Ocean Sci. Discuss., 10, C557–C561, 2013
www.ocean-sci-discuss.net/10/C557/2013/

Ocean Science
Discussions
Open Access

Interactive comment on "Observed decline of the Atlantic Meridional Overturning Circulation 2004 to 2012" *by* D. A. Smeed et al.

Anonymous Referee #1

Received and published: 22 October 2013

The authors study the temporal variability of the Atlantic Meridional Overturning Circulation (AMOC) as observed at 24.5°N between 2004 and 2012, using Gulf Stream transport estimates through Florida Strait, satellite derived Ekman transport, and mid-ocean geostrophic transport derived from the RAPID mooring array. The authors report a statistically significant negative trend in the AMOC magnitude from their 8.5 yrs time series. This trend is shown to result from an intensified subtropical gyre circulation in the upper layers and a compensating decreasing transport of Lower North Atlantic Deep Water (LNADW) at depth. The relationship with atmospheric forcing and deep water formation in the North Atlantic sector is discussed.

By providing a robust quantification of recent AMOC trend from observations, the paper makes a useful contribution to knowledge of climate natural variability on relatively

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

short timescales and stand as a solid benchmark for improving climate predictability. The paper is well-written and easy to read. I do not have major issues with the scientific results although I think presentation could be slightly improved at some places in the paper. I therefore recommend publication in Ocean Sciences with minor revisions. These are listed below.

Some general comments (which the authors are free to address):

1) As the authors discussed the relationship between the observed AMOC decline at 26°N and the rate of deep water formation at higher latitude, a link could be made with recent estimates of the MOC variability in the subpolar gyre, as presented in Mercier et al, (2013) (see reference below). Using repeat hydrography and ARGO data, the authors report a decline of the MOC of about 2.5 Sv across the A25-Ovide section between the early 1993 and 2010. Although the RAPID time series is shorter, this might support a meridional coherence of AMOC changes between the subtropical and subpolar gyre. For information, an observational study recently submitted (Desbruyères et al, 2013) report a relatively weak impact of deep convection variability in the Labrador Sea (1990's - 2000's) to the basin scale magnitude of the AMOC in the subpolar gyre - in line with the relatively constant transport of UNADW reported here ? A weak impact of LSW formation rate on the MOC strength at 26°N was also reported in model simulation (see for instance Marsh et al. 2005).

2) The AMOC decline reported here is shown to represent a strengthening of the subtropical gyre above the main thermocline, and a compensation within the LNADW depth range. The authors may want to relate this to a basin-scale view of changes in the gyre circulation in the 2000's, revealed for instance by the extended time series of the altimetry-derived gyre index (Hakkinen et al, 2013). Observations and models suggest a weakening of the North Atlantic gyre circulation accompanied by an increasing penetration of subtropical waters towards the northeastern Atlantic and a warming of the subpolar gyre from the 1990s to the 2010s. How does this reconcile with the change in gyre circulation presented here, that is an intensification of the southward return flow

OSD
10, C557–C561, 2013

of subtropical waters during the 2000's?

Can the strengthening of the subtropical gyre observed across 26°N be related to the windstress "gyre mode" (second wind stress curl EOF mode) that is shown to dominates variability in the upper circulation? The authors provides an interesting discussion on how AMOC may drive SST and NAO variability, but somewhat neglect the actual regional atmospheric forcing of AMOC variability at 26°N. I think a short discussion on this may be useful.

3) An approximation of heat transport trend induced by the AMOC trend might appear useful in the discussion : dHT/dt = rhoCp dAMOC/dt *ΔT where ΔT could stand for a time-mean temperature difference between the upper and lower AMOC limbs, as deduced from the six hydrographic repeat at 26°N. How does dHT/dt compare with the rate of change of heat content north of 26°N (which has been mostly positive in recent years - see for instance Hakkinen et al. 2013) ?

Some minor comments:

P1620, l.7 : add (1 Sv = 106 m3s-1).

P1620, l16 - l17: As long as you consider the AMOC in the depth framework, this statement is mostly true in subtropical region. At higher latitude about half of the poleward heat transport is carried out by the horizontal circulation.

