Review of Manuscript TC-2021-65: *Development of a subglacial lake monitored with radio-echo sounding: Case study from the Eastern Skaftá Cauldron in the Vatnajökull ice cap, Iceland*

General Comments

This paper presents a new technique to monitor subglacial lake activity in Iceland using repeat Radio Echo Sounding (RES) surveys. The authors demonstrate the applicability of the new technique by deriving lake area and volume estimates between 2014 and 2020 for the subglacial lake below the Eastern Skaftá Cauldron (ESC), Vatnajökull. They then derive surface elevation changes from InSAR and airborne radar altimetry and compare these to the lake volume estimates to characterise two jökulhlaups which occurred in 2015 and 2018. Detailed long-term measurements of subglacial lake activity are rare but vital in understanding hazards posed by glacio-volcanic activity (e.g. jökulhlaups). The underpinning methods appear robust with some clarification required in placed and I've detailed these in the Technical Corrections below. In this context, the study is unique and worthy of publication in The Cryosphere, but subject to some revisions detailed below.

Specific Comments

The paper as it stands is quite long, stretching over 30 pages, and can be shortened – I've tried to provide suggestions in my Technical Corrections below to help the authors achieve this. For example, the Discussion section is 8 pages long and can be condensed by writing in a more concise manner. In particular, the authors sometimes discuss topics that are not relevant to a particular section and thus break up the flow of the discussion. For example, the discussion of uncertainties in the RES data pertaining to supra- and englacial water bodies is followed by a discussion on glacier hydrology and how this impacts jökulhlaup processes. These items should be discussed separately. Other suggested changes to the text are: breaking up the Results section into sub-sections and moving the discussion of RES errors into the methods section. In general, by ensuring each section is more focussed on developing the discussion pertaining to a particular section, each section will likely reduce in size and lead to a more concise paper overall.

Further, the writing in places is vague. The authors often describe the results with words such as 'seemingly' and 'almost' without providing quantitative statements from the results to back up their claims. In general, this can be resolved with a few simple calculations, but in other places the authors should consider referencing other suitable data sets or studies. This is particularly true in the Conclusion section which is written as more of a summary. Here, it would be better to provide some of the headline results from the study, backed up by quantitative statements, and state what the key take-home messages are from this study. I think the two main conclusions are:

- A new method has been developed for long-term monitoring of a subglacial lake which helps improve understanding of jökulhlaups.
- A unique analysis of jökulhlaups in 2015 and 2018 has been conducted that uses estimates of lake volume and surface elevation changes to understand the lake development before the jökulhlaups.

The methods underpinning this study are generally robust. However, the estimation of lake volume changes is dependent on having an accurate bedrock DEM. Is it possible that the bedrock outside and below the lake has changed over the course of the study period due to subglacial volcanic activity? One way in which you could quantify this is to find overlapping RES measurements representing the bedrock beneath the lake and calculate the vertical deviation between surveys. You have done this for areas outside the lake, but it might be possible to look at this below the lake.

Overall, if the authors can incorporate these suggestions and those in the Technical Corrections below, I'm sure this will make a very nice paper.

Technical Corrections (References to line numbers in preprint)

Abstract

L13: "The ESC is a ~3 km"
L14: "subglacial lake"
L15: "summer"

