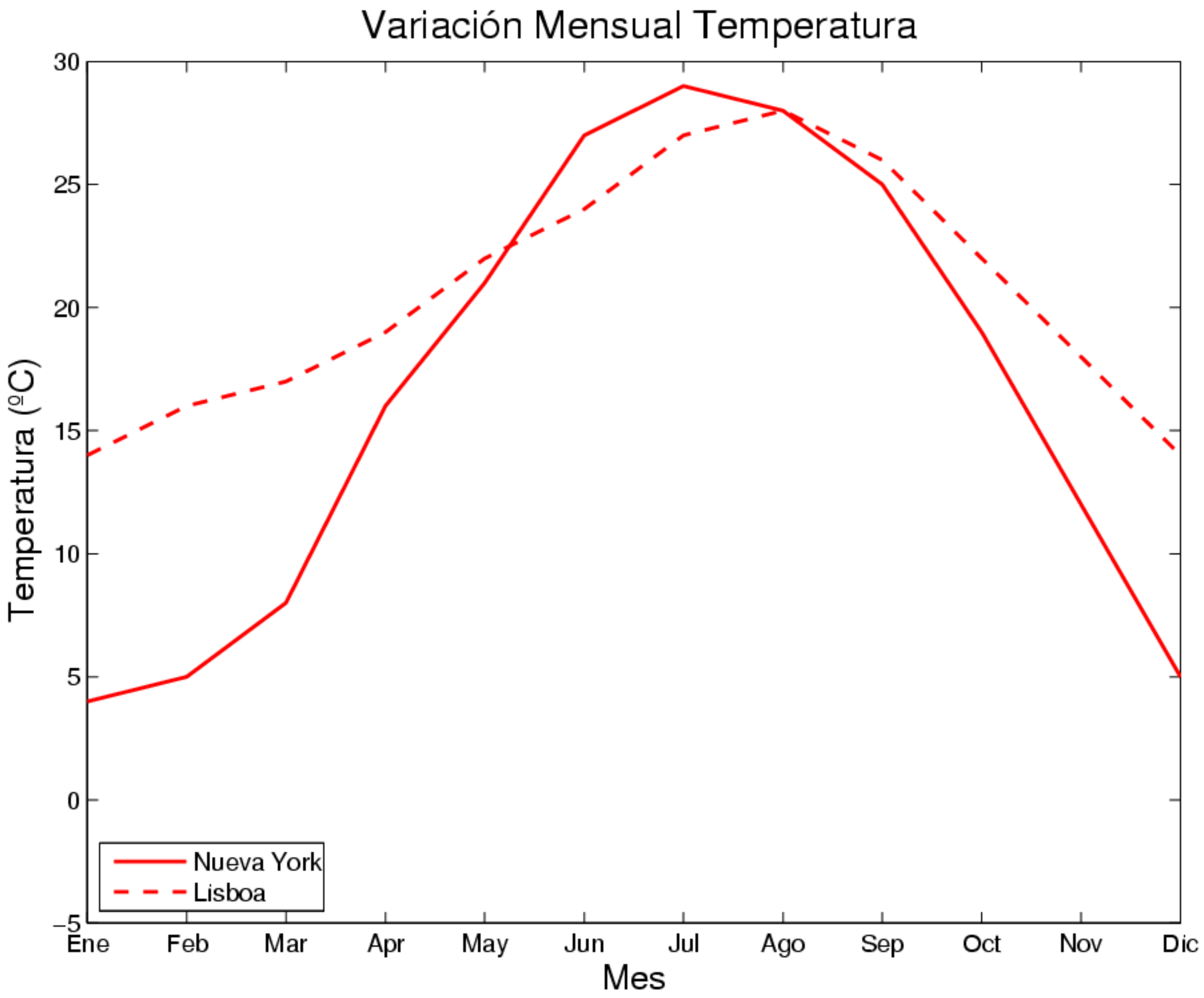
Deep Circulation



Talley et al. (2011)

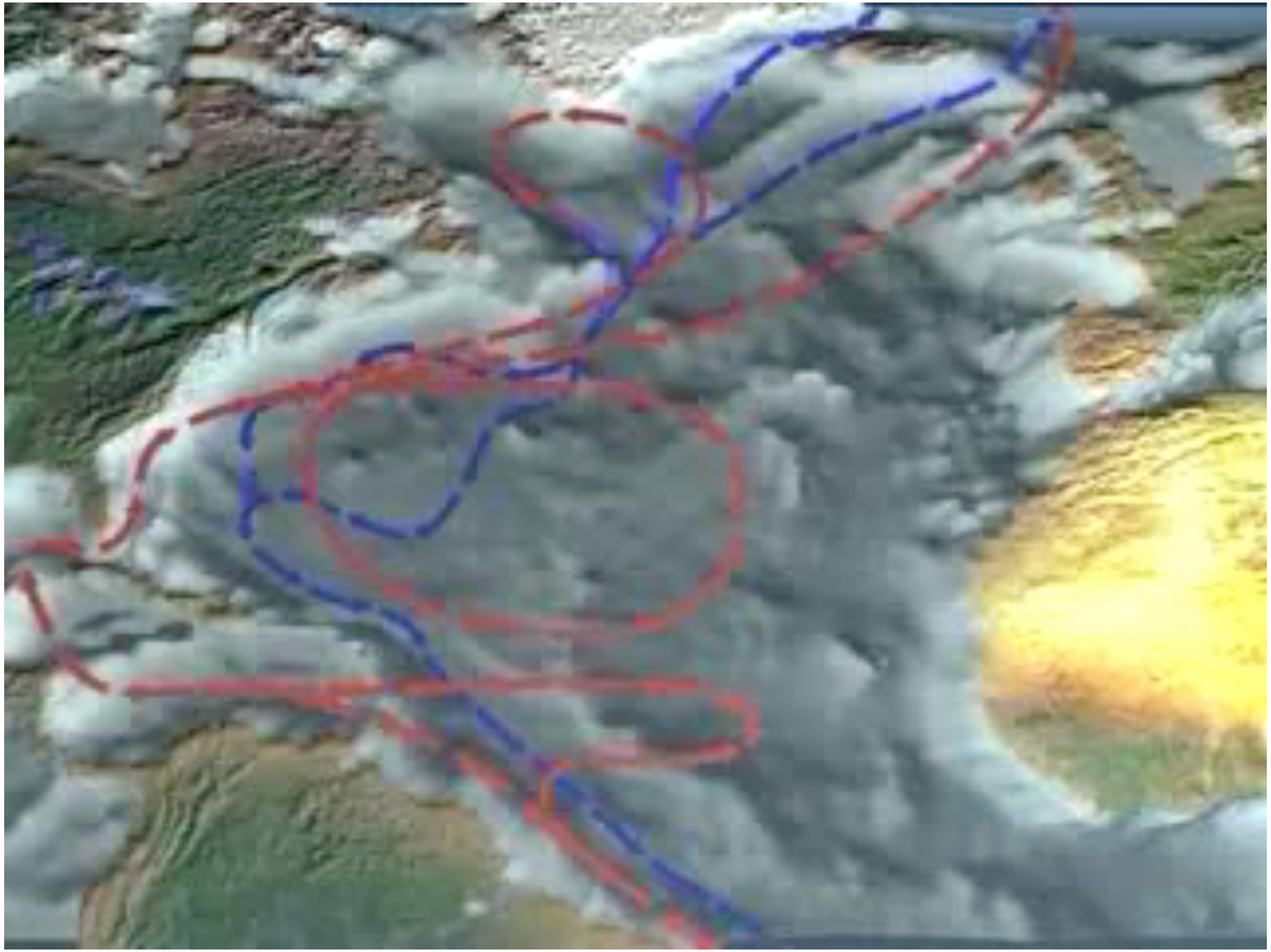
What is the effect of the buoyancy?





Variación Mensual Temperatura
Temperatura (ºC)
30
25
20
15
10
5
0
−5
Nueva York
Lisboa
Ene
Feb
Mar
Apr
May
Jun
Jul
Ago
Sep
Oct
Nov
Dic
Mes

What is it supposed to happen in a warmer atmosphere due to the climate change?

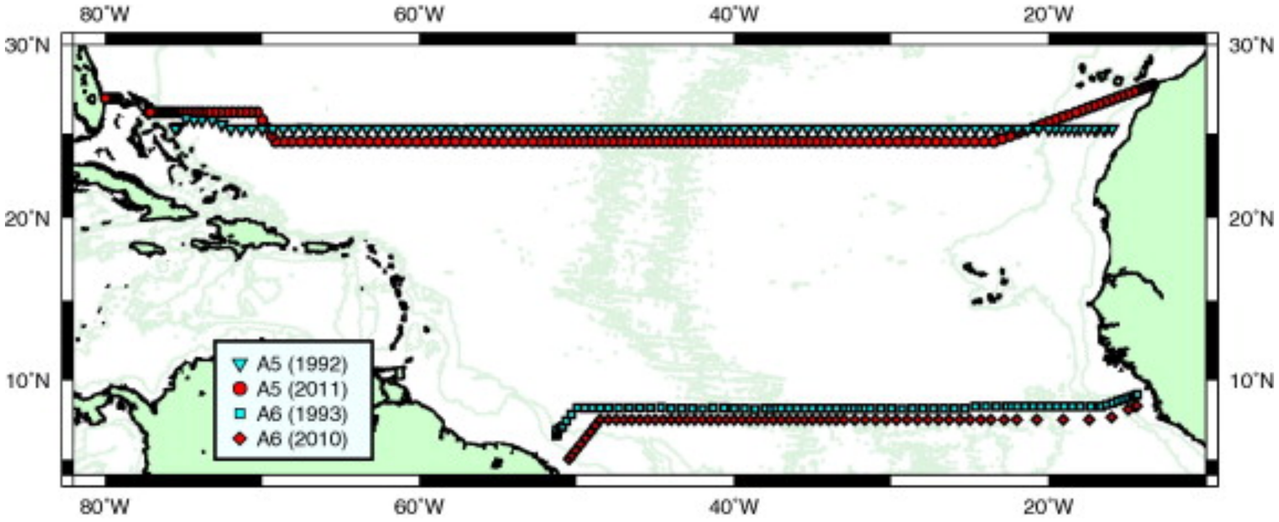


North Atlantic Circulation
Subtropical Circulation

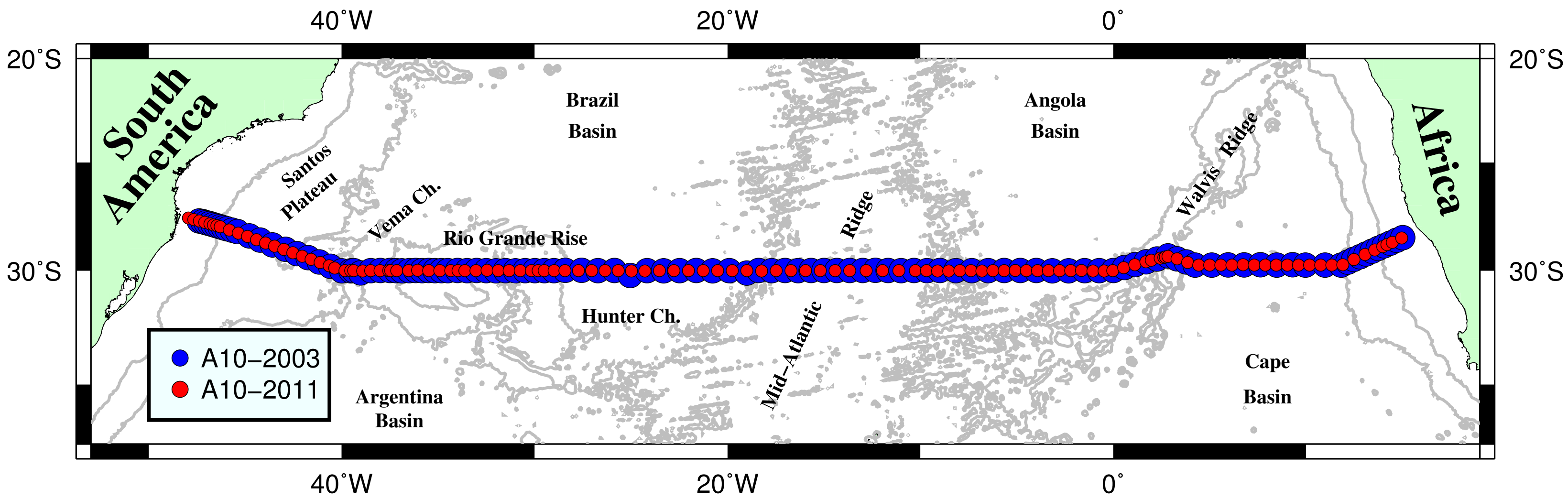
- The subtropical western boundary current: The Gulf Stream System and the North Atlantic Circulation
- The subtropical eastern boundary current systems: The Canary Current System and the Portugal Canary System
- The northern boundary: The Azores Current
- The southern boundary: the North Equatorial Current

How is the ocean study?

Atlantic Ocean (7.5°N – 24.5°N)

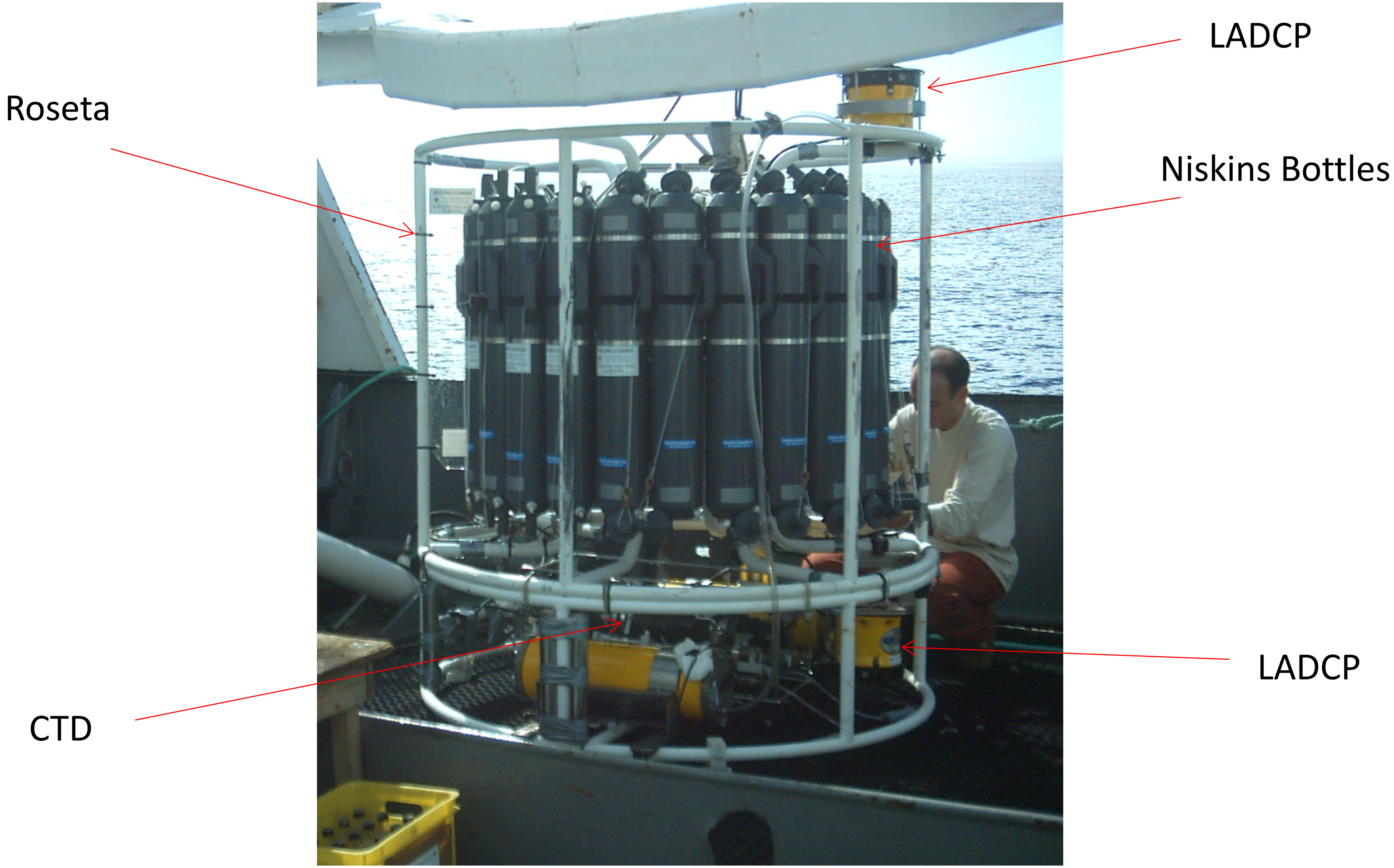


Atlantic Ocean (A10–30°S)

