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The Cryosphere Discussions

Interactive comment on "Past and future dynamics of the Brunt Ice Shelf from seabed bathymetry and ice shelf geometry" *by* Dominic A. Hodgson et al.

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Recently developing rifts in the Brunt Ice Shelf present an opportunity to assess ice shelf responses to large calving events, and their future stability. However, in the absence of robust knowledge of sub-ice shelf topography, efforts to predict its future stability and development are limited. Here the authors integrate a range of historical, recent, proxy and direct observational data to produce the best available topographic model of the continental shelf (including sub-ice shelf). This allows them to make some crude inferences about long term glacial history in the Brunt and Stancomb-Wills catchments and, together with the topography of the ice shelf base (i.e. its along flow variability in draft) permits an assessment of the likelihood of ungrounding/regrounding on sub-ice shelf topographic highs. I found it an interesting read that raises a useful

longer-term perspective on ice sheet/shelf behaviour in the catchment, as well as insight into the local topographic/substrate relationship with shelf stability and potential feedbacks with grounding line behaviour.

However, I suggest three general elements need some attention. i) A few aspects of the methods need clarification. ii) The conclusions regarding former grounded ice flow and retreat are at best weakly supported. The interpretations are certainly plausible, even likely if we draw on other continental shelf glacial retreat systems as analogues, but here there are as yet no data to support specific reconstructions of flow or retreat. Data currently reveal the overall trough shape (coarse resolution) and modern-day ice configuration (+ recorded changes over the past ∼100 years) – we don't yet have specific glacial geological information with which to constrain the history of glacial change here. I would suggest the authors present their interpretations more as hypotheses for future testing, rather than in the tone of 'we find that the ice sheet retreated in [. . .] way'. iii) On the other hand, I thought the final aspect of the Discussion – the potential future evolution of the system – was missing an element of evaluation, and in that regard, the paper does not meet one of its specified aims. I expand on these points below, followed by some minor corrections relating to figure clarity, captions, text edits and typos.

Methods – a few missing aspects or in need of clarification or justification

- Stage 4 of the bathymetry reconstruction suggests the model is constrained by observational data; how do these data differ from what was used as input in Stage 1? What is left to tighten the inversion?

- Can you clarify how the ice shelf base/draft was determined? Line 106 and line 210 both suggest radar data were used; line 166 (Methods) suggests only that shelf thickness (draft) was determined using an assumed density profile and the freeboard height.

- Are density assumptions valid, since the shelf is partly composed of (fused by) marine ice?

- Explain how Fig 5 shows that contact with the MIR is limited to <1.3-3 km2 (line 215).

- Fig 5 appears to show anomalies in surface elevation between different datasets (lidar flight lines vs stereo-image DEM), particularly closer to the grounding line – can you comment on or compare the (un)reliability of these datasets? If the ice surface heights are data-dependent, what does this mean for draft calculations?

- Which velocity measurements or model were used to convert distance to time in Fig 6? Could simply be stated in the figure caption.

Former grounded ice reconstruction

It would be useful to see the seismic profile across the McDonald Bank (line 61, line 225 – is it possible/permitted to reproduce this figure?) and also where, specifically, it crosses the bank (e.g. to inform your comment on line 228-229). What direction do these bedded glacial sediments dip in? What grounded ice geometry would be consistent with the seismic structure – your interpreted grounded ice flow trajectory (Fig 4) would suggest the bank was lateral to ice flow reaching the continental shelf edge, but is now perpendicular to flow from the shelf (switch from lateral to ice frontal position). I wonder whether there are sufficient seismic data (coverage or resolution?) to detect this switch, or to evaluate your reconstruction? Are there any structures related to the re-grounding of the Brunt Ice Shelf on this bank? Can different generations of sedimentation be detected?

Line 185-90: I suggest removing the references to grounding line positions from the series of brackets here, and making your interpretations separately. i.e. report in these few sentences where the topographic highs are, and then finish the paragraph stating that you interpret these high points as likely pinning points, perhaps both for grounded ice retreating from its maximum extent (grounding line positions) and stabilisation points for subsequently floating ice. On first reading it seemed as if you were calling on independent evidence of grounding line positions that you now match up with your new bathymetry, but I don't think that's the case. . .

Section 4.1: since the only evidence of glacial advance/retreat that could be considered diagnostic in this new dataset are the convergent troughs, the tone of this section is somewhat over-confident and some of the assertions cannot (yet) be supported. These assertions may well be likely but specific landform or sedimentological evidence is still absent, so I would rephrase the language more towards presenting likely hypotheses than definitive conclusions.

e.g. the maximum extent of ice during the last advance is assumed to be the trough end (continental shelf break) but there is no evidence for or against this.

e.g. line 230-1: 'development of interglacial conditions' and 'become starved of ice' reads as if we can see a progression of events in the dataset (also line 247: 'continued to thin'). The progression of events is assumed, based on an assumed start point (e.g. maximum extent/flow direction based on trough size) and today's state. It might be reasonable, but I suggest making the argument based on clear observations and stated assumptions: given that the supply catchments today are much smaller than the trough size would suggest, it must be a reasonable interpretation that at some stage the extended Brunt ice stream became supply starved. (In contrast to the neighbouring Stancomb-Wills. . . I also note that the flow direction distal to the Brunt grounding line has gone through a $\sim$90 degree switch, to westward – due to the much greater supply through SWG and lack of deflecting ice/topography that earlier sent discharge northward? Also worth commenting, perhaps.)

e.g. 236-240: topo highs present themselves as likely pinning points (comment on water depth, how viable would they be?) for grounding lines, and it is 'reasonable to assume' that these highs held the grounding line for a relatively longer time than the deeper basins, but we have no insight at all into whether those grounding lines might have been stable for 'significant periods'.

e.g. 241-242: how is it known that ice shelves occupied the Brunt Basin and could have stabilised on the same topo highs? This is entirely supposition. Interpretation of

push features on McDonald Bank sounds plausible, but this bank is much shallower than the other highs referred to.