Introduction

L26-27: "Subglacial lakes have been directly and indirectly observed beneath both temperate and cold-based glaciers. The sudden release of water from such lakes can lead to floods, commonly referred to as jökulhlaups, and can be of variable magnitude.". Reference?
L27-28: "In warm-bedded glaciers, jökulhlaups are known to enhance basal sliding and increase glacier flow over a period of days (e.g. Einarsson et al., 2016)"
L32: I suggest beginning this paragraph with a short sentence summarising how subglacial lakes have previously been observed before launching into the paragraph, e.g. "Documenting the existence of subglacial lakes has been achieved using a combination of radio-echo sounding (RES) data and satellite remote sensing, but routine monitoring of such lakes remains a difficult task.".
L34: The exact quotation here should be "thick water layer beneath the ice".
L34: "Since then,"
L35: "RES data"
L35-39: Suggest combining these sentences together: "However, many subglacial lakes actively drain and fill and as a result are difficult to distinguish in RES data (Carter et al., 2007; Siegert et al., 2014), hence SAR interferometry and repeat altimeter surveys have been used to identify hundreds of areas of surface elevation changes associated with active subglacial lakes in Antarctica (e.g. Gray et al., 2005; Smith et al., 2009)."
L40-47: Suggest combine with paragraph below and shorten. See next few comments.
L40-44: Suggested start of new paragraph: "In Iceland, subglacial lake drainage events that lead to jökulhlaups have been documented since the early 1900s (Thorarinsson and Sigurðsson, 1947; Thorarinsson, 1957) and are well known to cause widespread destruction of farms and infrastructure, as well as loss of life."
L44-47: "Subglacial lakes in Iceland are formed through localized geothermal activity, where enhanced basal melting forms topographical depressions on the glacier surface (ice cauldrons), creating a low in the hydrostatic potential and promotes water accumulation from both the glacier surface and bed (Björnsson, 1988).
L49: "the two skaftá cauldrons, denoted as the Eastern Skaftá Cauldron (ESC) and the Western Skaftá Cauldron (WSC).".
L50: Change "within" to "below".
L50: "and has historically been the source of large jökulhlaups that have drained from beneath the Skeiðarárjökull outlet glacier in Southern Vatnajökull (Wadell 1920)."
L53-56: Suggest combining these sentences together: "The first direct observation of the ESC was from a photograph taken in 1938 whilst the WSC was first observed in 1960 (Guðmundsson et al., 2018), suggesting the ESC and WSC have not always co-existed.".
L56-61: "The geothermal power beneath Grímsvötn has been estimated from the volume of water discharged through jökulhlaups and surface mass balance and is estimated to be approximately 1500-2000 MW (Björnsson, 1988; Björnsson and Guðmundsson, 1993; Guðmundsson et al., 2018; Reynolds et al., 2018; Jóhannesson et al., 2020). This is likely to be similar below both the ESC and WSC making the region some of the most powerful geothermal areas in Iceland.".
L62: "which resulted in 4.7 km^3 and 3.4 km^3 of water being released, respectively (Gudmundsson et al., 1995; Björnsson, 2002)."
L76-80: "In June 1987, low water levels within the Grímsvötn subglacial lake due to a jökulhlaup nine months previously enabled mapping of the lake bed with RES and active seismic observations (Björnsson, 1988; Gudmundsson, 1989). Taken together with knowledge of the thickness of the overlying ice, changes

