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Ocean Science Discussions

Interactive comment on "The Atlantic's Freshwater Budget under Climate Change in the Community Earth System Model with Strongly Eddying Oceans" *by* André Jüling et al.

Anonymous Referee #1

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Review of os-2020-76 – The Atlantic's Freshwater Budget under Climate Change in the Community Earth System Model with Strongly Eddying Oceans

This manuscript gives a very detailed description of the components of the Atlantic Freshwater budget and how it changes under future climate projections. The study uses two versions of the CESM with different resolutions, one which is strongly eddying and the other which parametrizes eddies in the ocean. The results show that the higher resolution model has smaller biases than the lower resolution model. The authors also show that there isn't much difference in the response of the AMOC to the future CO2 projections between the high and low resolution simulations. While there are aspects

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of the freshwater budget between the high and low resolution simulations that similar the high resolution simulation has the additional transport due to eddies at the gyre boundaries.

I feel that the detail of the freshwater budget presented in this study is of interest to the scientific community. However, while I feel that the scientific content is sound and contents is well organized, I believe there is quite a bit of room for improvement to this study.

Major Comments:

1. Throughout the entire study references to existing literature is a bit on the sparse side. For instance, the second paragraph of the introduction only has one reference. References where values based on observations/models are stated should be included (e.g. line 33 – Frajka-Williams et al. 2019 (or Smeed et al. 2018) for AMOC strength or line 7 – Woodgate and Aagaard 2005 for Bering Strait through flow). Another example is when discussing the freshwater budget comparing how the results in the paper support or contradict other previous studies (i.e. Skliris et al. 2020 in their figure 11 do something very comparable to the manuscript's figure 9, Similarly, the studies Yin and Stouffer 2007 and Mecking et al. 2016 also do freshwater budgets).

2. A major difference between the high and low resolution simulations is the model's ability to handle eddies. Therefore, it would be nice to see a figure showing the differences in the eddy activity between the HIGH and LOW models (e.g. something similar to Delworth et al. 2012 their figure 14).

3. The short names HIGH and LOW used through the manuscript when they aren't followed by the word simulation makes a quick read of some sentences confusing (e.g. line 158,178,213,etc).

4. It would be very helpful to have some of the figures include extra panels (redone to show anomalies (differences between CTRL and RCP) as opposed to just the absolute

values. In particular, this would be very helpful for Figures 7 and 9, making it a lot clearer what the changes in the future climate projections are. The text would probably benefit from a few small tweets to reflect these figures this as well.

5. For several reasons I find Figure 9 nice but at the same time too complex. I really like comparisons of budgets using bar charts since the make it easy to see the relative differences between the different components. Panel a is good but panel b contains too much information. There is a lot of information on panel b, perhaps breaking panel b down into several panels will make it simpler, e.g. have a panel of surface flux break down and another for advection break down. The axis on the bottom of panel b are also confusing, first of all that they are different sizes for horizonal and vertical and where do the units, Sv/100yr come into play? Also, the arrows on the end of the bars are difficult to see differences between the HIGH and LOW simulations. It would be helpful to make an anomaly version of this figure.

Minor Comments:

1. At a few points in the manuscript a freshwater and salinity budget is mentioned, but only the freshwater budget is discussed. Even though they are quite similar it is probably worth just mentioning freshwater budget. (e.g. line 1 and other places)

2. Line 26 – Mecking et al. 2016 also showed this

3. Lines 32 and 37 – Do you mean approximately instead of some?

4. Line 44/45 – What about heat flux changes? i.e. Gregory et al. 2005

5. Lines 51-66 – The references Weaver et al. 2012 and Liu et al. 2014 are also quite relevant for this paragraph.

6. Line 66 – reference? Is this line even needed?

7. Line 90 – You are comparing ocean-only (Deshayes et al. 2013) to coupled simulations (Mecking et al. 2017). The ocean only simulations use salinity restoring which

is potentially the reason why the ocean only simulations have a negative FovS as opposed to the difference in resolution.

8. Line 113/114 – What impact does only using CO2 have?

9. Line 139 – reference for HadISST missing

10. Line 141-142 – Is there a warming trend in the beginning of CTRL before the reference period for this study is taken? Since the reference period of HadISST is 10 years before 2000 and 20 years after, I would naively not expect a warming.

11. In some 2D figures there is a line of missing data for the LOW simulations (e.g. Figures 1,3c,i,4b,6).

12. Line 148 – Refence to indicate that the warming hole response is expected i.e. Drijfhout et al. 2012

13. Line 162/Figure 2e – The integration of the surface fresh water fluxes is typically done North to South because that's the direction of the barotropic flow through the Atlantic (i.e. Skliris et al. 2020 Figure 6, Mecking et al. 2017 Figure 6), this way it will line up to the difference between inflow into the Bering Strait and outflow at 34S

14. Table 2, it would be nice to also include the transports at 34S (or as close to it as possible, see Bryden et al. 2011 for an observational estimate)

15. Table 2 – how is salt transport defined and how does it relate to freshwater transport?

16. Line 180 – I don't understand the barotropic streamfunction computation, the constant of integration should have an x/longitude dependence and not along the coast of the Atlantic side of Africa