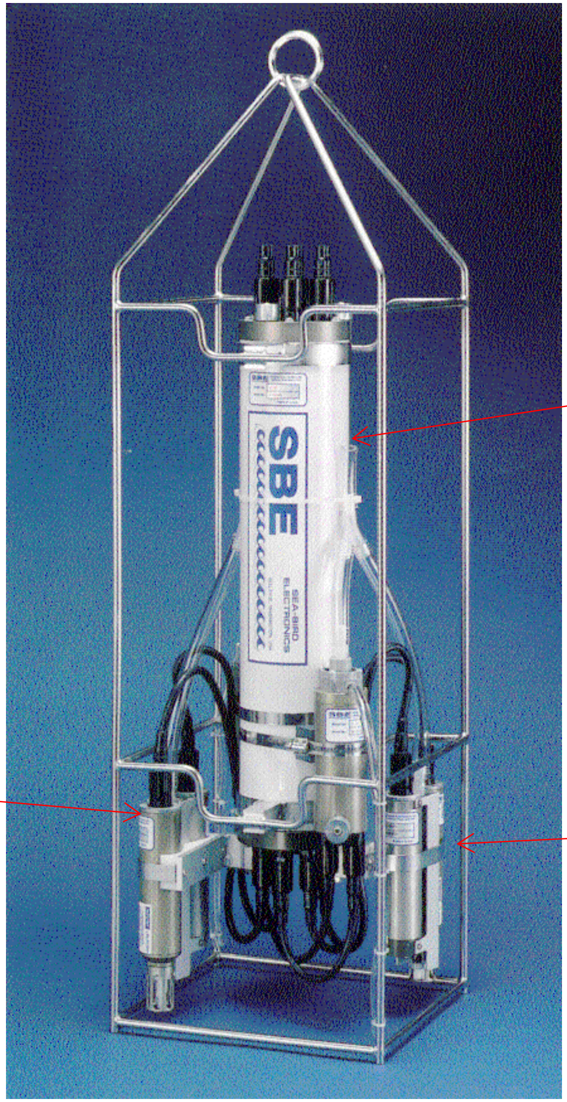


Oceanographic Vessels

Instruments - Rosette



Instruments - CTD

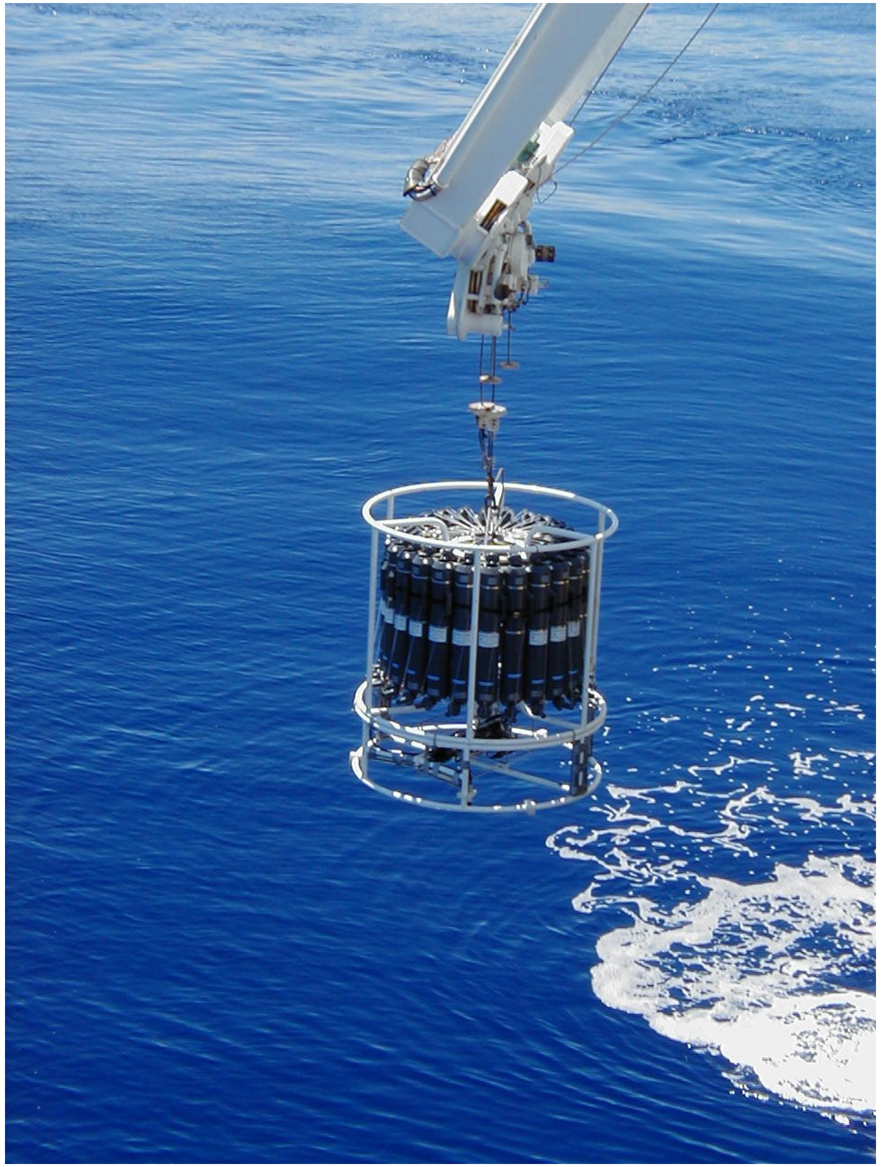


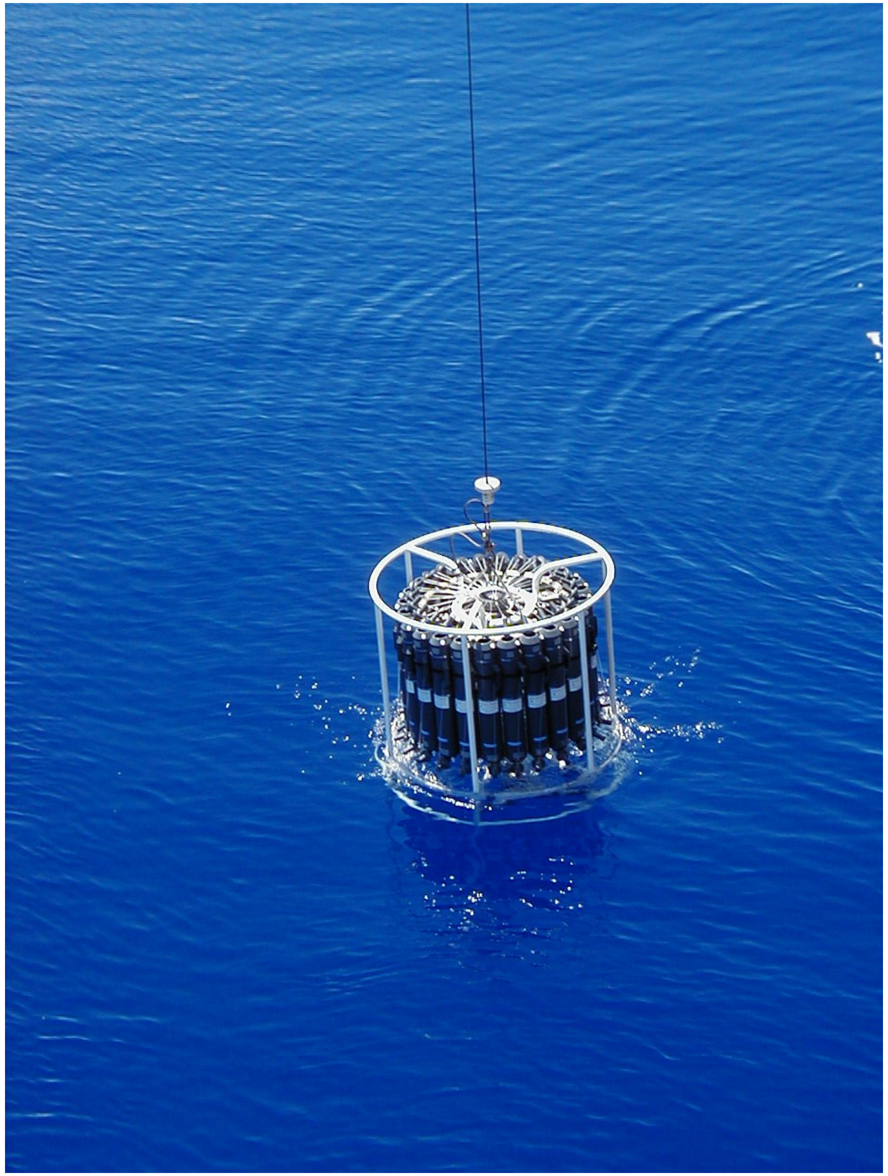
Electronic

Conductivity, Temperature and Pressure

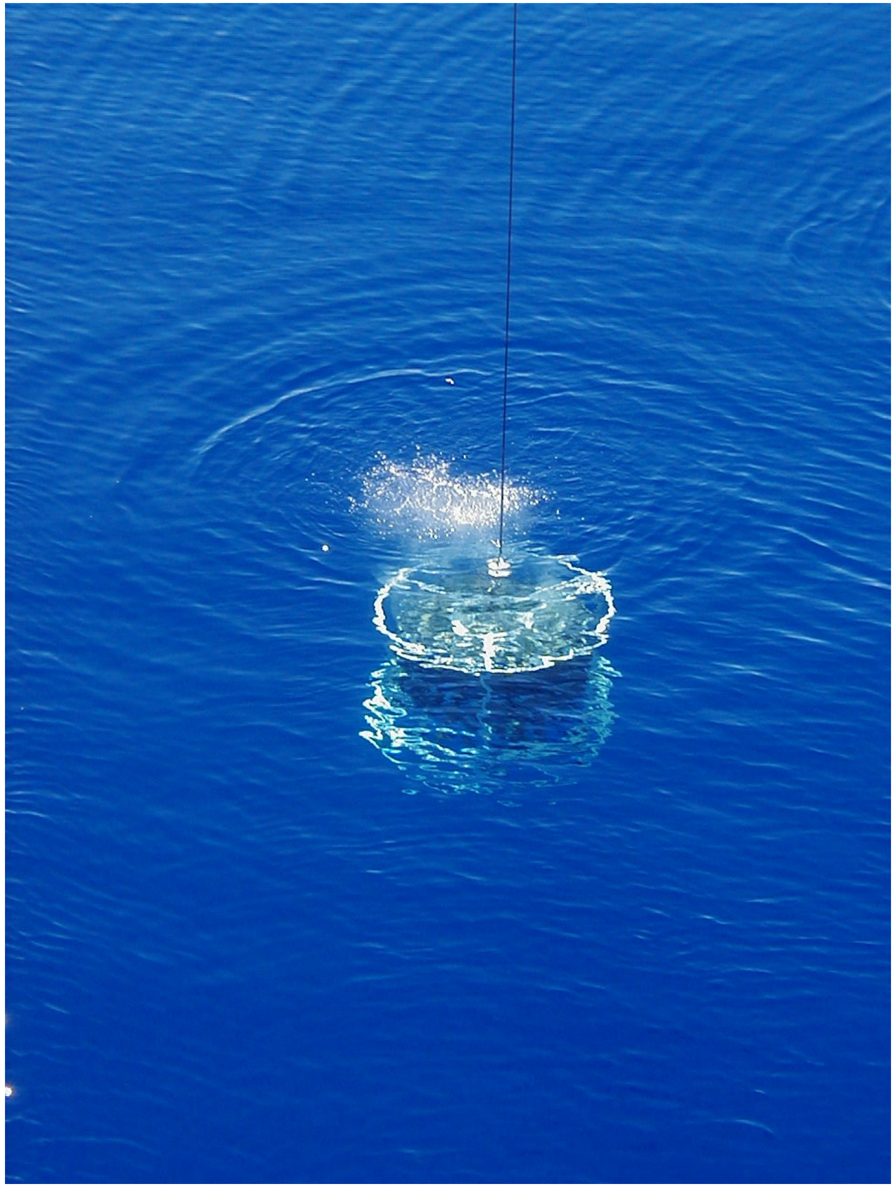
Conductivity, Temperature and Pressure

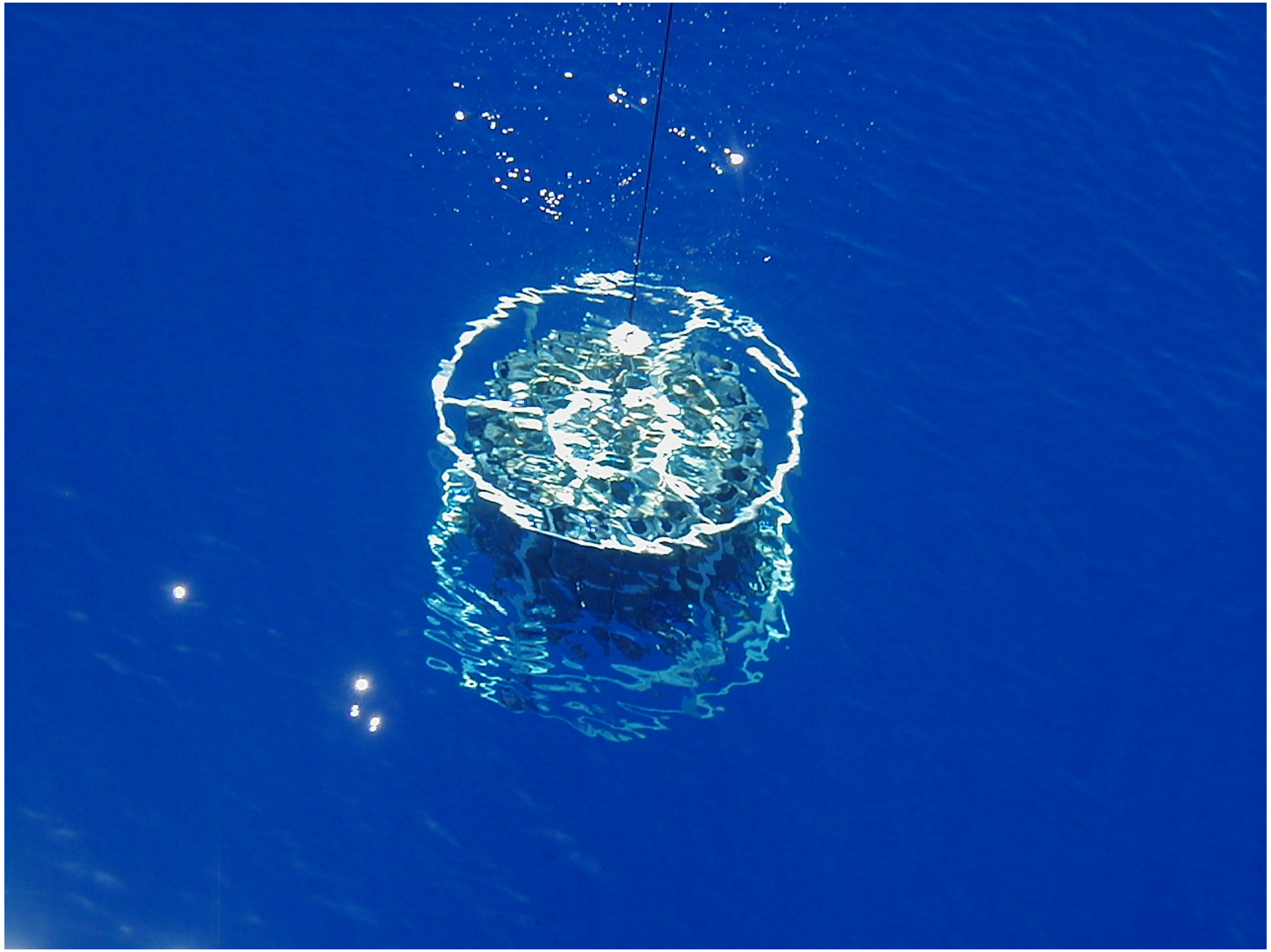
Instruments



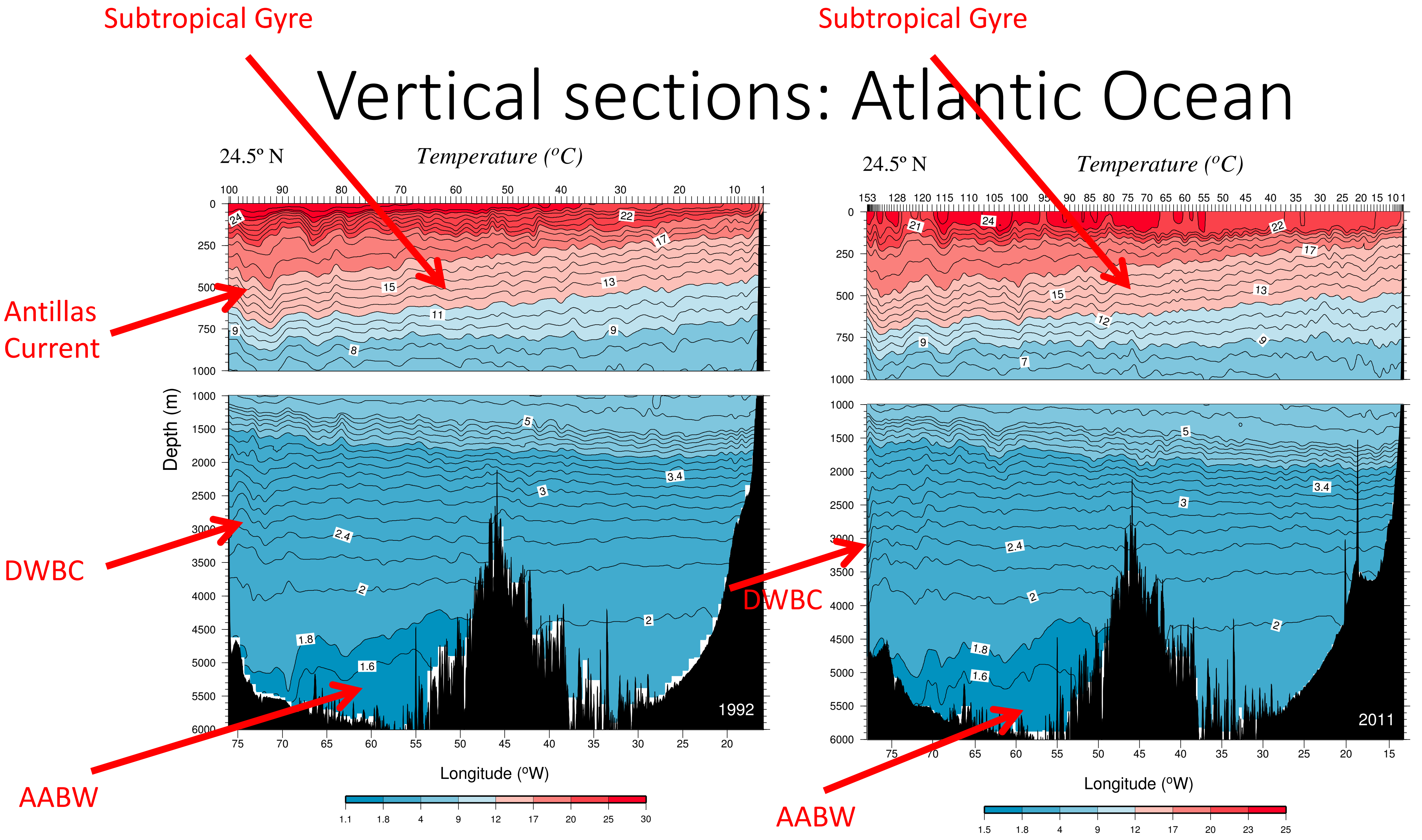


Instruments

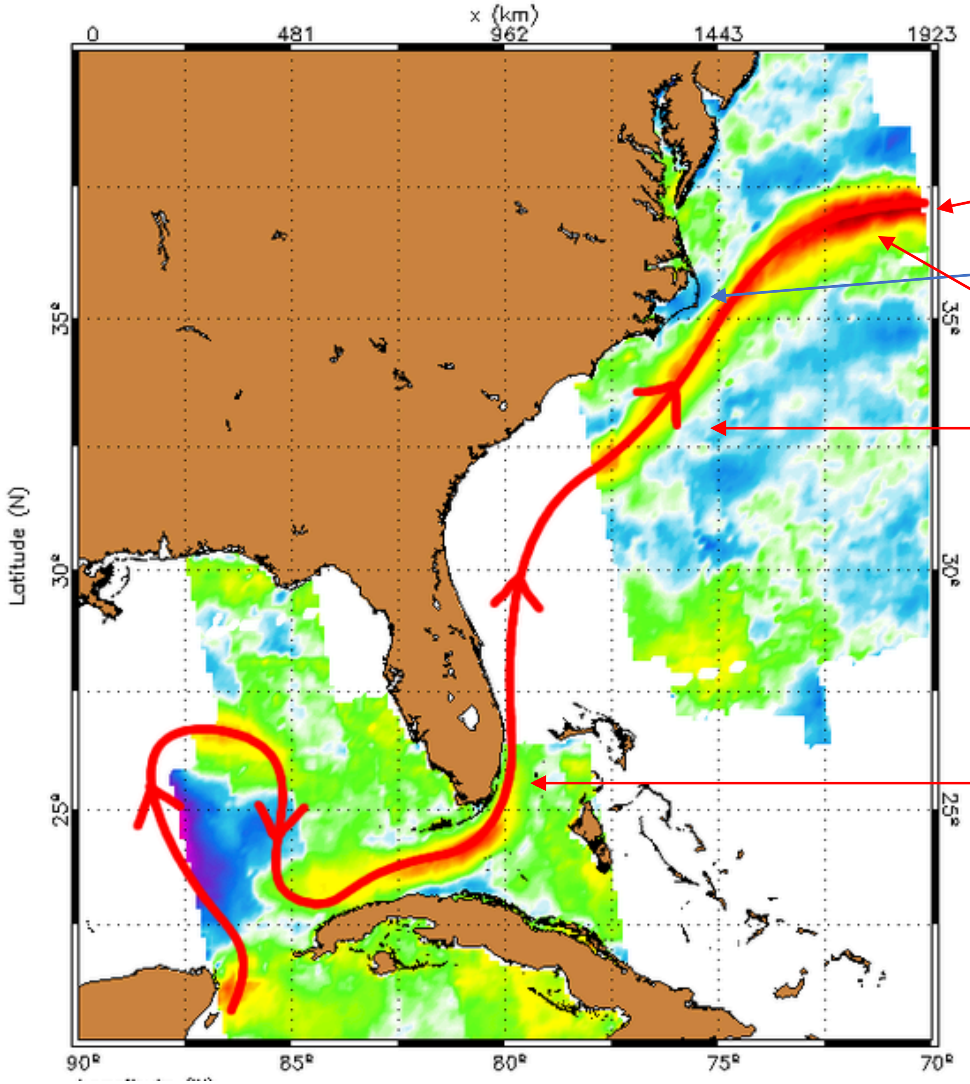




Vertical sections: Atlantic Ocean



The Gulf Stream and the Florida Current



Gulf Stream extension

Cape Hatteras