in the volume of the subglacial lake can be measured by observing changes in surface elevation (Björnsson, 1988; Gudmundsson et al., 1995).".
L80-81: This is a slightly vague statement. I suggest change to: "Mapping the lake bottom during low water levels enabled accurate quantification of lake volume change that has previously not been possible beneath ice cauldrons.".
L81:84. Suggest a rewording "However, the relationship between surface elevation within an ice cauldron and the volume of the subglacial lake beneath is not clear. Intense melting at the bed and strongly converging ice flow leads to substantial spatial and temporal variations in glacier thickness above the lake, which is particularly true after jökulhlaups when the walls of the ice cauldrons are much steeper.".
L85-101: Suggest to combine these sentences into a single paragraph. Suggested rewording is provided below.
L85-91: This section is a slight repetition of the previous paragraph and can be shortened: suggested rewording: "Despite these drawbacks, the volume of water released through jökulhlaups can be quantified by monitoring changes in the surface elevation of the ice cauldrons. For example, the surface elevation of the Skaftá cauldrons have been regularly monitored since the late 1990s using GNSS, airborne radar altimetry and additional Digital Elevation Models (DEMs) from various sources (Guðmundsson et al., 2007; Guðmundsson et al., 2018; http://jardvis.hi.is/skaftarkatlar_yfirbord_og_vatnsstada).".
L92: "In Iceland, attempts to"
L93: "RES data were"
L94: "This particular jökulhlaup destroyed"
L95-98: "Subsequently, RES data have been acquired up to twice a year over the same survey lines covering the Mýrdalsjökull cauldrons, with the aim of detecting abnormal water accumulation at the glacier bed (Magnússon et al., 2017; in review). This novel approach to monitoring subglacial lake activity has now been applied to the ESC, where RES data has been acquired annually since June 2014."
L100-101: "The unusually long pause as well as the insignificant rise in ESC surface elevation since 2011 motivated the acquisition of annual RES data."
L101: Suggested start of new paragraph which highlights the aims of this paper.
L101-103: "In this paper, the results of the annual RES surveys over the ESC are presented. Firstly, the RES data are used to derive annual DEMs of the bedrock beneath the cauldrons, which are then used to estimate the area, volume and shape of the lake every year between 2014 and 2020."
L103: "Secondly, we present a…".
L105: "2018, with a maximum discharge…"
L106-107: "This provides a unique insight into how the rapid drainage of a subglacial lake, whose geometry has been mapped using RES data, influences elevation changes at the surface of 200-400 m thick ice."
L107-110: Rather than providing the conclusions here, I suggest the final sentence of the introduction summarises the main aim of the paper: "Finally, the combination of annual lake volume estimates and surface lowering following the jökulhlaup events is used to demonstrate the applicability of repeat RES surveys as a tool for monitoring water accumulation and drainage beneath ice cauldrons in Iceland.

Data and Method
L113-122: Have you considered presenting this information as a table? Example below. I found it useful generating this table as I read through the subsequent data processing, analysis, and results sections. This means you could then condense this paragraph significantly.

Survey Year	**Date**	**Additional Details**
2014	5th June	Original RES survey lines.
2015	3rd June	Repeat survey lines from 2015.
2016	9th June	Large crevassing prevented some of the RES profiles from being surveyed.
2017	7th June	Supraglacial lake formation and covering of snow over winter led to some RES profiles becoming defect.

2018	4th June	Supraglacial lake formation and covering of snow over winter led to some RES profiles becoming defect. The density of the survey lines were doubled (200-250 m between profiles).
2019	31st May	An englacial water body probably formed tens of meters below the surface, affecting the RES measurements.
2020	3rd June	An englacial water body probably formed tens of meters below the surface, affecting the RES measurements.

