

Response to Anonymous Referee #2:

We respond to the referee's comments in blue font below.

General comments

The manuscript by Guo et al. presents a new version of the Norwegian Earth System Model, i.e., NorESM1-F, that is designed for millennium-scale and large ensemble climate simulations. The paper describes the major developments of the model from its predecessor, NorESM1-M. These developments lead to substantial improvement of the computational efficiency, and better representations of the atmospheric and oceanic physics as well as ocean biogeochemistry. The model performance is documented by examination of the equilibrium state of a 2000 year spinup and control run forced with pre-industrial conditions, and evaluation of the model transient climate using observations and NorESM1-M as benchmarks. In general the model shows a satisfactory equilibrium with only a slightly cooling trend in 1000 years, and a good agreement with the observational estimates of the present day climate state. In comparison with the NorESM1-M, the new model demonstrates comparable or reduced biases. A particular feature of the improvements lays in the much more realistic strength of the simulated meridional overturning circulation, which results in more realistic atmospheric heat transport in the Atlantic Ocean and reduction of the warm and saline bias in the deep Atlantic. The more realistic physical ocean consequently improves the simulated interior ocean biogeochemical tracers. Overall the manuscript is well written, and clearly documents the major development and performance of the new model version of the NorESM. As large ensemble has become an important way forward in understanding climate variability and quantifying climate change projections, I believe the NorESM1-F with its computational efficiency, will make important contributions to studies of the millennium-scale climate change as well as to the Coupled Model Intercomparison project 6. I recommend publication in GMD subject to the following minor (and mostly technical) revisions.

We thank the reviewer for his/her assessment and overall positive comments on our manuscript. We respond to the specific and minor comments below point by point.

Specific comments

The authors demonstrate that the simulated Atlantic meridional overturning circulation (AMOC) in NorESM1-F is improved greatly and is much more realistic in comparison with NorESM1-M. This is a very encouraging improvement. As getting a realistic AMOC is often a difficult task in climate modeling, and to my knowledge, it is also a long standing problem in NorESM models. It is thus worth to discuss which model developments lead to such an achievement. This is potentially important for future model development.

We agree with the reviewer that reducing the strength of AMOC in NorESM1-F is an encouraging improvement. We have stated in the manuscript that (P8, L28-30) "Contributing to the reduced AMOC in NorESM1-F is reduced deep convection in the Labrador Sea due to stronger upper ocean restratification by the reformulated GM and modified parameterization of ocean mixed layer restratification by submesoscale eddies."

Minor comments

Page 2, line 32-32: What is the vertical resolution of the atmosphere and ocean component of the NorESM1-F? It is not mentioned in the manuscript. These can be state here, where the horizontal resolutions are given.

We thank the reviewer for pointing this out. We add the following sentence - "There are 26 vertical levels in the atmosphere and 53 vertical layers in the ocean component, respectively."

Page 2, line 34-35: do you really ran the model configured with the biogeochemistry using less cores than the model with the biogeochemistry deactivated? This doesn't sound logic to me.

We actually carried out the production run on an older HPC that is scheduled to be depreciated soon. The reported model throughput in the manuscript is the *test speed* on the new HPC "FRAM" that we will be using.

Page 4, line 23: here "thus" should be "that"?

We think that "thus" is OK here.

Page 10, line 23: "cleanly" should be "clearly".

adopted.

Page 10, line 28: what is AABW stands for?

AABW stands for Antarctic Bottom Water. We have replaced AABW with its full name in the revised manuscript.

Page 14, line 28: "the" should be deleted.

Yes, indeed.

Page 27, figure 6: I suggest to add zero lines in the figures to increase the readability of the figures.

We have added the zero lines in the updated figure.