Gulf Stream: ~ 100 Sv

Florida Current: ~ 30 Sv
Between Florida and
Bahamas

How is the beginning of the GS?

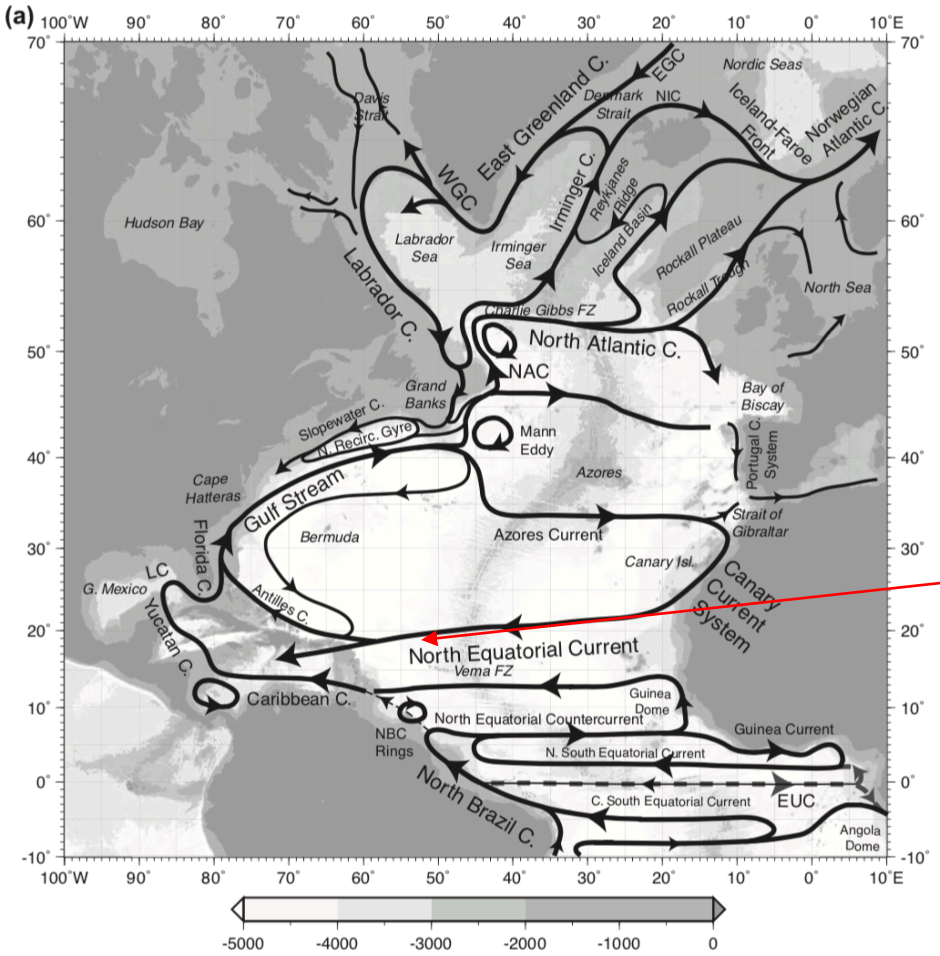
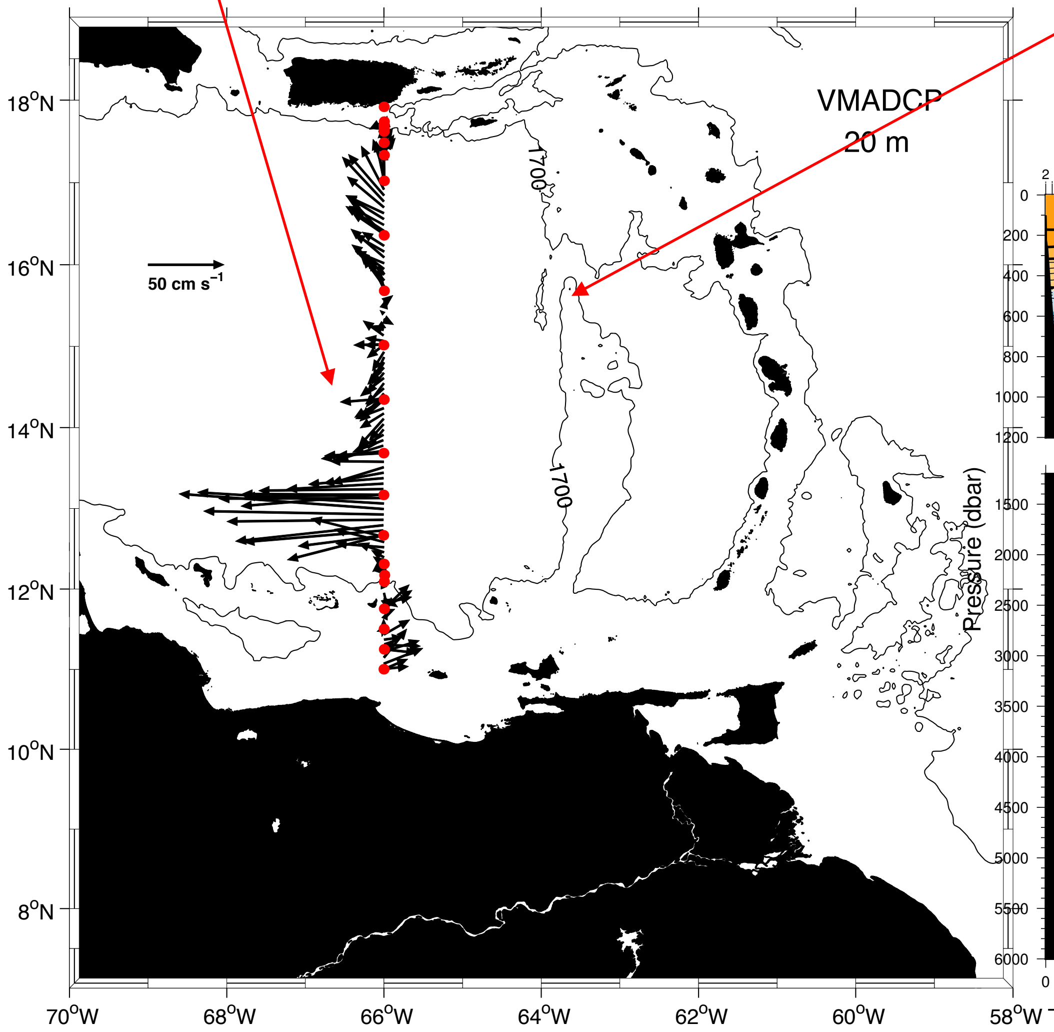


FIGURE 9.1 Atlantic Ocean surface circulation schematics. (a) North Atlantic and (b) South Atlantic; the eastward EUC along the equator just below the surface layer is also shown (gray dashed).

The North Equatorial Current entering the Caribbean Sea
And a contribution from the southern hemisphere
And a Contribution from the Antilles Current

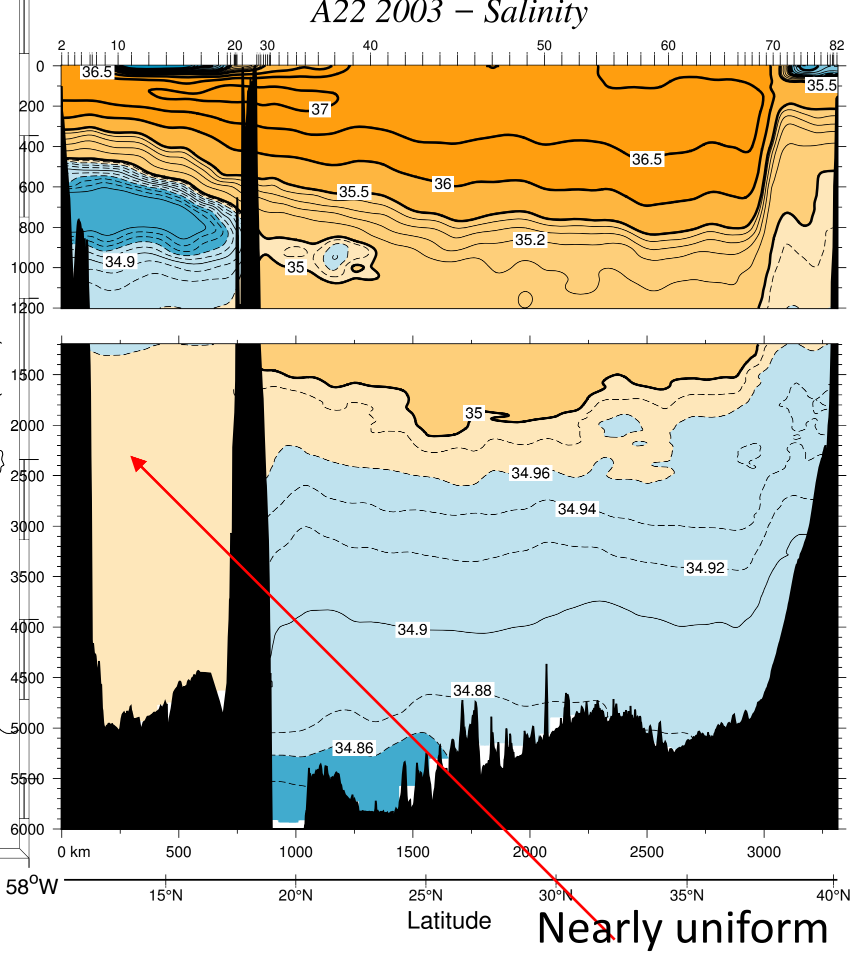
How important is each contribution?

