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Discussions
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Interactive comment on "Could promontories have restricted sea-glacier penetration into marine embayments during Snow ball Earth events?" *by* Adam J. Campbell et al.

Anonymous Referee #1

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Review for The Cryosphere: *Could promontories have restricted sea-glacier penetration into marine embayments during Snowball Earth events?*

1 General comments

In this study the authors explore how square obstacles modify the flow of floating ice in a channel with the objective of quantifying thin ice regions or ice shadows in which life could have persisted during snow ball Earth. The scientific question is and interest-

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ing one and I believe this study has a potential to give useful insight to the proposed theories of how life could have persisted when oceans were covered by glaciers. Nevertheless, as it is, this manuscript appears to be only a small extension to Campbell et al., 2014. The methods and model used here are identical to Campbell et al., 2014 and the setup for the modeled domain is very similar as well. Specifically, the only modification to the previously studied setup is that before the upstream inflow boundary condition of constant thickness was applied where the channel is narrowed and so its interpretation was a narrow entrance to an embayment. In the current setup the upstream inflow boundary condition is moved further up past the narrowing and so the interpretation of the narrowing inside of the channel is that it is a promontory. This shift of a narrowing further inland and shift of the inflow boundary condition further upstream is what supposedly allows the current ice shadows to possibly persist unlike before. But it seems that it really just comes down to how far away from the narrowing the ocean body lies, if that is the case, it seems that such conclusion could have been reached without further modeling (especially since the ocean is not included in the model). I think for this study to provide some new insight that has not been shown in Campbell et al., 2014 yet, further extension should be included possibly focusing on one of the following questions mentioned in the manuscript, but not elaborated on:

1) It is unclear why authors chose to use a model which has such high minimum thickness requirement, given their main motivation is to answer the question weather life could have persisted in ice shadows of much smaller thickness than allowed by this particular model. There are many other models available that solve the shallow shelf approximation and that allow for much smaller thickness. Using a more suitable model thus could make it possible to answer the question of the aerial extent of zones with light transmission, which the authors express the pity not to be able to answer. Further, it may be worth validating the model with the examples of current climate that are provided in the manuscript. Applying the validated model to known specific embayments from the past and evaluating where life could have persisted would be of great use, thought the later is probably past the scope of this study.

2) In case the main motivation is not to exhaustively answer the questions regarding ice shadows as refugee for life, but to study the flow of floating ice past obstacles, this study should be a bit more comprehensive and less hand wavy. For example, it would be useful and interesting to analyze for which relative size of obstacle to channel width can a model which uses floating ice only be used as an upper bound for sea glacier penetration length (see specific comments). The authors claim but do not show that this model can always be used as an upper bound. Also the discussion of promontory efficiency should be more elaborate and the speculation that series of small promontories could be more efficient than a large one should be modeled and analyzed rather than speculated about.

2 Specific comments

P2_L21-23: A finding from previous work of the authors (Campbell et al., 2014) is used as a motivation for further work. These ice free zones formed on the sides at narrow entrances to embayments were however concluded not to be suitable as refugee: *Sea-glacier-free zones near the channel entrance would grow thick ice locally if they are located in a cold region of the inland sea. We conclude that none of the sea-glacier-free zones observed in our models near the channel entrance would act as refugia, because they are only observed with colder temperatures that would locally generate thick sea-ice.* Is moving the obstacles away from the open ocean rather than keeping them at the entrance where they would not persist because of the closeness of the ocean body the only thing that distinguishes this work from the previous article? If not, some discussion would be useful regarding of why the obstacles considered in this paper could persist while those in the previous one could not. How far in the embayment does the promontory need to be located and is $x = 0.85L$ far in enough to be shielded from the main body of the ocean? For what ratio of L to W is $x = 0.85L$ a suitable choice? I would suggest elaborating on and justifying some of these choices.

P3_L2: Section 2 does not provide theoretical framework, it only provides intuitive explanation of the mechanisms involved.

P3_L20-21 & Fig 2a: It would be useful to show thickness contours superimposed on top of or even instead of the satellite image. From the simple photograph it is not obvious where exactly is the ice shadow and how significant it is.

P3_L26-28 & Fig 2b: This example doesn't seem relevant to this study which only considers floating ice, while this is a grounded ice example.

P4_L17 & P4_L17: For consistency, give values of W and L used in the model and/or express L_p considered in terms of W or L.

P4_L17 & P7_L30-32: Can you show that the following statements are always true? If not, then you cannot speak of an upper bound or conservative approach to be guaranteed by this model unless specifying when exactly it is true:

P4_L17: *This approach is conservative because other wall configurations could increase drag and reduce sea-glacier penetration.*

P7_L30-32: *However, a grounded sea glacier flowing over a promontory would still tend to slow because of the additional basal resistance, and the penetration length L would be decreased, increasing the probability of a refugium farther along the channel.*

I suspect that as $L_p \rightarrow W$ there could be a point when L_g reached by flow through the narrow opening will be smaller than L_g reached by flow over the promontory.

P4_L24-26: This sentence is a bit strange, just say that you solve the Shallow Shelf Approximation in steady state, later you repeat what it is anyways.

P5_L1: By no-flow conditions do the authors mean no-slip? How do you justify this choice in the context of wanting to be conservative in computing L_g as was emphasized before?

P5_L4: Penetration length was previously called L_g not L

P5_L9: Why is the minimum thickness requirement so high? It looks like in your previous study 5 m thick ice was possible. Why not use then a realistic thickness that allows for sufficient light penetration?

P5_L13: typo - through in stead of tjhrough

P5_L13: keep consistent terminology, keep clear when referring to sea ice and when to sea glacier.

P5_L22-26: The discussion on albedo seems a bit out of place given solar radiation is not included.

P5_L28-29: Reformulating the first two sentences may be helpful. First statement is completely generic. Second sentence is just a fragment and it is unclear what it connects to.

P6_L2-3: Does this length scale come out of the equations or is it just by eye comparison?

P6_L12: The naming of this metric as thickness drop is a bit deceiving as it includes both thickness increase and thickness decrease so it is counting the same thing twice. Perhaps a better way to quantify thickness drop would be to compare the thickness past the obstacle to the thickness in the control run. With the metric as it is a hypothetic situation of ice thickness increasing upstream from the obstacle and no change of the flow showing downstream would show as a thickness drop. Using a more general metric would be useful for example to compare thickness drop for the case of narrow entrances to an embayment as in Campbell et al., 2014.

P6_L26-30 & Fig 5b: This paragraph suggest there are two regimes, 10-60 km and 70-100 km, however the figure shows rather smooth transition.

P7Ł9: What happens to the efficiency of promontories as defined here when $L_p \to 0$ and does it make sense?

P7_L11-14: I would suggest this effect of an array of promontories and the effect of spacing between them to be included in this paper for completeness, rather then hypothesizing about it.

P7_L16-18: It seems that this study would be a right place to include this generalization to rectangular geometries.

P8_L2-5: Perhaps mention earlier the reason you keep using 50 m for minimum thickness - this choice was not justified earlier and seemed strange. Also give reasonable values of ice thickness for light transmission to be sufficient for life to persist.

P8_L14: *Modern examples and analogues can be found of both grounded and floating ice that thins as it flows around obstructions* - is not really a 'conclusion' of this study.

Fig 4: flow speed in stead of flow rate

Fig 5: Why is there a sudden drop for the 75m thin ice percentage for $L_p = 100$km? Does the trend continue for higher L_p and if so what is the reason for the reversal of the trend?

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