

Prof. Marzeion,

We have completed revisions and responses to the second round of review. We appreciate the reviewers' willingness to do a second round, as well as your input. In addition to addressing specific and technical comments, we worked through the manuscript with an eye towards improving overall readability. We regret if our initial responses and revisions didn't adequately address these concerns – we agree there were still some areas to improve clarity. We think our overall structuring (which admittedly differs from an explicit methods-results-discussion format) can work well for integrating a theoretical framework with data analysis as done here – that being said, we acknowledge this choice requires special attention to readability to avoid losing the reader. So we appreciate the nudge to revisit these issues.

Our changes are detailed in the response document, but in brief, we have clarified our structure “roadmap” closing the introduction; revisited figure captions to minimize redundancy with text, and have reviewed instances of inline equations and expressions for clarity, fleshing out some expressions with text where necessary.

We have sought to address the spirit of the concerns raised by reviewer #2, which we hope have improved overall readability. On some matters we've retained our preferred style, such as the use of inline equations, but have reviewed these for clarity. On these matters we believe we are within the bounds of previous publications in TC, but of course defer if we've missed any specific house rules here.

Finally, we have responded to the more technical points raised by both reviewers, which we also think improve clarity. In particular, we have added some annotation to Fig. 9 which we think helps with visualizing uncertainty. Reviewer 2 also highlighted an issue related to (sub)-regional variations. We recognize that readers will be interested in this information, so have added Table A2 to the appendix, which presents our key results categorized by RGI second-order region, along with a brief description of regional variations in Appendix A.

We hope these revisions address the remaining issues and we look forward to your assessment. Thank you for your consideration.

On behalf of the authors,

Responses to Reviewer 1

Green = reviewer comments, black = responses

We thank the reviewer for their constructive second review and for confirming that our revisions have adequately addressed their concerns. We appreciate their attention to detail in identifying the remaining minor issues, and we have addressed each of their specific comments. We are grateful for their contribution to improving the clarity and accuracy of the manuscript! We have responded with comments interspersed into their review.

The authors have done a very nice job of addressing my previous revision. I still have a few very minor comments, but otherwise I feel that this paper is ready for publication.

We are grateful to the reviewer for their time and contributions in providing a second review.

L67: Figure 1a refers to a temperature change as Δt and not T' . I think they are referring to the same thing?

Thanks. The reviewer is correct that these both refer to temperature change, but our notation in the figure caption was inconsistent with the text. We've corrected the caption to use T' .

L75: Does the absolute value sign have some meaning? Isn't $L' - L'_{eq}$ greater than or equal to 0 when you are talking about committed retreat? Or is that $|L' - L'_{eq}|$ is the disequilibrium, which just happens to be positive when a glacier is retreating?

We've included a sentence explaining our choice to readers. Retreats are negative numbers, and subtractions of negative numbers can cause temporary confusion as a reader has to go through the step of subtracting a bigger negative number to get a positive number. The use of absolute brackets saves the reader this step. Moreover, it might also confuse the reader that the "committed retreat" is a positive number, since retreats are negative. We now concretely state that it is the magnitude of the difference we are interested in. The use of brackets at all makes it a grouped term, which is useful since we refer to it often in the paper.

L78: "matches" or "approximately matches"? Is this referring to line 110?

This indeed refers to line 110. Put another way, $dL/dt - dL_{eq}/dt$ approaches 0 as $t \rightarrow \infty$. We have reworded slightly to clarify that this exact match of retreat rates occurs in

the context of the linear model, though it is generally the case that retreat initially lags but then accelerates.

L87 and elsewhere: I am still unsure about the use of the terms PDF and CDF for the plots that you've generated. (I'm not an expert in probability and statistics, so I could be wrong about this. If so, my apologies!) My understanding is that when you integrate a PDF from x_1 to x_2 , you get the probability that a randomly selected sample will fall between those two points. Let's say you have a bin that goes from 0 to 100 and has a value of 0.001. If you integrated from 0 to 50, you would find that the probability of a random sample falling between those two numbers is $50 \times 0.001 = 0.05$. Similarly, if you integrated from 50 to 100, you would also find that the probability of a random sample falling between those two numbers is 0.05. So essentially you are saying that the probability doesn't change within a bin, but then undergoes a step change at the edge of the bin, which seems strange. This is why I suggested using empirical CDFs and CCDFs, which don't have that issue. Maybe the graphs should be referred to as histograms or binned PDFs? Regardless, any changes you make here wouldn't affect the outcome of the paper.