The Caribbean Sea



Hernández-Guerra & Joyce (2000)

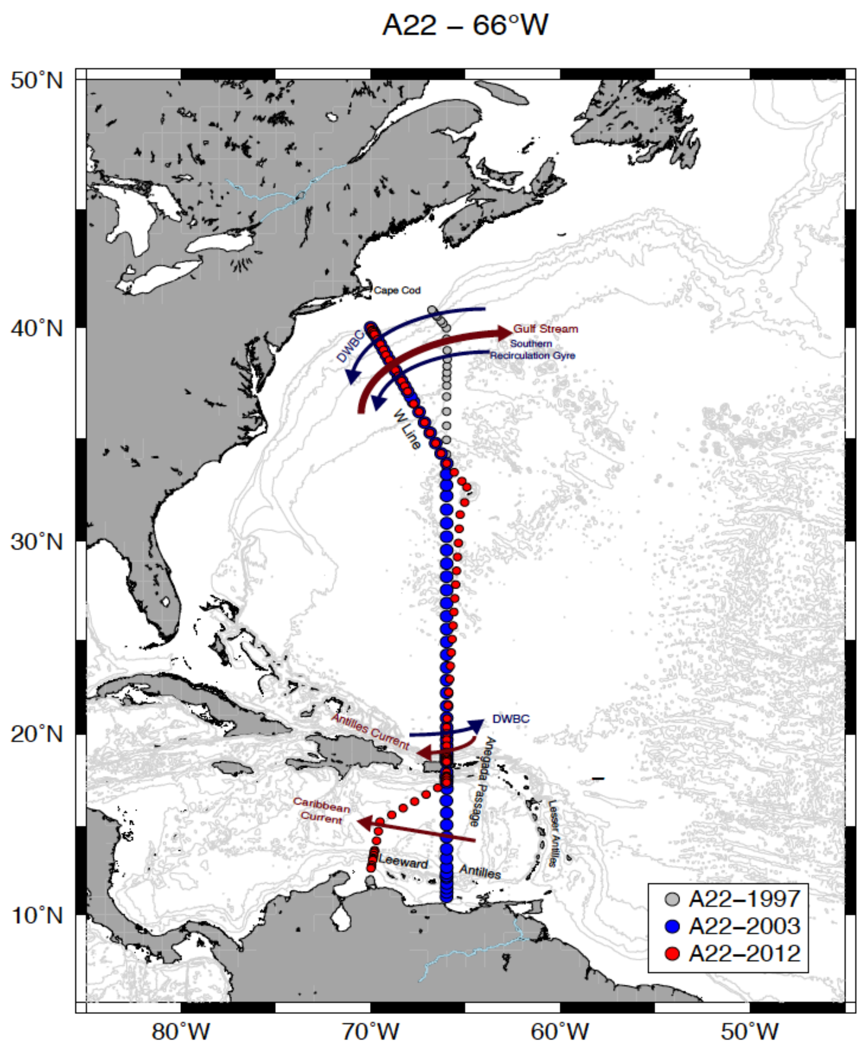
The maximun depth for currents entering the Caribbean is 1815 m

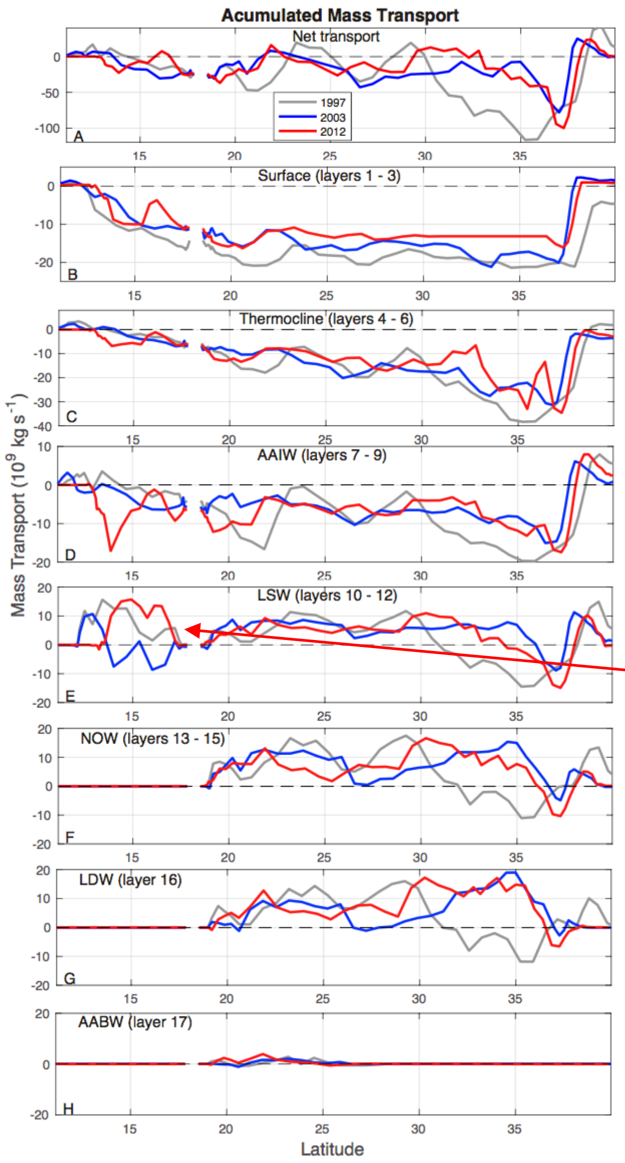


Nearly uniform properties

Casanova et al. (2018)

The Caribbean Sea





Westward transport in the Caribbean:

1997: -24 Sv

2003: -24.4± 1.0 Sv

2012: -24.2± 1.1Sv

Cyclonic circulation below 1700m transporting ~15 Sv, not present in 2002

Joyce et al. (2001)
Casanova et al. (2018)

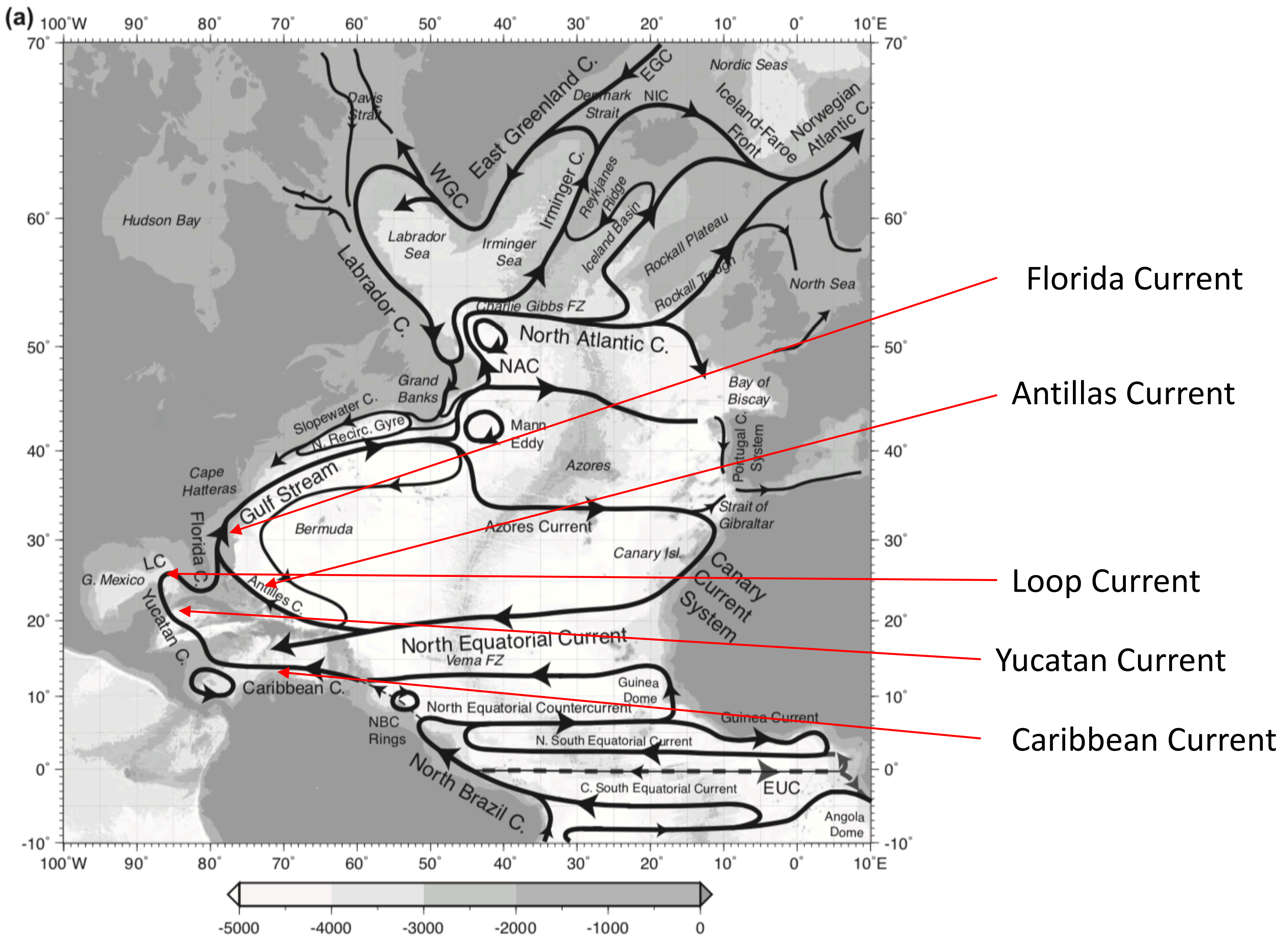


FIGURE 9.1 Atlantic Ocean surface circulation schematics. (a) North Atlantic and (b) South Atlantic; the eastward EUC along the equator just below the surface layer is also shown (gray dashed).

Antilles Current

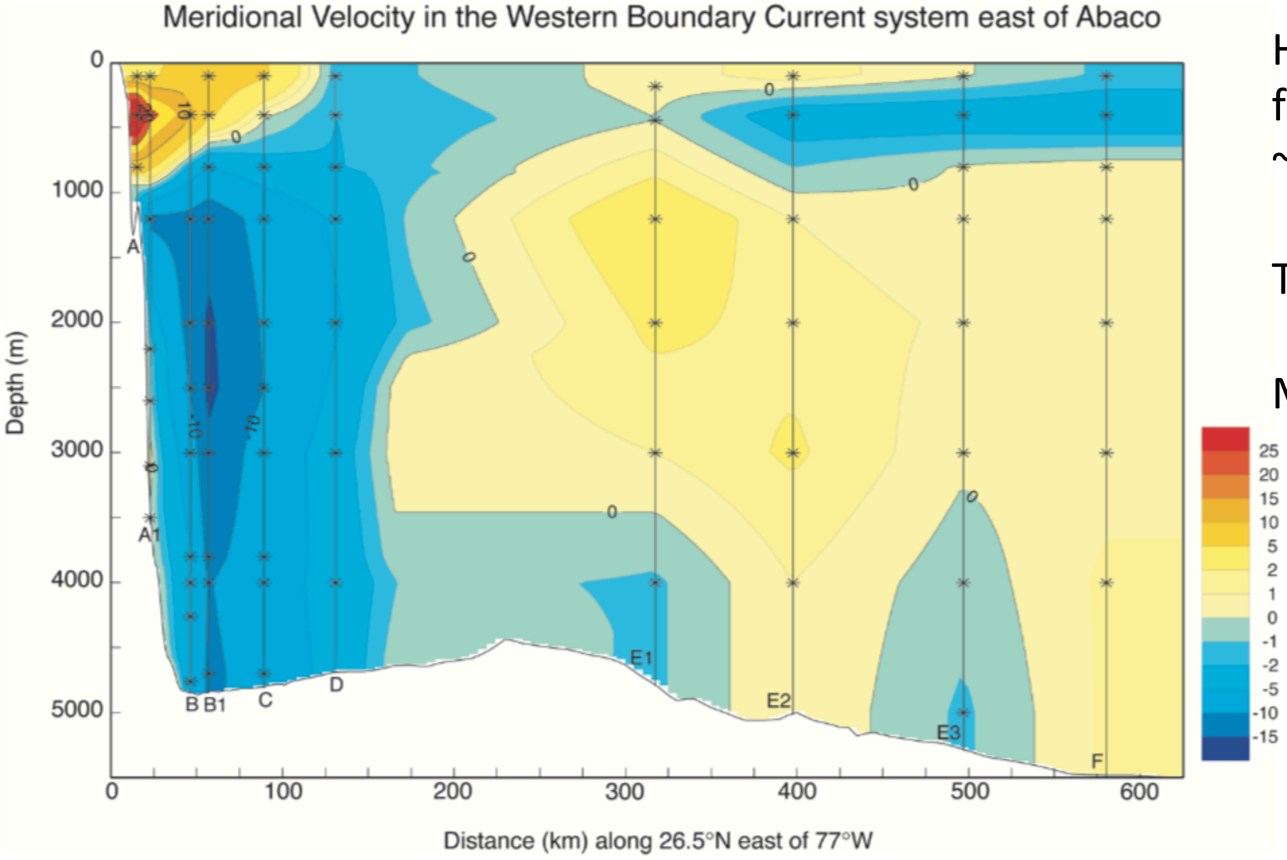


Figure 4. Structure of the time-averaged western boundary current system east of Abaco out to an offshore distance of 625 km. Mooring and instrument locations indicate where time-averaged meridional velocities (cm s^{-1}) have been estimated to provide the basis for the contoured section.

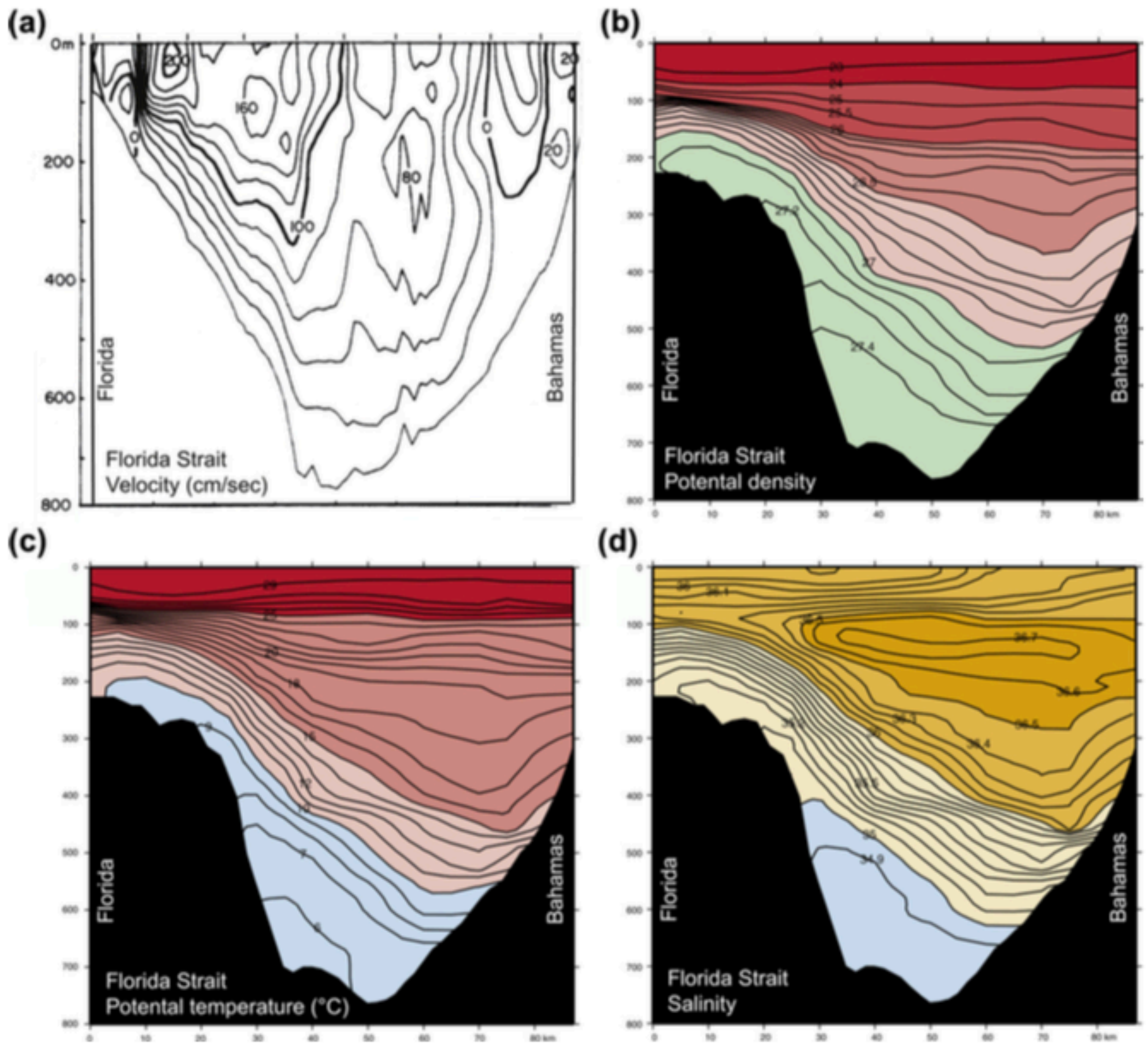
Highly variable current from the surface to ~1000m depth

