Review of Barnett et al. (2025) ‘Simulating the Holocene evolution of Ryder Glacier, North Greenland’

Summary
This study presents the results of an ensemble of model runs of Ryder Glacier in northern Greenland across the entirety of the Holocene, aiming to explore the drivers of its early-Holocene retreat and late-Holocene re-advance as derived from geomorphological and sedimentary records. The paper shows that the initial retreat of the glacier at the start of the Holocene was almost certainly driven by changes in SMB – probably both warming temperatures and reduced precipitation – whereas later retreat was chiefly due to oceanic forcing. Crucially, the paper demonstrates that the late-Holocene re-advance of the glacier can only be explained by changes in both atmospheric and oceanic conditions, and that the geometry of Sherard Osborn Fjord exerts a major local control on the glacier’s behaviour.

I think this is a good, well-structured paper that convincingly addresses its titular subject. The ensemble of simulations captures the observed evolution of the glacier and the authors provide a thorough discussion of their findings, including sensible explanations for why the model does or doesn’t match well with different observations. The figures are also well thought-out and clear, which greatly helps the reader understand what is happening.

I do, however, have a couple of major concerns that I would like to see addressed before publication with regards to the modelling strategy. This may be as simple as adding a few sentences explaining some choices the authors made, but as it stands, I don’t fully comprehend why the authors chose to use the Blatter-Pattyn approximation when this is a situation that cries out for a full-Stokes treatment, nor how they can be sure their reference value of their calving parameter is correct for this particular glacier. More details are below and I hope it is a straightforward case of adding a little bit more explanation, rather than something more complicated!

Page and line numbers refer to those in the clean version of the submitted manuscript.

Major Comments

- Choice of model: This study is very heavily focused on correctly modelling the grounding line and retreat of Ryder Glacier. Why then did the authors choose to use the Blatter-Pattyn approximation of Stokes, which is not valid at the grounding line (not in hydrostatic equilibrium), rather than a full-Stokes formulation? At the very least, there needs to be some acknowledgement in the paper that this might be a problem or limitation.
- Sigma_max values: The authors use a reference value of sigma_max, the key parameter in their calving law, based on studies at neighbouring Petermann Glacier. However, sigma_max should be calibrated to each domain, as the ‘correct’ value for one glacier may or may not be the same as for another one. Now, Petermann and Ryder are reasonably similar, so it might well be fine, but they’re not the same. And Ryder during the HTM or the YD or similar is definitely very different to Ryder now. I think the authors need to show that 300 kPa works as a reference value by showing that it reproduces observed contemporary behaviour at Ryder at the very least, before being able to assume that it’s a reasonable choice. Or some more elaborate justification needs to be added beyond ‘it works at Petermann’.
- Language: The authors will notice that a lot of my minor comments are to do with slightly infelicitous phrasings, typos and poor word choices, to the extent that I’m pointing it out here as a problem (I will also say that I only noted down the ones that really bothered me – I might recommend a thorough re-read before submitting the corrected version to make sure there aren’t any others). I admit that I’m pickier about this than some, but there are quite a few cases where I found it impeded my understanding of the point the authors were trying to make. Really, I just want to highlight that it makes the entire review process much smoother if the authors pick these up before submitting the paper (and means reviewers will be better able to engage with the substantive points of the paper if they’re not having to spend time puzzling over what the paper is actually saying).

Minor Comments

- p.1, l.17: ‘analogies’, not ‘analogous’

- p.2, l.31: ‘the ice sheet’s’
- p.2, l.36: ‘affect’
- p.4, l.64: ‘Innuitian’
- p.4, l.77: Remove the ‘s on the end of Glacier
- p.6, l.112: Blatter-Pattyn isn’t valid at grounding lines, though, and this is a study largely focused on the grounding line of Ryder Glacier. This maybe seems a curious choice of approximation – why not use a full-Stokes setup?
- p.6, l.117: ‘extent’ not ‘extend’
- p.6, l.119: OK, in Figure 2 it’s ‘Saint George Fjord’, here it’s ‘Saint Georges Fjord’ (and possibly should be ‘Saint George’s Fjord’). Which one is correct? Later in the paper, it’s consistently ‘St George Fjord’, so I assume it’s that one. Just make sure to be consistent.
- p.6, l.119: ‘effect’, not ‘affect’
- Section 3.1: Maybe I missed it, but I can’t see where the authors state what surface topography is being used to initialise the model? I assume it’s also BedMachine (the caption to Figure 4 and Section 3.5 bear this out), but it should be stated clearly here too.
- p.7, l.154: Some confusion on dates here. If the simulations start in 12,500 BP, then today is year 0 and the simulations run for at most 12,500 years. If the simulations start in 12,500 BC, then running to AD 2000 makes a total of 14,500 years. Either way, I’m not quite sure how a total runtime of 12,550 years is achieved with the dates as written. Either put both dates in AD/BC (or CE/BCE, it’s the same thing), or define when ‘P’ is in BP so that it’s clear when the simulations actually start and how long they run for.
- p.9, l.198: Maybe put ‘temperature and precipitation’ in brackets to make the sentence a bit easier to read? Also, ‘an 1850-2000 mean’ here and on the next line.
- Figure 4: Might it be possible to extend the x-axis slightly farther (to 150, say)? As it stands, the YD glacier cross-section butts up right against the chart edge, which doesn’t look great.
- p.10, l.213: Yes, fair enough, I’m sure it would be lower, but is there any justification for that reduced deepmelt parameter beyond a) it works and b) it’s lower? It’s the spin-up, it probably doesn’t matter that much, but there maybe needs to be a bit more effort here to justify the value. I assume it’s the lowest value of melt recorded in the observations and modelling, following Section 3.3, but it bears restating clearly here why the choice was made.
- p.11, l.233: I think ‘where’ is meant to be ‘were’, and the comma immediately before it should be deleted, or the sentence doesn’t make much sense.
- p.11, l.230-237: Yes, but Petermann isn’t Ryder, so a sigma_max value that works for Petermann may or may not be in any way correct for Ryder. Especially not Ryder at a different time in a fundamentally different set of climate conditions. Did the authors check that 300 kPa was a sensible reference value for Ryder by, for example, running some contemporary simulations to show the model reproduces observed behaviour at the glacier well with that value?
- p.12, l.253: ‘comparison with’ not ‘comparison on’
- p.12, l.263: ‘retreat’, not ‘retreating’
- p.17, l.310: ‘sheer’
- p.17, l.321: ‘increased’
- p.17, l.328: Should the second simulation be Low/High: *Calving Low*?
- p.17, l.330: I don’t think you mean ‘perceived’ here. It’s not a case of your perception being that the model has advanced; it’s a model, either it’s advanced or it hasn’t. I might choose a different word.
- Figure 9 caption: ‘set of’ and ‘used’
- p.18, l.371: ‘For using’ should probably just be ‘For’?
- p.19, l.373: ‘a final ice margin’
- Figure 10 caption: ‘set of’ and ‘used’
- p.21, l.386: Just ‘Ryder Glacier’, not ‘the Ryder Glacier’
- p.21, l.390: I’m not sure ‘invoke’ is the right word here. I think the authors mean ‘cause’, ‘lead to’, ‘result in’ or another synonym, of which ‘invoke’ is not one
- p.21, l.392-394: Delete the semicolon, replace it with a comma, and then replace ‘that ranges’ with ‘ranging’
- p.21, l.395-401: The comparison to Cuzzone et al. (2022) is nice, but at the same time I could summarise this section as ‘two different glaciers in very different settings exposed to very different environmental conditions behave differently’, which isn’t much of a surprise. I would suggest

