Review of Humbert et al. 'Precursor of disintegration of Greenland's largest floating ice tongue'

General comments

The authors combine remotely sensed datasets and numerical modelling experiments to assess the stability of the 79N Glacier ice tongue. Based on an observed switch in the calving style in a region of the terminus between two pinning points, they conclude that the tongue appears to be primed for an imminent disintegration. Using diagnostic modelling experiments, they go on to assess the impact on ice discharge, of removing this near terminus region, and regions of the ice tongue further upstream. From this they find the near terminus region would not increase discharge by much, but that further removal could increase discharge by 8%. This paper is a useful and timely contribution, presenting the evidence for the potential destabilisation of the 79N Glacier ice tongue, and more broadly assessing the impact buttressed ice shelves have on increased ice discharge and sea level rise. In general the paper is well structured and written and the figures are appropriate. I have a couple of general comments outlined below prior to publication, followed by some specific comments line by line.

I read the paper in the order it is written and at several points found it difficult to understand the results presented because the methods are hidden in the appendices. I would suggest moving the methods into the main text, either as a dedicated methods section or as subsections to your observational results and modelling results sections. If the methods are not moved to the main text, at the very least there needs to be better signposting, or summary methods sentences at the start of the results sections to make it clear what data/experiments were used to make statements in the results. I've included some suggestions in the specific comments below. The paragraph at the beginning of Section 3 is very clear, so perhaps a similar paragraph at the beginning of Section 2 (stating the type/date range of imagery used) would be sufficient.

The modelling experiments are well thought out and the second experiment was a useful addition to the first that just removed the region that appears to be about to collapse. However, I did wonder if a third experiment would be interesting, where you remove the entire ice tongue to see what the total/maximum impact of ice tongue loss would be. This would be particularly interesting given that you show that the regions close to the grounding line appear highly buttressed.

Specific comments

Line 3: I think the link to sea level rise in the future due to ice tongue disintegration could be more convincing here

Line 5: Specify what 'recent changes'

Line 6: Perhaps state when these cracks progress further upstream compared to 2010.

Line 17: Rephrase 'since more than a decade', perhaps 'In the last decade, mass loss has reached northern Greenland...'

Line 21: Would be useful to refer to Figure 1 when you state the ice front is in contact with the ice rises. The second half of this sentence is a little vague, can the statement be more convincing, along the lines of 'the impact of ice rises on stabilising the ice front. Consider changing 'object' to 'location'

Line 23: You mention basal melting as a mass loss mechanism but do not then discuss it elsewhere in the Introduction. While I appreciate the focus is on calving, I think at least a sentence on melt

rates beneath the ice tongue would be useful, making reference to previous work e.g. Wilson et al., 2017

Line 26: I think floating ice sheet should instead be 'ice shelf/tongue'

Lines 27-31: Given that a number of ice tongues in northern Greenland have recently disintegrated (ZI), or calved large tabular icebergs (Petermann Gl.), it would be good to include some context for the calving style you are referring to here, and how this compares/contrasts with calving elsewhere in Greenland from floating ice shelves/ice tongues.

line 35: Given that Zacharias Isbrae is often also referred to as Zachariae Isstrom it would be useful to include both names here. Also state the time period (decade) over which the ice tongue was lost.

Line 39: Add in the size/length of the ice tongue, either here of line 20 where you state it is the largest ice tongue.

Line 42: Re-state what style of calving that was. Also where is the evidence for the style of calving in the 1980s, from satellite imagery? that was examined as part of this study? It needs a reference if not.

Lines 47-50: Given that you calculate buttressing, and discuss this when conducting your modelling experiments, it would be nice to include a sentence here to state how it impacts upstream flow.

Lines 51-54: Before launching into the summary of the methods and imagery used, I think there should be a clearer statement of the research aim and justification. It would also be useful to state the time periods over which the study is conducted, e.g. datasets used for xx to xx

Figure 1: Most people may know where in Greenland 79NG is, but I think an inset map of greenland and a box/marker showing the study region would be useful. This inset map could also include the modelling domain used too. Also, include the time period of the crack formations A-F so it is clear when the 'oldest' and 'newest' refer to. Consider adding 'IR1' and 'IR2' labels to panel a) as well.

