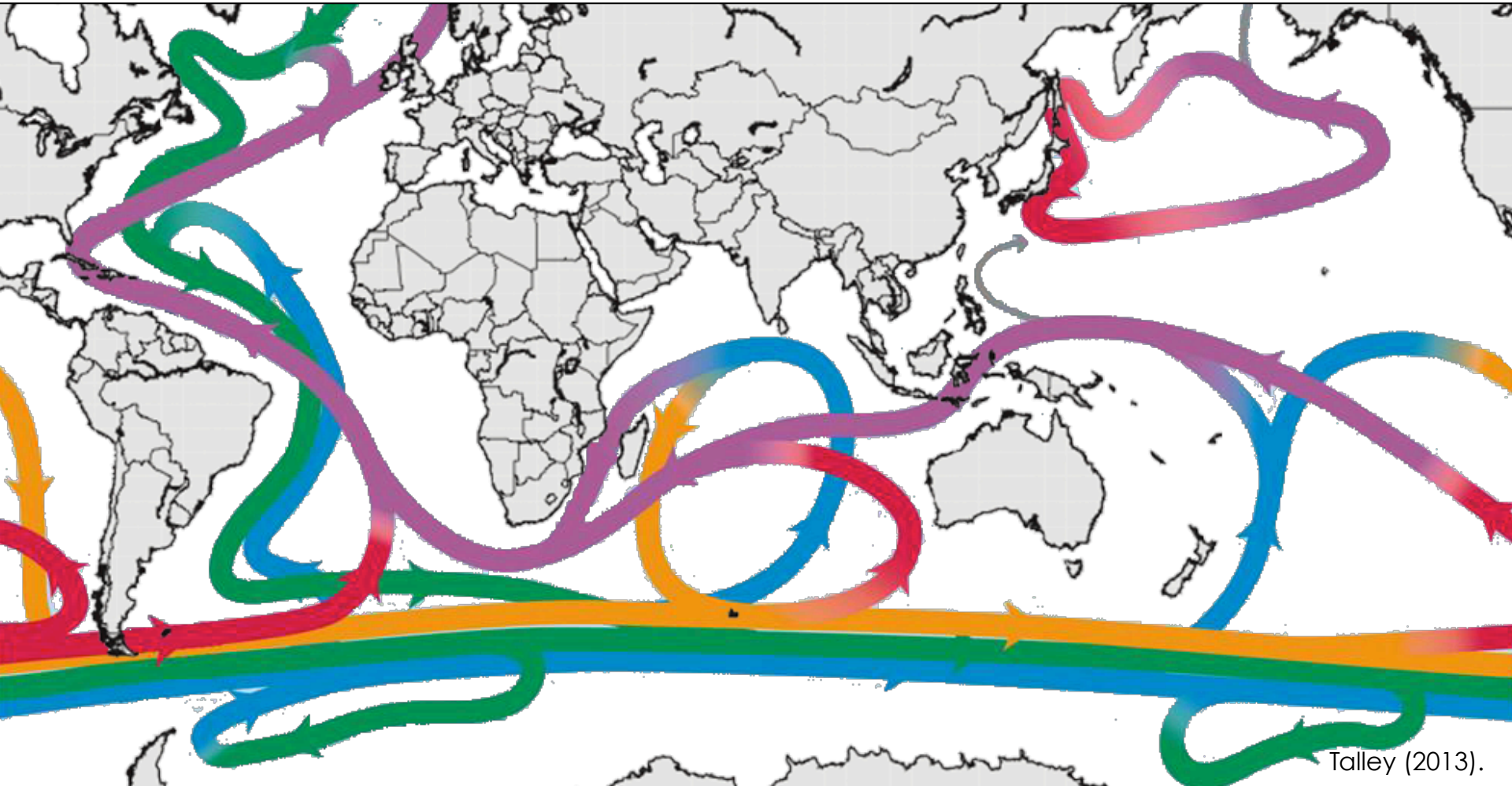
# The Meridional Overturning Circulation

## Large-scale ocean circulation driving our climate

Natália Tasso Signorelli



Talley (2013).

# Meridional Overturning Circulation...
## What?

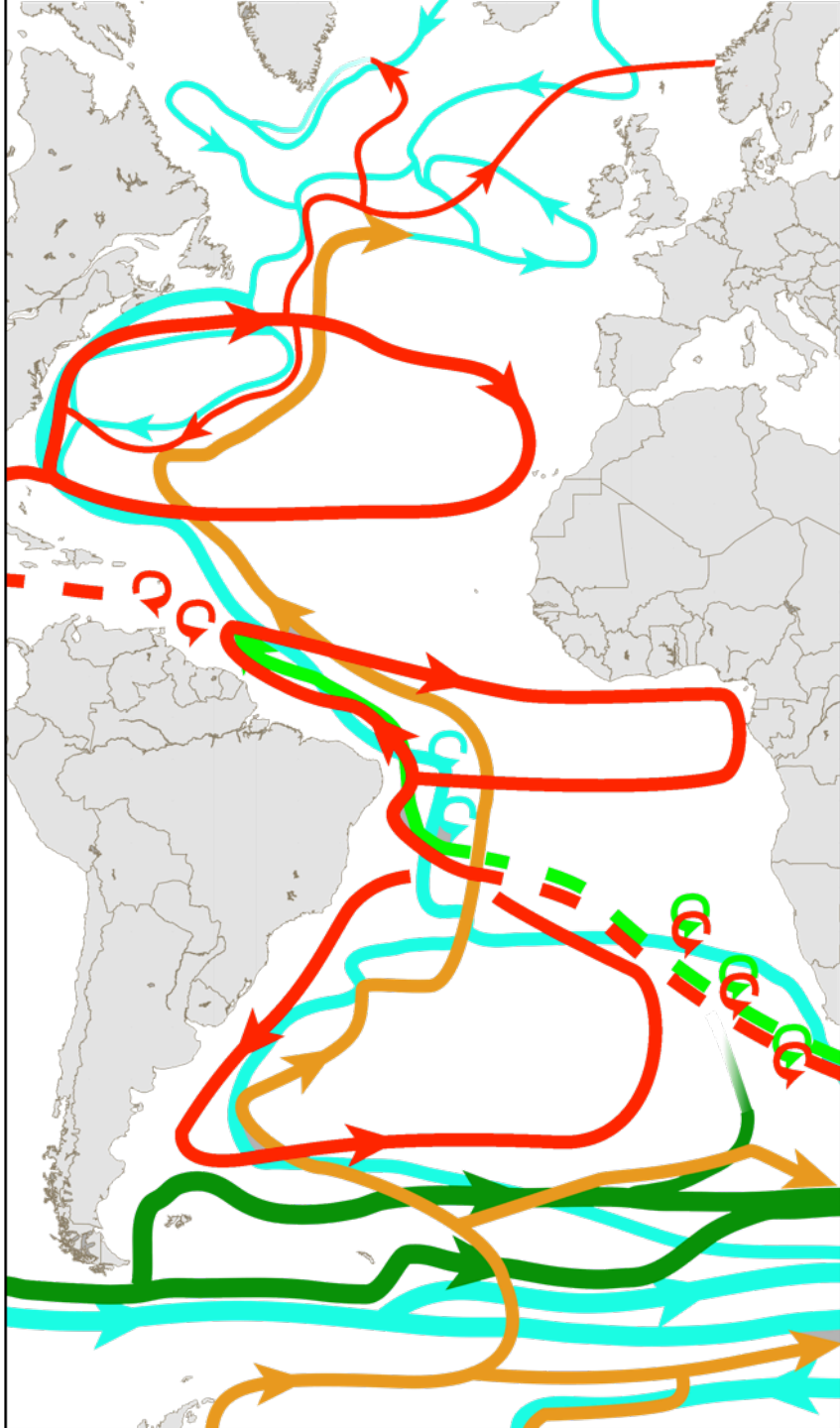
Pole to pole circulation, responsible for our climate:

- Distribution of heat.

