

Interactive comment on “Boundary layer models for calving marine outlet glaciers” by Christian Schoof et al.

Anonymous Referee #2

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This manuscript extends the boundary layer theory of Schoof (2007) to the case for calving marine outlet glaciers. Lateral drag from sidewalls provides another constraint on stable grounding line positions for confined outlet glaciers; the authors show that steady grounding line positions can be obtained on upward sloping beds with this effect considered. Since the length of any floating ice shelf affects the amount of lateral drag, the authors identify calving as an important mechanism and derive grounding line flux as a function of relevant calving parameters for two calving laws. These are the CD model and one for calving at flotation.

The work presented is an extension of Schoof (2007), taking the analytical model further. While it is already known that sidewall drag influences grounding line positions (e.g. numerical solutions by Gudmundsson) a boundary layer formulation such as this one has not been written down before and this paper therefore provides a worthwhile

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extension to previous work. Furthermore, the authors provide the code, which will allow others to analyse effects with different calving laws.

I have not gone through every mathematical detail, but it certainly appears that the authors have been thorough in their approach. Most of the corrections I suggest below are relatively minor. The main thing I would like is a bit more discussion surrounding the background to the calving laws and why these ones were chosen. Perhaps introduce a subsection into the model section describing the calving laws and their background in a bit more detail and in a general context. Furthermore, I think it would be useful to have some discussion towards the end of the paper about how, qualitatively, you expect processes to be affected by e.g. different choice of calving laws, which include different mechanisms, and basal melt (exclusion of it mentioned line 14, section 2). Perhaps insert a separate discussion and conclusion. This would help make the paper more accessible to a general reader who is interested in what the key parameters really are.

I would also really appreciate a table of variables being included. There were several points in the manuscript where this would have been useful to reference as so many different variables are used.

Minor comments

- **Abstract, line 3-4** Re-phrase as confusing ordering at the moment. I suggest 'The length of any floating ice shelf present also affects the lateral drag, hence calving is an important process'.
- **Abstract, line 9** 'increasing depth to bedrock' - better at this point to refer to as 'retrograde bed slope' as this how people usually think of it?
- **Intro, line 19-23** Sentence far too long. Insert full stop after first part. i.e. '...that can alter the flux-to-bedrock-depth relationship. These include...'

- **Intro, line 15 onwards** Can you insert a sentence or two justifying choosing these two calving laws over others? Or say you'll do this in model description section and add discussion in there as mentioned above.
- **page 3, line 10** Why using B, rather than more standard choice of A for Glen coefficient?
- **page 3, line 24** Can you extend discussion here with a couple of sentences about limitations of this parameterisation?
- **Figure 1** Table of variables would certainly help reader when looking at this figure. Also, for a grounded terminus shouldn't inequality for h actually read $h_f \leq h_c$ as still grounded if calving happens *at* flotation. Alternatively, perhaps you could insert a third lower diagram illustrating $h_f = h_c = h_g$ since this could then be used as a reference when describing the second calving law you use (page 5, lines 1-2)?
- **Figure 2** Grey shaded regions do not show at all when printed. Make darker.
- **Figure 2** Insert space 'Panel (b)' in caption
- **equation 1h** I think this is the first time d_w is used but you do not explicitly state that it is water depth. At least have in table.
- **equations 1h/1i** Can you line these up properly so 'at and if' are in line (and do similarly at several other points in paper).
- **page 7, lines 1-12** As mentioned above I think you want more discussion and context here. Given the length of this section I think it would also be helpful to split section 2 up into a couple of subsections e.g. 'ice flow model', 'calving laws'. This would help remind reader where to reference back to when thinking about the different parameterisations later.

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- **section 3.1** a few more words reminding us what equations are e.g. page 8 line 5 'if $rh \geq b$ i.e. flotation.
- **page 9, line 9** '...glacier terminus, *which are* of the form'
- **page 9, line 14** change to 'monotonically downward'
- **page 11, line 24ish** confusing now having 'B' as a rescaled b and having the \bar{B} etc earlier for Glen. Preferably change Glen to A but at least introduce table.
- **page 12, line 27** Physical interpretation of λ being small?
- **page 13, line 4-8** Long sentence, difficult to take in. Split up.
- **page 14, line 1-2** 'on the then-redundant parameter Λ to write alternatively' -> 'on the now-redundant parameter Λ to simplify the expression to'
- **page 14, line 25** 'the CD model produces the same result as..., which is reassuring'.
- **page 17, eqn 11** insert fullstop.
- **page 22, line 13ish** Sentence between the two equations (line numbering gone askew here) should read 'Integrating and applying the boundary condition shows that extensional stress...'
- **page 22, eqn 23** insert fullstop.
- **page 25, line 16** You seem to sometimes talk in terms of the rescaled B (like here) and at other points in terms of depth to bedrock b (e.g. line 20). I would stick to the variable b ?

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- **page 26, line 16 onwards** Yes, this and the following discussion are good points but then the paper ends rather suddenly. Could you put this into a bit more context and suggest extensions/alternative approaches.
- **page 27, line 8** 'may be possible at least in principle' - awkward wording.
- **page 27, line 12** 'At issue' change to 'An important issue'
- **page 28, line 13** 'meaning a functional relationship' change to 'giving a functional relationship'

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