Conclusion line 350: advance of shelf ice after retreat following glacial maximum is not supported; the presence of shelves/ice tongues could equally well, based on the data presented here, be a product of grounding line retreat with persistent floating ice that has gone through relatively minor cycles of calving.

The *Discussion* does not evaluate the future development of the Brunt Ice Shelf, as the article introduction states as its aim (line 94), only outlines four possibilities. A paragraph or so of synthesis seems to be lacking here, and I think there is some room for evaluation without going too far out on a limb. Whichever of the four scenarios will develop depends, at least in part, on feedbacks between ice shelf grounding on a distal pinning point, the ice shelf flow regime, the production of ice shelf (berg) keels, the draft and the packing of those keels (inherited from the shelf-sheet grounding line?) Such feedbacks are alluded to through the manuscript, but are not drawn together to inform some of the possibilities that the Discussion scenarios raise.

e.g. 199-202: velocity feedback with iceberg packing (faster supply -> more closely packed icebergs) – does this have any effect on significant keel depth, e.g. as the shelf enters a more compressive zone?

e.g. 295-6: distribution and depth of iceberg keels determines the future grounding potential of the ice shelf. What determines the distribution and depth of iceberg keels, and how would that process respond to pinning point ungrounding? Icebergs calved from a deeper grounding line should reinforce the ice shelf better, once propelled forward to the McDonald Bank. And more icebergs (more densely packed) calved from the grounding line would stabilise the shelf better. Will shelf stability feed-back with sheet-shelf grounding line position via the style/magnitude of 'calving' off the icefalls?

There is precedent for 'recovery' following a more restricted shelf (after the 70s calving event) and reduced coupling with the pinning point – but is this only in extent, or in

strength of grounding also (area of grounding or (vertical) proximity to flotation)? Based on the timeline in Fig 6b, presumably the modern ice shelf base is inherited in some way from any grounding line response to that earlier event? Can we learn anything from that?

Line 325-9: the SWG is fed by a much larger (and faster flowing?) supply basin, so presumably sustains a significant ice tongue partly due to high input, even though it's unbuttressed. Does the very different supply catchment for the BIS not make this a poor analogue?

How limited do you think your conclusions or interpretations of future ice shelf development are by the specific three flowlines you have chosen to analyse shelf draft? This is the broad flowline reaching the shallowest part of the McDonald Bank; is it also the deepest draft zone of the shelf? Could keels along other flowlines eventually reground on other topo highs on the McDonald Bank?

Figures, annotation & captions.

1. I wonder about the choice of satellite imagery – these show the geography clearly, but don't visualise the structures as well as, for example, Fig 1 in King et al 2018.

3: several missing features either in annotation or caption

- I don't see any shading corresponding to swath bathymetry or other sonar data (pale blue shading, in the caption).

- the white lines – calving line and grounding line (should be stated in caption) – from which source and year?

- what are the grey blobs offshore? Iceberg outlines? From what source/year, and are they really needed (could mask out)?

- could you separate the seismic sites for water depth estimates from the historical depth soundings (use different symbols)?

- what's the pink triangle? Halley VIa?

4: missing or unclear features in annotation or caption

- the depth scale isn't particularly straightforward to match to the shading on the panels, which appears more intense and has hillshade effects. Try a classified colour scale, rather than ramped, perhaps? Or make it clearer at what depth the colour bar saturates and/or at what depth the shelf break is, for reference. Also, consider shifting the blue-brown shift to 0m, rather than the unintuitive brown = submarine as well as terrestrial.

- add a label for 4d to the box in 4c

- note the black dots = seismic soundings

- remove the iceberg(?) polygon outlines, these don't seem to be necessary here

- what are the green outlined features?

- label Fig 6 flowlines on the panel itself (rather than in caption)?

- flow arrows and grounding lines are both hypothesised. Suggest something like 'Probable orientations of fast grounded ice flow. . .' and 'Inferred former grounding line positions based on existence of topographic highs. . .'

4d/5: use either decimal degrees or degrees & minutes (latitude labels) consistently on all figures.

5: label Chasm 1, 2, Halloween Crack to better follow discussion.

6: suggest label/arrow ice flow direction.

Line 191: how does Fig 4d support this statement? Info on sonar (single beam or multibeam) coverage seems to be missing from Figs 3 and 4

Line 196: are these 'smaller scale topographic highs', 'some . . . crescent-shaped' what are indicated in green on Fig 4b?

Minor text edits and typos:

Abstract language is in places unclear and in places pre-supposes some specific knowledge of the Brunt system. e.g.:

- line 16: suggest 'remains in contact with its topographic pinning points'

- line 22: suggest 'then retreated, the grounding line pausing at least three times on topographic highs and transverse flanks of the basin.'

- line 25: I find the phrase 'overlap between ice shelf thickness and the bathymetry' awkward. Having read the paper it becomes obvious what you mean, but it wasn't clear at first reading. Suggest maybe 'overlap between ice shelf draft and bathymetric highs'?

- line 26: suggest delete 'incorporated iceberg'

Line 201: later -> latter

Line 205: I assume here you mean that as we move from the 35km position to the 22km position, the shelf draft increases? I suggest writing out the 'from' and 'to' to make the direction of change clearly correspond to the rest of the statement.

Line 260: citation for the relief of 'most ice shelves'?

Line 271: 'no further downstream increase'

Line 309: what do you mean by 'occupation'?

Line 348: has -> have

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