It summarizes the system of currents:

- a net northward upper ocean transport;
- southward deep ocean transport.

Lumpkin & Speer (2007),
Speich, Blanke & Cai (2007),
Garzoli & Matano (2011).



# Meridional Overturning Circulation

## A summary? Really?

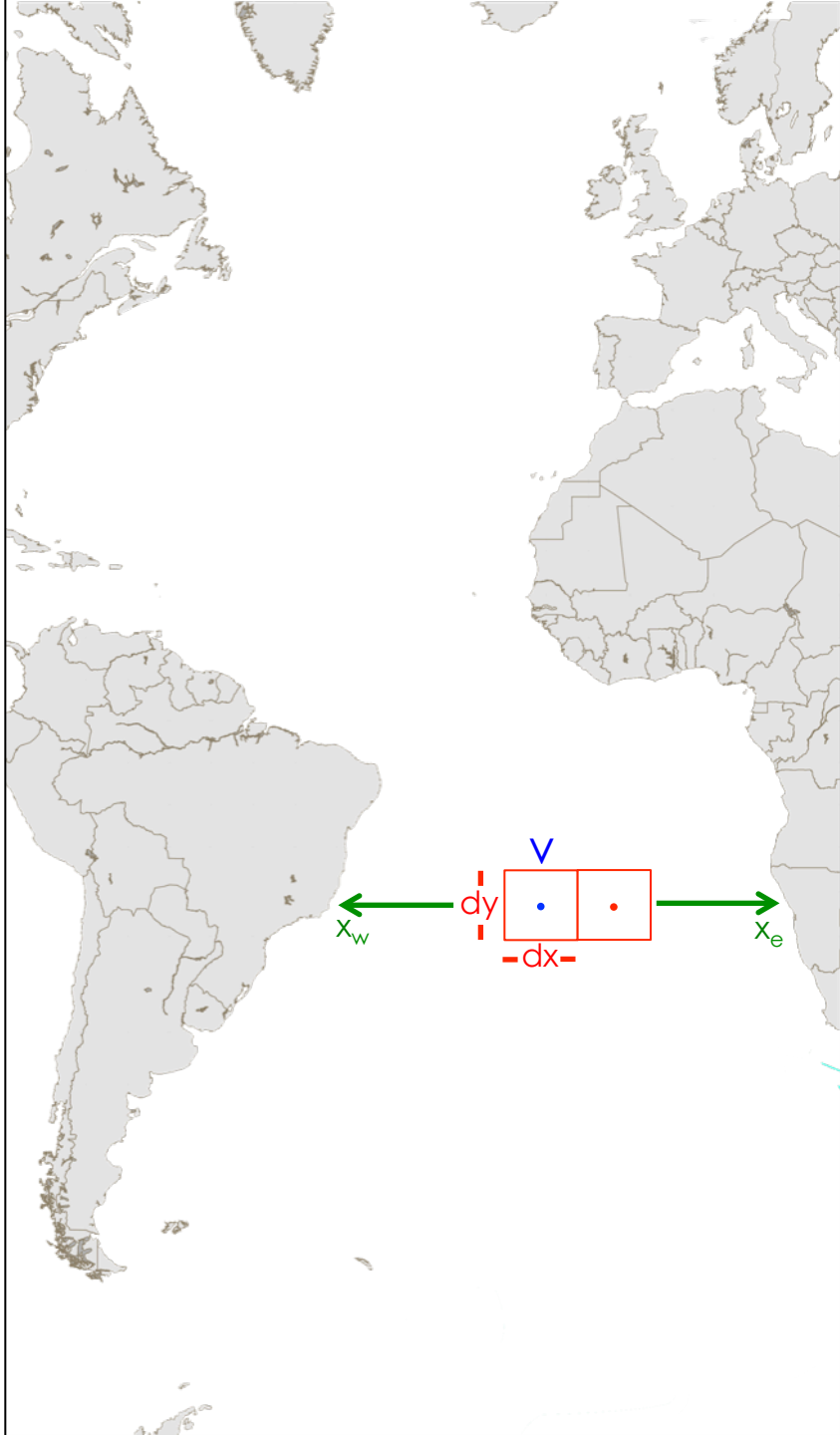
Mathematically (and to make things **easier** – believe me!):

$$\psi_{MOC}(y,z) = \int_{x_e,\,y}^{x_w,y} \int_{-H}^{z} v(x,y,z) \cdot dz\, dx$$

- Sum of every v•dx in each latitude (y) from east to west;
- Cumulative sum of every v•dz from the bottom (z = -H) until the top (z = 0).

The result:

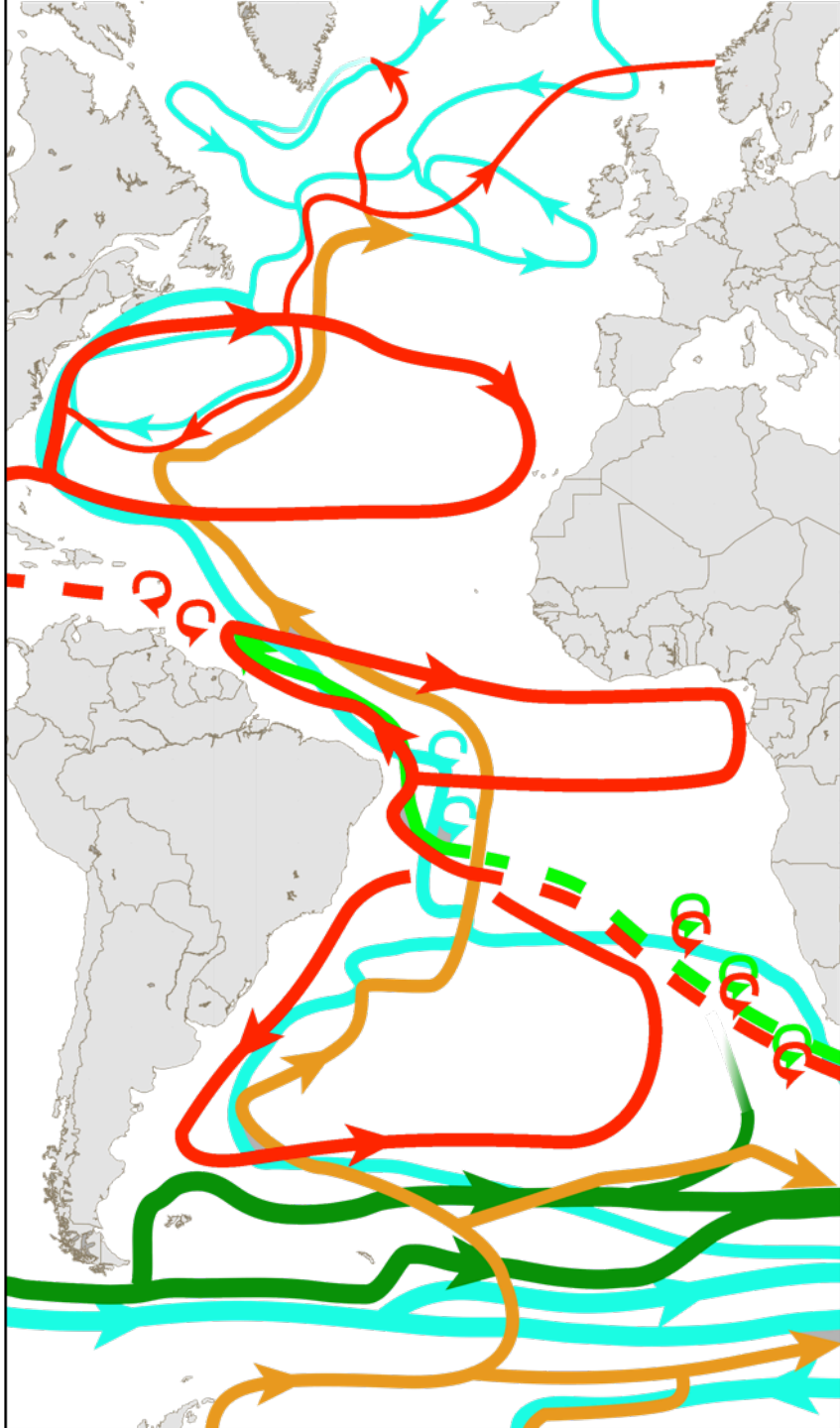
- Transport (Sv = $10^6$ $m^3 \cdot s^{-1}$).



