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 Blåsø, 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]

Many thanks for the review and for the positive comments. We address the suggestions and comments individually below.

General comments

Epishelf lake:

To my knowledge this paper is the first to describe Blåsø 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 Blåsø 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 Blåsø. 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 as 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).

We will add some extra description and context for epsihelf lakes and for Blaso and its

catchment to address these comments and those from Reviewer #1. The suggestion to more effectively use Gibson and Anderson as a framework is very helpful.

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?

See response to reviewer #1 – we will expand this discussion but the difference is well outside measurement uncertainty.

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-3 and sub-shelf water density of 1023 kgm -3? 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?

Bedmachine v3 is currently state-of-the-art for the subglacial topography for Greenland (and the same applies to the ArcticDEM for the ice surface). The production of both have detailed processing workflows but an explanation of these is beyond the scope of this paper but we have provided brief additional clarification and we have made direct reference to the source publications. In relation to the choice of the ice shelf and sub-shelf water densities: we used the values applied by Schaffer et al., 2016 (not Morlighem et al., 2017 as we originally stated – this has now been amended). We chose the lower value for water sea density in order to be conservative in our calculations i.e. while we have indication of a direct connection in the eastern basin we do not have the same in the western. However, we recalculated the ice shelf draft assuming a water density of 1027 kgm-3, which resulted in only a minor change to the grounded ice in the west and no change in the east (see screen grabs). So the choice of densities within this range has no influence on our results.

- What is the error in the radar thickness/draft and InSAR?

The geographic precision of the flight trajectory and so the radar and laserscanner data is around 0.05m. Uncertainty of the GNSS altitude and thus laserscanner elevation is usually within 0.1m. The laserscanner is calibrated using runway passes and runway crossing. The uncertainty of ice thickness is usually within 20m.

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.

See response to Reviewer #1. We will include a longer description of AIW and of the Ice-tethered mooring site.

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 Blåsø water properties to the ITM data at a specific moment in time. How consistent is this water at the rift ITM?

See above.

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?

We will clarify the timing by noting labels in panel a apply also to b and by making the explicit links between the ITM oceanographic measurements and the modified-AIW at depth in Blaso.

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?

See above

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.

We will include an along-fjord profile in Fig 1 and a map of ice shelf thickness. See other responses on bathymetric contours.

Detailed minor comments

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

OK

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

We will correct – this should read 'will be double the global mean ocean warming by 2100'.

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

Inclusion of the along-fjord profile will help clarify this sentence.

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.

We will attempt to clarify the configuration of Midgardsormen by bringing some text forward, but we are unsure why the reviewer refers to 'backward' flow. We will revisit to clarify text.

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

OK

line 107 - synthetic Aperture Radar Interferometry (capital S)

OK

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).

Yes – see response to Reviewer #1 where we have agreed to add some extra text on epishelf lakes.

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

It is odd – although it a sonar system the manufacturers still use CHIRP as a descriptor, presumably inherited from nomenclature of radar systems because they use the same principle of sampling multiple frequencies as the original CHIRP radars. We will add the word 'sonar' to read 'CHIRP sonar', and thus remove ambiguity.

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

We will clarify by giving this as an equivalent water depth measurement.

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

And for this one too.

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

See response to reviewer #1 – we will make these (and other) units consistent

line 276 – 79N Glacier [capital G]

See response to reviewer #1 – we will use consistent nomenclature

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?

See response to Reviewer #1 – it is helpful to know the magnitude of the Milne fjord internal waves. This discussion will be expanded but the emphasis on internal waves reduced.

line 317 79N Ice Shelf – proper name capitalization.

See above

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

OK

line 363 – can you give error/uncertainty here?

Not really – these are complex spatial patterns and don't translate well into simple quantifiable differences. We think they are well illustrated in Figs 5-7.

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?

See response to reviewer #1 – We will improve Fig 1 for visualization of the bathymetry and will add a map of ice shelf thickness and a long profile of the fjord (See also Reviewer #2)

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.

Yes on the colour ramp, but kriging would not be supported for our spatial density of sampling.

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

OK

Figure 2 – the grey line is hard to see.

How far away is the Dansmarkhan tide gauge?

OK

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.

Thanks – nice idea and we will do this.

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?

We will correct to 'precision'.

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.

Midgarsormen line is green in the figure and yellow in the legend. Need a legend for the toppography (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 an 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?

See response to reviewer #1. We will consolidate this figure to occupy less space and to pick up the errors picked up by this reviewer and Reviewer #1.

Figure 6

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

We will correct to (b)

Figure 7

The numbers in b are very small and hard to read

We will expand

Table 1 – need to add degree symbol and minute symbol

OK

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.

Citation in our response

Schaffer, J., Timmermann, R., Arndt, J. E., Kristensen, S. S., Mayer, C., Morlighem, M., and Steinhage, D.: A global, high-resolution data set of ice sheet topography, cavity geometry, and ocean bathymetry, Earth Syst. Sci. Data, 8, 543–557, https://doi.org/10.5194/essd-8-543-2016, 2016.