We appreciate the close attention to this! This understanding matches ours. We chose to keep the figures as histograms because we feel they make it easier for a reader to do this probability calculation by eye, and to see the distribution of density throughout the range. Per the reviewer's suggestion, we added a note at the introduction of these plots to clarify that they are histograms.

L104: Is this necessarily a step-change, or just a change from one steady-state climate to another?

This is a good distinction. The solution for L_{eq} indeed refers to any transition between steady-state climates. However, for the transient response, the sigmoidal shape mentioned is specifically for a step change. We've adjusted the wording to remove this stipulation where unnecessary.

L151: Is it possible to say in a half-sentence or so why your model doesn't work for small glaciers? Is this essentially referencing Fig. C1?

Yes, and we've added it! This actually was not meant in reference to Fig. C1, but the reviewer points out an interesting connection.

L172-174: In my initial review I had a comment about not fully understanding the area weighting. I think it makes sense now. When discussing response times, for example, I think the area weighting essentially tells you the response time for a randomly selected area of glacier ice. Since you are more likely to select a random area from a large glacier, that will shift the PDF and CDF to the right. Perhaps it would be worth adding a sentence to this effect?

The reviewer has the right idea, but we would frame this differently, as it is difficult to conceptualize the response time of a small component of a glacier (it better describes the full system response). If you were characterizing the effective response time for a population of glaciers, however, you might want to take account of the fact that a larger fraction of the population's area comes in bigger glaciers with larger response times. The area weighting reflects that.

L289: Isn't $\dot{b}_t$ the only other thing affecting τ ?

Our estimates of both H and b_t are affected by using the modern glacier geometry. However, this error is minor compared to the larger uncertainties in estimating glacier thickness and terminus mass balance, particularly for large glaciers.

L384: Should this be "We consider this to be a reasonable estimate"?

Yes, thank you.

Fig. 9: Have you tried including the uncertainty in τ in the plot? I wonder if it would be easier to understand the uncertainty if there were shaded regions.

Both reviewers made this suggestion. We hope we've found a way of conveying that on the new graph in a way that is helpful and not distracting.

L387: "we assess"

Nice catch! Thanks.

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Responses to Reviewer 2

Green = reviewer comments, black = responses

We thank the reviewer for their thorough second review and for their patience in working through this manuscript again, and we have taken their additional feedback seriously. In this round of revisions, we have worked to address their concerns about readability while maintaining our analytical approach. Specifically, we have added Table A2 with regional breakdowns as requested, reduced redundancy between text and captions, and improved the flow of inline equations and expressions. We have responded with comments interspersed into their review.

Summary:

This is my second time reviewing the manuscript. This study investigates the state of disequilibrium of ~5600 glaciers in Alaska using a well-published “model”/equation that links mass-balance anomalies and retreat in terms of length. The analyses focus on how different response times and the shape of the climate forcing affect the state of disequilibrium. Overall, they find the glaciers are in a state of severe disequilibrium and thus a lot of retreat is already inevitable in the future. The manuscript is suitable for the Cryosphere and contains new knowledge about Alaskan glaciers. The revised version of the manuscript is much easier to follow, albeit at times a bit redundant between description in figures and text. That said, in the first round, I had to read the article twice to understand what was done. This second round of review, I have the benefit of already reading the article twice, so it's hard to know how much improvement is from the slight changes they made to the sections compared to being familiar with it already. I'll also note that the response to many comments in the last round was that things were related to the authors' preferred writing style (e.g., use of acronyms, variables, in-line equations; not using a traditional convention of sections but rather merging results in the introduction, methods, etc.). I'll defer to the editor on whether these changes should be made or not. In my opinion, they greatly hinder readability, and I've highlighted some examples of these below so the editor can quickly assess for themselves. Assuming the writing style/format of the manuscript is suitable to the editor, I thus recommend minor revisions.

We thank the reviewer for their time in doing a second review. We are glad that the revised version was clearer. We certainly felt the revised structure of the introduction and section 2 was a big improvement, so we hope that the clarity is not just the result of multiple readings!