# Meridional Overturning Circulation

## A summary? Really?

And instead of this (for the Atlantic Ocean)…



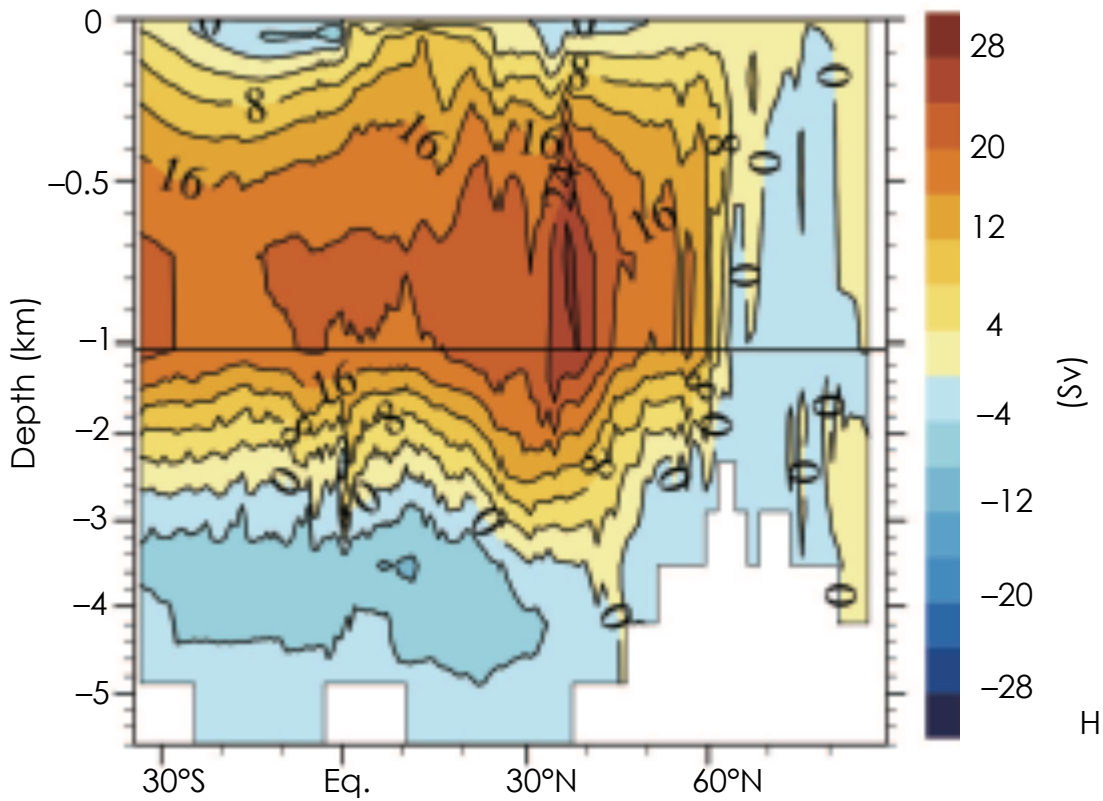
Lumpkin & Speer (2007),
Speich, Blanke & Cai (2007),
Garzoli & Matano (2011).

# Meridional Overturning Circulation

## Yeah, baby!

We now look at this!

$$\psi_{MOC}(y,z) = \int_{x_e,\,y}^{x_w,\,y} \int_{-H}^{z} v(x,y,z) \cdot dz\, dx$$




Huang et al., (2014).

# Meridional Overturning Circulation

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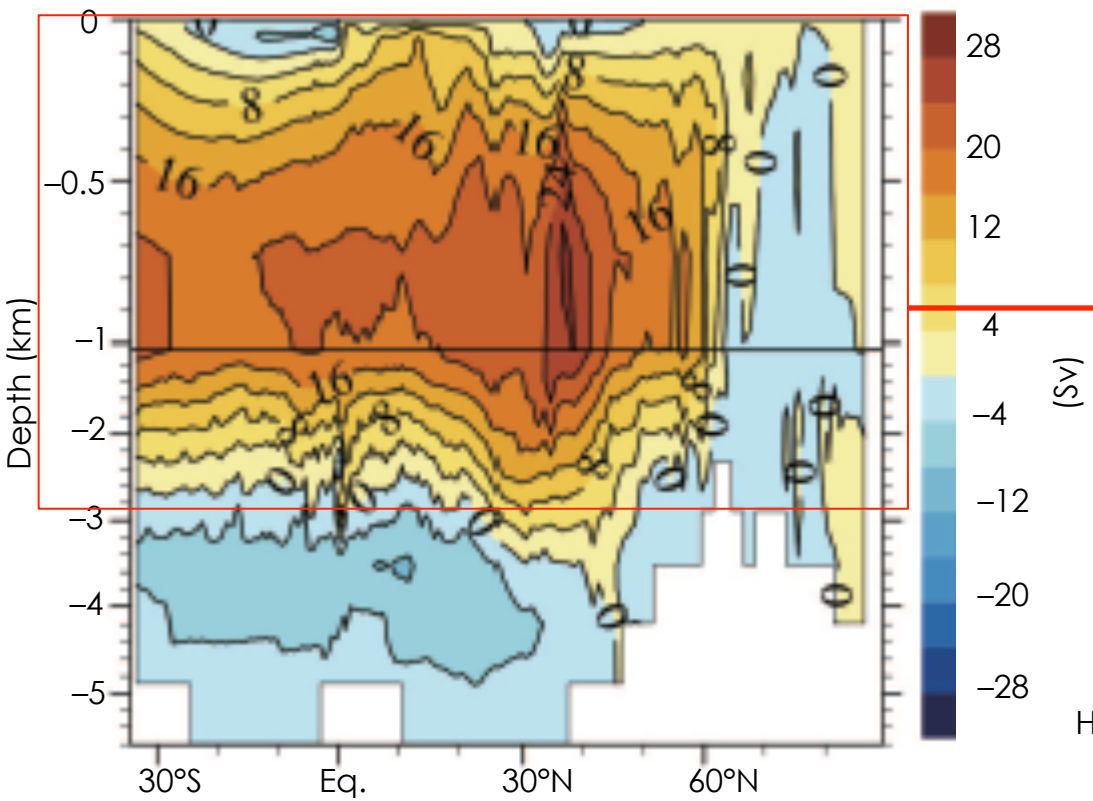


Upper branch:
warm and northward.

Huang et al., (2014).

