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Geoscientific Model Development Discussions

Interactive comment on "Description and evaluation of NorESM1-F: A fast version of the Norwegian Earth System Model (NorESM)" *by* Chuncheng Guo et al.

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General comments The manuscript by Guo et al., presents a new version of the Norwegian Earth System Model (NorESM) featured as computationally fast and efficient with the main goal to be utilized in long-term paleoclimate simulations. The model efficiency is mainly achieved by using reduced complexity prescribed atmospheric chemistry as well as employing tripole grid in the ocean and sea ice domains which produces more stable solutions and allows longer time steps compared to the previous model version using dipole grid. The paper describes major model developments among which are energy formulation change in CAM4 physics, COARE-3 algorithm for air-sea flux

exchange, updated GM parameterization of eddy induced transport on neutral surfaces instead of isopycnal changing the vertical re-stratification, k-e turbulence closure scheme of second order parameterizing the diapycnal shear mixing substituting the previous K-profile vertical mixing scheme in the MICOM ocean component , more comprehensive particulate sinking scheme in the HAMMOC ocean carbon cycle component. The model fidelity is evaluated in terms of mean state, equilibrium, variability and climate sensitivity. Major model improvement compared to the previous model version is the more realistic AMOC.

Overall, this manuscript documents the major model developments and improvements in the NorESM models family which sets their entrance in the next Climate Model Intercomparison Program 6. I recommend publication after minor revisions.

Specific comments

- Weddell Sea polynya and Southern ocean deep convection

The authors have discussed improvement of the temperature and salinity biases in the intermediate layers and degrading of the SST and SSS biases in the surface layers, in the new model version NorESM-F compared to the previous NorESM-M. Since the goal is to use NorESM-F in a long term paleo simulations I think it is important to extend the model fidelity evaluation to the deep water formation and bottom water properties. Although, I do acknowledge the brief mentioning of AAWB production in the end of section 4.1 (lines 26-27, p.10)

Particularly, I found interesting the emergence of the Weddell Sea (WS) polynya in the new model version which doesn't seem to be evident in the earlier model version. This might be due to the improved sea ice simulation, but also due to the different vertical mixing and re-stratification representation. However, the occurrence of the Weddell Sea polynya signature in sea ice concentration/thickness September climatology (fig.8d) for the industrial period (1979-2005), when it was rarely observed (not present in the Hadley climatology), is a concern. It suggests that the WS polynya either emerges too often or for too long periods. This in turn implies that the new model is producing deep water in the Southern Ocean (SO) with unrealistically intensified open water convection - common feature in the majority of the CMIP5 models.

On the other hand, earlier studies on the SO deep convection in CMIP5 models disagree about the convective behavior of the previous NorESM-M model. While de Lavergne et al (2014) and Heuzé et al (2013) classified NorESM-M as non-convective, Behrens et al (2016) using more comprehensive T-S analysis have shown that NorESM-M family may be classified as convective.

I recommend to add discussion in the current manuscript about the deep water convection in the NorESM-F and compare the new model to the previous by using some of the metrics in the published studies, e.g. showing the difference with WOCE climatology of the mean bottom potential density $\sigma 2$ and August mixed layer depth as in Heuzé et al (2013), see their Figure 2 or/and T-S diagram showing time mean ventilated volume as in Behrens et al (2016), see their Figure 6. The differences/similarities might also highlight the effect of some of the new model developments.

- Representation of the ice sheets/glaciers melt

Interactive ice sheet modeling is still under development in the current generation of fully-coupled climate models. Still the effect of the melting ice-sheets and glaciers can be important in a long term millennial simulations. Particularly, for more realistic representation of ocean re-stratification and water mass properties, as well as, for sea level rise implications. Is there any representation of the ice sheet/glaciers melt freshwater/heat/volume flux in NorESM-F model? If yes, can you please add discussion in the manuscript.

Technical corrections

- p. 2, l. 10 For completeness and quick comparison could you state the resolution and performance metrics of NorESM-L. - p.4, l.11-15 Can you also state ocean time step

and coupled frequency - p2, l. 26 Typo “fugure” instead of “future” - p.4, l.31-32 Please reword the last two sentences on p.4 Maybe as: The implementation of this algorithm improved the evaporation-wind stress relationship, which appears too steep in CAM4 compared to observations (see supplementary Fig.S3) - Fig.8 Sea ice plots – enlarge – panel of 2x2 - I wasn′t able to see the supplemental material. I dowloaded the .zip archive from the website but when I unzipped it on my Mac, the system didn’t recognize it. All I know it is a single binary file which is neither executable or readable.

References

Behrens, E., G. Rickard, O. Morgenstern, T. Martin, A. Osprey, and M. Joshi (2016), Southern Ocean deep convection in global climate models: A driver for variability of subpolar gyres and Drake Passage transport on decadal timescales, J. Geophys. Res. Oceans, 121, 3905–3925, doi:10.1002/ 2015JC011286. Heuzé, C., K. J. Heywood, D. P. Stevens, and J. K. Ridley (2013), Southern Ocean bottom water characteristics in CMIP5 models, Geophys. Res. Lett., 40, 1409–1414, doi:10.1002/grl.50287

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