Figure 2: It's quite difficult to see the calving fronts in panels (a) and (b), can you increase the contrast of these images? and perhaps also digitise the calving fronts so that it is obvious where they are.

Line 55: Given that the material on the modelling simulations is all in the appendix, I think a clear summary sentence on the experimental design and purpose of these experiments is needed here.

Lines 68-69: It is not clear to me where the evidence for the statement that the tongue type calving style has been present for 28 years. It was also not clear from Appendix A1 what the date range of imagery that was used in the study. Did you examine imagery from 1975 in order to make this statement? Please clarify, both here, and in Appendix A1 (see later comment on this).

Line 71: Can you instead provide a summary/overarching statement about how the the calving front has changed, instead of using 'tremendously'

Figure 3: Some minor suggestions: add scale bars to (a) and (d), or state in the caption they have the same scales as (b) and (c). (b) state the time period of the surface elevation data. Change to 'photo from the Canon camera'

Line 76: As mentioned above, where does the evidence for tongue-type calving in 1975 come from?

Figure 4: It would be useful to show this track on a study figure or inset map so it is clear where it is located.

Line 82: Restate here when it was formerly grounded and when 'recent past' refers to.

Line 87: State the tidal range here, including references, or refer to the Appendix section where it is mentioned.

Line 89: Consider making Fig.C2 a panel of Fig.1, it would be nice to see the location of the profiles in the main text.

Line 89: The second half of this sentence needs rephrasing for clarity.

Line 90, Figure 5: As you talk about radar profiles for 2021 and 2013 in this section, I think it would be useful if both appear in the main text rather than the appendix. Why not add a second panel to Fig.5 with the 2013 radargram?

Line 94: Can you include a measurement of how much crack A has widened?

Line 96: I don't find 'intersect the ice entirely' to be particularly clear, consider rephrasing, perhaps 'propagate through the full ice depth'

Line 99: see previous comment related to 'intersect the ice shelf'

Line 106: What evidence is this statement based on? the timing of lake formation/drainage did not coincide with changes in the cracks? Please expand on this.

Line 108: State why this eastern part is 'interesting'

Lines 110-113: I wonder if these sentences on crack modes would be better placed in the introduction when you first use the term 'tongue-type calving style'

Lines 127-128: Rephrase these sentences for clarity.

Line 145: Explain the characteristics of a 'kind of bridge'. I appreciate you do this on line 148, but I think it would be better to explain the ice bridge at 79NG first, and then refer to the Wilkins Ice Shelf.

Line 155: Restate the time over which the calving style changed.

Line 158: I'm not sure how useful this comparison to Wilkins Ice Shelf is, given that they have different settings, is there anything to suggest they would be similar in size? Perhaps make it clear why this comparison is necessary. Also, refer to a Figure or the location of glacier draining into the ice bridge from the south on Line 160.

Line 170: Given that the methods are in the Appendices, please add a sentence to the main text that presents how your model replicates observations, e.g. the misfit between observed and modelled velocities after the inversion or how the grounding line flux calculated by the model compares to published estimates of grounding line flux/ice discharge.

Line 175: It seems that the impact of removing the ice tongue from the ice rises, and even removing it half way up the fjord, was relatively small, <10% increase in ice discharge. Therefore I'm wondering why you stopped there, and didn't follow up with a third potentially 'high-end' scenario in which you remove the entire ice tongue. This would be particularly interesting as it seems from your buttressing maps that the region closest to the grounding line is highly buttressed. This would be complementary to the impact of removing sections of ice tongues/ice shelves close to the grounding line in other regions (e.g. Petermann Glacier Hill et al., 2018 and Larsen C (Mitcham et al., 2022).

Line 179: Again, as the methods are hidden in the Appendix (see major comment), there needs to be summary statements or better signposting in the main text. Here for example, it would be better to say something along the lines of 'We calculated ice shelf buttressing following the method presented in (ref) and found that...'