# Meridional Overturning Circulation

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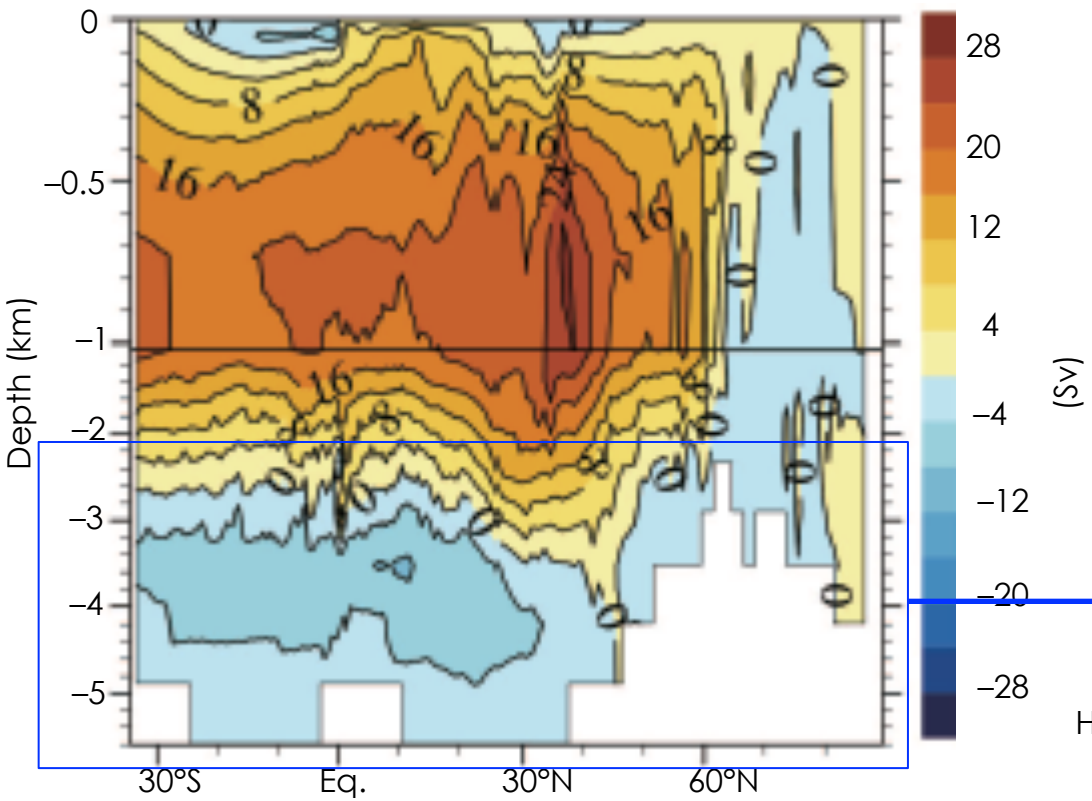



Lower branch:
cold and southward.

Huang et al., (2014).

# Meridional Overturning Circulation

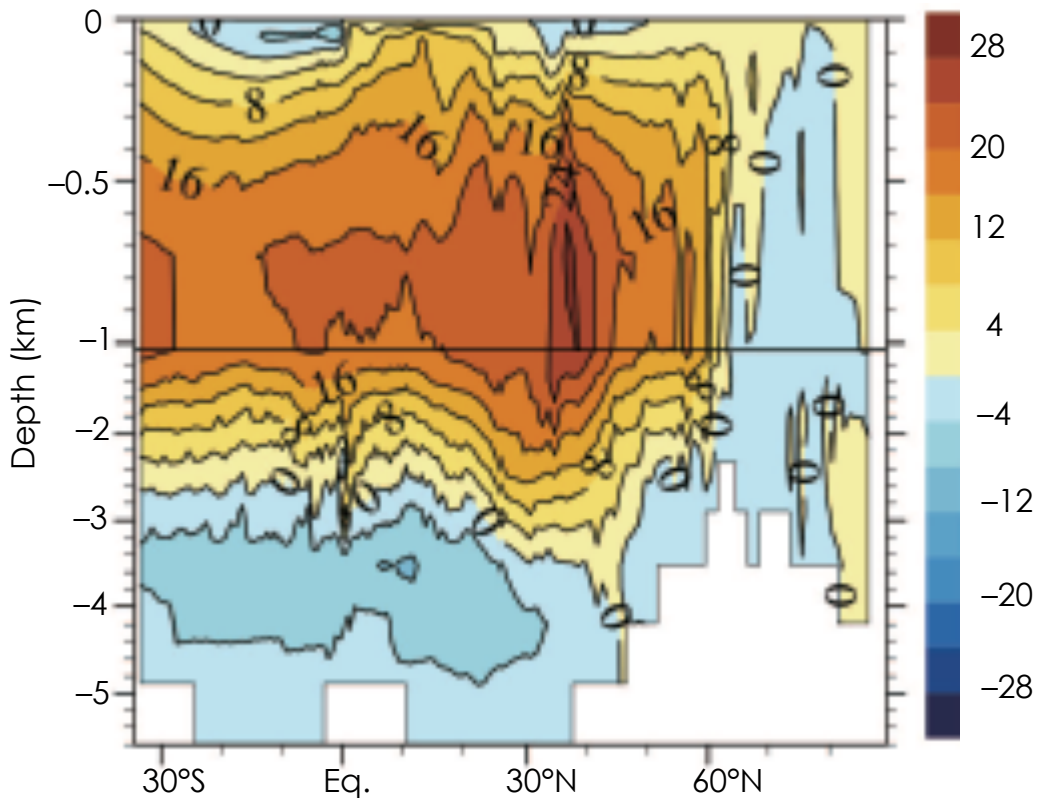
## Easy to work with, but not to explain!

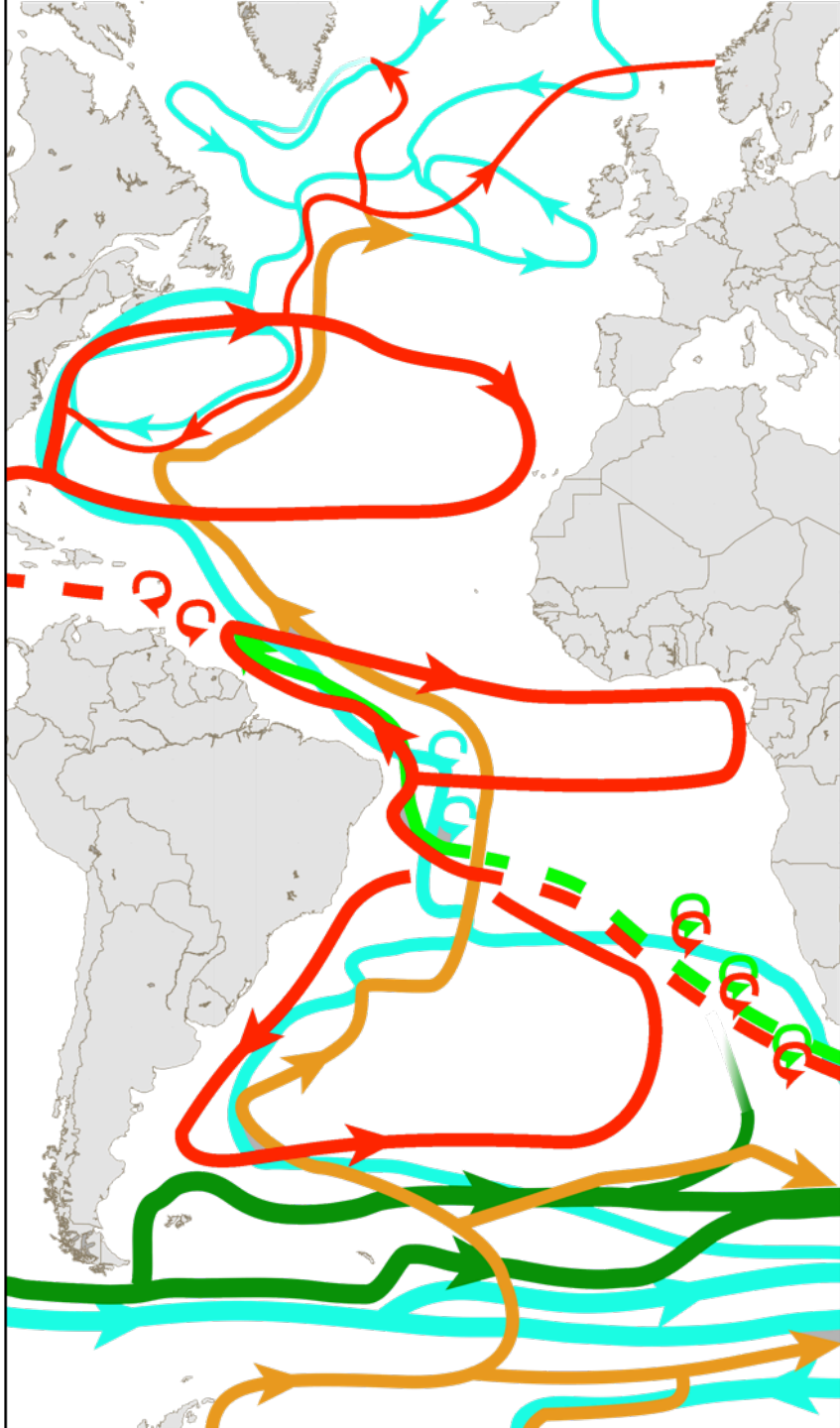
Advantage:

