The Cryosphere Discussions

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Comment on tc-2022-133

Anonymous Referee #1

Referee comment on "Southern Ocean polynyas and dense water formation in a high-resolution, coupled Earth System Model" by Hyein Jeong et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2022-133-RC1, 2022

"Southern Ocean polynyas and dense water formation in a high-reslution, coupled Earth System Model," by Jeong et al.

Over the past decade, general circulation models (GCMs) have significantly improved in terms of resolution and parameterizations of sub-grid scale processes. However, the bottom-water formation on the Antarctic shelves remains a key challenge due to small and local formation sites related to coastal polynyas. The study by Jeong et al. contributes to the study of coastal polynyas and the formation of dense/bottom water in GCMs. The authors use a high-resolution coupled Energy Exascale Earth System Model (E3SM-HR) with a horizontal resolution of ~8 km over the Antarctic continental shelves to study dense water formation south of 60 ^{o}S and compare the results with a lower-resolution version of the same model and available gridded datasets based on observations and reanalysis. They find that the increased resolution improves the representation of coastal polynyas. However, the associated bottom-water production is too weak and does not produce sufficiently dense bottom water to compare with observations.

The manuscript is well written and includes high-quality figures to support the main results. The methodology is sound and builds on state-of-the-art coupled Earth System Model (ESM) development. However, the discussion section is too brief and offers limited new insight into the main topic of missing dense-water formation in the coastal polynyas in GCMs and ESMs. I summarize key aspects the authors should address to improve the manuscript and its contribution to the ESM development near the Antarctic shelves:

- Increasing the resolution of the E3SM improved the representation of coastal polynyas, but the associated dense-water formation was too weak and did not produce dense water with similar characteristics as the observations. What is your advice to the ESM community to further improve the polynya representation?
- You show that the winds over the continental shelves are too strong, resulting in a too strong Antarctic Slope Front which prevents shelf-ocean water exchange. What means

can you do to get a better representation of the winds over the Antarctic shelves? Would it be possible to run the E3SM-HR with an idealized wind forcing near Antarctica to test the response to strong and weak wind scenarios? Including such a test in the manuscript would strongly increase the relevance of this study to the modeling community.

- You describe plans to include landfast ice to improve the model further. How will the representation of landfast ice improve the model if the winds remain unchanged?
- The Southern Ocean is an area of upwelling. How well is the E3SM-HR representing the water mass characteristics in the Southern Ocean, and how are these characteristics affecting the formation of open-ocean polynyas?
- The E3SM-HR does not include ice shelf cavities where dense water interacts with the ice shelf base to form the densest versions of shelf water (Ice shelf water). How are the missing ice shelves and the presence of ISW affecting the model performance?
- The modeled sea ice is much thinner than the observations in OOP years over the whole WS. How is this affecting the dense water formation and the likelihood of increasing the lifespan of an OOP?
- Are there any caveats in comparing the model with the SOSE database? Could it make sense to also compare the transects in Figures 7-9 with CTD sections?

Minor comments:

Line 159: It is very hard to see the "relatively higher latent heat flux…in East-Antarctica" in Fig1a.

Line 256: It is very hard to see the easterly winds in figure 6b.