

November 12, 2015

Dr. Andreas Vieli,
Associate Editor
The Cryosphere

Dear Dr. Vieli,

We would like to thank you for the thoughtful, extensive, and constructive comments you have given us over several iterations of this manuscript. Additionally, we would like to thank Dr. Motyka and two anonymous reviewers for their comments. We believe net result of these comments is an improved paper, both in clarity and content, and we look forward to its publication.

In light of your suggestions and those of the third reviewer, we have made a few larger content-related changes to the manuscript, as well a numerous small changes revolving around language, syntax and sentence structure.

Here is a summary of our primary changes:

- We have clarified our language surrounding surface melt, calving, and ablation. Following both the comments from the re-review, and your suggestions, we now clarify that surface melt is only of glacial ice (and therefore below the snowline). We have ensured the language is consistent throughout, and specifically define these terms in our Introduction.
- We have undertaken further uncertainty analysis with the distributed energy balance model, by running the model under a variety of scenarios to test the sensitivity of the various parameters to our primary modelling assumptions. These results are discussed in Sections 7.2 and 7.4.
- We have also revised the discussion to more clearly compare the results from Bridge Glacier to other lake-terminating glaciers worldwide.

Please find attached the most recent version of our manuscript, as well as our point-by-point response to itemized edits made by yourself and the most recent anonymous reviewer. Our comments are presented in **bold**.

Sincerely,

Matthew Chernos, Michele Koppes, and R. D. Moore

Editor Decision: Publish subject to minor revisions (Editor review) (02 Nov 2015) by Andreas Vieli

Comments to the Author:

Decision based comments of two reviews, the major revisions undertaken and a re-review (Oct 2015) of this revised version.

Editor decision and comments by A. Vieli:

This paper received two initial reviews that both highlighted the significance of the publications research of lake calving glaciers and thought in principle it should be published, but they both also listed a lot of issues regarding the methods, explanations, visualisation and in particular in terminology.

The authors therefore undertook major revisions and addressed a lot of the points satisfactorily and commented them carefully. They clarified the methods and figure and improved the terminology. The re-review was again rather critical but in principle did not identify any fundamental issues and indicated improvement of the manuscript. However it still identified a few issues that are however of rather minor nature and can easily be addressed (see detailed comments by re-review). The re-review also questioned slightly the significance of the research, but based on the two initial reviews and the currently limited understanding of lake calving systems I think the manuscript provides a substantial valuable contribution to this topic and should therefore in principle be publishable.

Before accepting this manuscript the authors should address the mostly relatively minor issues listed in the re-review (see very detailed list). The main points that in this respect should be addressed are:

a) The terminology of using the term 'ice loss' (or similar) still causes some confusion. I acknowledge that the authors added in the revised version an explanation of how they use the term 'ice loss' but this is at the end of the introduction, and the term is used before in abstract and introduction and later in the discussion it still is not that clear that it actually only refers to 'ablation' (below snowline/ELA and more specifically surface ablation and ablation through calving).

So I suggest to in general (throughout the manuscript) use the proper term so it is really is clear what it means, for example:

-in abstract line 6 replace 'glacial ice loss' by something like 'terminus ice loss' or 'mass loss through ablation'.

-abstract line 10: should it not say 'ablation' instead of 'ice loss'

-...

This should be done consistently throughout the manuscript (see also specific suggestions of re-review).

We have gone through the manuscript to ensure we are using terms consistently (and correctly). Throughout the manuscript we now employ the following terms, which we also define in the introduction:

- **Ablation: the process by which ice is lost from the glacier, both surface and frontal**
- **Surface Melt (below the ELA): to refer to all net ablation of glacial ice through melting at the surface (assumes ablation of snow is not significant, and not counted)**
- **Calving flux: ablation of glacial ice via frontal melting and iceberg discharge at the terminus**

b) related to above make clearer that your conclusions are based on observations/investigations/analysis of solely the terminus region (up to ELA) and briefly explain uncertainties regarding total glacier change related to this assumption/focus. And certainly try to avoid the term 'total ice loss' there as this is not what you derived.