- 3D circulation – 2D circulation.

Disadvantage:

- Mixing of physical process.



# Meridional Overturning Circulation

## Why the Atlantic Ocean?

Because it is connect to both poles:

- Formation of deep (NADW, Labrador Sea) and bottom (AABW, Weddell Sea) waters masses.

# Meridional Overturning Circulation…

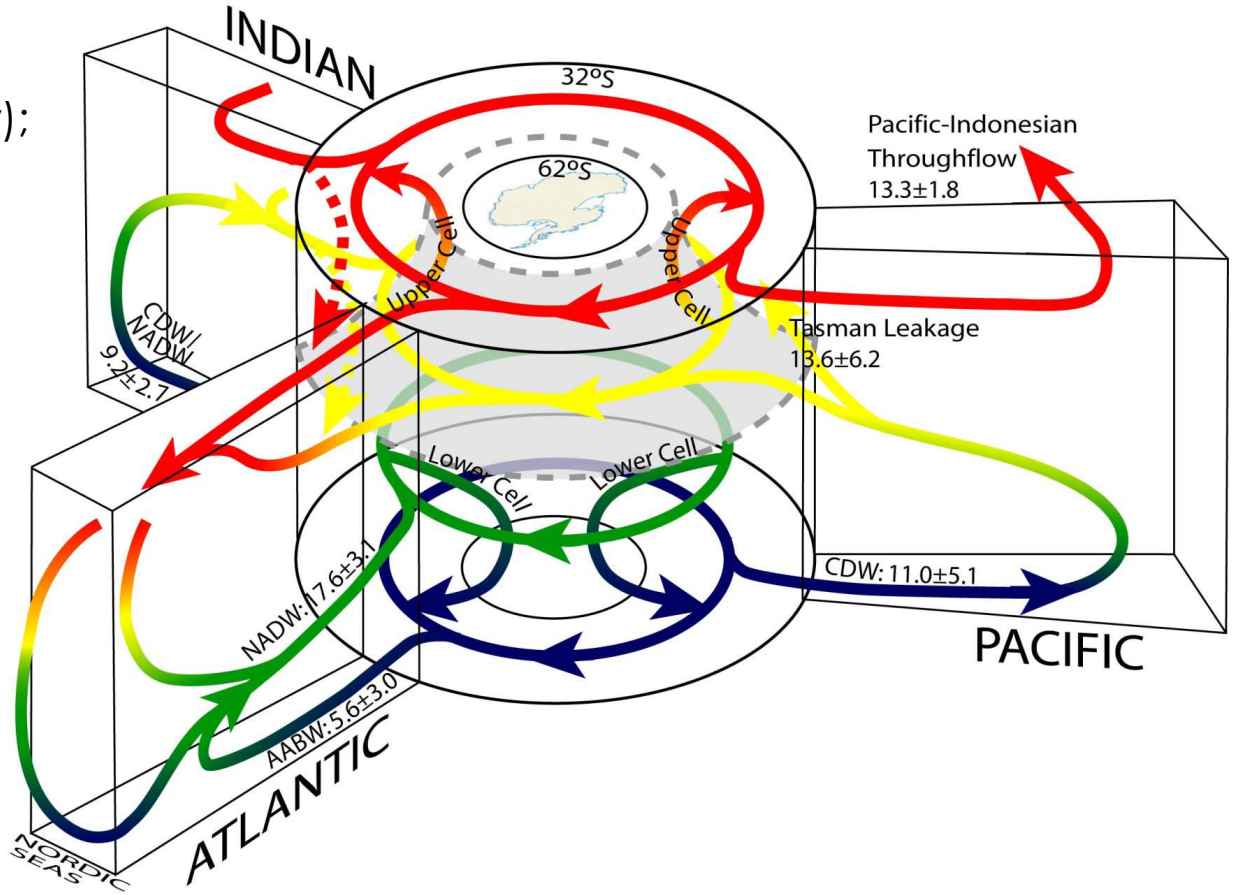
## And the others?

Export of deep waters in Pacific and Indian Oceans

- CDW (precursor of AABW);

Main part:

- Upper branch (return flow);




Lumpkin & Speer (2007).

# Meridional Overturning Circulation

## Water masses?

Amount of water with similar characteristics:

- Temperature;
- Salinity;
- **Density**;
- Oxygen…

Named according to the:

- Position on the water column;
- Place where it was formed.

For instance:

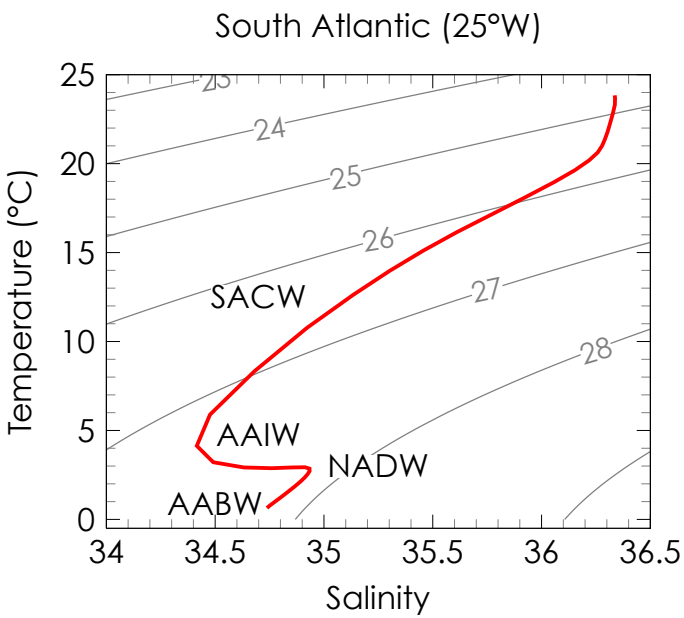
- North Atlantic Deep Water;
- Antarctica Bottom Water.