Transports: -15 to 25 Sv

Mean transport: 5.1-6.0 Sv

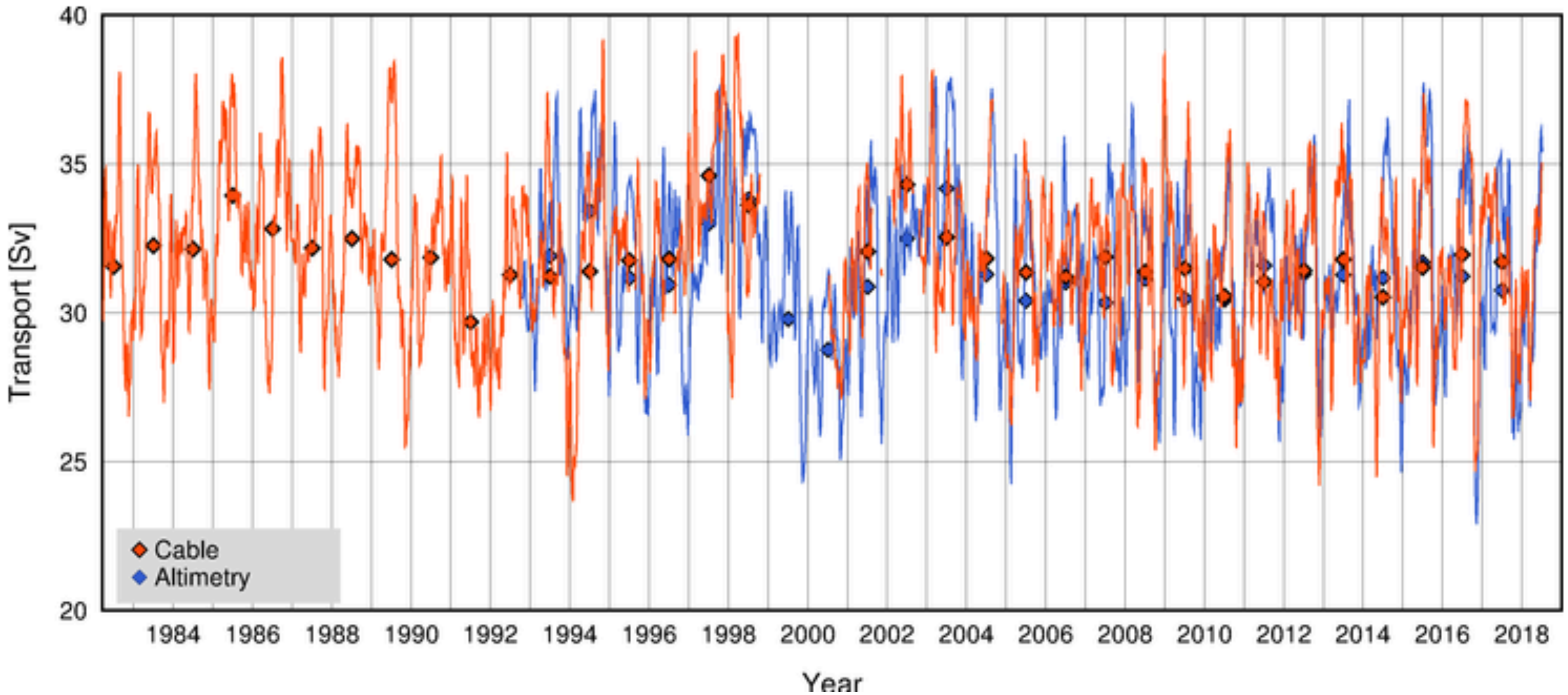
Bryden et al. (2005)

Florida Current



Roemmich (1983)

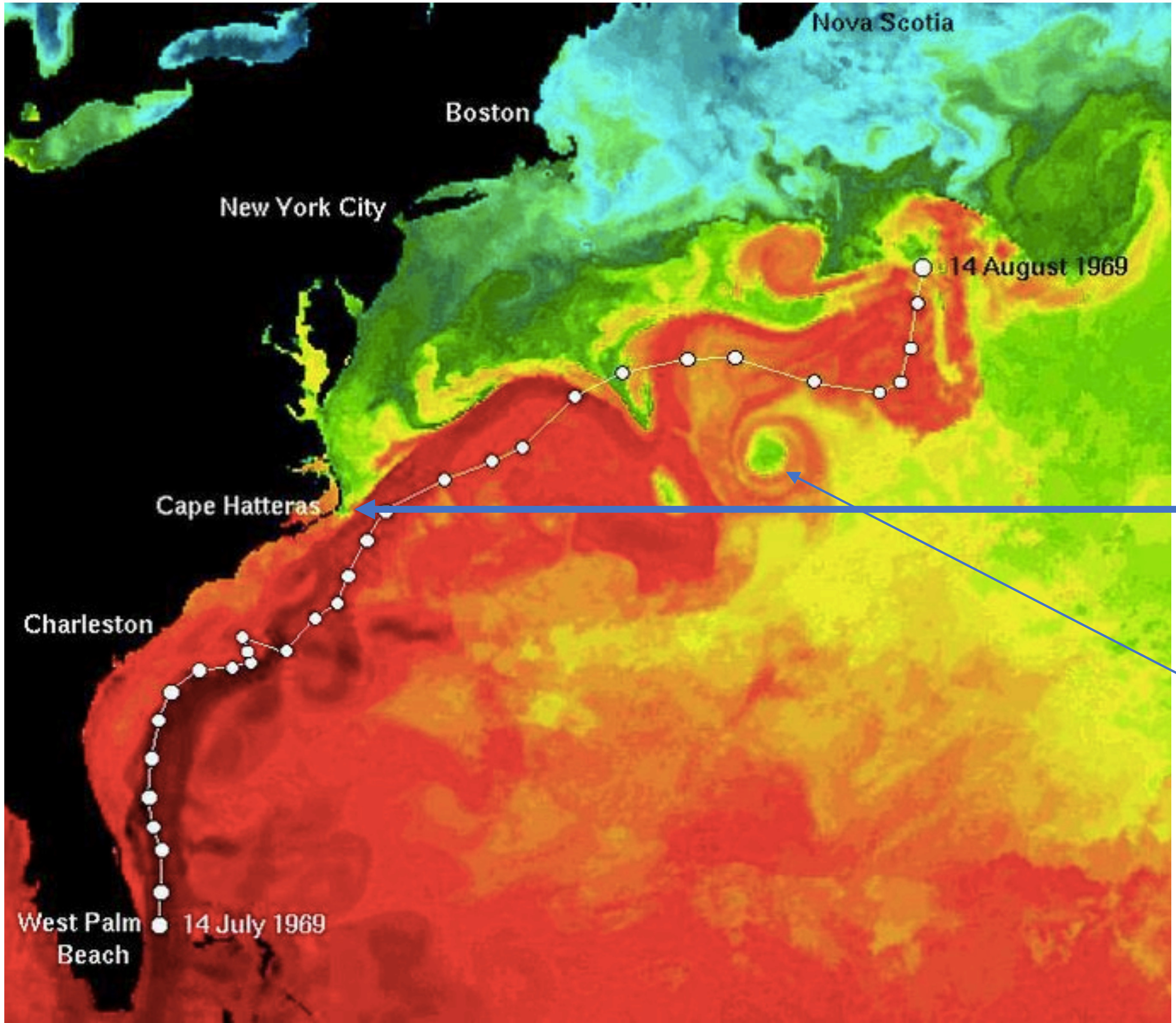
Florida Current



Mean transport: 32 Sv with a seasonal and interannual variability of 2-3 Sv

Baringer and Larsen, 2001

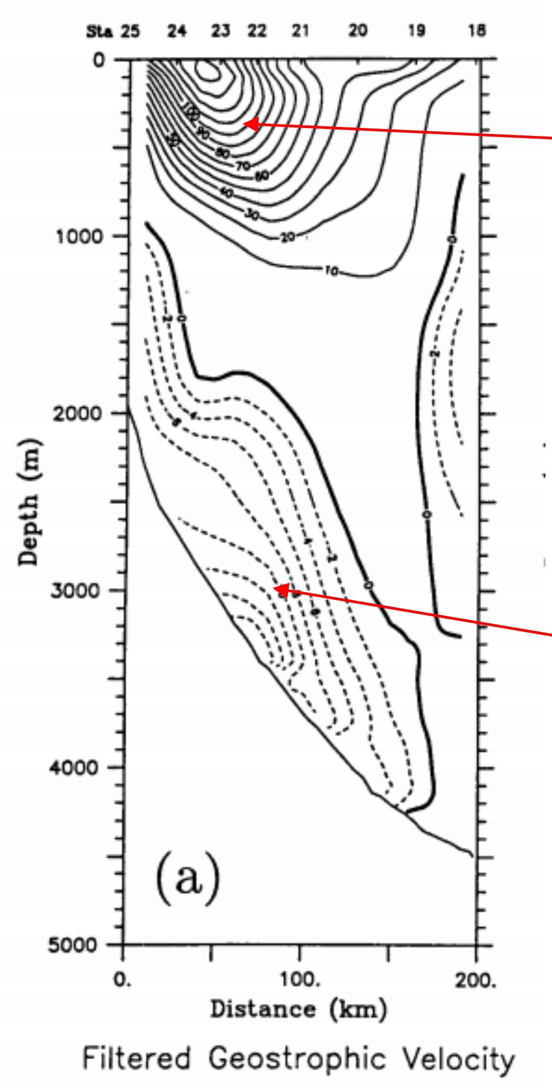
Gulf Stream



Cape Hatteras = Separation Point

Eddies from the meansers of the Gulf Stream

Gulf Stream at Cape Hatteras

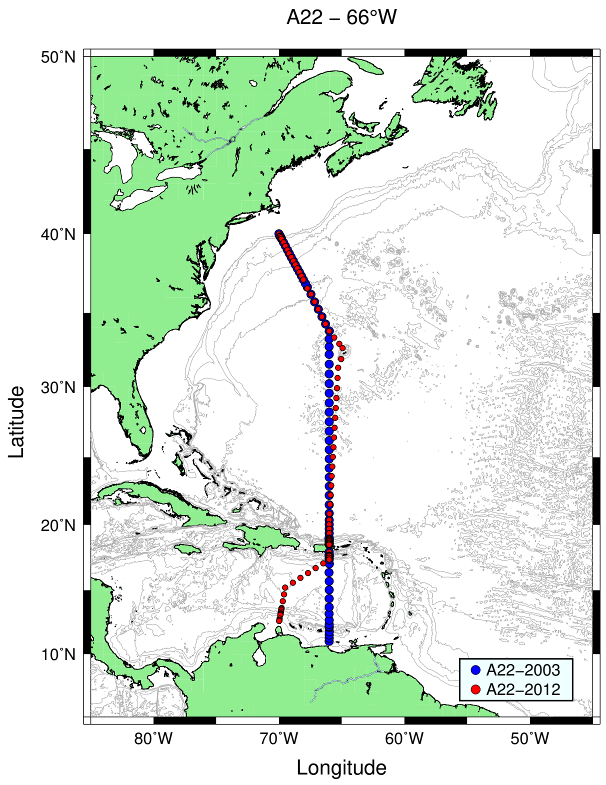


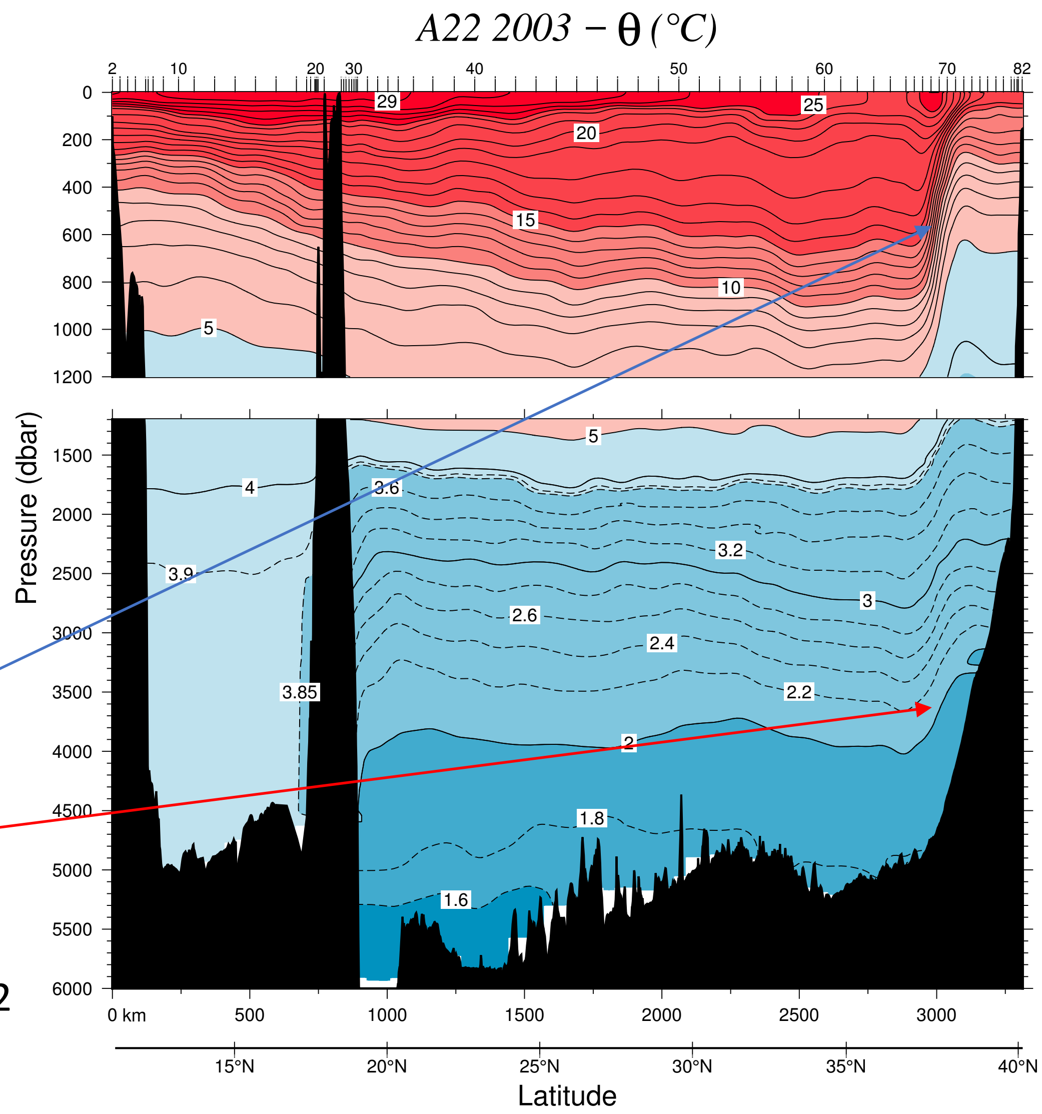
Gulf Stream
- It extends to the ocean botoom with a high barotropic component
- Width < 100 km
- Mass transport ~90 Sv (fed by a westward flow from the Sargasso Sea and the recirculation gyre)

Deep Western Boundary Current

Pickart & Smethie (1993)

Gulf Stream DownStream





Gulf Stream:

- Mass transport: ~ 140 Sv
- Average velocity: ~150 cm/s
- Maximum velocity: ~250 cm/s
- It reachs the oceam bottom with velocity > 2 cm/s
- Width: >120 km (narrow)
- Very warm

Casanova et al. (2018)

Recirculation of the Gulf Stream

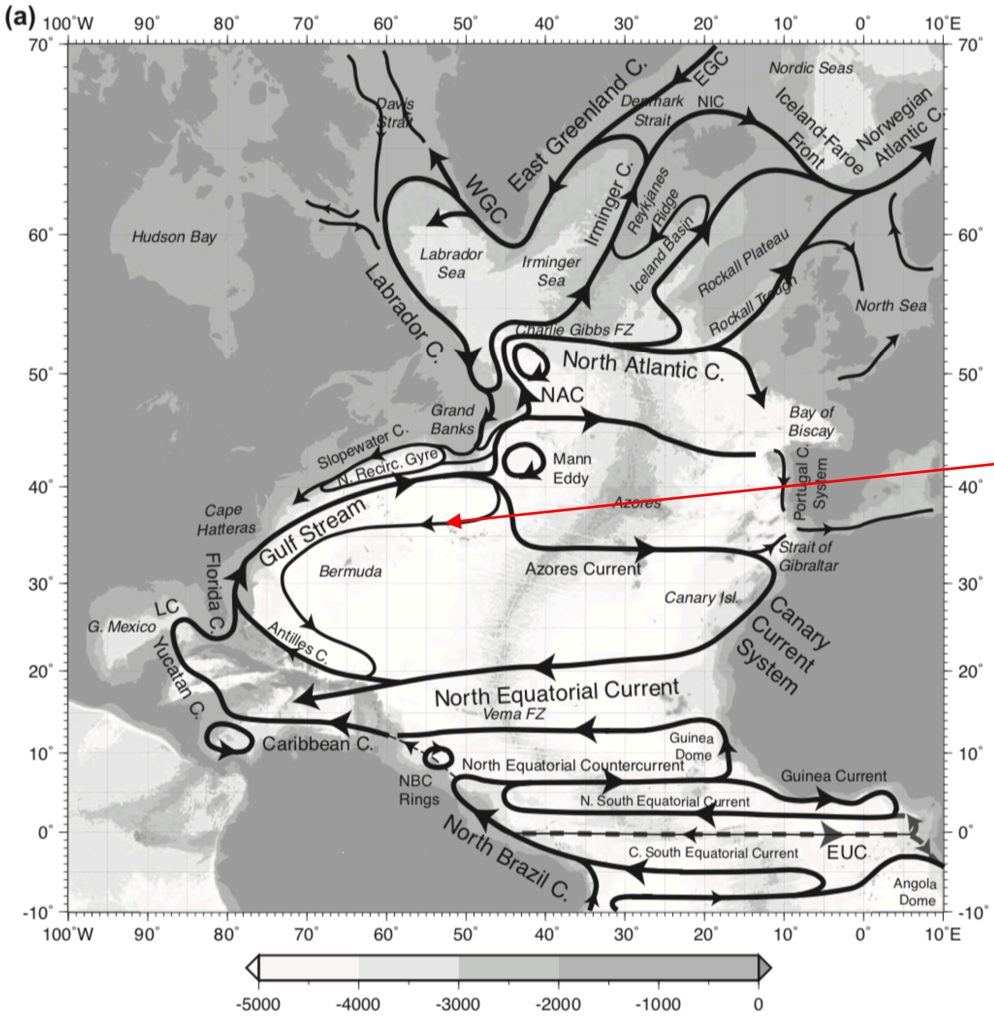


FIGURE 9.1 Atlantic Ocean surface circulation schematics. (a) North Atlantic and (b) South Atlantic; the eastward EUC along the equator just below the surface layer is also shown (gray dashed).