We have rewritten our conclusions to more clearly reflect that that this study focuses on a comparison of surface and frontal ablation mechanisms, and not on total mass balance. We have removed the term 'total ice loss' throughout, and now refer to ablation by surface melt and calving.

c) some additional comments/explanations of uncertainties regarding the assumption of the mass balance model (sensitivity of choice of mass balance gradient).

We have amended our uncertainty analysis within sections 7.2 and 7.4 in order offer better clarity, and a more rigorous treatment of our uncertainty in the DEBM, and mass balance model.

d) the last sentence in the abstract and conclusions could perhaps be formulated differently along that lines that it seems despite enhancing retreat and geometry change your study shows that ablation by calving is relatively small compared to surface melt and will get less important in future.

We rewrote the sentence and now state:

"Despite enhancing glacial retreat, calving remains a relatively small component of ablation, and is expected to decrease in importance in the future. Hence, surface melt remains the primary driver of ablation at Bridge Glacier, and as such, projections of future retreat should be more closely tied to climate."

Below also a few additional comments by me (editor) that should be looked at:

Fig. 1, make labels (elevation numbers) to contours bigger and add the snowline/ELA (2103?) in the map.

Have made contour labels larger, and have noted ELA in figure caption. We felt there were already too many lines on the map, and adding the snowline made the figure too cluttered.

Line 12-13: 'driven ... by water depth' is not quite correct, it is 'influenced/affected' by water depth.

"Calving has been enhanced primarily by buoyancy and water depths"

Line 49-50: this last sentence of the paragraph can probably be deleted.

Deleted.

Line 51-62: in this paragraph it may be worth to briefly explain the known influence of the bed topography (in particular overdeepenings) on the dynamics of calving glaciers (instability). Seems important for interpretation of Bridge glacier retreat.

Added:

“Terminus flotation can also be achieved by terminus retreat into deeper parts of a proglacial lake or fjord. The geometry of these water bodies is a function of glacial erosion, where channelized overdeepenings are excavated into bedrock, leaving behind depressions below that which would be expected by other erosional processes (Lloyd, 2011).”

Fig. 6: The fit of a single line through the shown points are perhaps up for discussion but I am a bit puzzled why the mass balance between 1400m and 1800m are roughly the same and almost independent of elevation. Maybe could be briefly discussed.

We have now added this paragraph:

“The ELA uncertainty estimate is to account for errors that cannot be adequately quantified without additional historical data. For example, it is difficult to confirm the linearity of the net balance gradient without several seasons of mass balance measurements, which changes annually depending on summer weather and winter snowpack depth and distribution. For the 2013 study period, the shape of the DEBM-derived mass balance gradient mirrors the seasonal snowline retreat rate derived from the Landsat images, where early in the season the snowline retreated quickly, while the snowline rose less than 50 m from August onwards.”

Fig. 10 and Fig Fig 11: again make clear here that this is not total ice loss but rather net ablation or ice loss through ablation.

We have changed the appropriate axis label to “Ablation (km³ w.e.)”

Fig. 12: while I think it is useful to put your results in the wider perspective of lake terminating calving glaciers, I think this figure is a bit ‘dangerous’ as only lines are shown, implying that calving rates are clearly linearly related to water depth. These lines are only linear fits to some relatively noisy single data points and we know today that the relationships are likely not exactly linear and that calving rates may actually increase faster than linearly. if the authors would like to keep the figure, they should add at least the data points to the lines.

We have removed this figure, as we agree it does not add much to the discussion. We now highlight our results within the wider body of studies in Table 2.

Re-Review of manuscript „Ablation from calving and surface melt at lake-terminating Bridge Glacier, British Columbia 1984-2013“ by M. Chernos, M. Koppes and R. D. Moore.

This paper reports on a summer season study of Bridge glacier in British Columbia in 2013. A comprehensive data set was collected and used to drive distributed energy balance model for the lower part of the glacier to estimate the surface melt and a simple model for the calving flux is applied with the measured velocity and estimated thickness of the lake terminating glacier to estimate the ablation due to calving, the frontal ablation, subarial or subaqueous is not considered. The study is limited because not enough data is available to estimate the total mass balance of the glacier, so the mass turnover for the season is not known.

General comments:

Confusing terminology, authors need to clarify in many places that they are not estimating the total ice loss, or the mass balance of the glacier, but only the summer surface melt below the ELA.