L115-116: "This profile grid has since then been re-measured as accurately as possible every year Figs. (2-4)." Could you provide some further detail here? Did you have an automated GPS tracker? Were there significant offsets between years?
L123-125: "The RES data were acquired using standard surveying practices developed previously in Iceland (e.g. Björnsson and Pálsson, 2020; Magnússon et al., in review). The low frequency pulsed radar transmitter (5 MHz centre frequency) and receiver unit were placed on separate sledges, 35-45 m apart, in a single line and towed along the ice surface using a snowmobile." You might also want to adda sentence here stating why a 5 MHz radar was used as opposed to slightly higher frequencies.
L127-130: "The radar transmits a pulse which is then detected at the receiver. To increase the Signal-to-Noise Ratio (SNR), 256 or 512 measurements are stacked. As the system is towed along the ice surface, a 2D backscatter image is created which gives each RES measurement location on the x-axis and the travel time of the backscattered pulse on the y-axis."
L129-130 I suggest moving "but receiver measurement is triggered by the direct wave propagating along the surface from the transmitter." To the next paragraph where it is discussed further.
L129-131: I think this sentence could be made clearer. How did you measure the separation between the transmitter and receiver? If my understanding is correct, I would suggest the following change: "The centre position, **M**, between the transmitter and receiver for each RES acquisition was derived from the DGNSS positions of the snowmobile and receiver unit. By knowing half the separation between the transmit and receiver units, and the distance between the receiver and the snowmobile (~20 m), the position of **M** can be found."
L136: "(the sounding plus processing time of the stacked measurements varies by ~1 s)"
L144-145: Here I suggest incorporating part of the paragraph above: "The receiver measurement is triggered by the direct wave that propagates along the ice surface from the transmitter and is estimated as the average waveform measured with the RES over several km-long segments. This is then subsequently subtracted from the corresponding RES measurement.".
L146: Is your amplification of the signal relative to depth a simple range correction (i.e. geometrical spreading)? What is your scaling factor?
L146-149: "The 3D location of **M**, the transmitter and the receiver were used as inputs…"
L150: "assuming a radar signal propagation velocity through glacier ice (c_{gl}) of 1.68×10^8 m s^{-1}"
L152: "and a 500 m radar beamwidth illuminating the glacier bed."
L153-156: "The x-axis corresponds to the profile length with a horizontal resolution of 5 m, and the y-axis corresponds to m a.s.l. with a vertical resolution of 1 m. This corresponds roughly to the horizontal sampling density when measuring with a ~1 s pulse interval at ~20 km $hour^{-1}$, and an 80 MHz vertical sampling rate (in 2014-2017; it is 120 MHz for a new receiver unit used in 2018-2020)". Is the new receiver unit used in 2018-2020 a different model to that used in the previous campaigns?
L164-166: Without being able to see the Magnússon et al. (in review) paper I do not know how these steps were conducted. It would be best to briefly expand on these here.
L167-193: I think Section 2.2 can be condensed and made clearer – I have made some suggestions below.
L167: When you say the profiles were projected onto the same length axis, do you mean truncated so that the profiles can be compared directly i.e. they only represent overlapping areas? Unclear as written.
L167-176: Suggested change: "Each RES profile containing the traced reflections from the subglacial lake and bedrock are projected onto a common profile, where profiles 2014-2017 are projected onto the 2014 profile and profiles 2018-2020 projected onto the 2018 profile. When comparing the traced bedrock reflections (i.e. outside the rim of the ESC) between surveys, the median elevation difference was <2.5 m

for profiles 2015-2020 relative to 2014 (in 2018 and later the shift is obtained from comparison with an interpolated bedrock DEM based on surveys from previous years). Assuming these bedrock areas are unchanged between surveys, we correct each survey 2015-2020 by this vertical bias."
L180-181: How do you approximate the lake area in between RES profiles? Have you manually drawn the boundary (this could be subjective)? Whilst you discuss this for individual years in the sentences below, it would be useful to know what general procedure you adopted. An indication of uncertainty (even just a crude approximation) would also be useful.
L183: "guide the"
L184: "lake margin"
L185: Remove "where this limitation applied to the 2014 survey"
L185-186: "was however guided by the RES data alone."
L187 and L189: "Corrupted" isn't necessarily the right word here, I would use "obstructed".
L189: "is expected to be more accurate than the preceding year."
L191: "somewhat uncertain" is slightly vague, are you able to quantify how less accurate it is?
L193: Do you mean the upper limit of its expected size or the upper limit of the expected accuracy?
L197: "within the ESC and below the subglacial lake"
L197-198: "The traced bedrock reflections has good coverage across the bedrock beneath…"
L198-199: "In addition, the bedrock elevation beneath the cauldrons has been measured… "
L200: remove "fortunately"
L200: Did you validate your interpolation using the borehole measurements? If not, this could be a useful piece of analysis to validate your bedrock map and provide an indication of bedrock DEM uncertainty.
L201-202: "has been constructed using the kriging interpolation method (processed using Surfer 13 © Golden Software LLC)"
L203-205: Combine "The filtered…at that time" with paragraph below.
L204-206: I would remove "An independent…(see section 4.1.3)" as it is not relevant here.
L216-217: "…were then differenced from the interpolated bedrock DEM to obtain…"
L217-219: "The lake outlines are converted to points and are prescribed a lake thickness of zero before interpolating each lake thickness map…"
L227: Change subheading to "Elevation changes and released volume of water juring jökulhlaups in 2015 and 2018"
L229: Suggested change to "acquired by the TanDEM-x and TerraSAR-X spaceborne bistatic interferometer"
L231: "Differencing the two DEMs reveals…"
L235-236: Remove "a correction was deployed"
L236: "a ~500"
L238-239: "reference area and then subtracted from the elevation differences between the two DEMs."
L241: "4 June during"
L259-264: Does the lake margin correspond to the area of elevation change in 2015? If so, you could use this to constrain the elevation change area in 2018.
L265-266: Where do these biases come from?
L267269: Please state exactly why this correction needs to be applied.
L259-275: This feels like it should be in the results section. I suggest putting into the results under the heading "Water volume released during jökulhlaup in 2015 and 2018".