With regards to style, we apologize if the tone of our response came across as overly dismissive. Obviously we do have some different opinions with regards to style, but we did not consider the specific instances in enough detail.

In response to particular comments below, we respond on having “results” in the introduction (we’ve moved things round a bit to avoid being jarring, but maintaining a brief description of outcomes is our preference); redundancy of text and captions (we’ve reduced overlap between caption and text, and trimmed several captions substantially and removed the conversational tone that was there); we’ve gone through the manuscript to ensure that in-line equations and expressions read fluently to us (we altered several instances where they did not).

On using acronyms, we tweaked the text where the acronyms are defined to alert a reader more clearly about their usage. If a long label is used often enough, we feel it is acceptable to use an appropriate short hand.

On using symbols in the text, in a fairly math-intensive paper, we do believe that consistent usage of defined symbols is clearer than constantly switching between words and symbols. In the revisions here we’ve gone through the paper and tried to make sure that the text (including symbols and in-line expressions/equations) can be read out loud and sound fluent and meaningful.

Major Comment:

L433-435: It should not be on the reader to determine regional variations. Furthermore, as the authors noted in their response to other comments, they have chosen to deliberately “guide a reader” through various aspects of the study but then leave this entirely to the reader. Specifically, they are now asking a reader to (i) look at a table in the appendix that breaks down various metrics as a function of size, (ii) go to Figure 2 and use the color-coding in Figure 2a paired with Figure 2b to get a sense of the regional variations in size, and (iii) to form an interpretation of what these regional variations look like. I have spent a couple minutes trying to do this and it’s borderline impossible to infer anything meaningful. If regional variations are an important aspect of this study, then there should be a short summary here of the main takeaways. Even better, is to provide a table in the appendix that explicitly breaks things down by region. If the authors do not deem this to be important, then remove this reference or state that future work could investigate regional variations or something similar.

We acknowledge the reviewer's concern about the accessibility of regional information. While regional variations of disequilibrium are not the central focus of this study, we recognize that readers will likely want more detailed information about regional variability than can be interpreted from Fig. 2a and Table A1 alone. In response to this feedback, we have added Table A2 to the appendix, which presents the same results as Table A1, but instead categorized by RGI second-order region (as in Fig. 2a) and eliminates the need for cross-referencing. We have also added a brief description of the key regional variations in Appendix A to accompany Table A2.

Specific Comments:

L53-56: The authors have chosen to keep results in the introduction. I don't understand the rationale for doing this, so defer to the editor on whether this is appropriate or not.

See response to next comment:

L56-61: The stark contrast between “traditional” writing practices (e.g., ending the introduction with a statement on what each section does) and “non-traditional” writing (e.g., mixing results with the introduction, methods, etc.) is a bit jarring. This was noted in the last round of reviews, so I defer to the editor on whether this is appropriate or not.

We now realize the reviewer is highlighting that one issue was that we put our “results” ahead of the section roadmap. We've moved it so it comes as part of discussing Section 5, where it fits much more naturally, since it briefly states the main outcome of Section 5. We hope that is an improvement, and agree that it could have been jarring in the previous location.

On the general issue of whether the main outcome of the paper can be included in the introduction, we did a little looking around. There appear to be strong opinions in either direction! We found [one amusing poll](#) on the topic, with about 20% of respondents favoring either extreme. For the senior author in this study (GHR) this is the first time he's encountered this particular reaction in a reviewer comment. If there is a house style for this journal that precludes an outcomes summary in the introduction we would certainly remove it. It is our view that an introduction can be enhanced by a brief description of where the paper is taking a reader to. Our inclusion of specific numbers is to provide readers with an idea of what we mean when we say “severe disequilibrium”.

L75: are absolute brackets needed? It seems preferable not to be absolute in order to show the direction of change.

We've included a sentence explaining our choice to readers. Retreats are negative numbers, and subtractions of negative numbers can cause momentary confusion as a reader has to go through the step of subtracting a bigger negative number to get a positive number. The use of absolute brackets saves the reader this step. Moreover, it might also confuse the reader that the “committed retreat” is a positive number, since retreats are negative. We now concretely state that it is the magnitude of the difference we are interested in, and that we focus on the context of warming. The use of brackets at all makes it a grouped term, which is useful since we refer to it often in the paper.