Please see comment #1 in our response to the editor. We have attempted to clarify and use proper terminology throughout.

Weak error analysis is presented with a lot of handwaving, a rigorous sensitivity analysis on the mass balance gradient, zero elevation change assumption and the ELA estimates should be relatively simple to perform for the simple ablation model. Also, a sensitivity test for the constant albedo assumption in the DEBM could be done to assess the impact that assumption has on the results.

Thank you for the constructive feedback. We have re-written our uncertainty analysis, and have performed a sensitivity analysis on the DEBM using a variety of scenarios, including the two suggested here. Those results are found in Sections 7.2 and 7.4.

In the Discussion session is a comparison of the estimated ablation of Bridge glacier, due to calving and surface melt below ELA, to values from other glaciers that use the mass balance of the glaciers. This comparison can be misleading as the ablation and velocity of glaciers can be large even though the glaciers are in balance and not losing mass. It is therefore not clear what the current mass balance of Bridge glaciers is as we do not know the accumulation or snow melt in the modelled years.

The primary focus of our discussion is a comparison of the calving dynamics of Bridge Glacier to that of other lake-terminating glaciers worldwide, as we highlight in table 2. For many of these glaciers, the mass balance has not been measured, and therefore we were not able to compare calving rates with surface melt rates, as we have done for Bridge Glacier . For the few glaciers where mass loss has been measured, which include Yakutat and Mendenhall Glaciers in SE Alaska, we limit our comparison to the measures of ablation only.

While we acknowledge that we have not undertaken an analysis of the mass balance or the total mass loss of Bridge Glacier in this study (this is the focus of continuing work), the steady retreat and thinning of the glacier, and of the other glaciers to which we are comparing, all indicated negative mass balance and net mass loss over the past few decades.

Conclusions need rewriting, still a confusion of „total ice loss“ and „surface melt below ELA“. The final sentence is a very general statement that would apply for all glaciers in the world and therefore not clear why the extensive study of Bridge glacier is needed to come to this conclusion, suggest to rewrite the last sentence, see comment below.

Please see comment to part d) in our response to the editor, above.

Specific comments

Abstract: some clarifications are needed

Line 8 23% of what (missing in the text)

“Calving is responsible for 23% of total ablation during the 2013 melt season...”

Line 11 clarify what kind of calving and surface melt estimates, calving estimates based on area change, velocity and floatation assumption and surface melt below ELA.

Have clarified in this sentence and the two before.

Line 12 „typically“ is very general, do you mean for the period 1984-2013? Then state that

Removed ‘typically’

Line 15-16 this is always the case for glaciers, I think authors want to make the point that calving ablation will have increasingly smaller contribution to the glacier total ablation, especially after the glacier has retreated out of the lake, suggest to make that clear in the last sentence of the abstract.

Have re-written, please see general comment #3.

Introduction

Line 33, what do you mean by „climate stations“ suggest to use „climate change indicators“ or be precise and state that glaciers will respond to changes in temperature and precipitation and therefore will changes in their size give information about large scale climate change.

“...variations in glacial size and volume serve as important high altitude climate change indicators.”

Line 34 „respond at least partially independent of climate on decadal timescales“ – not clear what authors want to state here, suggest to rewrite to clarify what they mean. Suggest something like the response is not only controlled by climate forcing.

“Due to their sensitivity to air temperatures and precipitation, variations in glacial size and volume serve as important high altitude climate change indicators (Oerlemans, 2005; Kaser et al., 2006). However, glaciers that terminate in bodies of water have been shown to exhibit changes in mass balance that are at least partially independent of climate on decadal timescales (Warren and Kirkbride, 2003; Post et al., 2011). This blurring of the climate-glacier signal is due to calving, which can be an important additional source of ablation (Benn et al.,

2007a). Unlike land-terminating glaciers, the retreat of calving glaciers cannot be fully predicted through climatic signals (Van der Veen, 2002; Motyka et al., 2002). However, the potential for calving glaciers to lose large volumes of ice over single seasons (even during years of positive mass balance) suggests that they can contribute disproportionately to eustatic sea level rise (Meier and Post, 1987; Dyurgerov and Meier, 2005), highlighting their important role in glacier response to climate."

Line 35 „this blurring“ not clear what authors mean, are you referring to other dynamical factors that can influence the retreat rate of lake terminating glaciers?

