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.

Meridional Overturning Circulation
A summary? Really?

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

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

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

The result:
- Transport \( (Sv = 10^6 \text{ m}^3 \cdot \text{s}^{-1}) \).
Meridional Overturning Circulation
A summary? Really?

And instead of this (for the Atlantic Ocean)...

Lumpkin & Speer (2007),
Speich, Blanke & Cai (2007),
Meridional Overturning Circulation

Yeah, baby!

We now look at this!

\[
\psi_{MOC}(y,z) = \int_{x_e,y}^{x_w,y} \int_{-H}^{Z} \mathbf{v}(x,y,z) \cdot \text{d}z \text{d}x
\]

Huang et al., (2014).
Meridional Overturning Circulation

Yeah, baby!

We now look at this!

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

Huang et al., (2014).
Meridional Overturning Circulation

Yeah, baby!

We now look at this!

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

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.
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.
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).
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

Levitus et al. (2005).

Boyer et al. (2005).
Meridional Overturning Circulation...
And climate change

More at:


• 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;