- It is just south of the Gulf Stream.
- With the Gulf Stream, it forms the recirculation gyre also called Worthington Gyre.
- The recirculation of the Gulf Stream was predicted by Munk (1950).
- It turns eastward to join the westward flow of the NEC and AC.
- The entire recirculation form the "C-shape" of the surface gyre.

Slope Water Current

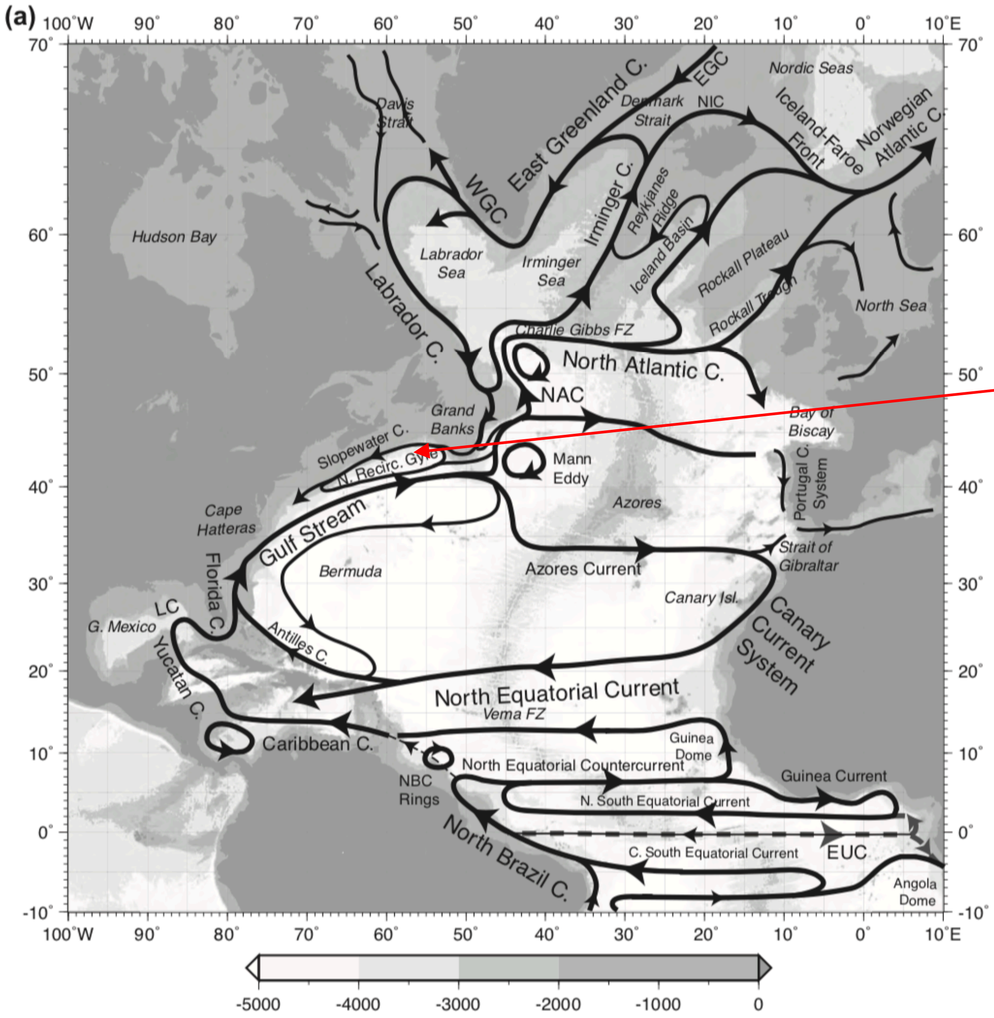
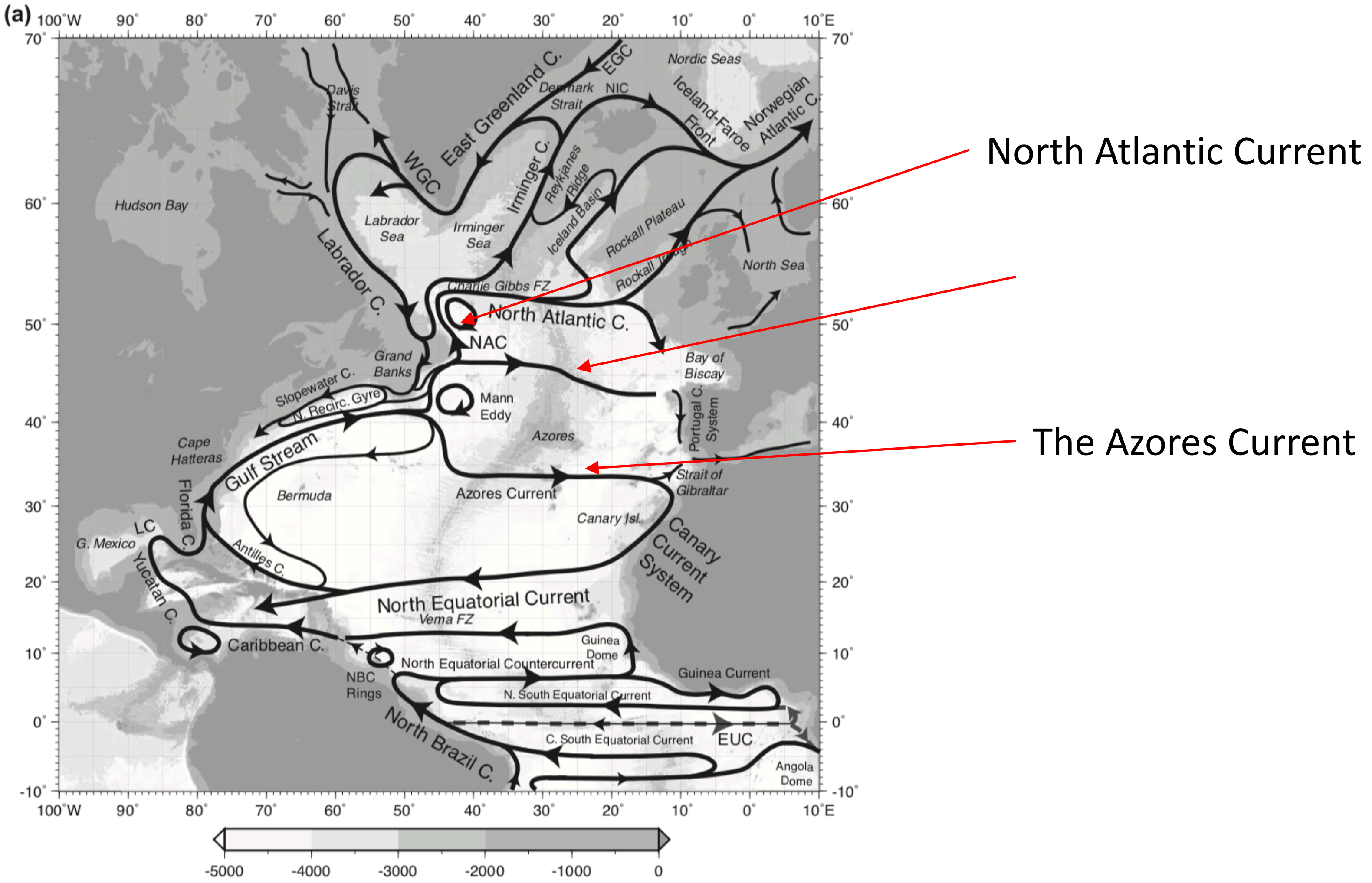


FIGURE 9.1 Atlantic Ocean surface circulation schematics. (a) North Atlantic and (b) South Atlantic; the eastward EUC along the equator just below the surface layer is also shown (gray dashed).

- Westward flow
- Together with the Gulf Stream form an elongated cyclonic gyre called Northern Recirculation Gyre
- The wind stress curl drives upwelling
- The westward current is also fed by the Labrador Current (surface)

Split of the Gulf Stream



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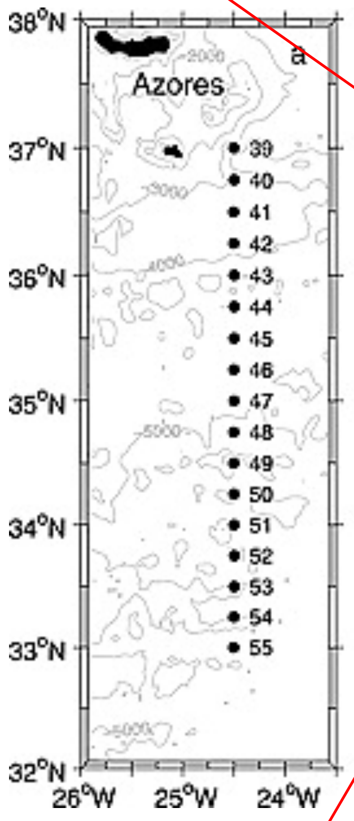
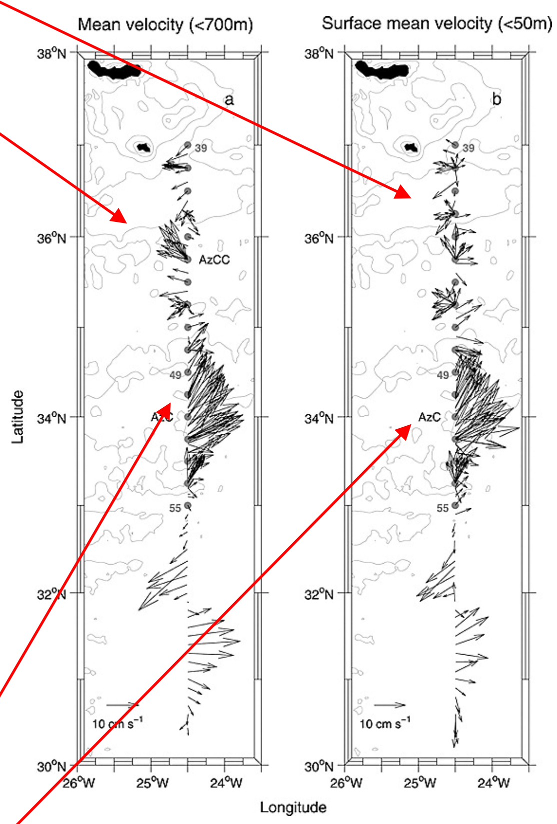
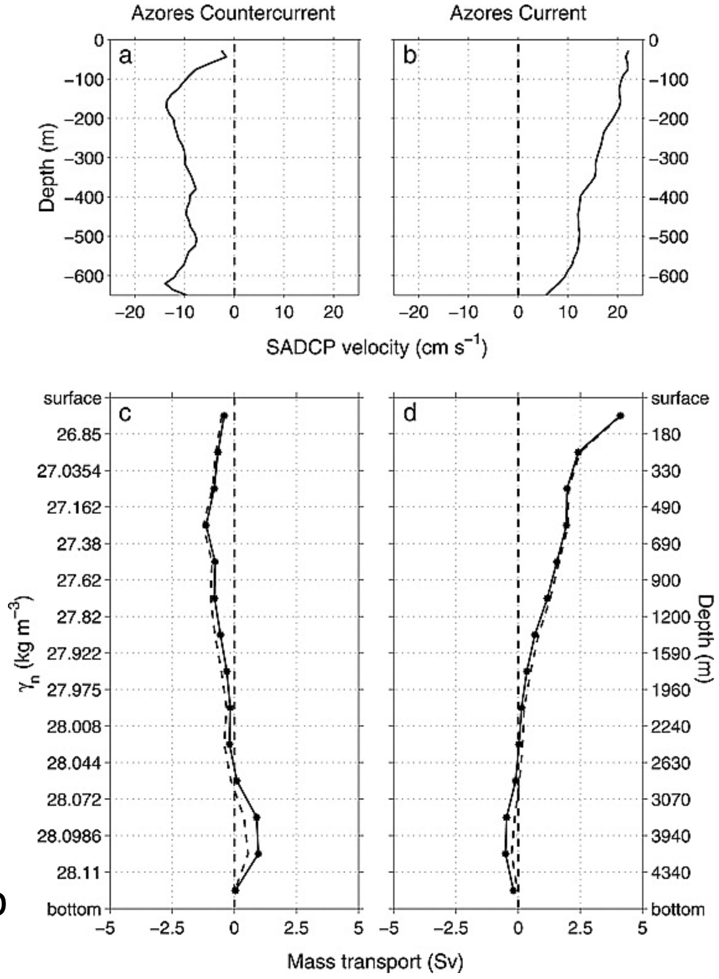
The Azores Current

Azores Countercurrent







Azores Current

- Both currents: 110 km wide
- Both currents: 2000 m deep
- AzC: 13.9 Sv with the maximum associated to the Azores front
- AzCC: -5.5 Sv

Comas-Rodriguez et al. (2011)

The Canary and Portugal Current

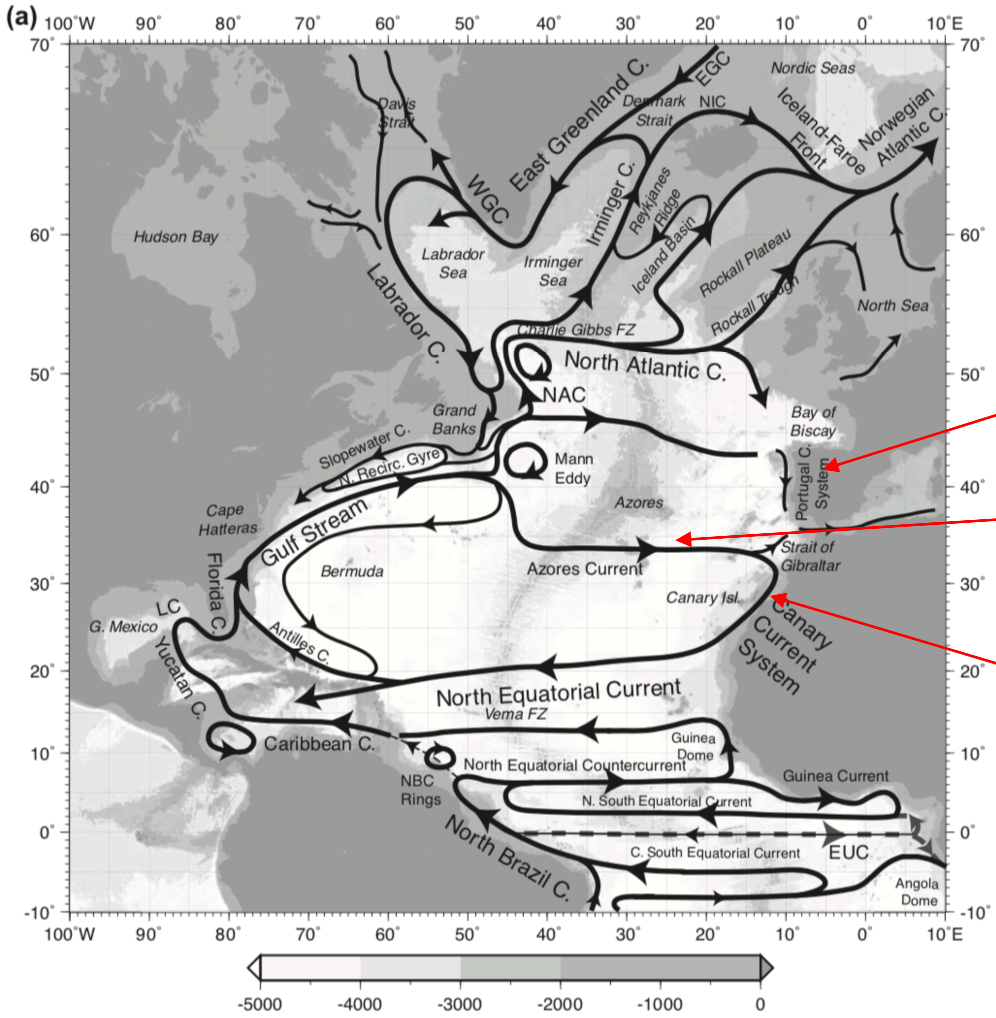


FIGURE 9.1 Atlantic Ocean surface circulation schematics. (a) North Atlantic and (b) South Atlantic; the eastward EUC along the equator just below the surface layer is also shown (gray dashed).