Please see preceding comment.

Line 38, „their inherent instability“ what do you mean here, in previous sentence authors talk about other forcing than climate on calving glaciers, but not inherent instability, what is that referring to, clarify

Please see preceding comment.

Line 55, move reference to the point they are referencing to, suggest to move the reference to after „calve“

Have done.

Line 65 insert (DEBM) as it is only introduced in the abstract text, not the main body of text

Have done.

Line 79 for what period is this snowline observation? Clarify

“...from 1985 – 2013”.

Line 86 m2 do you mean m3 for the size of the icebergs? Do you have estimates for their thickness?

We do not have iceberg thickness estimates. There is likely a large range of thickness, depending on the age of the iceberg. We discuss the surface area of recently calved icebergs.

Line 94 „significant predictor“ this statement needs a reference, how can you state this?

($r^2 = 0.65, 0.32$) - added to text.

Line 96 Suggest to change the title of section to „Data“ as here the data is presented

Done.

Line 108 TLC is never written out, what does it stand for?

“Nunatak TLC on Figure 2 (map)”.

Below we define “...tracking features from two time-lapse cameras (TLC), at Nunatak TLC, and Lake TLC...”

Line 111 and 113 suggest to replace „ground-truth“ with „evaluate“ or „assess“

Changed to 'evaluate'.

Line 111 „from“ is two times in row

Deleted.

Line 117, reference for the instruments needed

We added reference: Lowrance (2011).

Line 124 suggest to replace „calving flux“ with „calving front“

Changed.

Line 127 suggest to add „on photographs taken by“ before „two time-lapse camera“ (you did not track the features from the cameras, did you?)

“...tracking features on images taken by two time-lapse cameras”

Line 149 what do you mean by „In order to impose the snowline elevation in the distributed energy balance model“? (here you could use DEBM as it is introduced in abstract and also in line 66 if introduced there) This wording is unclear. It seems like you want to state that you used the snow line elevations from Landsat images to validate the DEBM results, or do you use them to constrain the model?

Now rewritten to state:

“Because the intent was to model only ice melt, and not the melting of snow cover, the DEBM was constrained to the area below the snowline. Daily snowline elevations were determined by linear interpolation of snowline elevations estimated from nine Landsat images obtained from the LandsatLook Viewer (U.S. Geological Survey, 2014) between June 1 and September 19, 2013. Multiple measurements of snowline altitude across the glacier surface were taken for each image, and averaged to produce a basin-wide snowline elevation.”

Line 156 what do you mean by „digital artifacts in the data“ explain better

We have now added “...remove unrealistic elevation changes produced at the junction of two map tiles.”

Line 161 suggest to replace „total ice loss during the summer“ „surface ablation below the ELA“ see comment above about terminology

Corrected.

Lines 177, 180 confusion, (K) is not in the equation, suggest to add (K) after shortwave in line 177

“...where S and D are the direct and diffuse components, respectively, of incident shortwave radiation (K_{\downarrow}), and ...”

Line 188 suggest to add „computed“ after „integrals are“

Corrected.

Line 191 „is not expected“ how do you know this? You could make a quick sensitivity test by applying variable albedo in your model (within the range you would expect the albedo to vary) and assess how large impact it has on the results, this way you could quantify the impact this assumption has on the resulting melt volume.

Thank you for this constructive comment. We have run sensitivity analyses with the current dynamic value for the albedo, and with a value of 0.4 across all exposed ice sections. This is now explained fully in Section 7.2.

Line 201 the skyview factor needs more explanation or reference to where it is defined and what values it can have.

Now reads: “Following Oke (1988), ...”

We have added the following reference: Oke, T.R. 1988. Boundary Layer Climates

Line 202 This is strange, first you state because of heterogeneity it is not measured and then that a constant value is assumed. Again, this assumption can be tested by applying variable values for the albedo and assess the sensitivity of the results.

Have added/re-written: “Due to the difficult logistics (and likely spatially variable results) involved in measuring the albedo for the surrounding non-glaciated terrain... ..This assumption is minor in practice, given the that sky view factors for the glacier are high (≈ 0.95).”

Line 223 add „radiation“ after „longwave“

Corrected.