P1620, l18 : add (PW = 1.1015 W)

P1621, l.6 - l10: This sentence seems a bit long to me. Maybe split the ideas in two separate phrases.

P1622, l.15-l20 : How the applied external transport is involved in the UMO trends described latter in the text ? Surface geostrophic velocities from satellite altimetry can sometimes be an efficient way to reference the relative velocity field. Has this method been tested at 26°N ?

OSD
10, C557–C561, 2013

P1623, l23: Is there a typo here? You first mention 90% confidence interval, and then a 95% confidence in the overturning reduction.

P1624, l.22-l.23 : Again, you mention 90% c.i whereas table 3 mention 95% c.i.

P1624, l25: What "those" refer to is unclear.

P1624, l.27 : could the authors add the UMO trend value in the text ?

P1625, l3 - l18: Should the description of the uncertainty arrive before in the section? Confidence intervals appear several times in section 3.1 and 3.2 before the reader is informed on how they are actually calculated. I suggest the authors to move the whole paragraph at the beginning of the section.

P1626, l.7 : can you provide a reference for the UNADW/LNADW distinction ?

P1626, l.11-l.13 : how much greater ? What point the authors want to make with this quantification ? Please clarify.

P1626, l.16-l.17 : where exactly are the density profiles taken from ? A particular mooring ? An average for the whole western array ? This should be precised.

P1626, l.24 – l.26 : I found this paragraph a bit confusing, maybe because the link between Fig.6 (right) and Fig.4 (right) is not straitghforward as the authors only show the western density profile.

- If a similar increase in density than the one observed on the western margin above 500m is observed on the eastern margin (inducing a zero UMO transport change for that layer), then is the statement " changes on the west are much greater than those on the east. . ." (l.16-l.17) true ?

- If, as stated, density variations are not responsible for the decreasing transport observed above 500m, I guess it is solely due to a weaker (Gulf Stream + Ekman) transport ? This is not obvious from the value of 0.7 Sv (0.5+0.2) reported in table 2 and the transport change profile in Figure 4. Is the applied external transport involved ?

OSD

10, C557–C561, 2013

Interactive Comment

- The authors could add the TINT/TEXT/GS/EK contributions to the transport changes per depth profile in figure 4 – as well as a third subfigure in Figure 6 showing the density profiles on the eastern boundary. Apologies if I missed something here.

P1627, l.4-l.5 : Again, you mention 90% C.I whereas table 2 mention 95% C.I. This issue occurs several time in the paper – be sure to check it out.

P1630, l6-l11: I do not find the "uplift" argument very convincing and the reference to Cunningham and Alderson should be in my view further developed/discussed.

Figure 4-6 : depth should be noted with positive values.

Figure 6 : (black between) → (black) between

References

Variability of the meridional overturning circulation at the Greenland-Portugal OVIDE section from 1993 to 2010. Herlé Mercier, Pascale Lherminier, Artem Sarafanov, Fabienne Gaillard, Nathalie Daniault, Damien Desbruyères, Anastasia Falina, Bruno Ferron, Claire Gourcuff, Thierry Huck, Virginie Thierry. Progress in Oceanography (accepted)

The Meridional Overturning Circulation in the Subpolar North Atlantic as assessed from repeat measurements at the AR7W and A25-Ovide lines and altimetry data. Damien Desbruyères, Nathalie Daniault, Herlé Mercier, Virginie Thierry, Pascale Lherminier, Artem Sarafanov, Igor Yashayaev. Submitted to GRL.

Thermohaline circulation at three key sections in the North Atlantic over 1985–2002. Robert Marsh, Beverly A. de Cuevas, Andrew C. Coward, Harry L. Bryden, and Marta Alvarez. GRL (2005). Northern North Atlantic sea surface height and ocean heat content variability. S. Häkkinen, P. B. Rhines and D. L. Worthen. JGR (2013).

Interactive comment on Ocean Sci. Discuss., 10, 1619, 2013.

OSD

10, C557–C561, 2013

Interactive Comment