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The Cryosphere Discussions

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

Alberto Alvarez

alberto.alvarez@cmre.nato.int

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This paper presents an idealized simulation of ice-ocean interactions within a lead, with focus on the fluid dynamics below the ice. The study finds the daily generation of convection cells in response to shortwave-driven sea ice melt. I find the approach and results interesting and worthy of publication, but there are a number of issues related to the presentation of the study and the approach that I feel need to be addressed first.

R: I thank the reviewer for his/her encouraging comments to the manuscript. His/Her suggestions have been considered to improve the manuscript as detailed below:

Major - Introduction: -The introduction includes a very nice discussion of observational studies on leads, but what about other numerical studies? Ramudu et al., 2018 discusses NSTM specifically and might be a good starting point, but I imagine there are many other numerical/fluid dynamics studies. -There is a very nice and thorough discussion of the seasonal evolution in a lead, but then the study focuses on the diurnal cycle. I suggest the author motivate this choice and perhaps focus the discussion on the time of year he is focusing on.

R: I thank the reviewer for highlighting this reference. I agree with the reviewer that the Introduction Section lacks of an appropriate description about numerical studies related to the subject investigated. A paragraph will be included in this Section summarizing the numerical findings, in particular those of Ramudu et al., 2017.

-L68: The objective is stated here but it is very broad. Possible to be more specific on the question that is answered?

R: It is proposed to rewrite the sentence: An axisymmetric geometry and particular thermodynamic forcings are common features to summer leads. For this reason, this study focusses on the circulation under a summer lead resulting from the combined effect of the lead geometry, solar radiation and sea ice melting as well as its effect, if any, in the heat exchanges through the lead. The ultimate objective of the study is to assess if the circulation pattern under the lead could contribute to the formation of the NSTM.

-It is mentioned in the methods that the ice will be assumed as motionless. This is okay but really needs to be stated up front that you are *only* considering thermodynamic drivers from sea ice melt/formation. This needs to be properly motivated in the introduction too.

R: In addition to the answer provided above, it is proposed to rewrite the sentence: The ice plates are assumed motionless as only thermodynamic drivers are considered in this study.

-Methodology: The NSTM seems like an important part of the research question (and is stated in the title). As far as I know, NSTM is mainly discussed in the context of the Canada Basin (and the references in the intro are all for the Canada Basin too). So why is the initial profile used from the Eurasian Basin? The Canada Basin is fresher, has a shallower mixed layer, and has a stronger halocline that is closer to the surface. This will likely change a lot. I strongly suggest the author consider downloading observations from a few ITPs in the Canada Basin, get a sense of what the halocline looks like there, and go from there. Alternatively, they could hunt for a representative profile in papers like Toole et al., 2010; Jackson et al., 2010; Timmermans 2015.

R: Due to geographical proximity and the capability to perform future observations, the author is particularly interested in the Eurasian basin where the NSTM layer and its impact on sound propagation have been reported (Carmack et al., 2015, Freitag et al., 2015). The NSTM layer in the Eurasian Basin generates a sound channel (30-150 m depth) wider and deeper than in the Canadian Basin ($\sim$15-50m). The future warming and deepening of the NSTM resulting from climate projections in the Arctic Eurasian Basin, would drastically modify the underwater soundscape in the region. For greater geographical and seasonal consistency with the stratification employed in the model, new simulations will be done with a representative incoming shortwave radiation during June in the Eurasian Basin.

-Results: -Validation: Once the model is spun up, are the T,S profiles still realistic? I think this needs to be included somewhere to know if we can trust the analysis that follows.

R: This analysis will be included in the Result Section of the new version.

-Sensitivity to parameters: How sensitive are the results to the choice of initial conditions and other parameters? One particularly interesting question that might be worth looking into is the sensitivity of the convection cells to the initial stratification (observations indicate that this is changing and having an impact on NSTM).

R: Due to the long simulation runs (about 10 days each) only a limited sensitivity test can be done. In particular, it will be considered the sensitivity of the circulation cells with a shallower pycnocline.

Minor -L39: heat flux from the ocean and the atmosphere?

R: OK

-L40: although → even though? Despite?

R: OK

-L45: Earlier studies that showed this: Morison 1978, Lemke 1983

R: The following references are added: Lemke, P., Manley, T.O., The seasonal variation of the mixed layer and the pycnocline under polar sea ice, J. Geophys. Res., 89, 6494-6504, 1984. https://doi.org/10.1029/JC089iC04p06494 Morison, J., Smith, J. D., Seasonal variations in the upper Arctic Ocean at observed at T-3. J. Geophys. Res., 8, 753-756, 1981. https://doi.org/10.1029/GL008i007p00753

-L46: progress → progresses

R: OK

-L46: to → and?

R: OK

- L47: “Leads constitute then” ?

R: OK L49: Add comma after “In addition:

R: OK

-L57: Maybe add Timmermans 2015 too

R: Added: M. L. Timmermans, The impact of stored solar heat on Arctic sea ice growth, Geophys. Res. Lett., 6399-6406, 2015. http://doi.org/10.1002/2015GL064541

-L78: What is meant by lead spacing *below* 500m?

R: Corrected to: smaller than

-Fig 1: What is meant by “ground values”?

R: Corrected to initial temperature and salinity values

-Fig 2: How do you choose what time periods to use (a-f), and what time of the year to use?

R: The time periods were selected to be representative of the variation of the forcing by evenly distributing some time stations along the daily forcing evolution (Figure 2) to characterize the circulation patterns at this time stations. The forcing corresponds to the Julian day 99 of 1992. This would correspond to April. New simulations are done with an incoming short radiation forcing from June.

-L148-149: What is Qm exactly? It just says its “the linear relationship found by Perovich.” But what is the equation?

R: It is a linear relationship between the heat used in bottom melt (y) and the solar heat input to the ocean (x) with slope 0.89 ($y \sim 0.89x$-57). Perovich et al. 2011, indicate that: ”The slope of the line is 0.89, indicating an almost one-to-one increase in bottom melting with solar heat input to the ocean. The relationship holds for observations that vary widely in geographic location, ice concentration and bottom melting. This argues that the primary source of heat for bottom melting of the ice is solar radiation absorbed in areas of open water (Maykut and McPhee, 1995; Perovich and others, 2008).”

-Fig. 6: Add legend for the colors. Please also add time of day/ heat flux in corner of each panel so we don’t have to flip back to Figure 2.

R: This will be included in the figures

-Fig. 7: How are the bulk coordinates and characteristic sizes defined? Average? Note: There appeared to be many grammatical errors/typos, I do not list them all here.

R: Yes, average values. Typos will be corrected in the new version

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