Line 231 and 234 be consistent in variable names, use either ca or cair

Thank you, we have corrected.

Line 252 add reference for the chosen lapse rate

“...(as used in Stahl et al. (2008) and Shea (2010))”

Line 257 suggest to replace „differential“ with „difference“

Changed.

Lines 265-267 not clear if authors are describing observations or assumptions in the model here

We have re-written for greater clarity:

“When the measured wind direction at Glacier AWS was downslope, wind speed at Glacier AWS showed a positive linear correlation with (off-glacier) Ridge AWS air temperature, while upslope wind speeds showed no discernible trend. As such, when the wind direction at Glacier

AWS is upslope, wind speed is held constant across the glacier within our melt model, using measured wind speeds from Glacier AWS.”

Line 267 „show no significant change“ are these observations made on the glacier? From where?

Have re-written for greater clarity, please see above comment.

Line 279 „Since we found no significant elevational or east-west precipitation gradient“ how did you look for that? Are there available observations to assess the validity of this assumption?

Have re-written:

“Since we observed no significant elevational or east-west precipitation gradient between Nunatak AWS and Lake AWS, rainfall is held constant across the glacier.”

Figure 4 caption. Are you assuming that the inflection point and the grounding line is the same location? (I cannot see grounding line marked on the photo)

Have removed ‘grounding line’ from the caption. We agree that it would be difficult to accurately estimate this location without additional bathymetry measurements underneath the floating terminus. However, we do expect that surface expression of the grounding line would be an inflection point where the surface slope decreases to close to zero, as the terminus starts to float.

Figure 5 caption. Not clear what „(arrows to scale)“ means, there are no scaling arrows, or indication in the legend what the size of the arrows is in terms of magnitude.

Have added “length of arrows corresponds to map distance per year”.

(The arrows are color coded (i.e more red = faster) and their lengths are representative of distance per year (in same units at UTM coordinates on x and y axis).

Line 304. Here „annual surface melt rates“ are estimated, but „ice loss“ in line 161, what is the difference? Need some clarification and consistency in the terms.

Have clarified: “Estimates of historical annual surface ablation are derived...”

Lines 311-314 this sentence is not clear „underestimates“ suggest to write „gives lower estimated ablation than the DEBM results. Suggest to replace „mass balance gradient from the DEBM“ with something like „the results of the DEBM give the possibility to evaluate a mass balance gradient that can be used to estimate the gradient in the previous years“

“Results from the distributed energy balance model provide a means to evaluate the mass balance gradient for Bridge Glacier that can be used to estimate previous years. The coefficient value ($b_1 = 6.62 \text{ mm (w.e.)/m}$) taken from Shea et al. (2013) gives a lower estimate of surface ablation for the 2013 melt season relative to that calculated with the DEBM.”

Lines 315-316 „are considered in Equation 14“ not clear what you mean by this sentence, needs clarification or rewording, suggest something like „Areas that the ice had calved from in 2013 are estimated in equation 14 by assuming an elevation of 1400 m a.s.l. for all points.“

“All glacial surface areas that calved prior to 2013 are estimated in Equation 14 by assuming an elevation of 1400 m (a.s.l.). “

Line 318 What to you mean by „climatic indicator“ suggest to used „climatic variables“ or rename section to something like „retreat compared to climate variables“

Renamed: “Climate and Retreat”

Lines 321 and 324 suggest to replace „punctuated“ by some other word, not clear what you mean here

"...with occasional years of rapid retreat associated with calving of large, tabular icebergs..."

Line 323 from figure 7e it seems like that retreat accelerates after 2004, not 2009, is that correct?

Yes, typo has been corrected – thank you.

Line 326 „does not fully follow regional climatic trends“ - not clear what authors mean here, what is a regional climatic trend? Do you mean variability in precipitation and temperature measured in one location?

“...not fully follow glacial melt predictors such as summer air temperature, winter precipitation, mean annual streamflow, or equilibrium line altitudes. For example, air temperature anomalies became dominantly positive in the 1980s without a corresponding change in the retreat rate.”

Line 328 suggest to replace „from“ with „in“ and replace 7a with 7b in parenthesis

Done.

