Geosci. Model Dev. Discuss.,
https://doi.org/10.5194/gmd-2018-192-RC1, 2018

Geoscientific Model Development Discussions

Interactive comment on "Sensitivity of deep ocean biases to horizontal resolution in prototype CMIP6 simulations with AWI-CM1.0" *by* Thomas Rackow et al.

Anonymous Referee #1

Received and published: 26 September 2018

Review of "Sensitivity of deep ocean biases to horizontal resolution in prototype CMIP6 simulations with AWI-CM1.0" by Rackow and Co-authors

The manuscript looks into the role of increased horizontal resolution in select regions of the ocean component of a coupled model in addressing, i.e., reducing, some of the deep ocean temperature and salinity biases in the Atlantic and Southern Ocean Basins. The authors argue that the ocean biases develop primarily from the surface, propagating along related isopycnals to the deep ocean. Higher horizontal resolution in the outcrop regions of these isopycnals appears to reduce such biases at depth. Although it is an interesting piece of work, I find the analysis rather superficial and qualitative, for

example, relying on animations, rather than quantitative analysis. I recommend major revisions along the following lines:

1. The Introduction actually introduces some physical mechanisms based on several previous studies concerning how deep temperature and salinity biases can emerge. In particular, the role of vertical mean and eddy heat transports is mentioned. Unfortunately, the manuscript does not get back to these points until the last section, and more importantly does not present a quantitative analysis exposing the role of various mechanisms. I strongly think that budget analyses should be included in the manuscript, in particular, exposing the changes in vertical eddy transports with increased horizontal resolution.

2. The authors identify three regions for the source of deep biases. The first is the Strait of Gibraltar. I do not necessarily agree with the authors view that incorporation of tides will improve the representation of Mediterranean Outflow. The outflow / overflow processes require resolutions of order 10s of meters in the horizontal and meters in the vertical. Two possible solutions are an overflow parameterization and changes in the bottom / lateral topography at the outflow of the Strait of Gibraltar to minimize spurious entrainment. The second source is identified as the erroneous downwelling associated with anomalously deep mixed layers in the northeastern North Atlantic. This statement is not justified. How do you know that the downwelling is erroneous and that the mixed layer depths are anomalously deep? The third source is presumably related to a displacement of isopycnals which are identified as too steep when eddies are parameterized. First, the analysis is not quantitative and I do not really follow the argument. Second, this is likely due to the issues with the details of the mesoscale eddy parameterization used. A description of the parameterization as implemented in the model should be included. Furthermore, since the REF case is much cheaper, a couple of cases with modified versions of the parameterization could be tested as alluded to in the text. Incidentally, I am not sure what is meant by mean absolute error. Is this the root-mean-square (rms) error?

3. The text refers to higher resolution configurations as (regionally) eddy-resolving in various places. Are they? As far as I can tell, they are still mostly eddy-permitting. A definition of what is meant by eddy-resolving and spatial maps of eddy-permitting and eddy-resolving regions for each configuration should be included. The text says "resolving the Rossby radius", but that is not a quantitative statement. What is the physical justification for cutting of the eddy parameterization below 25 km resolution, knowing that the resolutions are mostly on the eddy-permitting side? Also, as far as I can tell, the number of vertical levels is not given in the manuscript.

4. I am unsure if all the cases represent an apples-to-apples comparison. Specifically, these are fully coupled, pre-industrial simulations. Changes in one component will undoubtedly introduce the need to retune the top-of-the-atmosphere (TOA) radiation budget. Please provide a table with the TOA values for each configuration. My point is that if the reduced bias cases show large negative TOAs in comparison to the REF case, then when the coupled model is retuned, then it is possible that the deep ocean biases will reappear. Additionally, please include comparisons of the Atlantic meridional overturning circulation (AMOC), Labrador Sea Deep Water formation / mixed layer depth, and the northward heat and salt transports to show that the reductions in the deep biases are not occurring at the expense of degradations in several other climatically important fields.

5. In the last paragraph of section 3.4, it is stated that "higher spatial resolution is needed .... to better simulate the position of the Gulf Stream." I thought that there were studies in literature showing that the high resolution is not really the silver bullet. Perhaps an expanded discussion should be included here. Also, I do not really follow the argument made in the last paragraph of section 3.4.1.

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