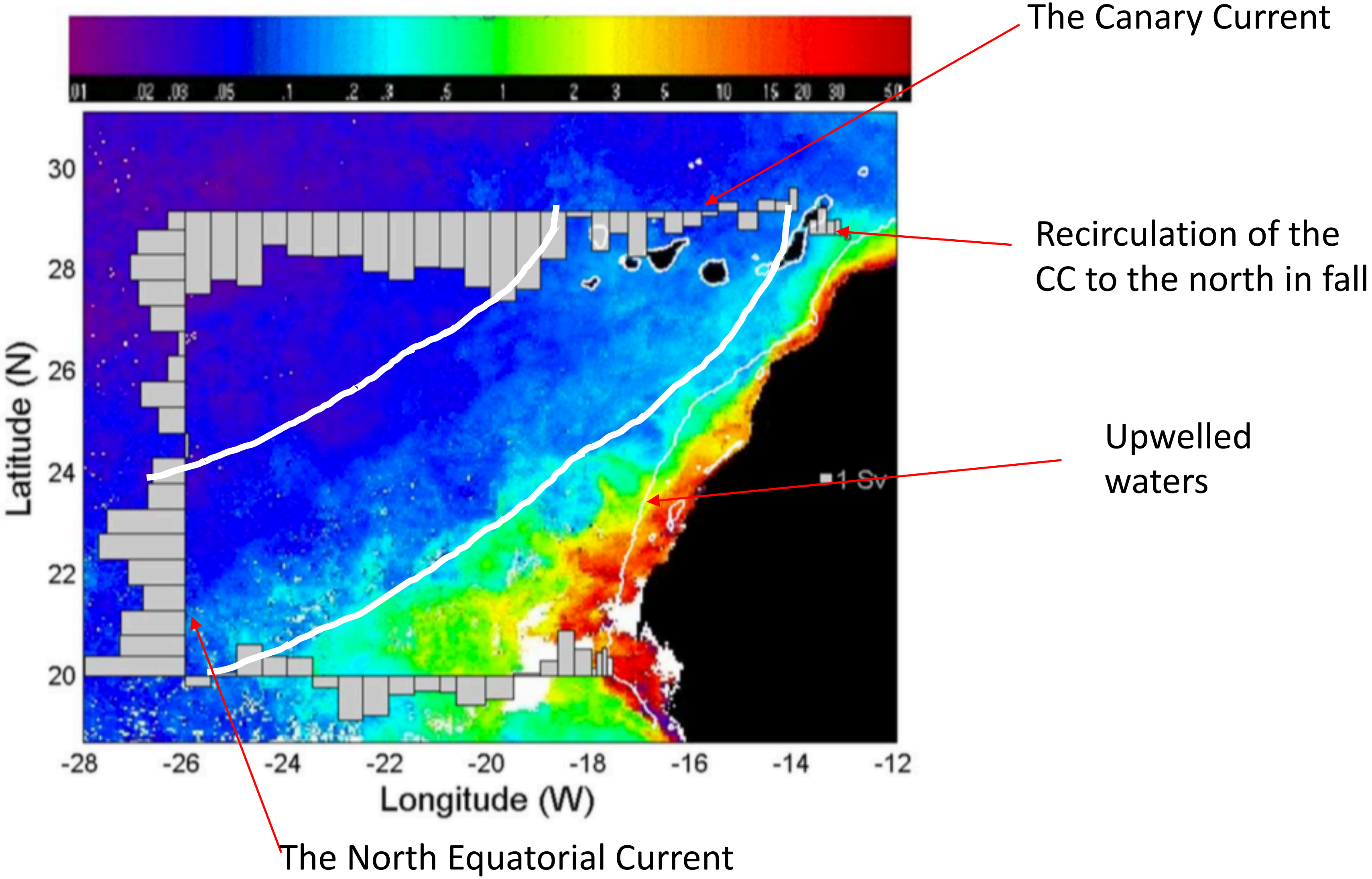
The Portugal Current

The Azores Current

The Canary Current

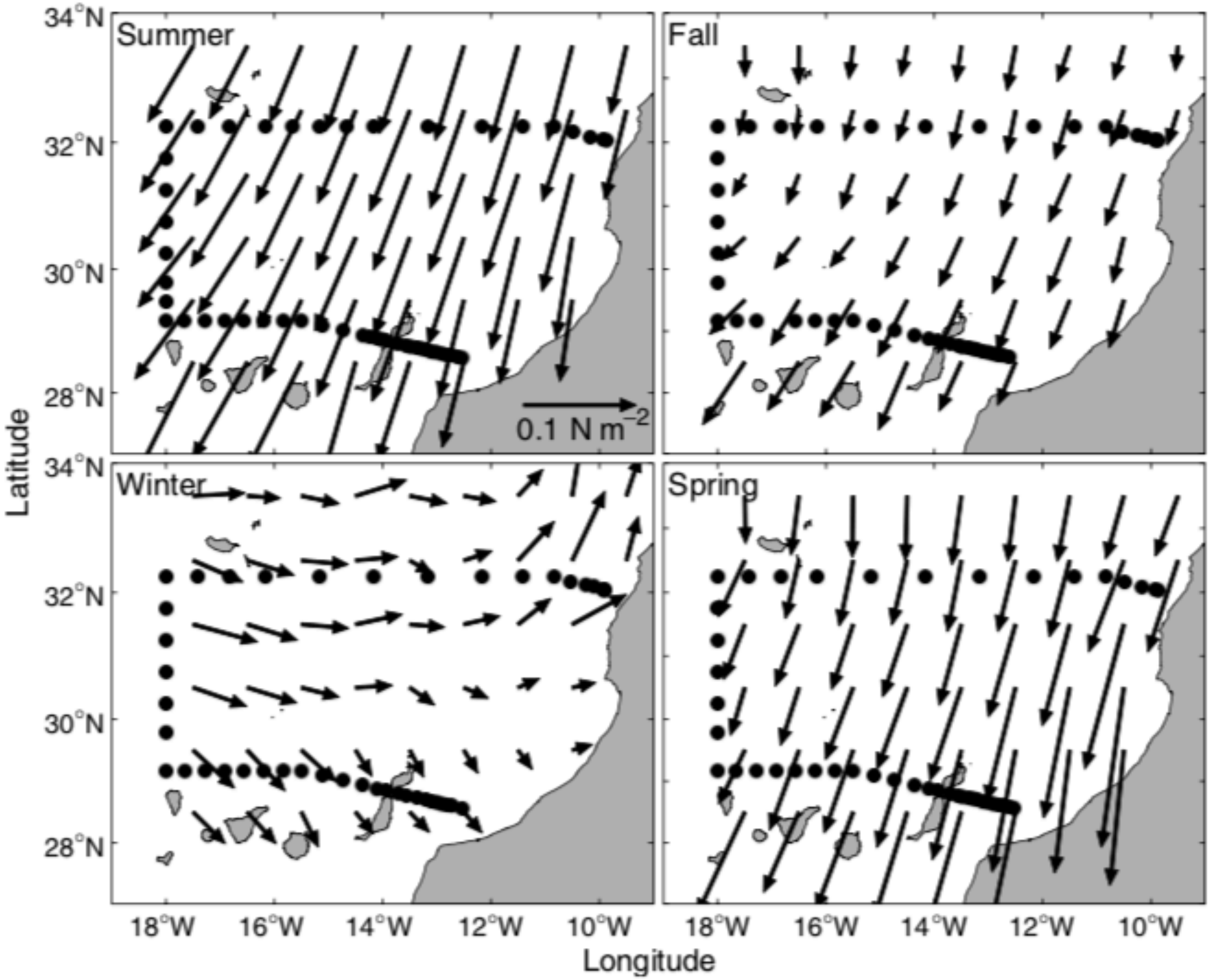
The Canary Current and the Portugal Current eastern boundary upwelling currents

The Canary Current



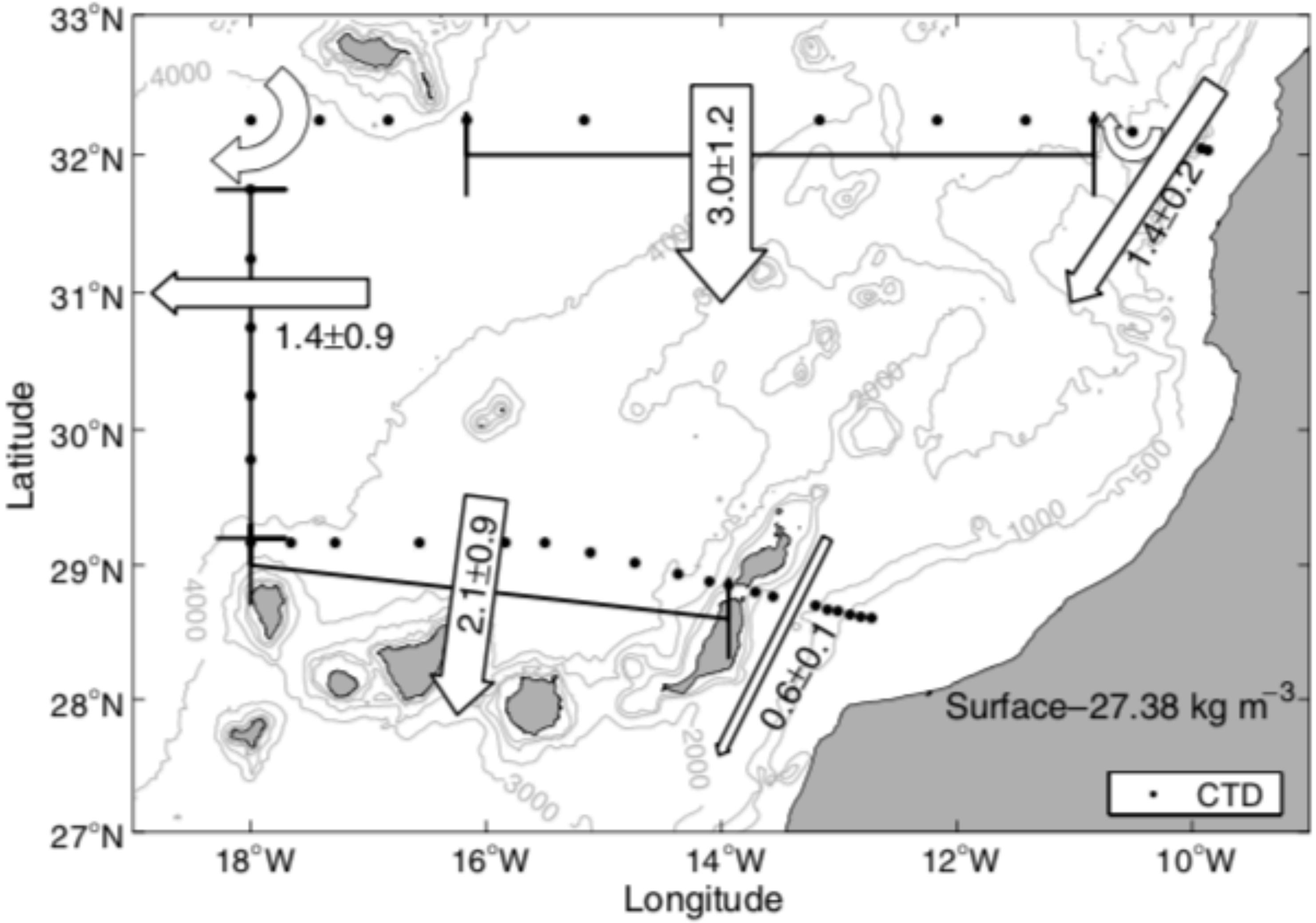
Hernández-Guerra et al. (2005)

Mean and seasonal variability of the Canary Current



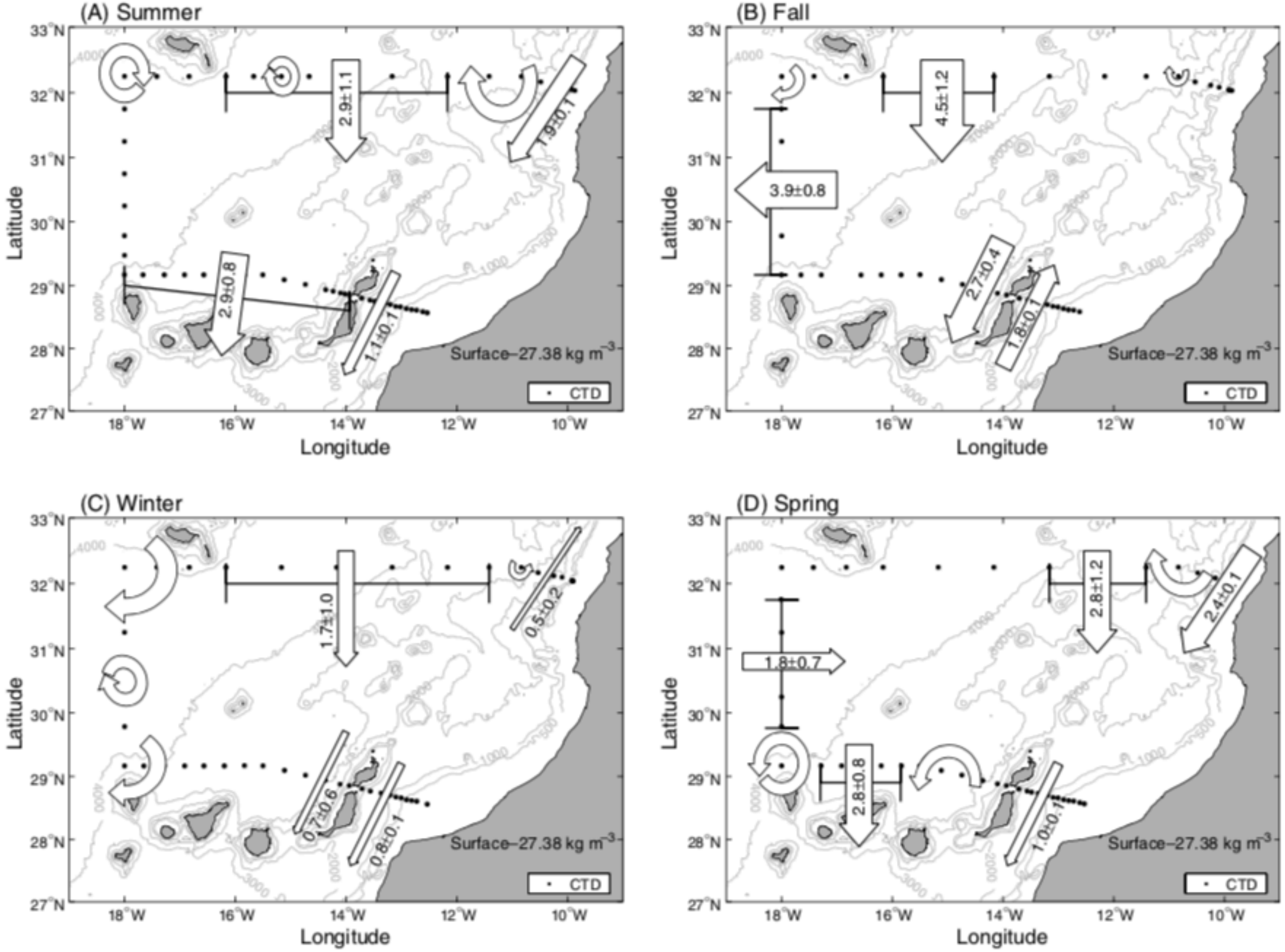
Machin et al. (2006)

Mean transports of the Canary Current



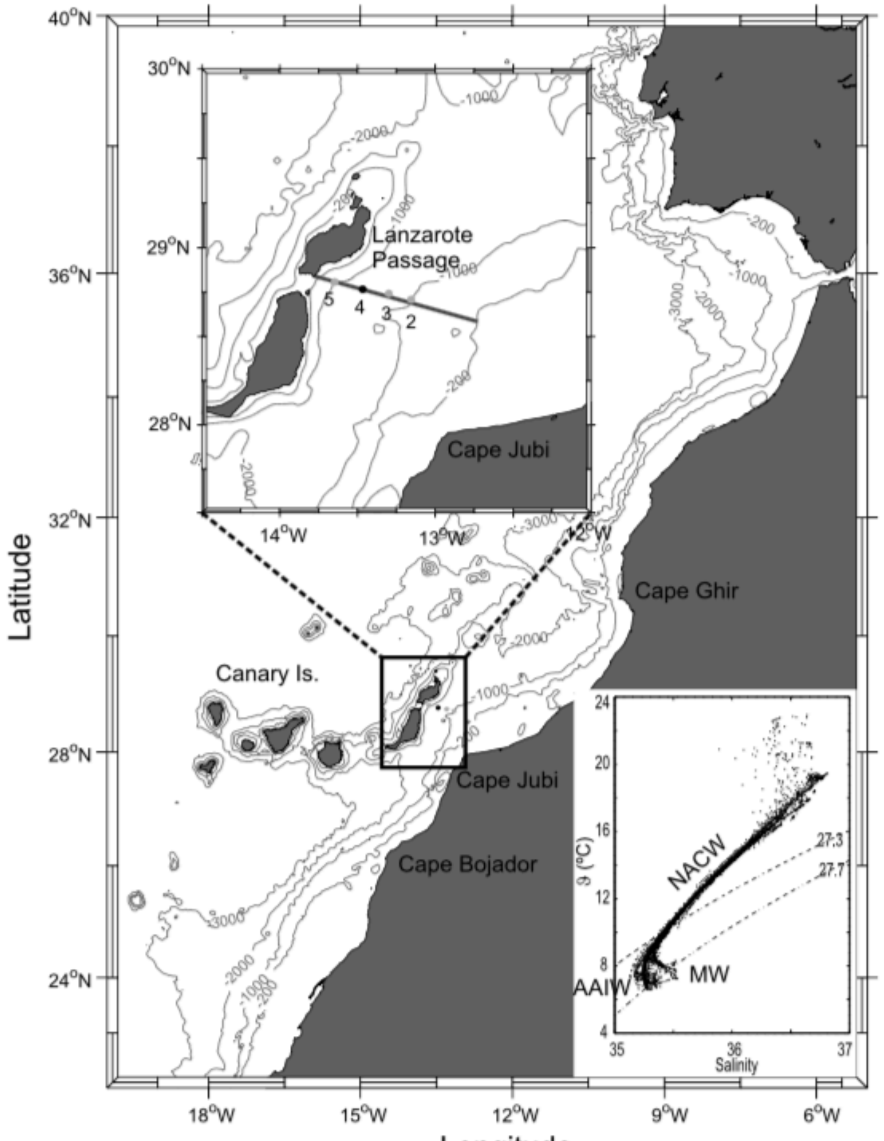
Machin et al. (2006)