Line 330 „it appears that retreat was decoupled from climate“ what do you mean by this statement? Clarify

“Since the mid-1990s, retreat appears that have been largely out of sync with regional climate trends”

Line 330 „it remains unclear... „ – are you not estimating this in the paper? Figure 11? Why is this sentence here?

Have removed sentence.

Figure 8 caption suggest to add „location of“ in front of ablation stakes

Have amended.

Lines 344 and 345 suggest to replace „ice loss“ with ablation or surface melt to be consistent with for example Figure 8

“surface melt”

Lines 346-347 not clear what the observation uncertainty is, is seems like authors estimate the observation uncertainty by how well the model fits the observations, is that true? If not, then the sentence needs rewording.

Have added:

“We estimate the uncertainty in our ablation stake measurements were ± 0.02 m for each survey (3 in total), corresponding to a total measurement uncertainty of ± 0.06 m. Additionally, we estimate that uneven glacial melt due to heterogeneity in surface debris cover, meltwater pooling, and uneven terrain was in the order of ± 0.15 m, based on our observations of the glacier surface. Therefore, we estimate a total uncertainty of ± 0.21 m for the melt measurements.”

Figure 9 it is not clearly stated how the error bars in figure 9 are obtained, neither for the observations nor the model

Have added text, please see above comment.

Line 350 „ may have been errors in measurements“ it seems strange to suggest that observations have larger errors than the stated uncertainty (the error bar in figure 9) when the model does not agree with them, suggest to rewrite this sentence.

“...suggesting that there may have been localized effects shielding the stake or otherwise inhibiting melt at this site relative to the higher melt rates observed elsewhere in the ablation area.”

Line 359 suggest to replace „comparing“ with „adding“

Amended.

Line 375-378 this sentence is unclear, suggest to turn the sentence around, by first discussing the variability in the „glacier ice loss“ (suggest to replace that with ablation or summer melt, to be consistent with previous text) which is due to the variability in the ELA, as a result of equation 14

Have re-written paragraph following suggestions, for better structure and clarity:

“Between 1984 and 2013, surface melt showed a minor decrease over time, which can be attributed to the loss of surface area in the lowest reaches of the glacier due to calving and retreat. Surface melt in 2013 was above the 30-year average, but within one standard deviation of the mean ($\bar{x} = 0.107 \text{ km}^3 \text{ a}^{-1}$), while the standard deviation was $0.018 \text{ km}^3 \text{ a}^{-1}$. The ELA varied between 1926 m and 2202 m during the period, in most years it was between 2050 m and 2150 m.”

Line 377 „surface melt“ suggest to replace with ablation or summer melt – be consistent, also in figure caption 11 „ice loss from calving“ and „surface melt“ do you mean ablation by calving and ice melt below ELA?

Have re-written, please see above.

Line 385 strange to state that the highest calving flux occur between 2003 and 2006 when there are higher values in 2008 and 2010, suggest to rewrite sentence

Have re-written following suggestions:

“Historical calving losses are characterized by several years of high flux, and periods of relative stability. The magnitude of the calving losses increased once the glacier achieved flotation in 1991, and were minimal before then. From 1992 to 1994, the calving flux increased to 0.020 - 0.029 km³a⁻¹ (19 - 27% of the total annual ice loss), before a two year period of low flux (< 0.015 km³a⁻¹). From 1997 to 2000, the calving flux increased again (0.023 - 0.052 km³a⁻¹), while calving fluxes were small in 2001-2002. Calving fluxes were high between 2003 and 2006 (0.030 - 0.084 km³a⁻¹) and from 2008 to 2011 (0.036 - 0.100 km³a⁻¹) with low calving rates in 2006-2007. As the calving flux increased from 2003-2011, surface ablation rates below the ELA decreased slightly, resulting in the calving flux becoming a larger component of the total ice loss in the 21st century. Ablation due to calving was roughly equal to surface ablation in 2005, 2008 and 2010 (44 - 49% of total ice loss).”

Line 387 suggest to replace „period of stability“ with „low calving rates“

Please see above

Line 387-388 „surface ablation rates decrease“ it is not clear from the figure that this is true, only year 2010 has lower surface melt - again be consistent, figure states surface melt, surface ablation is used in the text and it is not clear that only ice ablation below the ELA is discussed.

