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Geoscientific Model Development Discussions

Interactive comment on "Max Planck Institute Earth System Model (MPI-ESM1.2) for High-Resolution Model Intercomparison Project (HighResMIP)" *by* Oliver Gutjahr et al.

Anonymous Referee #2

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The paper examines a contribution to the HighResMIP project from the MPI. The climate state in MPI-ESM with different atmosphere and ocean resolutions are examined. The paper is quite clear and thorough. Major results include the fact that increasing atmosphere horizontal resolution degraded some aspects of the solution (forming a cold bias in NH) , but this was fixed by changing the ocean vertical mixing scheme: and that using an eddy-resolving ocean fixed much of the remaining bias in ocean and atmosphere temperature. These results (when well-explained) are valuable to the community trying to decide where to invest computer time: on different resolution or ensembles or improved physics. Another aspect of interest to the community is the freeze over of the Labrador Sea and steps made to alleviate it.

I have some comments, one of which could involve some major restructuring/reordering, others more minor.

Major

The paper starts by discussing wind, Tair and SST biases etc., and refers to many results shown later in the paper, such as the following in section 3.1.2: line 2 of page 6 "and briefly outlined in section 4" line 18-19 North Atlantic Current (section 4.1.1) line 25 (see section 4.5) line 29-30 (see section 4) The references to later in the paper are not ideal, and I think it would read better if either i) these references were removed or, probably much better, ii) the paper re-arranged. As many properties are related to AMOC, you could start with a discussion of the ocean circulation (4.3) followed by 4.6 (AMOC) followed by 4.5 (Mixed layer Depth) followed by 4.4 (Sea ice). Then perhaps describe the rest of the ocean state (sections 4.1, 4.2) and then move to section 3 (Atmosphere state). Hopefully this or something similar would make the paper flow better.

Minor comments 0. Some of the English language style could be improved. Please check thoroughly.

1. As the acronyms for model resolution are a bit hard to follow, you should refer to Table 1 much earlier, on page 2 (section 1) and again in 2.1. You may also want to clearly state: "atmosphere resolution is contrasted between HR and XR: ocean resolution between HR and ER or between XR and ER: ocean mixing physics between pp and kpp.

2. Page 5, lines 9-10. "diffusivities not matched at base of mixed layer" Do you think that this has any adverse effects?

3. line 20. Presumably you refer to the time mean of scalar wind speed, not the magnitude of the time-mean wind vector?

4. line 26. Changes in subtropics are very small, perhaps delete the comment

page 6, line 18 "partly caused" - I don't think it is solely the NAC problem.

page 7, line 1. I think it should be compared to HRpp, not HRkpp.

line 19. "does not modify the mean zonal wind " where are you referring to?

line 25. Another reference to a later section...

Fig. 4. Please add more contour levels to b-f), such as some combination of +/- 0.25, 0.5, 0.75K.

Line 28. "We conclude that eddies play a major role" - but it could be other processes, such as resolution of boundary currents, and eddies could play a direct or indirect (via effect on mean flow) effect

page 9 lines 12-15. This explanation is not backed up by results (of salt transport). It could be put in Discussion.

line 25. "less" to "little"

line 26-29. It would be useful to include maps of precipitation (P) and evaporation (E) , or P-E to i) look at their biases and ii) see if they relate to ocean salinity bias.

page 10, lines 8-12. We also see big effects of improving the Agulhas in our ocean simulation at different resolutions. I would like to see a map of the mean ocean currents (or just zonal velocity) in the Agulhas/Retroflection region in HR and XR and ER. Also, do you see similar changes (ER relative to HR/XR) in other basins? If not, it may discount the eddy-induced cooling hypothesis.

Also, it may be useful to show (as Supp. Figs) the temperature and salinity biases globally at around 700m depth.

page 11 line 24. Delete "slightly", it looks large.

line 26 add "compared to HRpp" at end of line

line 32-33. I did not follow "explain the positive salinity bias in N. Atlantic" Where and

why?

Page 12 line 12. "model resolution or using KPP, which increase..."

Fig. 9 The Lab. Sea freeze-over is hard to see - the south-west labrador Sea has small sea ice volume. Perhaps you can also show sea-ice extent, if only for case XRpp?

On this subject, other climate model centers have battled with Lab. Sea freeze-over. For example, in Community Earth System Model 2 development, several cases obtained freeze-over. CESM uses kpp. So, you show it is sensitive to using pp or kpp, while with CESM it seems to be very sensitive to run-off and surface salinity. (It is not fully understood).

page 15, line 2. "in XRkpp" compared to?

Line 11-13. Convection in the Labrador and Irminger Sea is governed by a number of complex factors in addition to those listed. The effect of eddies may be quite different in the eddy-permitting case than in the eddy-resolved case. An idea of the complexity of the eddies and convection can be found from Kawasaki and Hasumi 2014 (Ocean Modelling) and DuVivier et al 2016 (J. Climate).

Section 4.5.2. Although I understand you want to focus on high latitude convection and relationship to AMOC, it would also be interesting to look at MLD in the SubAntatarctic Frontal Zone (which ranges from latitudes of 40deg. in the South Indian Ocean to 60deg. near Drake Passage). Standard resolution models have a shallow MLD bias (Sallee et al 2013, DuVivier et al 2018, JGR Oceans https://doi.org/10.1029/2018JC014275) but there is a hint that high resolution models do better (Lee et al 2011, 24, 3830-3849, J. Climate, Li and Lee 2017, 47, 2755-2772, J. Climate.)

Page 17, line 32, "featuring reduced surface winds" where?

Line 24. "winter upper layer"?

Page 19, line 15-16. This sentence is awkward. It could be reworded like “Cold temperature biases in the Southern Hemisphere, and to a lesser extent in the Northern Hemisphere, are reduced”

Line 26-27. But doesn’t XRpp, with T255 , have negligible MLD in the sub-polar gyre?

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