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Interactive comment on "Multidecadal Polynya Formation in a Conceptual (Box) Model" *by* Amber Boot et al.

Amber Boot et al.

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Discussion paper

MS-No.: OS-2020-63
Title: Multidecadal Polynya Formation in a Conceptual (Box) Model
Author(s): Amber Boot, René M. van Westen and Henk A. Dijkstra

Point-by-point reply to reviewer #2

November 28, 2022

We thank Wilbert Weijer for his careful reading and for the useful comments on the manuscript.

1. *p.1, l. 12: Usually a distinction is made between MRPs, which are clearly related to bathymetry; and the larger Weddell Sea Polynyas (WSPs) which are not related to bathymetry, as exemplified by those observed in the mid-70s. I suggest that the authors note this distinction.*

   Author's reply:
   Thank you for the notification. We will address this issue in the introduction.

   Changes in manuscript:
   The distinction between MRPs and WSPs will be made in the introduction.

2. *p.3, l. 2: vertical -> vertically stacked.*
   } ***Author's reply:***
   Suggestion followed.

   Changes in manuscript:
   The text will be changed accordingly.

3. *p.3, l. 27: remove 'a'*

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Author's reply:
Suggestion followed.

Changes in manuscript:
The text will be changed accordingly.

4. *p. 5-6: In my opinion, the model description is adequate, maybe with the exception of the sea ice equation, which could use some clarification.*

   Author's reply:
   We agree, we will clarify the sea-ice equation.

   Changes in manuscript:
   The equations, including the sea ice equation, will be discussed more elaborately.

5. *p. 9, Caption Table 2: What do the 'bars' refer to? Overbars?*

   Author's reply:
   Yes, they refer to overbars.

   Changes in manuscript:
   The caption will be changed accordingly.

6. *p. 9, l. 21: So are these fluxes averaged over the polynya region?*

   Author's reply:
   Yes, they are spatially averaged over the 'polynya region' identified in Van Westen and Dijkstra (2020) ($2^{\circ}E - 11^{\circ}E \times 63.5^{\circ}S - 66.5^{\circ}S$). This is mentioned in Figure 2.

   Changes in manuscript:
   The spatially averaging will also be mentioned in the main text, and the caption of Table 3.

7. *p. 10, l. 7: It would probably be good to explicitly state that this is a prescribed 25-yr cycle.*

Author's reply:
Suggestion followed.

Changes in manuscript:
It will be explicitly stated in the text that the forcing in the box model has a prescribed 25-year period.

8. *p. 10, l. 9: I think it would be good to have a better justification of the advective terms somewhere. A source of heat or salt is of course a consequence of a /divergence/ of advective fluxes. Maybe a better paradigm is that the lower box is bathing in a water mass with ambient temperature T_{b2} and salinity S_{b2}.*

   Author's reply:
   The reasoning behind the advective fluxes is that the layers do not drift away from the surrounding water masses. This reasoning follows your suggested paradigm. This has not been made explicit in the text. We will do that.

   Changes in manuscript:
   The justification of the advection terms will be changed to give a more physical point of view, as suggested in the above comment.

9. *p.10, l. 16: I suspect you mean ocean cooling, so heat transfer from the ocean to atmosphere. This would mean warming of the atmosphere.*

   Author's reply:
   Yes, that is what is meant here.

   Changes in manuscript:
   The statement in the text will be clarified.

10. *p. 11, Fig. 3: I'm a bit concerned by the strong variations, especially in the later years. I assume that the authors have checked that this water mass was not influenced by a polynya in the CESM? Evidently, you want to force the box model with upstream conditions.*

Author's reply:
As was done with the forcing, we used spatial averages of the polynya region defined in Van Westen and Dijkstra (2020) (2°E – 11°E × 63.5°S – 66.5°S). The definition of this region is related to the occurrence of polynyas.

Changes in manuscript:
No changes necessary.

11. *p. 15, l. 25-29: Maybe you can leave out the inclusion of the factor 35 (or discuss it somewhere else)? As it stands, F_N is /not/ a freshwater flux, as claimed in l. 27, but a salt flux. Besides, it would result in a sign error.*

    Author's reply:
    Suggestion followed.

    Changes in manuscript:
    The text will be changed accordingly.

12. *p. 20-21: I think we are missing some rules for T_2 and S_2 in certain transitions.*

    Author's reply:
    You are right, those are missing.

    Changes in manuscript:
    The missing information will be included in the revision.

13. *In our recent paper (Kaufman et al. 2020) we studied the heat content in E3SMv0-HR (a close clone of CESM1), and also found that heat build-up preceded polynya formation. However, our analysis suggests that this heat build-up is driven by a reduced surface heat loss under ice-covered conditions, and not an enhanced ocean heat import (Fig. 8c). In fact, ocean heat advection appeared to counteract the heat accumulation by removing excess heat. I suppose that in the context of this box model, this situation would be represented*

by $T_2 > T_{b2}$ for long periods of time without polynyas. Does a situation like this occur in your model, and can you discuss the context of these occurrences?

Reference: Kaufman, Z.S., Feldl, N., Weijer, W. and Veneziani, M., 2020. Causal Interactions between Southern Ocean Polynyas and High-Latitude Atmosphere Ocean Variability. Journal of Climate, 33(11), pp.4891-4905.

Author's reply:
In our box model the situation that $T_2 > T_{b2}$ does not occur. The advective flux is thus always a source of heat to the subsurface layer. T_2 is always smaller than T_{b2} because the subsurface layer loses heat to the surface layer via the term $K_T(T_1 - T_2)$.

Changes in manuscript:
This will be discussed in the revised manuscript.

References:

– van Westen and Dijkstra (2020), Multidecadal Preconditioning of the Maud Rise Polynya Region, https://doi.org/10.5194/os-2020-25

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