

***Interactive comment on* “Sensitivity of Northern Hemisphere climate to ice-ocean interface heat flux parameterizations” by Xiaoxu Shi et al.**

Anonymous Referee #2

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Review of Sensitivity of Northern Hemisphere climate to ice-ocean interface heat flux parameterizations by Shi et al

This paper presents the impact of various ice-ocean heat flux parameterization on several aspects of the climate of the Northern Hemisphere within four models of increasing complexity. The paper is clearly laid out. I find the analysis ambitious and interesting but would need some clarifications to be satisfied of its robustness and significance. I am also curious as to the chosen focus on this process (among so many others). I suggest major corrections (see below) before the paper can be accepted for publication.

General comments:

1) The fixed depth mixed layer model in the 1D and stand-alone models is a clear sim-

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plification that could affect the key results. For example a thinner mixed layer warms up more under fragmented ice in summer and I expect this to really influence your conclusions. Please discuss and provide additional information. 2) I would like clarification on how the ice-bath model can be implemented in the ice-ocean coupled models. 3) Elaborate on the mechanisms that explain the weakening of the THC. 4) How does the mixed layer look like in the ice-ocean coupled models (i.e. depth, ...) 5) Scales on figures are chosen to essentially show the sign but not so much the magnitude of the differences (i.e, one can tell where ice is thicker or thinner but not by how much). Is that to hide the large differences that cannot be easily explained between model setups? 6) If the mixed layer temperature is so critical in controlling the temperature of the deep waters then it is all the more important to give a convincing description of its evolution and realism 7) A comparison with Tsamados et al (2015) would be useful especially as the author of this study found a small impact of the 3eqBC. Discuss 8) Is the most advanced thicker because of the reduced (even reversed) summer fluxes from the ocean to the ice? Again why is this results not so marked in Tsamados et al (2015) 9) I am really uncertain as to the significance of the impacts found on the ocean and atmosphere. How does this compare to internal variability within the models? I have heard in the past Notz state that sea ice physics does not play a significant role in the climate response (I might be misquoting and apologies if I do) but how do these finding square with this view? 10) Are the results presented reproducible. What if you analysed another 10 years or 100 years period? 11) I wonder why you do not use the same setup to analyse several other sea ice processes (albedo, melt pond, form drag, as per the recipe of Tsamados et al 2015 etc. ...). Is it too good to be true? 12) Not clear how the prescribed atmospheric forcing subdues the impact on AMOC. Please elaborate.

Specific comments:

P1 L18 expand on motivation and justification P1 L20 clarify this paragraph. Which freezing temperature... P1 L27 Here is a good place to expand on the analogy and

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differences between momentum and heat transfer and write the equations and if need be criticise what is missing in either of them. At the moment it is too vague. For example what do you ‘differs from the exchange of momentum” in what way? P2 L42 a local phase P2 L50 , Tsamados et al (2015) P4 L85 together with the freezing equation (1) P4 L 91 2003) and as implemented in CICE by Tsamados et al (2015) P5 L137 fixed mixed layer depth? P6 L141 version? Expand + maybe P6 L150 again default mixed layer of fixed depth. Not realistic, this affects your Tmix and hence your results P6 L153 same issue with salinity should change with mixed layer depth P6 L160 expand P6 L165 The repartition? Rephrase slightly P6 L169 wouldn't it better to have it at 1 deg and run for 100 years? Or is that needed for equilibration? P8 L187 and ice concentration P8 L210 more slowly P10 L221 a smaller ... for a deeper ... P10 L226 are larger ... P10 L238 I am surprised that you needed a 90 years spin-up for a stand-alone sea ice model P13 L257 what do you mean by far-field? Mixed layer? Also typo...at the interface P13 L268 I am not clear on how you can obtain an ice bath situation in the ice-ocean coupled models P13 L269 how significant is this cooling in COSMOS? How does it compare to model internal variability for example? Fig5 why don't you show CICE? P13 L274 doesn't less ice mean more growth in winter (negative feedback) and hence more brine release? P13 L280 the small differences between COSMOS-2eq and COSMOS-3eq35 indicates that once mixed layer allowed to evolve impact of this parameterisation is small? P13 L278 I don't get this explanation P17 L288 where are these regions of deep water formation? P17 L289 I am not sure I follow why thinner means fresher mixed layer. The system rapidly equilibrates to a thinner state and then no reason to have fresher ML P17 L293 could it be because these results are coincidental Fig S2 caption -> departure from

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