17. Line 211 – By colours do you mean shading?

18. Line 221 – Refence for AMOC strength

19. Line 229 – The freshwater loss seems large (i.e. larger than CMIP5, see Skliris et al. 2020 Figure 6)

20. Line 234 – Which linear trends are being referred to here?

21. Figure 7 – why is 36N masked?

22. Figure 7 – Do freshwater transports through the Bering Strait and Strait of Gibraltar change?

23. Figure 7 and 10, most obvious in Figure 7, the thick and thin line thicknesses are very difficult to distinguish.

24. Line 256 (some other places later) – it would be nice to reference earlier figures/figure panels at the end of sentences to help make connections i.e. line 256 – Fig. 6k/l and line 266 Fig. 7

25. Figure 8 – Is it worth including 34S section and/or Atlantic zonal meam?

26. Figure 8 – the freshening trend in the SPG is in line with the warming hole that goes along with a weakening AMOC (i.e. Menary et al. 2018, Fig. 7) – should be mentioned in the text below

27. Line 305 – Any idea why there are these differences in salinity?

28. Line 321 – durface should be surface

29. Line 361 – Also in Liu et al. 2014

Frajka-Williams, E., Ansorge, I.J., Baehr, J., Bryden, H.L., Chidichimo, M.P., Cunningham, S.A., Danabasoglu, G., Dong, S., Donohue, K.A., Elipot, S. and Heimbach, P., 2019. Atlantic meridional overturning circulation: Observed transport and variability. Frontiers in Marine Science, 6, p.260.

Smeed, D.A., Josey, S.A., Beaulieu, C., Johns, W.E., Moat, B.I., FrajkaâĂŘWilliams, E., Rayner, D., Meinen, C.S., Baringer, M.O., Bryden, H.L. and McCarthy, G.D., 2018.

The North Atlantic Ocean is in a state of reduced overturning. Geophysical Research Letters, 45(3), pp.1527-1533.

Woodgate, R.A. and Aagaard, K., 2005. Revising the Bering Strait freshwater flux into the Arctic Ocean. Geophysical Research Letters, 32(2).

Skliris, N., Marsh, R., Mecking, J. and Zika, J.D., 2020. Changing water cycle and freshwater transports in the Atlantic Ocean in observations and CMIP5 models. Climate Dynamics.

Yin, J. and Stouffer, R.J., 2007. Comparison of the stability of the Atlantic thermohaline circulation in two coupled atmosphere–ocean general circulation models. Journal of climate, 20(17), pp.4293-4315.

Mecking, J.V., Drijfhout, S.S., Jackson, L.C. and Graham, T., 2016. Stable AMOC off state in an eddy-permitting coupled climate model. Climate Dynamics, 47(7-8), pp.2455-2470.

Delworth, T.L., Rosati, A., Anderson, W., Adcroft, A.J., Balaji, V., Benson, R., Dixon, K., Griffies, S.M., Lee, H.C., Pacanowski, R.C. and Vecchi, G.A., 2012. Simulated climate and climate change in the GFDL CM2. 5 high-resolution coupled climate model. Journal of Climate, 25(8), pp.2755-2781.

Gregory, J.M., Dixon, K.W., Stouffer, R.J., Weaver, A.J., Driesschaert, E., Eby, M., Fichefet, T., Hasumi, H., Hu, A., Jungclaus, J.H. and Kamenkovich, I.V., 2005. A model intercomparison of changes in the Atlantic thermohaline circulation in response to increasing atmospheric CO2 concentration. Geophysical Research Letters, 32(12).

Weaver, A.J., Sedláček, J., Eby, M., Alexander, K., Crespin, E., Fichefet, T., PhilipponâĂŘBerthier, G., Joos, F., Kawamiya, M., Matsumoto, K. and Steinacher, M., 2012. Stability of the Atlantic meridional overturning circulation: A model intercomparison. Geophysical Research Letters, 39(20).

Liu, W., Liu, Z. and Brady, E.C., 2014. Why is the AMOC monostable in coupled general

circulation models?. Journal of climate, 27(6), pp.2427-2443.

Drijfhout, S., Van Oldenborgh, G.J. and Cimatoribus, A., 2012. Is a decline of AMOC causing the warming hole above the North Atlantic in observed and modeled warming patterns?. Journal of Climate, 25(24), pp.8373-8379.

Mecking, J.V., Drijfhout, S.S., Jackson, L.C. and Andrews, M.B., 2017. The effect of model bias on Atlantic freshwater transport and implications for AMOC bi-stability. Tellus A: Dynamic Meteorology and Oceanography, 69(1), p.1299910.

Bryden, H.L., King, B.A. and McCarthy, G.D., 2011. South Atlantic overturning circulation at 24 S. Journal of Marine Research, 69(1), pp.38-55.

Menary, M.B. and Wood, R.A., 2018. An anatomy of the projected North Atlantic warming hole in CMIP5 models. Climate dynamics, 50(7-8), pp.3063-3080.

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