

I apologize to the authors and journal editors for being late with this review. I got carried away with other responsibilities but thoroughly enjoyed reading the manuscript and appreciate the opportunity to comment on it.

This manuscript blends geophysical, remote sensing, hydrographic, glaciological, oceanographic and limnological datasets together to 1) demonstrate conclusively that Blåsjø, a fresh/brackish body of water at the ice shelf margin, is an epishelf lake and to 2) argue that Atlantic Intermediate Water (AIW) can reach the grounding line 79N glacier and is interacting with the ice there. The paper is well presented and of significance to the readership of this journal. I have no hesitation recommending it be accepted for publication in The Cryosphere as long as some minor comments/suggestions are addressed.

Derek Mueller, Carleton University [2022-12-17]

## General comments

### *Epishelf lake:*

To my knowledge this paper is the first to describe Blåsjø as an epishelf lake. These lakes are rare and unique so it was somewhat surprising that the significance of this was not highlighted as much as it could have been.

Gibson and Anderson (2002) was cited and it might be a good idea to explain examine Blåsjø within the framework they illustrated in their Figure 2 where there are two types of epishelf lakes – Type 1, “with freshwater directly overlying marine water” (I assume this is the case for the east basin) and Type II – “with indirect connection to the marine environment” (perhaps a more suitable description for the west basin – if there is a conduit on that side?). There could also have been more description of Blåsjø. How big is the catchment? How much of it is glacierized? How common is summer ice cover? Is there more to say about water mass 2 in the eastern basin and water mass 3 in the western basin? How did they form and how does they persist?

You write [for a Type 1 epishelf lake] “the depth of the transition between marine and brackish/fresh water is controlled by the draught of the floating ice” but this should really be the *minimum* draft [draught] of the ice shelf (whether this point is in local hydrostatic equilibrium or not). A caveat here is that epishelf lakes can over-deepen in the summer due to freshwater input (see Hamilton et al., 2017 and Bonneau et al. 2021).

As a consequence of the above, it is challenging to find the minimum draft of the ice shelf that is controlling the outflow. The radar transect presented in Fig 7 is likely the best approach available, far better than estimating draft using hydrostatic equilibrium. So, I agree that the airborne radar (and InSAR) are more reliable (stated on ms line 328), although it is fine to include all the data for context. The fact that the minimum draft you highlight (150 m) is so close to the interface between water mass 2 and 4 is pretty convincing (but also see below).

### *Uncertainty/Errors:*

It would be helpful to know more about the uncertainty of the various datasets that are used in the analysis as most of the data is presented without any associated error bars. The propagation of errors and comparisons of the datasets can then be discussed. For example:

- The water mass 2 - 4 interface varied by 5 m (n=2) so how well is this constrained?

- How are bedmachine data produced? What error is associated with this product under grounded and floating ice?
- Is it reasonable to follow Morlighem et al., (2017) and assume an ice density of 917 kgm<sup>-3</sup> and sub-shelf water density of 1023 kgm<sup>-3</sup>? You may not have any ice density measurements on hand (not many do), but is this water density realistic, given data from Figure 4, water mass 4?
- What about DEM precision and accuracy? How does this and density uncertainty impact the HE calculations?
- What is the error in the radar thickness/draft and InSAR?

#### *Oceanography and ice-ocean interactions:*

I have not read Lindeman et al. (2020) but I feel there are probably answers to the following questions within it. These could be brought into the text so that it is clear in your manuscript without readers having to go elsewhere to find info.

There is mention of AIW being present at 500 m in the rift mooring data but I have the sense from the description that this varies over time. Please explain the dynamic nature of the AIW – what depths is it found at, what range in salinity and temperature, what is above (and below, if relevant) this water mass?. It would be helpful if this explanation also cleared up why you match Blåso water properties to the ITM data at a specific moment in time. How consistent is this water at the rift ITM?

Figure 4 shows mixing lines from the 500 m level at the ITM mooring at 3 times of year and some daily values (unclear what time of year they are from). These melt lines align with water mass 4 properties and this is used to infer that AIW interacted with the ice shelf at some depth (presumably between 500 m and ~200 m). But are there any other water masses or combinations of water masses that could account for the water properties seen year? In other words, are there any alternative hypotheses to explore before espousing your interpretation that AIW is the culprit?

