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Interactive comment on "Modeling the response of Greenland outlet glaciers to global warming using a coupled flowline-plume model" *by* Johanna Beckmann et al.

Anonymous Referee #2

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PAPER SUMMARY

This paper investigates, by means of numerical modelling, the evolution of 12 outlet Greenland glaciers in the next century (2100). The employed numerical models are a 1D flowline glacier model and 1D (ocean) plume model, they are coupled together.

Two aspects represent important limitations of this work: the use of a 1D glacier model for confined glaciers and the methodology followed in forcing and using the 1D coupled plume model. Some of the assumptions of this work are not properly addressed or discussed, as well as some of the consequences on the obtained results.

This paper is clearly written, with the exception of some paragraphs that may lead to

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Discussion paper

some confusion about the experimental setup (e.g. It is not clear if you actually run SICOPOLIS or not. Including a “methods section” may ease the reading).

MAIN COMMENTS

On the plume model:

I think that using the coupled 1D plume model is a great improvement. However some experimental choices limit the validity of this improvement.

At page 5 – line 2 is written that “since the plume model in some cases underestimate... we also scale the simulated melt rate profile by a factor Beta...”.

I have some comments on this: the relation between the plume forcings (temperature, salinity, shelf/tongue slope, subglacial discharge, . . .) and melt rate is given by robust physical equations (Jenkins, 2011; Beckmann et al. 2018). I believe that tuning the obtained melt rates with a multiplying factor waste all the efforts made in using (and coupling) the plume model. What is the need of this sophisticated model if then the computed melt rates are scaled to observed melt rates? Then why not using a simple depth dependent parameterization (e.g. Martin et al., 2011)?

You tuned the computed plume melt rates on present day oberved melt rates. How can you assume that this “present day” scaling will still be valid in 50/100 years? This choice is crucial in terms of providing a robust basal forcing for the glaciers evolution. I think that this assumption should be discussed.

Given the inherent large uncertainties in forcing conditions (both in CTD and in re-analysis, page 8 line 3) what about forcing the plume model with a range of plausible temperature and salinity (from CTD and/or reanalysis) and with a range of subglacial discharges instead of tuning the computed melt rate?

It is not clear why you decide to use reanalysis data at 200, 400 and 700 meters of depth instead of using continous vertical profiles. Moreover, for future simulations you say: “...closest 400m-depth-point neighbor...”. Is this motivated by line 29 to 31 at page

8? I understand this choice but I believe that you shold explain this better, clearly motivating also at page 9.

On the glacier model:

I get why you decide to use a 1D flowline model: however I think that the limitations related to this approach (neglect of processes at the lateral boundaries and of buttressing, which play a crucial role in the evolution of ice masses) are not properly tackled and are mostly addressed by saying that 1D models are the only one available for this kind of study.

This is probably right if you want to model 12 (or more) glaciers at the time, but for single glacier the last few years have seen important improvements in modelling alternatives that have produced results for some glaciers that are also modelled in this work (Chaulet et al., 2012; Seddik et al., 2012; Muresan et al., 2016; Peano et al., 2017; Goelzer et al., 2017). I think that the discussion about 1D model limitations should be expanded.

SPECIFIC COMMENTS

Page 1 – line 15: “factor analysis”. With factor analysis it is usally meant a statistical method like the Empirical Orthogonal Functions (EOFs), in your work you just exclude (one at the time) the different forcings, I would not strictly define this procedure as a factor analysis.

Page 2 – line 5: instead of “global” I would use “atmospheric”

Page 2 – line 4 to 8: I found this paragraph ok, but I would rearrange it a little bit putting the described processes in the same order you are introducing them.

Page 2 – line 6: “marine terminating” instead of “marine- terminating”

Page 2 – line 16: “In order to...” this should be a new paragraph

Page 2 – line 32: “that” is repeated two times

Page 2 – line 35: “Since we are..” this should be a new paragraph

Page 3 – line 1: I would say that the main (and only) improvement consists in using the coupled plume model. I consider the fact of studying more glaciers just as an “extension” of Nick et al. 2013 work. Moreover, from the scaling perspective, are we sure that the considered glaciers are really representative of all the Greenland glaciers? especially given their variety in terms of glaciers and of confining fjords geometries/conditions.

Page 3 – line 4: ok, but submarine melt rate depends also on the geometrical features of the tongue (shape, slope,...)

Page 3 – line 9 to 11: Maybe you can think about shortly describing how the scaling works.