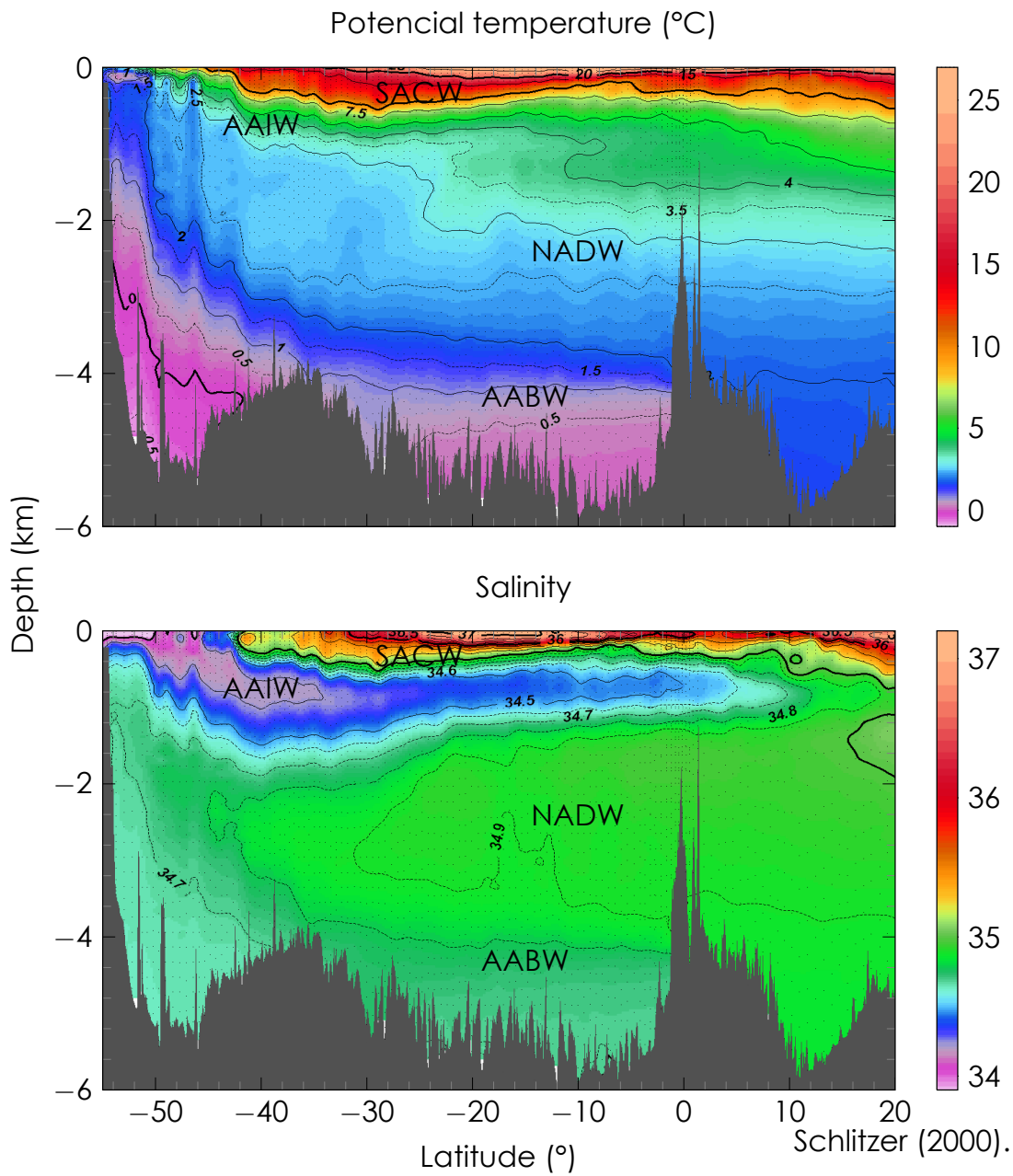
# Meridional Overturning Circulation

## Water masses?

Mainly water masses:

- Antarctic Intermediate Water;
- North Atlantic Deep Water;
- Antarctic Bottom Water.



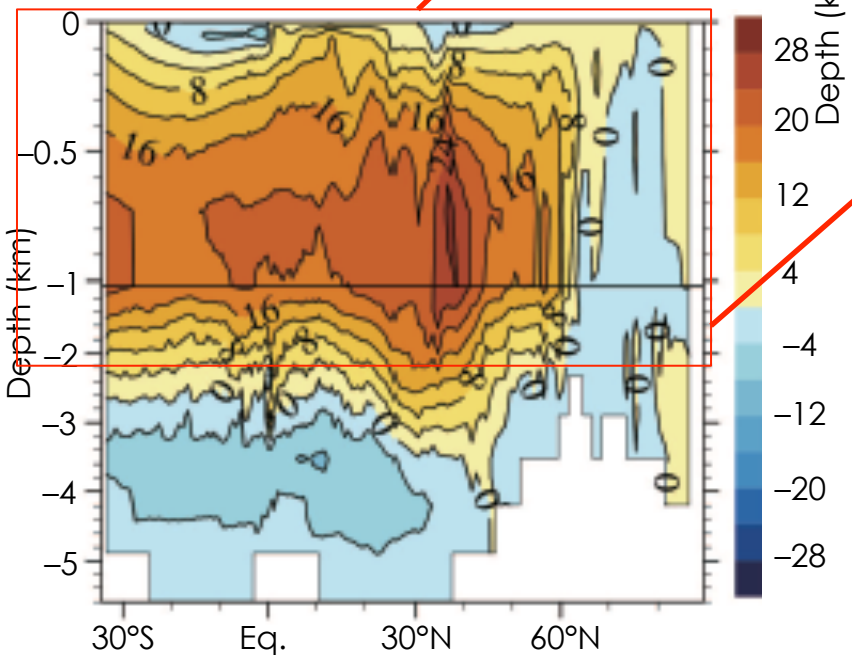

Schlitzer (2000).