Results
L279: "At the time of this observed maximum lake area in 2015,…"
L280-281: "In comparison, the lake had expanded to 3.2 km^2 in June 2018, two months priors to the 2018 jökulhlaup."
L281-283: Suggested change to: "The strong positive linear correlation between the area and volume of the subglacial lake is demonstrated in Fig. 6i.". This may also be impacted by the fact the same bedrock DEM is used throughout. Could the bedrock have changed over the acquisition period from e.g. subglacial volcanic activity?

L285: “lake volumes”
L290-291: Remove “indicating the applicability of our RES survey approach to evaluate the expected hazard from a jokulhaup.”
L292-314: This paragraph is interesting. You explain the offset of the 2014 and 2015 lake volumes extracted from the RES surveys by the different measurement densities, but 2016 and 2017 were also coarsely sampled. Could it be then that the offset is simply due to slightly different subglacial lake refilling rates? A better comparison would therefore be the linearly regress 2015-2017 and 2018-2020 separately. You could even try the same regression with the 2014-2015 data to see the result of this as well.
L321: “The shape of the subglacial lake margin also differed between 2015 and 2018. ”
L321-323: “Steep side walls surrounded the bulk of the lake, although the thickness of the lake was typically 10-30 m away from the lake margins (see Fig. 6f and left side of Fig. 7b).”
L324-325: You should also reference Fig. 8a-b as this is where we see the greater lake thickness in 2018 – Fig.9a only shows the volume calculations.
L328-329: “The outward migration of the lake margin, typically by 50-150 m, was characterised by the outward propagation of the steep sided ice walls that defined the lake margin.”.
L328-332: I would caution this discussion of the steep-sided subglacial lake walls. The interpolation was guided by setting the rim of the lake walls to zero. Whilst there is clear good evidence for steep-sided ice walls, there may also be interpolation error that could bias some of the lake shapes.
L353-355: It appears to me that the maximum surface lowering regions are at the centre where the lake is not at its thickest – the largest lake thickness is to the eastern side of the ESC.
L355-369: This paragraph is a useful summary, but I think you the need make it clear what the terms ‘thickening’ and ‘thinning’ are referring to. If, as is stated in text, this refers to changes in ice thickness, you should also then state that this assumes the lake has completely drained. This means that for a completely drained lake, if the difference between the lake thickness and the surface lowering is positive, then the ice has thickened. I would try to reword this paragraph to make this more clear. Do you have additional data to suggest that the entire lake has drained?