To tie together the above 2 paragraphs, if you had a profile in the east basin from January 2018 would you hypothesize that it would be on the July 2017 melt line?

Lastly, I think adding bathymetric contours to the map in Figure 1 or elsewhere and an along fjord cross-section of the bathymetry, and ice draft and elevation to complement text on lines 45-50 and 60-70 would be very helpful.

#### **Detailed minor comments**

line 35 - exhibited little response to atmospheric and oceanic warming [in or over] the decades

line 38 - Model projections suggest that ocean warming around Greenland will double. Do you mean the rate will double or the temperature relative to some reference period? Explain

line 47 - grounding line (~600 m below sea-level). This doesn't seem to match the ice shelf thickness of 300 to 100 m.

line 88 – Midgardsormen ridge description is unclear here. Why did it flow backward? How much landward migration was there. This feature becomes clearer later in the text but it would help to have a better explanation here.

line 104-108 – You could include characterizing Blåsø as a specific purpose of your paper in the statements here

line 107 - synthetic Aperture Radar Interferometry (capital S)

line 113 - The depth of the transition between marine and brackish/fresh water is controlled by the [minimum] draught of the floating ice. This is true if the adjacent ice shelf is not grounded (whether or not it is perfectly in HE or not).

line 143 - CHIRP (Compressed High Intensity Radar Pulse) - I am really unclear on this. Does radar actually work underwater? Are you not using sonar?

line 148 – For pressure is that +/- 0.05% of the pressure value or the full scale – if the latter, please share what that is.

line 159 – please give full scale or convert to accuracy in pressure units

line 225 34.4 to 34.7 g/kg. change to gkg-1 to be consistent

line 276 – 79N Glacier [capital G]

line 315 – thank you for explaining the 5 m discrepancy – It is true there are internal waves in Milne Fiord epishelf lake. I certainly don't recall them being on the order of 5 m. Maybe there is another explanation for this?

line 317 79N Ice Shelf – proper name capitalization.

line 357 – replace measurement x1 with a synonym to avoid redundant text

line 363 – can you give error/uncertainty here?

Figure 1A

Would it be possible to see a bit further to the west?

Would it be possible to add some bathymetric contours to this figure?

Why are there 2 ESA CCI 2017 grounding lines?

Figure 1B

Would it be possible to krig and contour the bathymetry in addition to the CHIRP data? The colour ramp could use some intermediate values between 0 and 212 m.

Fig 1 caption

Red dots show where moorings have measured [water] flow direction [no s – only one arrow] in (yellow arrow)

SG = Storstrømmen Glacier – remove comma

Figure 2 – the grey line is hard to see.

How far away is the Dansmarkhan tide gauge?

Each of the 3 records could be centered on the tide gauge data by offsetting by the difference in the average values of coincident records. They would still have arbitrary datums but would be aligned.

Figure 4a caption

The shaded range indicates the instrument accuracy - do you mean precision?

Daily values -from ITM – are these for specific times of year or for the entire record?

Figure 5a

Unclear what the red dashed line is

The dashed grounding line are 2 mutually exclusive options for how the GL could go? It should be clear.

Midgardsormen line is green in the figure and yellow in the legend.

Need a legend for the topography (colours)

Note the inset maps c and d might be better placed in the cross sections under 5d, e and f. (along with the transect). There should be space for them there under the lake – with their own scale bar too. The legends can move over to the right

Fig 5e – there is no partially grounded dashed purple line

Fig 5f – explain the 6c and 6b lines

Figure 5 caption -

Midgardsormen (yellow line) is green

eastern calving front at the point where the extent of grounded ice is narrowest (see Fig 5). - but this is Figure 5 – do you mean somewhere specifically?

Figure 6

In E, short arrows show possible grounding of the Midgardsormen. There is no E

Figure 7

The numbers in b are very small and hard to read

Table 1 – need to add degree symbol and minute symbol

### **Citations I made that are not already in the manuscript**

Bonneau, J., Laval, B. E., Mueller, D., Hamilton, A. K., Friedrichs, A. M., and Forrest, A. L.: Winter dynamics in an epishelf lake: Quantitative mixing estimates and ice shelf basal channel considerations, J. Geophys. Res. Oceans, 126, e2021JC017324, <https://doi.org/10.1029/2021JC017324>, 2021.