Page 5 – line 1 to 5: I would expand the plume paragraph since it is the real innovative part of this study. Maybe a short introduction of the basic physics and equations. Otherwise is not clear what do you mean with the E entraiment parameter unless looking at Beckmann et al. (2018) (or already knowing what you are talking about).

Page 5 – line 17: “to the vertical mass balance term B”, add the equation number

Page 5 – line 18 to 20: I imagine that when the plume detaches the melt rate is set to zero but this is not written explicitly. Is this the case?

Page 5 – line 21: this part confused me. “...off-line using the ice sheet model” which one? This is the first time that you mention the use of an ice sheet model. Later it appears that it is SICOPOLIS.(see comment to page 6 – line 15 to 25)

Page 6 – line 1: “did we” “we did”. Could you explain better in what this upscaling consists and how it works?

Page 6 – line 2: it would add more clarity defining what is meant with “melting to calving ratio”

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Page 6 – line 12: just a detail: I would number the figures in the order of appeareance in the manuscript

Page 6 – line 15 to 25: From here it looks you actually run the ice sheet model, is this correct? (look comment to page 10 – line 6).I suggest to introduce explicitly the fact that you have run SICOPOLIS.

Page 6 – line 23,24: "...is assigned to the closest glacier within a maximum of 50 km". This is an important approximation since is related to the plume forcing, however is not properly discussed, expecially in terms of uncertainty in the obtained results.

Page 6 – line 27,28: "neglect the effect of grounding line retreat".As above, this represents another important assumption but it is not properly discussed.

Page 8 – line 12: "...presence of sills in the fjord...in the vicinity of the glacier front." I would explain why is that after this line, instead than explaining it later for the continental shelf (at page 8 – line 24 to 30).

Page 9 – line 16: could you provide a table with the prescribed submarine melt rate and the range of values for the dynamic parameters? (maybe in the supplementary)

Page 9 – line 25: with "...only factors.." do you mean that since temperature and salinity are "held constant" (thus not changing) their contribution in impacting melt rates is constant in comparison to the impacts due to a varying grounding line depth and tongue shape/slope? I suggest to reformulate this paragraph

Page 9 – line 29 "...is close to equilibrium state.." what do you mean with equilibrium? Later you speak about stable state. Do you mean steady? I would argue that currently Greenland glaciers are definitely not in a steady condition.

Page 10 – line 5: "...each glacier 3.4..." something is missing between glacier and 3.4

Page 10 – line 6: "...glacier individually 3.3..." something is missing between individually and 3.3

Page 10 – line 6: Here it is not clear if you took the data from Calov et al. 2018 or if you actually run the model

Page 10 – line 22,24: this part about the interplay between melting, calving and bedrock is interesting. I would add few more details.

Page 11 – line 6: a space is missing before “Enderlin”

Page 11 – line 15: “model versions” do you mean the the spin-up ensemble?

Page 11 – line 16: why not changing also the subglacial discharge? It is such an important forcing for the plume and comes from several approximations (fixed grounding line and closest neighboring approach).

Page 11 – line 17: at page 10 (line 8 to 10) is said that also the unforced model drift is calculated. Then this drift is removed by subtracting it from calculated values. This implies that a linear behaviour for glaciers is assumed. I think that this should be properly discussed.

Page 11 – line 25-27: as above, this implies linearity but glaciers are definitely not linear systems.This issue is just slightly addressed at page 12 – line 4. Page 12 – line 21,22: you attribute the source of uncertainty to Beta, this comes from the fact that Beta is responsible for the imposed melt rate (through the tuning procedure). However Beta is just a model parameter, I think that avoiding the use of Beta (as suggested in the main comments) could also improve this part of the work, it will allow you to relate uncertainties to physical quantities.

Page 13 – line 18 to 20: something is wrong here, an entire sentence is repeated.

Page 13 – line 33: same as above. Your results are not affected by CTD/reanalysys temperature and salinity because the Beta tuning incorporates all the uncertainties.

Page 13 – line 35: “...observational constraints on submarine melt...” as explained in the main comments I think that we should rely on melting formulation as less as

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possible dependent from a tuning on observations, especially for future projections.

Page 14 – line 4: “and” repeated two times

Page 14 – line 7: “our” repeated two times

Figure 3(a): I think that using white dots is a bit unfortunate, also the red star is not very visible.

Figure 11: “from” instead of “vom”

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