Overview

The paper examines a handful of numerical experiments to analyze the relationship between AMOC strength, the vertical structure of density and streamfunction, and external forcing such as wind. Most of the experiments are done at high resolution, and because of computational expense this necessitates short runs and hence conclusions only apply to decadal timescales. The paper attempts to isolate separate effects of Southern Ocean wind (associated with global-scale features) and northern hemisphere wind (associated with North Atlantic features only). It also attempts to link changes in the vertical scales to changes in volume transport.

The results are potentially interesting, but the writing is so difficult to penetrate that the manuscript needs a major revision before I can fairly judge the scientific content. I do worry that the small number of experiments and relatively light analysis are not able to support the conclusions of the paper about the relationship between depth scales and volume transports. However, maybe these issues will become clearer after a rewrite. I give more information about my problems with the writing in the sections below.

1. Motivation of Work

The paper is very poorly motivated. In the Introduction, the 1st paragraph is okay, the 2nd paragraph is a little dense, and the 3rd and final paragraph is very hard to read and does not do a good job of explaining why these particular experiments were done.

The 3rd paragraph of the Intro skips back and forth between mentioning subtropical gyre theory (Luyten et al), thermocline behavior due to diffusion and Southern Ocean wind stress (Vallis 2000), and northern high latitudes (Cessi, 2018). Three depth scales are mentioned, but the “advective depth” isn’t defined. Wind stress curl (Cabanes et al, 2008) is mentioned, but again without much explanation. Reference is made to “local” versus “nonlocal” wind influence but its unclear if “local” refers to wind and thermocline thickness in the same hemisphere, wind and thermocline both in low/mid latitudes, or wind and thermocline in the same latitude band. For this reason the paper does not clearly state what question is being asked. It doesn’t give motivation for the particular wind patterns used.

Intro also does not explain why an eddy-resolving model is used; this is important because the computational expense of an eddy-resolving model forces the experiments to be very short compared to the adjustment timescale of the large-scale thermocline to wind.

Finishing the Intro with only a vague idea of what the authors were trying to learn, I found the discussion of the results hard to follow as well.

2. Sec 3.1 results confusing

Figure 3 shows wind effects on isopycnals, as stated in para 2 of the section. However, paragraph states “displacement is scaled by η_w”. How do we know this from the figure or from the experiments? Why do “We expect considerable changes in the level of no motion”?

After stating that its easy to see why changing the stratification changes the Level of No Motion, the paragraph gives an argument I can't follow. "displacement of the isopycnals... is small" because "change in deep vertical shear is presumably small". I don't see how one is related to the other, or why the change in deep shear is presumed small. And why do density differences at the advective depth imply changes in velocity at mid-depth? What is mid-depth – 2 km? The paragraph mentions that zonal pressure gradients are related to the Level of No Motion, but I don't see how that fact helps us since the paper doesn't present any information about the zonal pressure gradients.

3. Some Sec 4 results not new?

Sec 4 shows that the subtropical cells are largely confined to the top few hundred meters, which has long been known (see for instance McCreary & Lu, 1994, JPO). Para 2 asserts that this suggests that "η_ψ is a proxy for ψ_t rather than... ψ_g". Doesn't it show the opposite? If the Ekman cells are above η_ψ, shouldn't their transport be independent of η_ψ?

The last paragraph of the section seems to say that if we assume that the vertical shear is constant (why should it be?), than changes in η_ψ produce changes in volume transport. However, it is unclear to me if the paper actually shows that. Again, the difficult writing style makes it harder to tell.

4. Generally Opaque Writing Style

In general, almost every sentence is difficult to read. The authors add words to the sentences that do not give any information, and they omit words that would specify what they are talking about. Often the connection between one sentence and the next is not clear. Below, I give some examples of difficult paragraphs. Unfortunately, many paragraphs have similar problems.

It would help if paragraphs were not so long. For instance in the 2nd paragraph of the Intro, "The depth scale itself is determined..." can start a new paragraph, "Different assumptions like..." can start a new paragraph, and "The present study addresses" can start a new paragraph. Similarly, paragraph 3 can be divided into 3 or 4 paragraphs, as can many other paragraphs throughout the paper. Ideally each paragraph gives one main idea, otherwise its easy for the reader to get lost in overlong blocks of text.

Examples of Difficult Paragraphs

Original text in black. Red text refers to **boldface** parts or, if no boldface, the entire sentence.

(a) From Abstract:
Our findings deviate from the common perspective that the AMOC is a nonlocal phenomenon only, because northward transport in the inter-hemispheric cell **can only be understood by analyzing** nonlocal Southern Ocean wind effects and local wind effects **in the northern hemisphere downwelling region** where Ekman pumping takes place.