Line 180: Explain the term 'overbuttressed'

Lines 193-194: Re-state the 14 month period that this 15% area was lost, and the decade over which it as remained in this 'intermediate state'.

Figure 9: (a) It looks like the velocities near the northern part of the calving front go off the bottom of the scale? Are they zero here? or excluded from your domain? In (b) can you somehow highlight (e.g. polygon, shading, arrow) the region that has been removed during the experiment. Same for (c). Then refer to this Figure/panels when presenting the experiments in the main text. Panels (d-f): white is not a good colour for the highly buttressed regions given that the background is white, consider changing the color bar. In the caption, state what a value of 2 represents.

Lines 201-202: Is there a reference for this statement that the tongue of ZI was highly heterogeneous in the 1980s.

Line 204: It is a little bit confusing to refer to locations (e.g. 'northeast part') of ZI's ice tongue without referring to a figure. Consider labelling these locations on existing figure or creating a new figure/panel on existing figure (e.g. Fig.1).

Line 213: Can an 8% increase in ice discharge be considered a 'significant contribution to sea level rise'? If so, some additional context/justification is needed. Consider referring to other examples of observed or modelled ice tongue calving/collapse elsewhere in Greenland and Antarctica.

Line 213: Change 'is already' to 'would' because the calving in Fig.9c,f has not happened yet.

Line 217: What about air temperature changes between 1990 and 2020? Also in the following sentence, make a clearer link between thinning at the calving front and the potential for collapse in the near-future.

Line 217-218: I think it would be useful to expand on this discussion about thinning of the ice tongue near the calving front into the context of the rest of the ice tongue, i.e. the oceanic forcing is important for high rates of basal melting elsewhere on the ice tongue and thus responsible for the observed thinning (e.g. Mayer et al., 2018).

Line 227: Can you obtain measurements of basal melt rates to clarify this statement 'presumably small'

Line 243: You use a number of different satellite senors and I think it would be useful to include a table somewhere of the dates and sensors used. Also include the full time period for which your study covers.

Line 278: Why not include Figure C2 in Appendix A? Same for other figures in Appendix C and D.

Line 284: 'usually better' by how much?

Line 311: It looks like the resolution is also refined based on distance to the grounding line and calving front? If this is the case it would be worth mentioning.

Lines 329-330: Is it a common approach to assume the ice rigidity is constant over the grounded areas? Perhaps refer to other studies using this approach/temperature value.

Line 338: Rather than state excellent agreement, can you instead include the final value of the cost function, or some measure of the misfit between observed and modelled velocities.

Technical comments

Line 117: Change 'figure' to 'Fig 6c'

Line 125: Add 'the' before 'direction'

Line 130: 'at the end' instead of 'in the end'

Line 136: 'Remarkably there are'

Line 156: Delete 'with changing'

Figure 6: (d), there are no arrows shown in light yellow (<10) so this could be removed from the legend.

Line 188: Change 'featured' to 'features'

Line 307: 'mosaic' spelling

References

Hill, E.A., Gudmundsson, G.H., Carr, J.R. and Stokes, C.R., 2018. Velocity response of Petermann Glacier, northwest Greenland, to past and future calving events. The Cryosphere, 12(12), pp.3907-3921.

Mayer, C., Schaffer, J., Hattermann, T., Floricioiu, D., Krieger, L., Dodd, P.A., Kanzow, T., Licciulli, C. and Schannwell, C., 2018. Large ice loss variability at Nioghalvfjerdsfjorden glacier, northeast-Greenland. Nature communications, 9(1), pp.1-11.

Mitcham, T., Gudmundsson, G.H. and Bamber, J.L., 2022. The instantaneous impact of calving and thinning on the Larsen C Ice Shelf. The Cryosphere, 16(3), pp.883-901.

Wilson, N., Straneo, F. and Heimbach, P., 2017. Satellite-derived submarine melt rates and mass balance (2011–2015) for Greenland's largest remaining ice tongues. The Cryosphere, 11(6), pp.2773-2782.