Seasonal transports of the Canary Current



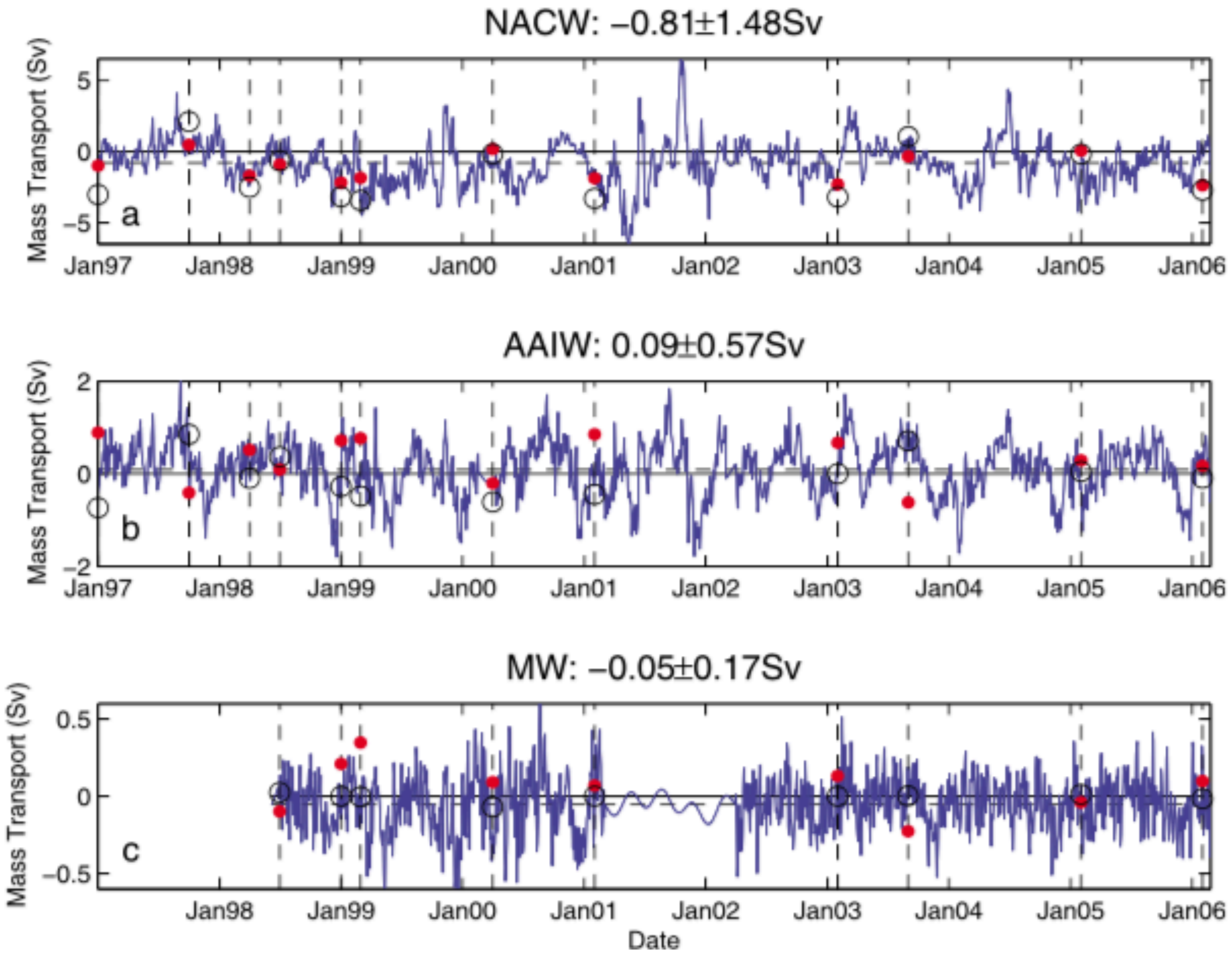
Machin et al. (2006)

Transport in the Lanzarote Passage



Fraile-Nuez et al. (2010)

Transport in the Lanzarote Passage



Fraile-Nuez et al. (2010)

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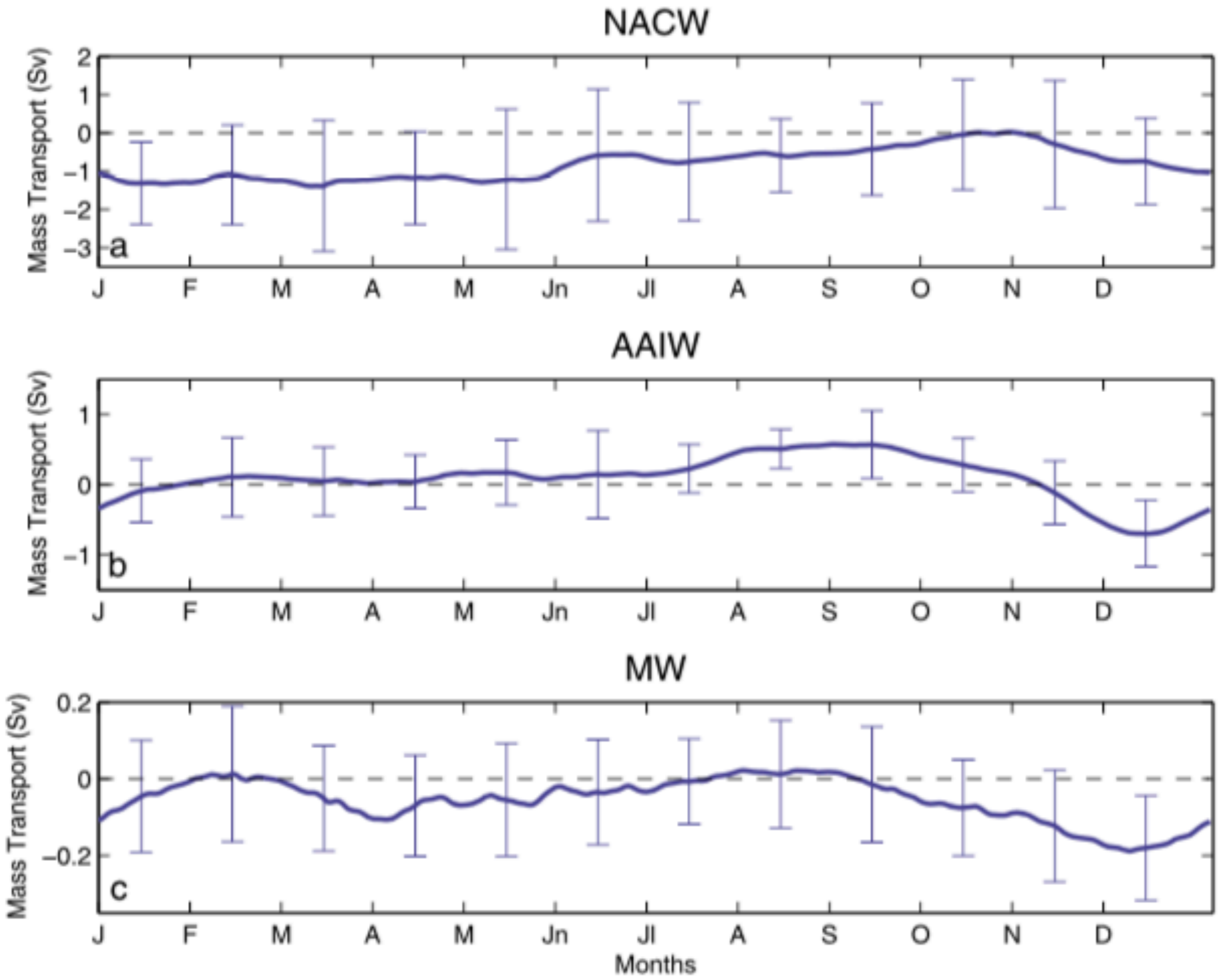
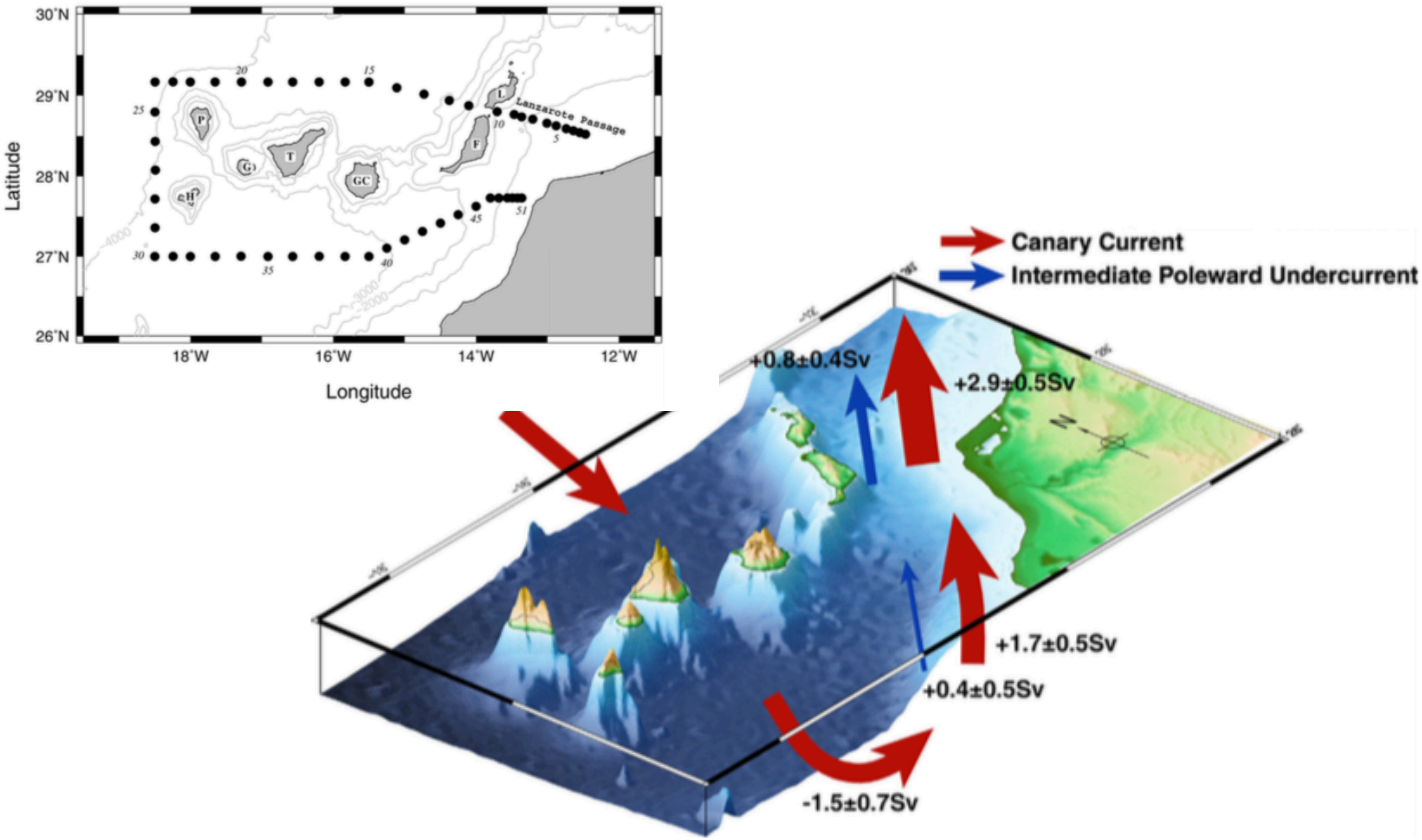


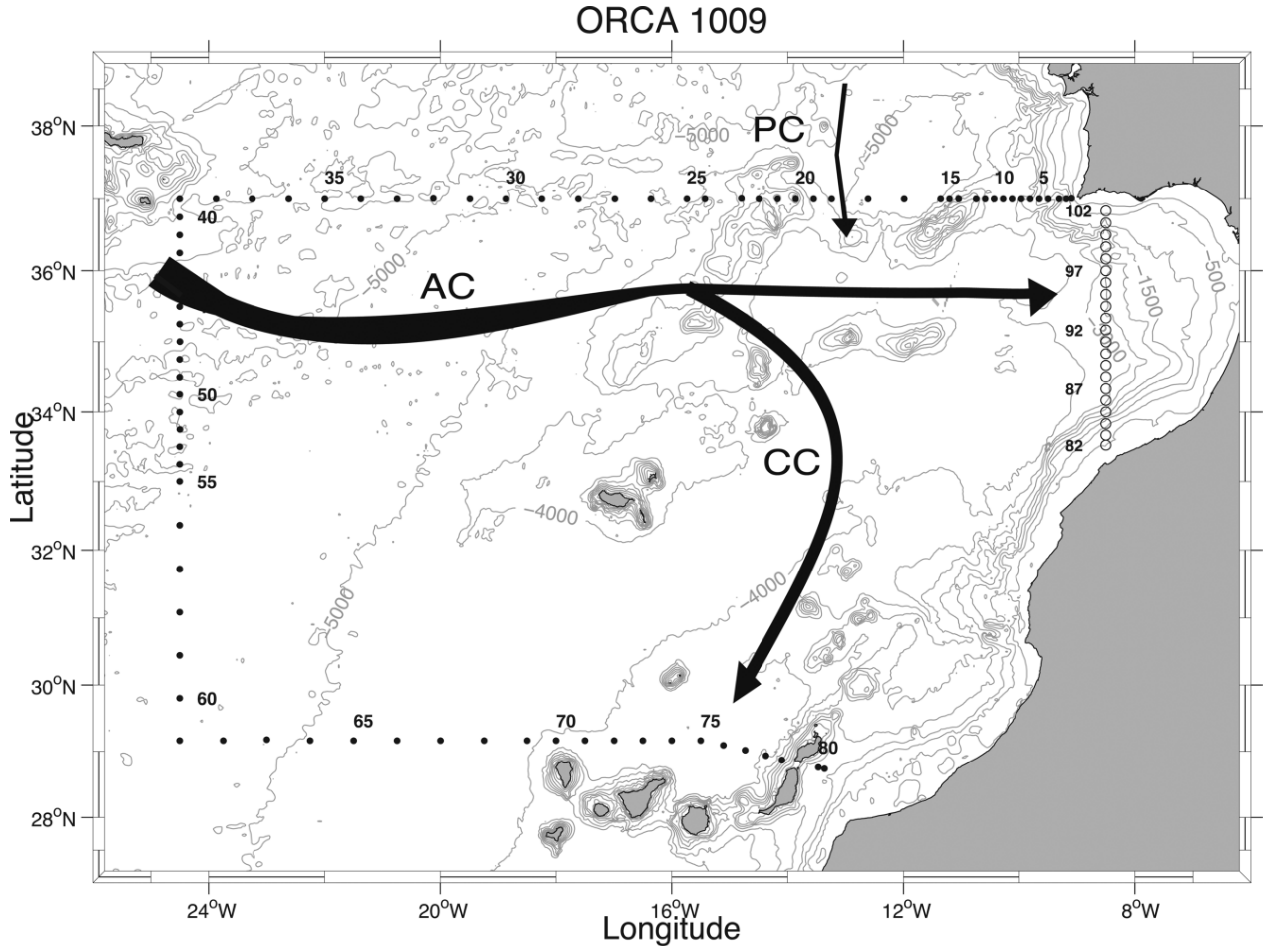
Fraile-Nuez et al. (2010)

Transport in the Lanzarote Passage



Hernández-Guerra et al. (2010)

The eastern Subtropical Gyre of the North Atlantic Ocean



Perez-Hernandez et al. (2013)

Thank you