Discussion
L371-383: This paragraph provides results that are then discussed in the subsequent sections. To improve the flow of the text, it might better to have this as a separate section (4.1.5.) and use it to summarise the contributing errors and state the accuracy of 10-20%. The authors may leave this suggestion if they do not see it as useful.
L374-379: This is a long sentence. Suggest shortening: “The RES surveys before the jökulhlaups in 2015 and 2018 show a good agreement with the derived surface lowering patterns (Fig. 8–9). Together with a close linear relationship between the time elapsed since the previous jökulhlaup (Fig. 9b) except when the lake is small and not hazardous suggests lake volume errors from RES measurements are typically 10-20%.”
L394: Has the 20% error been calculated based on the data gaps created from the supraglacial lakes? You should state this here to be clear.
L393-399: Even though this discussion refers to RES data gaps, I think it is best placed under Section 4.1.4 and I would suggest moving it there.
L401-404: Suggested shortening to: “In most glaciological applications, only 2D migration of RES data is possible but even this requires the assumption that all radar reflections originate from directly beneath the survey profile. This is often not the case beneath glaciers that flow over volcano’s, where the subglacial topography is particularly complex.”
L405: Remove “but much smaller when the slope and profile directions are in parallel” and combine with sentence spanning Lines 405-406.
L406-410: “If the traced reflective surface is not directly beneath the RES profile but cross-track, the obtained ice thickness is underestimated and the mapped surface below the profile is estimated to be too high.”
L410: “This has been shown using an experiment…”

L411-412: “Similar results were obtained in a recent study on Mýrdalsjökll ice cap (S-Iceland) which has a similar topographic setting to the ESC (Magnússon et al., in review). In that study, 2D migrated profiles were found to be 10 m higher than the bedrock DEM obtained from 3D migrated data.”
L418: “allow for safe acquisition of data for 3D migration without reasonable effort”
L419-421. The two effects probably mostly cancel each other out, but given the complexity of the subglacial topography, I’m not sure this can be stated with confidence. I would instead note that in general the two effects cancel out, but across the complex topography described in this study, the effect is likely to be similar to the Magnússon et al. (in review) study.
L423-428: I think this paragraph should be placed in Section 4.1.1. as it discusses the effects of data gaps on underestimating subglacial topographic peaks. Lines 424-425 can be retained in this section as it is pertinent to the effects of the 2D migration processing.
L432: Remove “the”
L433: “that the actual”
L440-441: “shift both the lake roof and the bedrock in the same…”
L443-446: I think this section needs rewording. Suggestion: “If c_{gl} is too large, lake thickness is overestimated, and it is underestimated if c_{gl} is too low. For example, if the true value of c_{gl} is 1.60×10^8 m s^{-1} but a value of 1.68×10^8 m s^{-1} is used, the lake volume would be overestimated by ~5%. Considering the upper limit of c_{gl} is 1.70×10^8 m s^{-1}, a significant overestimate of c_{gl} is unlikely.”
L451: “…value of c_{gl} may differ significantly between some lake roof and bedrock measurements, leading to larger uncertainties at locations where such water bodies exist.”
L452-454: Are crevasses persistent around the cauldron rim or are they transient features? Are they seasonally filled in with snow?
L468: “hilly topography” is a little colloquial, I suggest changing to “undulating lake surface topography”
L475: Remove “minority” to “small number”.
L485-492: This is a worthwhile discussion but should be moved, possibly to Section 4.3.
L500-504: I don’t think this part is necessary, I would focus on the results you have presented in the paper and use these to develop your discussion.
L505-507: Reword to: “Temperature profiles within the subglacial lakes beneath the Skaftá cauldrons have revealed temperatures of 3-5°C that are mostly independent of lake depth, thus enabling effective convection to take place (Jóhannesson et al., 2007; unpublished data at the IMO). Chemical…”.
L509: Remove “a”.
L518-519: Here, you suggest enhanced geothermal activity is likely the reason for enhanced basal melting. Do you have additional data/publications to back this up? Could other factors play a role?
L537: Remove “of the tremor”
L558-359: “The GNSS station based on the ESC surface, operated by IMO, was operating during both jökulhlaups.”.
L539-541: I suggest remove this sentence as it is redundant.
L547-549: “The differences in lake area between 2015 and 2018 can explain the difference in surface uplift rates but not the slower initial subsidence in 2015”.
L550-561: This paragraph could be combined with the preceding paragraph and shortened.
L564-568: “Such a deceleration is not observed in 2015 and may be caused by floating ice atop the 10-20 m thick water layer moving against the bedrock a few hundred metres south of the GNSS station. Whilst a supraglacial lake inhibited complete mapping south of the GNSS station, traced reflections from RES data 450 m south of the station suggest the ice was grounded at this location.”.
L574: I’m not sure I see where the 2018 subsidence sped up again. Is it just before the 4-day mark? Either way, it seems relatively insignificant – the fact it is not apparent in the 2018 data should be highlighted as a difference between 2015 and 2018.
L585: Remove “near”
L593: “cauldron centre to be substantially…”
L595: “of ice at a given”
L596-598: The thickening is also partially due to the convergence of ice flow into the cauldron and should acknowledged here.

