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

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Review of: "Multidecadal Polynya Formation in a Conceptual (Box) Model", by Boot, van Westen, and Dijkstra.

In this paper the authors explore polynya behavior in a conceptual model. In particular, they focus on the role of heat accumulation at depth in preconditioning the area for deep convection.

I found the paper well-written, well-illustrated, and the research was carried out carefully. The research may not be a major advance of the field, but it's a nice contribution to the recent literature on polynyas. I don't have any main concerns, and would like

to congratulate the authors on this nice work. I only have minor comments, which, I'm sure the authors can address satisfactorily; and a point for discussion.

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.

p.3, l. 2: vertical -> vertically stacked.

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

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.

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

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

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

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.

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.

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.

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.

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

Discussion point:

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.

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