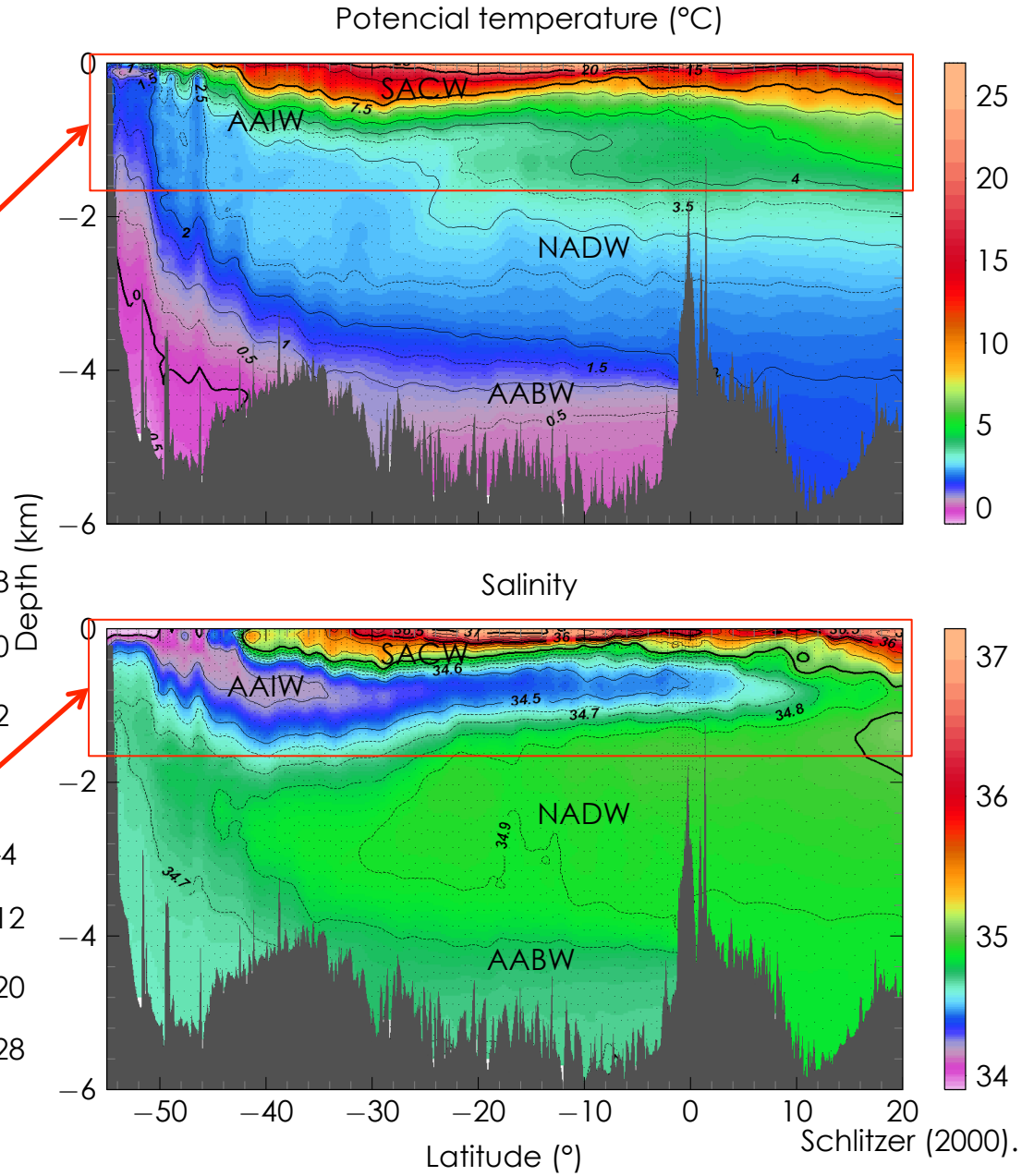
# Meridional Overturning Circulation

## Currents and water masses

Upper branch:

- Antarctic Intermediate Water;



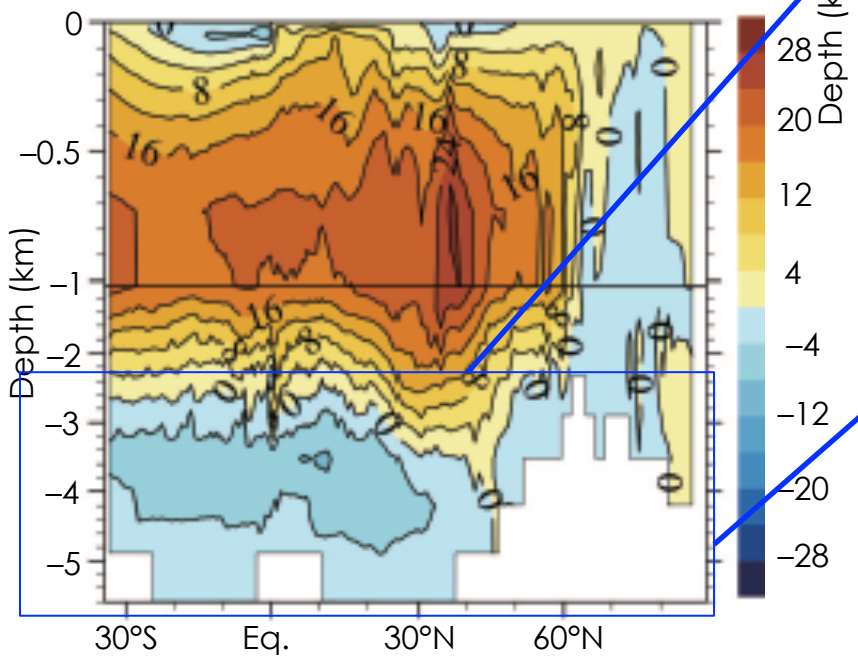

Schlitzer (2000).

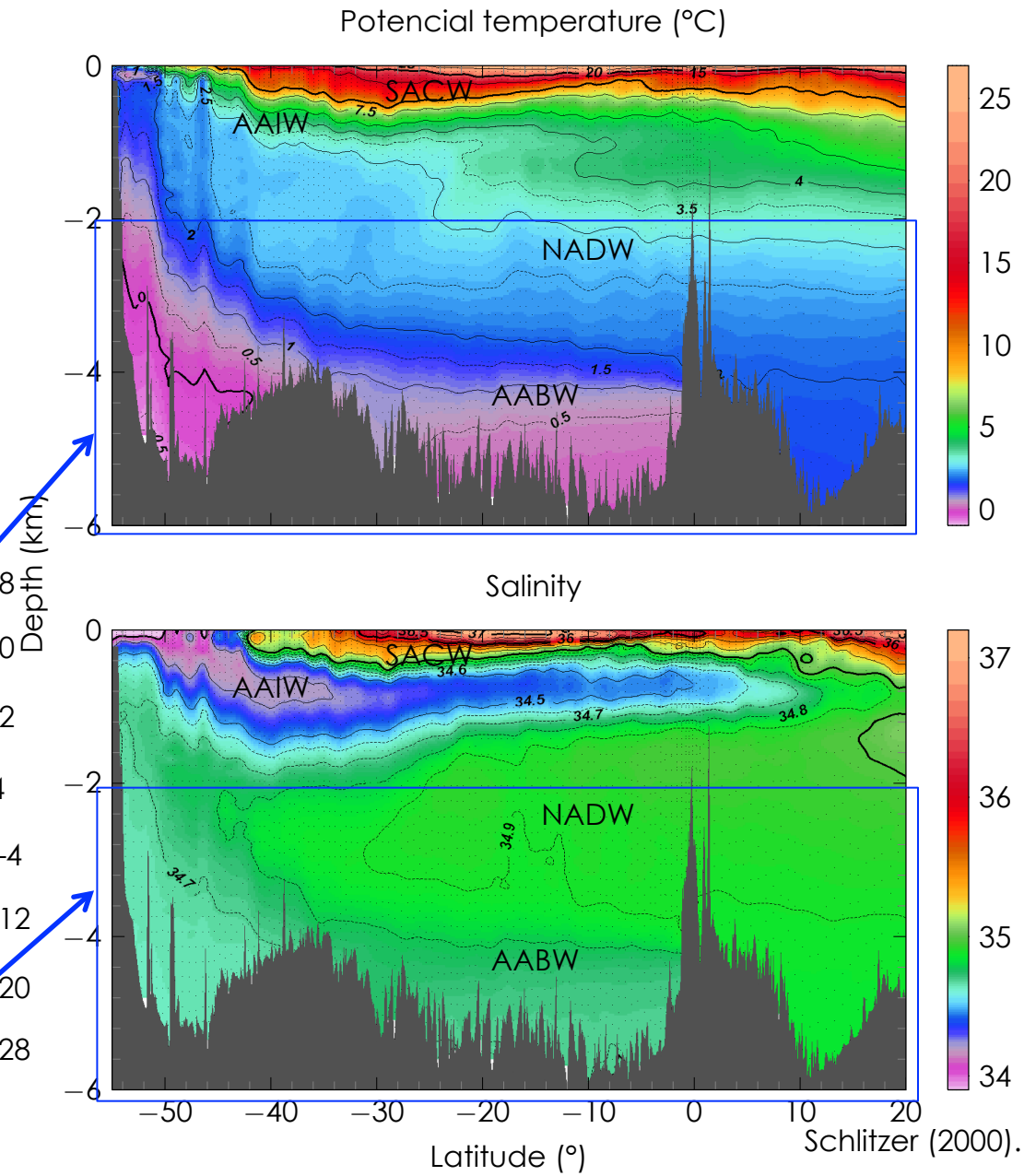
# Meridional Overturning Circulation

## Currents and water masses

Lower branch:

- North Atlantic Deep Water;
- Antarctic Bottom Water.




Schlitzer (2000).

