KEY

Reviewer comments (green italic)

Response (black)

New or changed text (blue)

Anonymous Referee #2 Received and published: 18 April 2020

In this study, the authors used simplified models to explore the response of ice flow to different sources of climate forcing, including perturbations at the grounding line and to the surface mass balance in the ice interior. I found this approach to be novel and very interesting. It successfully provides new insights into the connections between various forcings, in terms of amplitude and effects operating at different timescales.

The manuscript is well organised and very well written, overall. I support its publication after minor corrections.

Thank you for the encouraging review, and for suggestions that we think have led to a clearer manuscript. Please see our responses and changes below.

Comments:

-L. 93: delete "model" in "The PD12 model model. . ."

Fixed.

-L. 203: It isn't clear to me, what does "a different flowline model" refer to. Is it simply the flowline model described in section 2.2?

Thank you for catching this ambiguity. Robel et al. used a different flowline model to the one described here, which we now note more explicitly:

RRH showed that the two-stage model emulated the response of a flowline model forced with surface mass balance anomalies. Their flowline model (described in Schoof, 2007b; Robel et al., 2014) used a stress-based, as opposed to flux-based, grounding-line condition, but was otherwise dynamically similar to the PD12 model.

-L. 339: correct "instantaneous equilibrium"

Fixed.

-L. 372, and first paragraph after subtitle: it would be helpful to define "emergence and detectability" more explicitly. As currently presented, I am not sure how the paragraph (lines 373-377) introduces the section.

This paragraph is meant to establish up front that we are focusing specifically on the challenges posed by transient glacier dynamics. We agree that this may have been too abstract as written to properly introduce the section, and have made the following changes to clarify this:

3.2 The emergence and detectability of forced responses

We now turn to the topic of attributing outlet glacier retreats to natural or anthropogenic forcing. The attribution of an observed change to a particular cause (i.e., an external forcing) can be a challenge because of factors specific to individual glaciers, such as complexities in bed geometry, regional climate, or the local collection of ice-ocean interactions. It can also be a challenge because of factors intrinsic to the transient ice dynamics, which affect the amount of the forced response that can be expressed over a given time. We focus here on this latter set, and in particular on the contrasting implications of ocean vs. interior forcing.

-L. 381 and 382: Can you clarify how the glaciers' memory mentioned relates to the committed change discussed previously?

Great point to tie this to the previous section. We now reference Figure 5 on committed change.

-L. 386: Specify which "two types of forcing" you are talking about (ocean vs interior, presumably?)

Yes – clarified:

…two types of forcing (ocean and interior) and much longer response times…

-L. 399: can you specify "detectability. . ." of what?

Yes – we have re-worded to clarify:

…the very slow response to the trend in S means that the forced response is slow to emerge from the noise; it remains within 2σL until the late 21st century.

-L. 458: Did you mean a reference to Figure 7c?

Yes – fixed.

Generally, I find the figures to be clear, although I would suggest working a bit more on / completing some of the figure legends, in particular for Figure 1, Figure 2, Figure 5 and Figure 6. For example:

Figure 1: insert "(blue)" and "(orange)" after "omega" and "S" respectively, in caption d.

Fixed.

Figure 2: same thing for caption c, d, and e.

Fixed.

Figure 5: Caption needs to be more precise: aren't panels a, b and c showing the response of glaciers to idealized climate forcing? As it stands, it reads as if they show the climate forcing itself.

Agreed this was unclear. We have re-organized to clarify:

Glacier responses to idealized climate forcing over the industrial era. (a) Responses for glacier 1…

Figure 6: Similarly, some details and descriptions are missing. E.g., suggest completing the legend for panel b. I would also suggest making the titles currently in grey stand out a bit more.

Fixed. The figure and caption have been revised to be more descriptive:

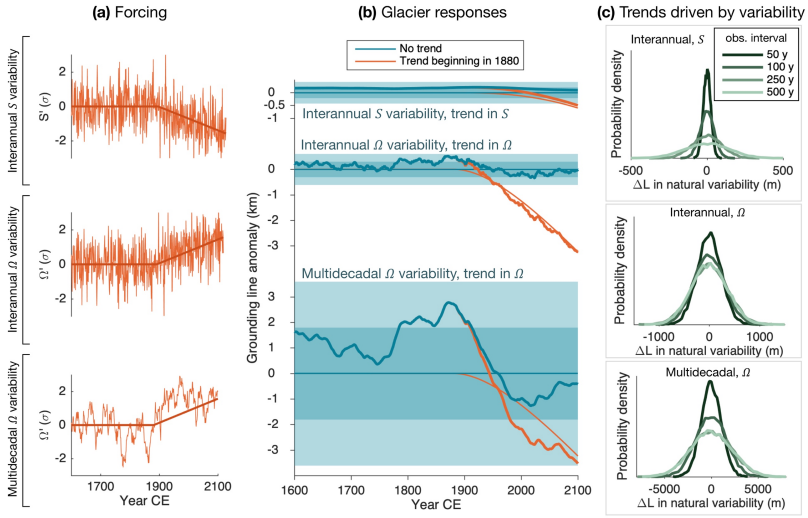

Figure 6. Detecting the response to a climate trend in the presence of natural variability. Three types of natural variability are considered in each column. The top row corresponds to interannual variability in S; middle row to interannual variability in Ω; and bottom row to multidecadal variability (τAR1 = 20 yr) in Ω. (a) The idealized climate trends (plus variability) beginning in 1880. In all cases, the linear trend reaches a SNR of 1 by 2020. (b) Grounding-line responses to each idealized trend. Shaded regions are the 1σL and 2σL bounds for each type of noise. The orange lines indicate when the trend has been applied. Thinner lines show the grounding-line response without variability. (c) Probability density functions for grounding-line trends driven by each type of natural variability, but no external forcing, over time periods from 50–500 years. Note the different length scales in each case. Trends on the order of km century^{-1} are extremely unlikely to occur due to variability in S alone (top), but commonplace if the glacier is sensitive to multidecadal variability in Ω (bottom).