Please see above

Lines 392-394 this is a strange statement and not rigorous error analysis, why do you expect differences to be smaller than calculated error (how is the error calculated?) the melt model is very simple linear regression using the height of the ELA, what about making a sensitivity analysis on the assumed mass balance gradient?

Have re-written paragraph for greater clarity:

“Errors in calculations of the net balance below the ELA are estimated assuming a ±75 m uncertainty in ELA elevation due to timing of available Landsat images to measure the snowline. The ELA uncertainty estimate is to account for errors that cannot be adequately quantified without additional historical data. For example, it is difficult to confirm the linearity of the net balance gradient without several seasons of mass balance measurements, which changes annually depending on summer weather and winter snowpack depth and distribution. For the 2013 study period, the shape of the DEBM-derived mass balance gradient

mirrors the seasonal snowline retreat derived from Landsat images, where early in the season the snowline rose quickly, then rose less than 50 m from August onwards.”

Line 394 „summer balance“ do you mean surface melt below ELA?

Re-written to:

“Errors in calculations of surface melt below the ELA are...”

Line 405 „summer balance“ see comment above

Corrected, see above comment.

Line 406 it would be in order to do a sensitivity analysis on the elevation change and assess this effect, by changing the elevation by a reasonable value for this period, then the authors would not have to be guessing, or assuming „a minor effect on modelling results“. A sensitivity analysis on the mass balance gradient should be included, see comment above.

We have added a new Table 1 with a summary of the effects of various assumptions on both the average surface melt difference and percentage ablation change to the DEBM model results, and have adjusted the text to reflect this here (and elsewhere in the manuscript).

Line 423 Turnover depends much on the overall mass balance of the glacier, it can have large velocities due to high precipitation and therefore not clear what is compared to what here.

Have re-written:

“Near-terminus flow speeds at Bridge Glacier are one to two orders of magnitude smaller than those observed at larger tidewater calving glaciers in Patagonia and Alaska, (Rivera et al., 2012; Koppes et al., 2011; Meier and Post, 1987; Motyka et al., 2003), and reflect a smaller mass turnover, similar to lake-terminating glaciers Mendenhall and Tasman (Boyce et al., 2007; Dykes et al., 2011).”

Line 428 suggest to replace „driving“ with „important“

Have changed.

Line 444 suggest to replace „trend“ with „amount of“

Have changed to “recent increase”.

Line 459 „calving and surface melt losses“ be consistent with other places in paper, suggest „ablation due to calving and surface melting below ELA“

“Historical reconstructions of calving and surface ablation suggest that climate is the largest variable affecting long-term ablation rates at Bridge Glacier.”

Line 459-460 „climate is the driving factor affecting the long-term health“ suggest to replace with something like „controlling the mass balance“

Amended, please see sentence above.

Line 461 „calving fluxes in most systems“ -what do you mean, not clear, suggest to rewrite

“...calving fluxes for most studied lacustrine glaciers are have been shown to strongly correlate with the terminus remaining in deep water.”

Line 463, 470, 473, 481, 500 not clear that calving rate is now „retreat due to calving“ suggest to clarify this, before the model was computing calving flux, m3/year, but here retreat due to calving m/y is discussed.

Thank you for the comment, we have added in section 7.3 (The 2013 Calving Flux):

“...corresponding to a terminus retreat of 281 m/yr.”

Furthermore, in line 484, we state, “Using the revised relationship from Warren and Kirkbride (2003), the modelled calving rate for Bridge Glacier is calculated as 268 ma^{-1} (within 13 ma^{-1} of the rate we observed in 2013).”

Line 465 suggest to replace „ice loss“ with retreat and „calving losses“ with „calving ablation“

Re-written to: “...suggesting that the current rate of calving is...”

Line 467 replace „glacier’s future health“ with „mass balance of the glacier“

Have amended.

Line 471 „falls in the middle of a continuum of magnitude and frequency of calving...” - this sentence does not make any sense, glacier does not fall into anything - and a continuum is meaningless in this sentence, do you mean „observations of magnitude and frequency“? suggest to rewrite

Re-written:

“Observations of the magnitude and frequency of calving at Bridge Glacier fall in the middle of a continuum of studied lake-terminating glaciers worldwide...”

Line 479 suggest to add the time of this observation, 2013, right?

Amended.

