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

Anonymous Referee #1

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After the boundary layer model for marine ice sheets, Christian Schoof and co-authors present in this paper an extension of the boundary layer model by investigating two calving laws, i.e., the CD model due to Nick et al; Benn et al., and one simple model based on calving at flotation. They find that for unbuttressed ice sheets, the flux according to the CD model can decrease with increasing water depth at the grounding line, which is counterintuitive with respect to the stability criterion that was proposed in Schoof (2007). This is the first rigorous assessment of the widely used calving model and allows for a better comprehension of its behaviour. Furthermore, it suggests that the fact that steady-state grounding line positions can be obtained on retrograde slopes are not necessarily due to an inland narrowing of the channel, but also due to the calving law.

The paper is quite lengthy but gives (in my opinion) a rigorous mathematical derivation

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Discussion paper

of the models and the boundary layer model derived from it. However, while the authors repeatedly state that they take the CD model at face value, they should - when presenting that model - demonstrate in a comprehensive way what the pros and cons of the model are. Moreover, as the CD model (and derivatives) are widely used, some more criticism and lines for improvement are in order. In that respect, Figure 3 is quite enlightening showing that grounding line positions for the CD model show this rather non-intuitive characteristic (as a function of accumulation rate).

Another important contribution of this work is that it lays out a basis for further analysis of new calving laws by adapting the code available in the supplementary section (see discussion and conclusions). This should also be mentioned in the abstract.

Throughout the paper, the authors investigate the case of a downward-sloping bed (prograde slope). However, as shown in Schoof (2007), retrograde (upward-sloping) beds do not allow for steady-state grounding line positions in absence of buttressing. Gudmundsson et al (2013) demonstrated that stable steady states on such slopes may occur due to ice shelf buttressing. Also in Greenland, where the CD calving law has been mostly applied, retrograde slopes occur. Therefore, it would be interesting not to limit the analysis to downward sloping beds, but to investigate (albeit briefly) the behaviour of the CD calving law in regions with overdeepenings.

Detailed remarks

Page 2, line 6: grounding line

Page 3, line 3: commas between references

Page 2, line 7: assumed constant in time

Page 4, line 4: even when neither of the two limits

Page 4: line 5-7: Given that the use of this model is essential throughout the analysis, it would be good to bring in some more solid arguments in favour its use. Stating that the simplification works reasonable well and that you analyse the model at face value

is somehow weak.

Page 9: bottom equation: [x] instead of]x]

Page 16, line 12: converges to the one (or state flux conditions instead)

Page 21, line 7: bigger -> larger

Page 22, line 18: formula -> eq.

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