

Point by point reply to reviewer and editor comments

Reviewer 1 (anonymous):

The manuscript presents new, recently exposed bathymetry data from the Pine Island Bay that show a former ice shelf pinning point and links this pinning point to changes in calving, rifting and movement of the Pine Island Ice Shelf over the last 10-20 years. This is an important and timely paper because it demonstrates the importance of such shallow pinning points for an ice shelf and is contributing to the ongoing debate of ice shelf stability. The paper is well written and structured, and I have only some minor comments:

When discussing the implication of the ridge to ocean circulation and the history of unpinning from the ridge it would be good to also discuss, and maybe compare, the effect of the major ridge to the SE discovered by Jenkins et al. 2010 (Nature Geoscience) and related unpinning there described by Smith et al. (2016; doi:10.1038/nature20136).

We added a sentence on the 1970s pinning point loss from this ridge and how this affected PIGs calving behavior in our discussion.

There is no discussion or analysis regarding the the impact of the unpinning on ice flow velocity of the ice shelf. This might be beyond the scope of this paper, but it might be interesting to see if there was a changes in ice flow velocities before and after the unpinning.

The focus of this paper is on the PIG calving dynamics related to the newly mapped bathymetric ridge and highs and are in agreement with the reviewer that a full investigation of ice-flow velocity changes would be out of the scope. Nevertheless, we have discussed in the manuscript that we expect further acceleration due to pinning point loss and calving line retreat.

Detailed comments:

page 2- line 15: rifts calving in 2015 occurred parallel to 'R1' and 'R2'. Figure 1 only shows 'R2'. Did the calving happen along rift 'R1', in which case the current ice front more or less represents 'R1'? If yes, the text could state this. If not and 'R1' has not calved off yet, this should be mentioned as well and 'R1' should also be labeled in Fig 1.

We revised the manuscript text, as well as Fig. 1 and the caption for clarification.

page 3-line 12-16: Ice thickness data. An alternative or addition to using published ice thickness data could be to use Operation Icebridge data (<https://nsidc.org/data/icebridge/>). There seems to be ice thickness data for Pine Island Glacier and the ice shelf available from the ice bridge flights and they could help reducing the uncertainty mentioned in the text. The flights 2009 – 2016, although I am not sure, if for every year.

We have also checked these data if they were suitable for our manuscript. Operation IceBridge data were not available for the location of the former pinning point. We could not use these data with an offset in our study as the PIG ice shelf thickness varies a lot

within short distances (see e.g. Dutrieux, 2014). We added this information to the Methods.

page4 - line 117: the text states that there is “no indication of ice contact”. However, the fact that the iceberg in 2015 did not move away with the initial break off and was then turning around the pinning point suggest that the ice still had some contact with the shallowest part of the ridge. This is described later in the text on page 5-line25 and discussed on page 6 and 7. I suggest adding this here as well, e.g. along the line of “However, movement of a ground iceberg after the rifting suggest light or partial grounding on the shallowest part of the ridge”.

We have added a sentence on this to the manuscript.

p6 - line 2/3 switch from ‘straight’ to ‘curved’ calving lines. It might be worth noting or stating more clearly that the most recent calving lines (2015, 2017) are straight again, but with a different orientation. The curved calving lines seem to be more a transitional stage as the calving front are reoriented.

We have now emphasized this in the revision.

p8-18: change “mat” to “m at”

Changed.

Figure 1 - The text mentions rift R1, R2, and R3, but only R2 is shown. I assume that R1 has already broken off and that R3 might not have formed yet (It’s hardly visible in Fig 5). Still, it would be useful to mark the approximate position of R3 on the map for orientation, e.g. with an arrow. It could say: R3 position is approximate since R3 isn’t really visible in the image yet. Some lighter/brighter colors for some of the ice front positions (e.g. the blue one) might make them more visible on the map.

We added the information that the calving lines 2015 and 2017 were produced by R1 and R2, respectively. Furthermore, we rephrased and added information to the figure caption. We also brightened up the blue colour of the 1947 calving line as suggested. We have not added an approximate location for R3 because this is not visible in this satellite image and most likely would confuse other readers.

Figure 2: I suggest adding the contour lines of the shoals to the legend.

Added.