Line 483, this need better explanation for the paper to be self contained, what is used in the revised relationship, how is this calving rate computed?

Have amended:

“Bridge Glacier’s calving rate in 2013 (281 ma^{-1}) also agrees 490 well with first-order linear models relating calving to water depth (D_W) (Funk and Röthlisberger, 1989). Using the revised relationship from Warren and Kirkbride (2003), where $U_C = 17.4 + 2.3D_W$, the modelled calving rate (U_C) for Bridge Glacier is calculated as 268 ma^{-1} (within 13 ma^{-1} of the rate we observed in 2013).”

Line 485 „falls along the linear spectrum of calving and water depth“ does not make sense, rewrite or delete, figure 12 does not give useful information as there is no data, only the lines that have been interpreted, without the data this figure is based on, it is useless and I suggest to omit this discussion. Figure 12 suggest to omit, without the data this figure is useless

Have omitted final sentence.

Line 491 how much larger is the lake (areawise), is the depth of 300 significant for this comparison? It is confusing to compare area and depth in the same sentence.

Have re-written :

“Bridge Lake, at 6.3 km², is small relative to the much larger lakes of Southern Patagonia, while only marginally shallower. As such, many large Patagonian proglacial lakes contain vast areas that are free of the strong cooling influence of glacier runoff and trapped icebergs, and can warm significantly, promoting thermal undercutting and enhancing further calving (Rohl, 2006; Rignot et al., 2010; Robertson et al., 2012).”

Line 507 in this paper the „total loss“ has not been estimated, only the ablation below ELA using a simple parameterisation based on the height of ELA and mass balance gradient, and calving ablation, based on simple models and observations of velocity and thickness of the glacier. It is therefore not comparable to the numbers for the other glaciers that present the net mass balance of the glaciers.

We highlight that we are comparing only ablation losses from Bridge Glacier to similar ablation losses from the few other lake-terminating glaciers where mass loss was measured. See comment above.

Line 511 replace „total ice loss“ with „ablation below ELA“

Done.

Line 511 „different stages in a relatively uniform ,life cycle““ is not clear and needs to be reworded, not sure what authors mean here, lake calving glaciers do not have „life cycle“.

“The differences in the relative contributions of calving to ablation points to different stages in a relatively uniform pattern of retreat present in lake-calving glacier.”

Line 514-517 This statement is strange, as what has been observed is that the calving rate is larger when the water depth is increased, it is therefore no temporal trend that can be applied to other glaciers across the globe, it is very localised and dependent on the lake bathymetry.

Have re-written:

“[Studies]...report glacier thinning, followed by terminus flotation and a rapid step-like retreat, something that is echoed at Bridge Glacier. These findings hint at a common large-scale behaviour of retreating lake-terminating glaciers, and suggests a broad applicability in the region and across the globe of a pattern of transient high calving contributions to ablation as the glacier retreats across an over-deepened lake.”

Line 524 replace „total ice loss“ with „surface ablation below ELA“ in two places add the year

Done.

Line 531 replace „total ice loss“ with „ablation due to calving and surface melt below ELA“ – or be consistent with above. Also, add which period is being discussed here.

“Although individual years had large calving fluxes, multi-year averages between 1991 and 2013 show that calving only contributed between 10 and 25% of the total ablation due to calving and surface melt below the ELA at Bridge Glacier.”

Line 533 isn't the glacier almost out of the lake? Is that not the reason for reduced importance of calving for the mass balance of the glacier?

“The rapid calving rates observed from 2009 to 2013 at Bridge Glacier are part of a transient stage in retreat as the glacier terminus passed through an overdeepened, lake-filled basin, and are not expected to remain a consistently large source of ablation in the coming decades.”

Line 536-537 This is very general statement and not clear why „therefore“ is needed, the mass balance of all glaciers in the world is controlled by ablation – and accumulation, actually the balance between the two, with additional calving ablation, where applicable. Perhaps the final sentence of the paper should be something about reducing importance of calving ablation as the glaciers is retreating to shallower water, or even out of the lake.

“Despite enhancing glacial retreat, calving remains a relatively small component of ablation, and is expected to decrease in the future. Surface melt remains the primary driver of ablation at Bridge Glacier, and as such, projections of future retreat should be closely tied to climate.”