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Interactive comment on "A model for the Artic mixed layer circulation under a melted lead: Implications on the near-surface temperature maximum formation" *by* Alberto Alvarez

Anonymous Referee #1

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This study uses a simple, idealized ocean model to argue for a new process contributing to the formation of the near-surface temperature maximum (a feature observed in the Western Arctic) relying on circulation associated with summer leads. My review is based on my experience with observations and climate-scale representations of sea ice and upper ocean processes. As such, I cannot comment directly on the suitability of the idealized numerical model.

Overall, this study presents an interesting new mechanism that could contribute formation of the NSTM locally in the Arctic. It is an appropriate subject for publication in The Cryosphere. However, the current manuscript leaves too many lingering questions

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Discussion paper

resulting from over-simplification of the problem and ignoring many important factors (i.e. wind, drift, appropriate solar forcing, sea ice geometry). This limits the utility of the study for informing understanding of physical processes in leads, and contribution to heat storage. I understand it is not likely that all realistic forcing conditions can be considered due to model constraints, but I think a revised version should at least demonstrate more consideration of which variables are important to include and discussion of the implications of those that remain excluded.

Major comments:

- Appropriate forcing. The SW forcing used here, shown in Figure 2 (from Mcphee Stanton, 1996) is for April north of Alaska. As the aim of this study is to explore circulation patterns of a summer lead with melting conditions, I see no reason why this would be the correct forcing to use. For the conditions you propose to explore, I would expect the forcing typical of Canada Basin (with minimal diurnal cycle) in July to be best suited – as this is where the NSTM is documented to form, but has more persistent summer ice pack than the area north of Alaska for which this forcing was obtained. Perhaps the forcing data from SHEBA would be appropriate.

- Consideration of geometry. Due to the scales over which the circulations are represented here, the fact that sea ice is not embedded in the ocean, but rather sitting atop (Figure 3) could have significant implications. It seems to me that this could disrupt the formation of circulation cells that are shown. If there is no way to represent this in the model, there needs to be significant discussion of the implications.

- Realism of atmospheric and ocean conditions. Ideally, some representation of impact of wind and/or sea ice drift can be included. (see e.g. Skyllingstad Paulson, 2005) Alternatively, more discussion of the extent to which this idealized scenario can/cannot represent realistic conditions is needed. There is also often substantial shear between the ice and ocean during the summer in many parts of the ocean. How low would drift need to be to observe convection as simulated in these experiments? How gentle wind would have to be to be considered "wind-less" as in these experiments? How often do these conditions exist?

- Presentation of results. The connection of convection cells formed in the model with heat storage (i.e. in NSTM) could be shown more clearly. At current, it is hard to see that this mechanism could truly contribute to regional formation of NSTM. For example, Fig. 8 focuses on evolution of horizontal heterogeneity whereas my understanding is that NSTM formation will require vertical heterogeneity, as shown in Fig. 6. Consider how you can connect these results to what we typically expect to see with formation of NSTM (i.e. Steele et al., 2011).

Additional comments

- Title: "melted lead" seems a strange word choice – even during the summer they're still often dynamically formed. Perhaps 'summer lead' would be better.
- L37-53: It seems strange to focus the background material on winter lead processes, as the study here is nominally focused on summer leads. I would suggest shortening this discussion of leads in winter and expanding the introduction of leads in summer, as there is additional literature that provides important context not included here (e.g. Richter-Menge et al., 2001; Skyllingstad Paulson, 2005).
- L24-26: I believe this point is still disputed (see e.g.: Blackport Screen 2021, Screen et al., 2018 Nature Geoscience). Perhaps better to make a more vague statement that it likely influences Northern Hemisphere weather.
- L42-43: Please provide a citation showing observation/indication of this process
- L95: The albedo of open water is typically estimated at 0.067. Why do you use 0.02 here?

- L98-99: If the effects of melting on ice-plate geometry are not considered, the impacts of this should be indicated. Can you confirm that the freshwater flux does not exceed what is realistic based on the ice volume? What are the possible feedbacks associated with ice thinning? (I.e. reduction in drag, reduction in albedo, etc.)
- L169: It's wasn't very clear to me what initial temperature salinity profiles were/why. I see now that they are shown in Fig. 1. How were these profiles chosen, and why is there an increase in salinity at 50 m? Please describe this in the text. Also, it would be better to start with a more realistic profile such as from observations (i.e. in Richter-Menge et al., or from ITPs)
- L220/Figure 4: Please show somewhere (or describe) the magnitude and time variation of the freshwater flux driving stratification and circulations.
- L225/Figure 6: It would be helpful to have on same figure the solar radiation values or time series and/or the times of each panel labeled.
- L225/Figure 6: What timeframe are the results being shown from? Are they from 1 specific date, or average from multiple days at the same time/solar radiation?
- L230/Figure 7: What are the bulk horizontal coordinate and bulk vertical coordinate? I assume these somehow correspond to the isothermals in Figure 6, but need to be defined.
- L273-274: More discussion on how you can ignore wind, drift etc is needed. Is there some other way you can parameterize the likely turbulent forcing in the near-surface? I suspect that the lack of background turbulence is leading to unrealistic horizontal heterogeneity (i.e. figures 4 5).
- L260/Fig. 8: This figure is the key result figure, and I find it does not adequately convey the information, or in the best way possible. Perhaps there is some more

simplified way of quantifying ‘strength of circulation/cells’ alongside vertical heat storage (i.e. integrated horizontally rather than vertically). The key feature of the NSTM is that it is sub-surface.

- Fig. 8: Also, consider re-orienting the time series (I feel time should progress downwards) and adding other supplementary information (i.e. gridlines for days, annotation of lead width, 0=white) that would make it easier to digest.
- L307-308: This statement is not very accurate. First of all, the NSTM is generally understood to be a regional feature (Canada Basin) so other features in the profile dominate elsewhere in the basin. Additionally, the NSTM captures the remnant warm water at the end of summer, but a large portion still goes to melt or back to the atmosphere. I have not seen a study quantifying the relative proportions to be able to say that a majority is captured in the NSTM.

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