

Interactive comment on “Projected changes in the seasonal cycle of the Atlantic meridional heat transport in MPI-ESM” by Matthias Fischer et al.

Anonymous Referee #2

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General Comment

In this manuscript the authors analyse how the seasonal cycle of the ocean heat transport in the Atlantic is affected by future climate change conditions, and the mechanisms responsible for these changes. The meridional ocean heat transport is known to be a key variable to understand the climate of the North Atlantic region. Thus, this analysis addresses convincingly a relevant scientific topic, by providing a mechanistic understanding of the potential future changes in the region.

Overall, I found the manuscript to be compelling and worthy of publication in Earth System Dynamics. The paper is well written and clear although there are some lingering points that need to be addressed.

I thus recommend acceptance pending a few revisions.

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My major concern relates to the way that some of the results are presented. Many of the figures show equivalent panels for the historical and the RCP simulations. And these are often discussed in terms of the differences. However, I find that the changes usually discussed are not so evident when one looks at the plots. For example, the temporal shifts commented in lines 27-28 of page are hardly discernible in Fig 8e-f. As I see it, it would be more illustrative for the reader to present the figures differently. Instead of the separate patterns for the historical and the RCP simulations, it is more helpful to show one of the two (e.g. the panel of the historical run, which represents a baseline configuration) and then additionally a panel on the differences (historical-RCP), like in Fig. 3c. The main advantage is that this will show directly the actual changes that you discuss later on.

Another indirect benefit of showing the plots on the differences is that they allow including some statistical tests on the significance of the differences. These tests are actually key to identify which of the reported changes from the historical period to the climate change projections are actually significant, and which ones are probably due to climate noise. I strongly recommend the authors to include such tests on their plots.

Please, find a list of other specific comments below:

#1 [Page 1, lines 1-2]: As it is written, the authors seem to suggest that the changes in OHT's seasonal cycle appear in response to the overall OHT strength reduction. This is not exactly true. As I see it, both (the OHT strength weakening and the changes in its seasonal cycle) are simultaneously responding to the strong GHG forcing in the future projections.

#2 [Page 2, line 1]: Please, substitute "expected" by "predicted".

#3 [Page 2, line 15]: It could be one cause or another, or both causes. So I suggest changing "or" to "and/or".

#4 [Page 2, line 34]: More than "to the ocean" in general they refer to "to internal ocean

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dynamics".

#5 [Page 3, line 10]: "Long-term variability" is too generic and depends on the length of the timeseries considered. The important thing to specify here is that they show decadal trends (which are an indicator of, at least, decadal variability in the overturning circulation and related OHT).

#6 [Page 3, line 21]: I presume that you refer to the "meridional" overturning. Please, clarify in the text.

#7 [Page 4, line 11]: Please, specify how this further increase is (Linear? Exponential?)

#8 [Page 4, line 30; and other similar entries]: "zonal-mean zonal wind" is a bit confusing. I suggest "zonally-averaged zonal wind".

#9 [Page 5, lines 2-4]: This sentence needs rephrasing. It is not to the NAO itself but to the zonal-wind pattern characteristic of a positive NAO that the shift in Fig 3b resembles. However, to support this claim, it would be good to include in Figure 3 an additional panel (Fig 3d?) showing simply the correlations between the NAO index and the zonally-averaged zonal winds. This result, to be confirmed, suggests also that the NAO is becoming more positive in the RCP runs. Have you checked if this is true?

#10 [Page 5, lines 8-9]: You first say that there is "only a weak increase" in the gyre strength, and afterwards that this is "suggesting that changes in the deep circulation are important". Please, rephrase, as both things seem somehow contradictory.

#11 [Page 6, lines 10-11]: Please, change to "The decomposition of ... is well established by considering. . ." #12 #13 [Page 7, line 13]: Please, change "shifted to the surface" to "becomes shallower" or "shoals". #14 [Page 7, line 16]: Please, rewrite as "The AMOC in density... indicates a similar shoaling of the AMOC cell..." #15 [Page 7, lines 17-18]: To guide the reader, I suggest to specify which are the levels involved in the wind-driven surface cell (~ upper 100m). Also, as opposed to this Ekman-driven cell, it would be good to mention that the deep cell mostly reflects the thermohaline

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circulation (as discussed in Kuhlbrodt et al 2007).

#16 [Page 8, line 11]: "from the Equator to the Pole".

#17 [Page 8, line 15]: I suggest ending the sentence with "to thus highlight the seasonally varying changes."

#18 [Page 8, lines 18-19]: It is not obvious to me how a northward shift can explain a temporal-shift.

#19 [Page 9, line 19]: Remove "during summer" to avoid repetition (as it appears also in the same sentence in line18).

#20 [Page 9, line 23 and Fig. 8g,h]: At first sight, the figure seems to suggest that the changes in the subpolar gyre are comparable to those in the subtropical gyre. Some readers might not notice that, indeed, the vertical axes are not the same in both panels. I suggest either to use the same scale in both cases, either to add something in the text like "please, notice that the vertical axes differ".

#21 [Page 9, lines 32-33]: The sentence is confusing. Please, rephrase.

#22 [Page 10, line 2]: Please, change to "similar than for".

#23 [Page 10, line 3]: The first bracket for Fig. 8a,b is missing.

#24 [Page 10, lines 3, 4, 9, 12]: I presume that you refer to Fig. 9 instead of Fig. 8.

#25 [Page 10, line 10]: "determines changes" with respect to what?

#26 [Page 10, line 13 and other similar entries]: Please avoid the use of "significant" as this adjective is commonly used for statistical analyses (which have not been considered here). I propose alternatives like "notable" or "remarkable".

#27 [Page 10, line 25]: "Intermediate circulation" is not a term commonly used. I suggest upper mid-ocean circulation, or simply upper ocean circulation.

#28 [Page 10, lines 30-32]: I don't follow. The two points made seem the same to me.

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Do you mean that the effect of the overturning dominates the intra-seasonal changes in the OHT, and also explains the differences in the OHT seasonal cycle from historical to RCP conditions? Please, clarify.

#29 [Page 10, line 33]: Please, change to "wind-driven via changes in the Ekman heat transport, which is mostly. . ."

#30 [Page 11, line 2]: "as well as with changes"

#31 [Page 11, line 10]: "remains under discussion"

#32 [Page 11, line 12]: "show a poleward expansion"

#33 [Page 11, line 18]: "and therefore in the associated"

#34 [Page 12, line 5-6]: "Based on our analysis. . . we conclude for the Atlantic Ocean meridional heat transport that:"

#35 [Page 12, line 22]: "vertical integral" of what?

#36 [Page 13, line 1]: "with σ_2 being"

Kuhlbrodt T, Griesel a, Montoya M, et al (2007) On the driving processes of the Atlantic meridional overturning circulation. *Reviews of Geophysics* 45: 2004RG000166.

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