L607: “motion decreases from”
L616-631: I think this is an interesting place to end, but I would also add that the RES survey design could also be improved so that the subglacial lake can be mapped at sufficient resolution to remove interpolation errors.

Conclusions
L633-634: “Repeat RES surveys over the Eastern Skaftá Cauldron (ESC) and a comparison with surface lowering during jökulhlaups was used to measure the volume of a subglacial lake beneath the ESC every year between 2014 and 2020. This novel data set has been used to demonstrate the applicability of repeat RES surveys for quantitative monitoring of subglacial lake volumes.”
L632-646: This is more of a summary than a conclusion. I think some key information is missing. For example, what are the uncertainties of the RES data, by how much has the lake volume changed over time and information relating to the two jökulhlaups (2015 and 2018). You should then frame these key results into a brief summary of the advantages and limitations of the repeat-RES approach and suggest possible future developments of the technique.

References
L766: Change “USAGE” to “ISAGE”

Figures
Figure 1: Good figure overall. Could you label the red boxes in panel (a) to make it clear which each is referring to (i.e. red box on inset panel is referring to panel (a) and inset in panel (a) is referring to panels (b) and (c))? Could you label ESC and WSC instead of “Skaftá cauldrons”? Is the glacier outline from GLIMS and does it need a reference? For panels (d) and (e), it is best to have the dates on the images to avoid excessive reference to the figure caption, with exact dates if you have them. For demonstrating the viewing angle, I think you should mark at the apex of the red line that this is the position of the camera, with an arrow indicating viewing direction.

Figure 2: Interesting figure. The red box on the inset map of Vatnajökull is annotated “ESK” which I assume should be “ESC”. In panel (a), I worry that red and green lines cannot always been seen by those with colour blindness, possibly change to blue or black? I would change the map of Vatnajökull to panel (a) and have the map of the profile grid as panel (b). Thus, change “(located on corner inlet)” to “(location in **a**). The legend details are a bit scattered. It might be better to put all of these (e.g. bed reflection, surfaces) at the bottom of each panel to avoid cluttering the graphs.

Figure 3: Good figure

Figure 4: Overall a useful figure. I wonder if panel **h** would be more instructive if it showed the survey lines in the same colour e.g. black, or possibly showing the sparse (2014-2018) and dense (2018-2020) survey lines in different colours.

Figure 5: Good figure

Figure 6: Good figure overall. Scale bar needs a label “Lake Thickness (m)” and the bedrock DEM also needs a corresponding color scale. In the figure caption, change “ESK” to “ESC”. Red might not be the best colour to use for the survey lines, suggest change to dotted black (or another suitable colour).

Figure 7: Very interesting figure. My only concern is that the figure suggests the surface lowering occurs without a change in the lake water level. You could caution this on the figure by writing the date the lake volume has been estimated.

Figure 8: Each color scale should have a label. The red and cyan lines could also be annotated on the map rather than having to refer to the figure caption. Otherwise, a good overview of the surface changes observed.

Figure 9: I have no major problems with this figure. If possible, it would be best to move the legend above the figure to avoid overfilling panel (a).

Figure 10: Was the GNSS repositioned to the exact same location before each jökulhlaup event? I would also state what the symbols mean in the figure caption or legend to make it easier for the reader to understand.