This is very vague – what about the transport can only be understood? What information does analyzing the effects give us?
The experiments compare runs with winds differing over the entire basin N of 30S, so how do we isolate effects of wind in downwelling region alone?
Southern Ocean wind forcing predominantly determines the magnitude of the pycnocline scale throughout the basin, whereas northern hemisphere winds additionally influence the **level of no motion** locally.
OK, except **level of no motion** (LoNM) is used in a nonstandard way here. In physical oceanography, LoNM refers to a depth where velocities are close to zero. In this paper, it refers to a depth where the zonal average velocity is zero. There may be strong velocities that cancel out in the zonal average. Its okay to use LoNM this way but could be confusing in Abstract.
In that respect, the level of no motion is a better proxy for northward transport and mid-depth velocity profiles despite the Ekman return flow which is found to be baroclinic.
This sentence is trying to discuss so many issues at once that the reader can not understand any of them.
We compare our results inferred from the wind experiments and a 100-year global warming experiment in which the atmospheric CO2 concentration is quadrupled, using MPIOM coupled to an atmospheric model.
Mentioning the comparison to the wind experiments just makes the sentence longer without adding information.
We find that the evolution of the level of no motion in response to global warming **represents changes in vertical velocity profiles or northward transport**, whereas the changes of the pycnocline scale are opposite to the changes of the level of no motion over time.
Don't know what that means. Represents in what way? What changes in profiles or transport? Maybe should just combine last 2 sentences, like "A 100-year global warming experiment shows that the pycnocline depth scale increases and the depth of the LoNM decreases." Note that I've written a simple, understandable sentence. The paper needs more of those!
Using the level of no motion as depth scale, the analysis of the wind experiments and the warming experiment suggests a hemisphere-dependent scaling of the strength of AMOC.
I don't understand how the words before the comma (",") connect to the words after the comma. AMOC strength depends on depth of LoNM? In a particular hemisphere?
Furthermore, we put forward the idea that the ability of numerical models to capture the spatial and temporal variations of the level of no motion is crucial to reproduce the **mid-depth cell** in an **appropriate way**.
What is that? The mid-depth flow is part of a top (surface to NADW) cell and a bottom (NADW to AABW) cell.
What is meant by that? Accurate? Dynamically correct?

(b) From Sec 2.2, para 1
We analyze the AMOC in the **inter-hemispheric region** south and north of the equator.
What region is that? Between 30S and 30N? Between 30S and 60N?
In this way, we explore the nonlocal response to changes in Southern Ocean winds and local wind effects in the **downwelling region** of the northern hemisphere.

How does studying the unspecified inter-hemispheric region tell us specifically about the downwelling region?

In general, the mid-depth cell strengthens with higher wind forcing over the Southern Ocean, but **we cannot** capture **the details** of the different experiments **in terms of spatial variations**.

Should tell readers what the study can do, not what it can't do. This is especially confusing because it seems that the point of the study is to capture the spatial variations.

Vague. The experiments have lots of details, but the paper is only about some of them.

Is this referring to spatial variations in the wind forcing, the transport, or both?

The surface meridional Ekman flux can be inferred from the surface levels of the overturning streamfunction; it scales with the zonal wind stress and is inversely proportional to the Coriolis parameter.

True, but why is this mentioned here?

In contrast to the surface Ekman flux which is negative south of the equator and positive north of the equator, the northward flow of the mid-depth cell seems to be continuous and contiguous throughout the basin, **and it is difficult to base inferences on purely regional dynamics.**

Inferences about what? Do you want to know if the subtropical Ekman transport influences the strength of the AMOC?

However, these surface Ekman fluxes already indicate that the flow is not as continuous as the AMOC streamfunction suggests, because they have to be compensated by an interior return flux which changes the force balance of the flow.

If the point of the experiments is to understand how the subtropical Ekman transport affects the AMOC, that should be stated in the Introduction, not in the middle of this paragraph.

Furthermore, the wind stress curl over the basin imposes a forcing that may change stratification locally, **in the sense** that the meridional transport and its depth **differ between the wind experiments.**

This phrase generally implies an equivalence, but change in stratification is a separate issue from change in meridional transport. This phrase is used in several places in the paper and probably should be replaced in all cases by something clearer.

Between which wind experiments? Paragraph was talking about subtropical wind, but no experiment discussed here only changes subtropical wind.

In the 4XCO2 experiment, the surface buoyancy fluxes change continuously.

I thought the paragraph was about wind variations. I still don't understand the connection between the Ekman issues described here and the papers' experiments, but now we have switched to talking about buoyancy fluxes. Why?

On a multi-decadal timescale, the mid-depth cell weakens and shoals after the forcing is switched on (Fig. 2d,e,f).

So what?

The 100-year simulation time series makes it possible to analyze multi-decadal changes and compare the 4XCO2 experiment and the wind experiments.

Is this sentence trying to justify doing a 4XCO2 experiment, or doing the simulation for 100 years? Why do we want to compare a 4XCO2 experiment with wind experiments?

The warming experiment provides conceptual understanding of the linkage between ocean heat uptake and changes in the depth scales of the AMOC and how they relate to northward transport.
This thought should come at the beginning of a paragraph, preferably in the Intro. You are hypothesizing a connection between depth scale and transport, and 4XCO2 is useful because both change?
We summarize the experimental strategy as outlined above in Table 1.

5. Small Issues

Sec 1 para 3: Paragraph emphasizes lack of work on effects of northern hemisphere wind on overturning, but Klinger et al (2003) and (2004) both looked a effect of Westerlies in both hemispheres.

Sec 2.2 para 1: Definition of streamfunction should be indefinite integral in z, not definite integral. Otherwise ψ won't be a function of z.