removing it, or reducing it to a sentence along the lines of ‘we expect these two glaciers to be different and they are’, as I don’t think it’s really adding much to the discussion as written.

- p.21, l.407: Another interesting vocabulary choice: ‘alluding to’ is not the phrase required here; ‘hinting at’ may be more appropriate.
- p.21, l.412: ‘in Baffin Bay and the Labrador Sea’
- p.21, l.417: ‘ensuring the survival’
- p.22, l.427: ‘invoked’ was correctly used at l.414, but here it’s not the right word again. It’s not a synonym for ‘cause’ or similar, which is the sense intended here (if I’m parsing the sentence correctly).
- p.22, l.441: ‘ostracod’
- p.23, l.452-453: I’m not sure I quite understand this as written. I think it’s just a case of removing the comma after ‘latter’, but it may be the authors intended something else here.
- p.23, l.468-473: I may have missed some subtlety here, but why would anyone expect the inclusion or not of calving and ocean melt to have any effect on land-based ice in the first place? I would rephrase this to just talk about the similarity between this study and the Cuzzone paper with regards to the effect of including calving and ocean melt on the marine-terminating margins. Or the authors need to add some text explaining why either process would affect ice not touching the ocean, thus making the comparison worthwhile, which may be harder.
- p.23, l.477: ‘inland’, not ‘in land’, is I think what is meant?
- p.23, l.479-480: ‘where retreat as calving cliff face produced exaggerated retreat’ is a phrase I’m not able to draw much sense from, to the extent that I’m entirely sure what to suggest as an alternative phrasing. Please have a look and rephrase.
- p.23, l.482: ‘aid’, not ‘aide’ (aide is the noun form. Or French)
- p.23, l.484: Delete ‘the’ before ‘Ryder’s’
- p.24, l.486: Strictly speaking, ‘protracted’ does just mean ‘lengthy’, but it always carries a negative connotation (one can have ‘a protracted meeting’, but not ‘a protracted party’ unless one is really not enjoying oneself), which doesn’t quite work here – a protracted timescale would be one that was unusually long compared to what was normal, whereas here the sense intended is just ‘a long time’ for something that is actually a long time. I’d replace it with ‘lengthy’ or ‘extended’
- p.24, l.489: ‘it’s very likely’
- p.24, l.494: ‘the ice tongue’
- p.24, l.500: ‘to re-form’
- p.24, l.503: ‘stress’ – ‘findings’ is plural
- p.24, l.504: nope, that’s not a semicolon – it should just be a comma
- p.24, l.518: ‘implemented in’
- p.25, l.523: ‘sit’ – there are two things there
- p.25, l.527: ‘with the latter able to weaken the floating’
- p.25, l.532: ‘that is also shielded from warm AW by a bathymetric high’
- p.25, l.535-536: ‘that will lead to a greater transfer of heat from the ocean to the glacier’
- p.25, l.536-537: ‘set to play’
- p.25, l.539: ‘relatively’
- p.25, l.548: ‘that resembles that of the mid-Holocene’
- p.26, l.555: Delete either ‘at’ or ‘with’
- p.26, l.557-558: ‘The retreat...is’
- p.26, l.560-563: See my earlier comment. Finding that the terrestrial margin is insensitive to what’s going on in the ocean is not really a significant finding. I would just focus this point on the terrestrial margin’s position being narrowly linked to SMB
- p.26, l.564: ‘the marine margin’
- Figure A1: What are (a) and (b) referring to in the caption? There’s only one panel….