Figure 3 Are the colors for the contours the same as in Fig 2 and 4?. The caption only states 400 m (red) and 450 m (blue), whereas the other figures have dark red, light red and blue. It would be good to have the same colors for all figures.

The 350 m contour line was missing, we changed this.

Figure 4: I suggest pointing out the curved calving line that is referred to in the text with an arrow and a label in fig 4b

We already mention the presence of the curved calving line in the caption of 4a and b. As there is only one calving line in each figure, we refrain in adding an additional label to retain a clear figure.

Reviewer 2 (Lauren Simkins):

Review summary This paper provides new bathymetry and satellite data for an area recently exposed due to PIG ice shelf calving line retreat, concluding that a seafloor ridge has been important for providing back stress in the ice shelf and iceberg calving. I find the paper well-written and only have minor comments, with the exception of their interpretation of lineations on the top of the ridge being formed recently by the ice shelf (see below).

Detailed comments:

Page 1, Line 20 – change to ‘current global mean sea-level rise’

Changed.

Page 2, Line 6 – mention how significant the buttressing effect of the PIG ice shelf to the upstream glacier (e.g. Fürst et al., 2016).

We reworded this sentence to make clear that ice shelf buttressing is important for maintaining the upstream glacier stability and added a sentence with information from Fürst et al. showing that 87.9% of the PIG ice shelf is providing backstress to the upstream glacier.

Page 2, Line 24 – misspelled ‘features’

Changed.

Page 5, Lines 18-20 – I am not convinced the lineations were formed by an ice shelf that likely had intermittent contact with bathymetric high, as one might expect slight differences in flow direction. The second explanation of the features forming over multiple glacial cycles is favored, especially considering the ridge is most likely composed of resistant bedrock. A resistant bed is also supported by the lack of iceberg furrows on the high, which would be expected in unlithified sedimentary beds.

The slight differences in orientation mentioned by Lauren Simkins most likely would not be detectable in this location due to the short length and the small number of the lineaments on the ridge. The subtle lineaments are only visible on the NW part of the ridge crest probably indicating a formation process similar to drumlins with sediments accumulated in the ice flow lee of bedrock bumps and not directly in bedrock. Hence, we agree that formation of such lineaments into bedrock would require multiple glacial cycles and we do not know which of these two processes formed the lineaments. We inserted a ‘probably’ to our discussion on their formation by the pinned ice shelf to balance out the probability of both discussed formation processes in the manuscript.

Fig. 1 – Consider adding another panel with a cross-section profile of the bed with annotated grounding line and calving front migration. Of course, there are lateral changes in bathymetry and ice position; however, a profile would show the landward dipping bed and the bathymetric highs nicely. This would also allow you to remove some of the water depths in the introduction section, which currently reads a bit like a list when discussing observed position changes.

Fig. 2 – Add cross sections of the ridge and across the streamline landforms.

We added a figure with several cross-sections to the supplementary (Figure S3). We think these data are not essential for our manuscript as they only show (1) new data that are shown already in Fig. 1 and 2 in a different manner and (2) data from other published work that are already referenced in the manuscript and which are important for the relevance of our manuscript but not for our results and discussion.

Editor Comments:

[...] I would encourage the authors to submit a revised manuscript, ideally also considering my comments in the initial editorial review.

Initial Editor Comments:

Originality (Novelty): 2/3

This appears to be a novel study that presents new bathymetric data from in front of Pine Island Glacier, alongside remote sensing data of the ice front position. That said, this is one of the most-studied glaciers in the world and it would have been good to see a clearer articulation of how this work builds on and extends previous work. The second paragraph of the Introduction reviews some key papers on this topic and the third paragraph simply states that an opportunity was presented to survey the bathymetry. I would have liked to see a more explicit statement about the aims and objectives of the research and/or the outstanding research question it aims to address that previous work was unable to address. This might be obvious to the authors but it is not explicit from the Introduction.

Scientific Quality (Rigour): 2/3

As noted above, the purpose of the work could be more clearly articulated, especially as so much work has already been undertaken on this glacier. That said, the methods and techniques would appear to be appropriate and the results are clear and supported by some good figures. The interpretations and conclusions seem valid, but it is not always clear how this builds on and extends previous work.

We inserted some sentences to the last paragraph of the introduction on the limitations that previous studies were facing making a clearer statement why this study offers a unique opportunity to investigate the calving behavior of Pine Island Glacier.

[...]