L84: remove the comma in the citation.

Nice catch! Thank you.

L97: delete the comma after the colon.

Done, thanks.

L163 or L167: If these are Order 2 RGI regions, state this explicitly.

Yes - we've changed this to "second-order regions" to be more clear (the terminology we see used by RGI).

Figure 3: is there a reason not to use "cumulative dens." To be consistent with the PDF in (a)?

We feel that the y-axis label "cumulative frac." is more easily understood than "cumulative dist."

L299-306: here are good examples of where in-line equations look odd and reduce readability. Rather than write an equation for L300-301 that $f_{eq} = 0.57$, one could write "The median fractional equilibration is 0.57 meaning the average glacier still has ..."

We have tweaked this particular example where the in-line equation follows an adjective, which we agree is stylistically questionable. The inline equation at the start of the paragraph here is to refresh the reader on the origin of f_{eq} and its interpretation. We feel that its omission would impair readability, but we add "fractional equilibration (f_{eq})" in the preceding sentence to further refresh the reader. Although we differ in preference around inline equations, we appreciate the reviewer's effort here and in the prior review in working to enhance the paper's readability.

We've gone through all the other in-line expressions and equations, and considered whether they read fluently within the text. We found a few where we thought improvements could be made, for example writing out both term and symbol (i.e. "fractional equilibration (f_{eq})") when it is first used in a section to refresh the reader. We also checked through a few math-heavy articles in recent issues of The Cryosphere. We don't think we are an outlier in terms of our use of in-line equations or expressions.

L301: "still has still has"

Fixed! Thank you.

L320-336: a good example of (i) the text repeating the figure caption and (ii) a considerable amount of methods in a "results" section. I understand the authors' desire to put relevant methods near results and not use a traditional layout. In my opinion, this writing style becomes redundant and breaks up the narrative. Again, I simply mention here to point out to the editor as the authors have already made their opinion clear.

The rules we try to follow are that the figure should be understandable from the caption alone, and secondly, that the main text guides readers to the features of the graph that the authors want them to appreciate. It is frustrating as a reader to have to visually root around a graph, where what you are supposed to be seeing hasn't been stated clearly. Inevitably those two rules lead to some overlap, and erring on the side of caution might cause extra repetition. Having said that, we appreciate the reviewer's reaction, and

we've gone through how we've described each figure and tried to trim unnecessary material (from both the main text and captions).

Figure 1. We use figure 1 to walk readers through the concept of fractional equilibration, and so we want to be really clear pointing out specific features in the text. We imagine a reader carefully working with figure 1 as they go through Section 2. However, we do think the caption of figure 1 was unwieldy, and have trimmed material from it.

Figures 2 and 3 seem fine to us. They are referred to mainly parenthetically in the text, and their description in the main text is appropriate. Technical information in the caption (Fig. 2, especially) is needed and not repeated in the text

Figure 4. We identified some unnecessary repetition, and removed it from the main text. Technical details in the caption are needed and appropriate, we think.

Figure 5. We think text and caption are appropriate. It is important for us to discuss the specific numbers in the text because they contain important information that we want to highlight.

Figure 6. We were able to trim a little out of the caption. It contains a nugget of interesting information that works well in there.

Figure 7. Seems good to us. Short caption. No real overlap with the main text.

Figure 8. We were able to transfer a piece of technical information into the caption, and trim some of the rest of the caption to reduce its conversational tone. The text needs to take some space to describe the scenarios because they are integral to the rest of our analysis. We changed the topic sentence of one paragraph to break up the style a bit.

Figure 9. We changed figure 9, based on both reviewers' suggestions, to include a graphic demonstration of how uncertainty in τ affects uncertainty in f_{eq} . As a result, the caption is longer, but it is not repeated in the text.

L365: appear to be missing a space after scenario,

Thank you!

Figure 9: move to Section 5.3 when it's first used. I assume this will be done in a typeset.

We've made this adjustment for the resubmission.

L384 & Figure 9: given the explicit mention of uncertainty, can you add the uncertainty onto the figure?

This was raised by both reviewers. We have added an illustration of this to Figure 9 and hope it is clear.