# Meridional Overturning Circulation…

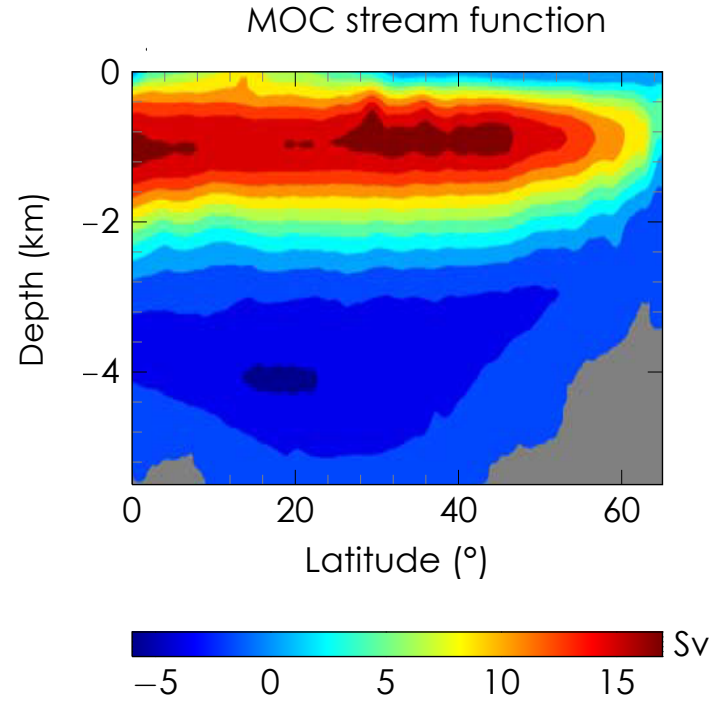
## Natural variability

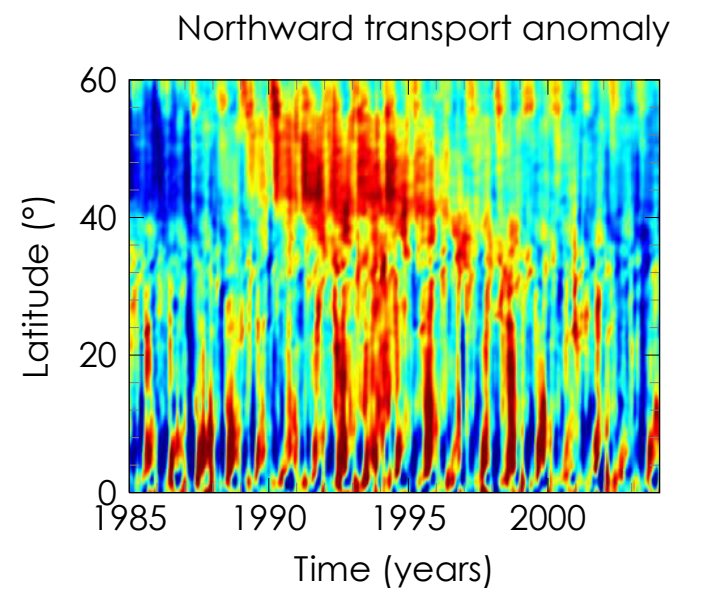
Many things affect MOC strength:

- Ekman transport and eddy variability (Biastoch et al., 2008);
- NAO, AMO, ENSO (Hodson & Sutton, 2012);

This variability has important socio-economic impacts (Knight, Folland & Scaife, 2006; Zhang & Delworth, 2006; Smith et al., 2010):

- Rainfall over Africa, India, North and South America;
- Atlantic hurricane activity.



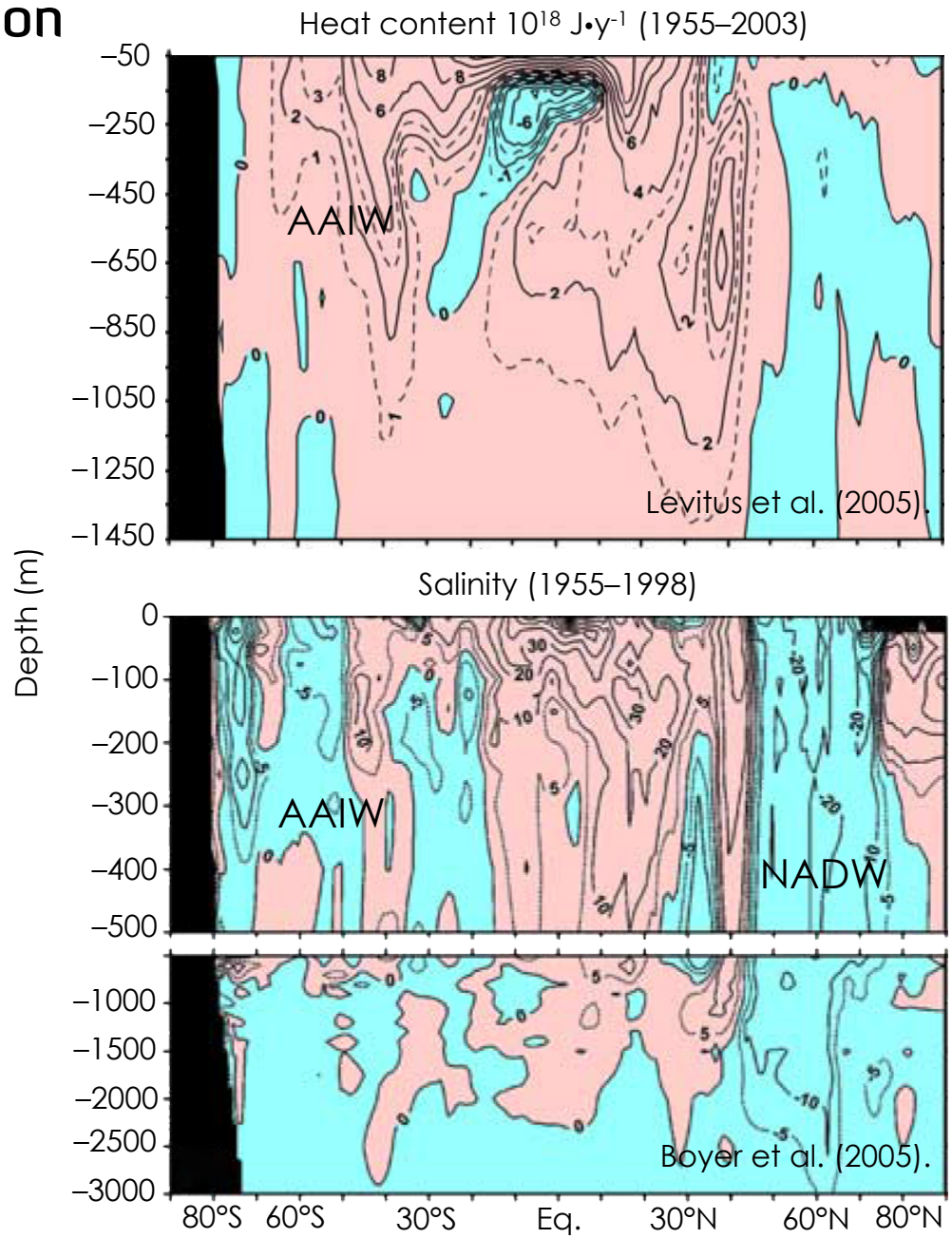

Bingham et al. (2007).

# Meridional Overturning Circulation

## And climate change

Increase of air and sea surface temperatures:

- Melting of sea ice;
- Changes in the salinity and temperature of AAIW, NADW, AABW;
- Changes in **density structure** of the ocean.
- Slowdown/shutdown of the MOC;
- Changes in the global distribution of heat.
- …



# Meridional Overturning Circulation…

## And climate change

More at:

- Is the thermohaline circulation really a risk?
  THOR Project (2012) http://vimeo.com/54353956;
- The great thermohaline Circulation
  NASA(2009) http://www.youtube.com/watch?v=3niR_-Kv4SM;
- The ocean: a driving force for weather and climate
  NASA (2012) http://www.youtube.com/watch?v=6vgvTeuoDWY;