Review of: “The relative contributions of calving and surface ablation to ice loss at a lake-terminating glacier”

M. Chernos, M. Koppes, and R. D. Moore

Reviewer: Roman J Motyka

This could be an interesting paper. Unfortunately, it has several serious flaws that need to be addressed.

My comments, not necessarily in order of importance follow.

<u>Specific Comments:</u>

1. There is a woeful lack of referencing recent publications, and also older ones, that are really pertinent to their work. A list of these references plus others is provided at the end of my comments. In particular, the authors would find Trüssel et al. 2013 and Trüssel et al 2015 instructive. It is surprising that at least the 2013 paper wasn’t referenced because it fits precisely within their stated desire to put Bridge Glacier into a ”contextual” framework. For additional “contextualizing”, see papers on Patagonia lake calving glaciers: Sakakibara et al 2013, Sakakibara and Sugiyama 2014, Warren et al 2001. You should also look at Larsen et al 2007 for additional information on lake calving glaciers in SE Alaska.
2. Perhaps the most egregious lapse in this paper is the use of terminology. The authors should avail themselves of the Glossary of Mass Balance and Related Terms, (2011) available online and acquaint themselves with the basic definitions concerning mass balance. All too often the authors use the term “ice loss” to mean summer surface melt below the ELA in a given year. This occurs in the title of the paper itself! In the context of mass balance, ice loss implies thinning and shrinking of the glacier, i.e., a net mass loss over time. If a glacier is in quasi-equilibrium, then ice lost in the ablation area is replenished by ice flux from the accumulation area. Even with negative mass balance, the summer melt is not equivalent to glacier ice loss, it is just summer the summer melt. Understanding the differences is important because other publications they cite compare calving losses to glacier mass balance and not summer melt. The entire paper needs to be rewritten to emphasize these distinctions.
3. DEMs: the authors need to state the date of the Lidar survey that they are using for hypsometry. Is it 2013? If so, is the glacier outline, particularly the terminus, from this Lidar survey? If not, what is outline based on? A graphic displaying the hypsometry would be useful.
4. But what about other DEMs? Isn’t there one from the original map for this region? And also the SRTM data from 2000? Can’t you compare the Lidar DEM to these older DEMs to get a handle on the actual amount of drawdown Bridge Glacier has experienced? Perhaps do a geodetic determination of mass balance? Perhaps someone has already done this?
5. Another egregious error is hind-casting their melt model without consideration of the so-called Bodvarsson effect: *Bodvarsson G (1955) On the flow of ice-sheets and glaciers. Jo¨ kull,5, 1–8.* Thinning due to a negative surface mass balance can cause the ice surface elevation to lower and expose the ice to warmer climate conditions. Progressively larger areas of the glacier then

lie below the equilibrium-line altitude (ELA). This effect becomes even more pronounced if the ELA rises to higher elevations due to changing climate.

6. When you are hind-casting, what climate conditions are you assuming in order to drive your melt model? Or are you just assuming same as 2013? If so, that is quite an assumption!
7. Firn line vs. snowline: if ELA rises high enough, then firn from previous years will be exposed to melting. Are you ignoring this in your analysis?
8. Regional climate indices: Why would Vancouver be representative of this mountainous region, which you previously said was under a mixture of climate influences? You need to defend your choice or find a closer index. Perhaps the mean annual flow anomaly is a better proxy but I am not sure since you don't state the size of the basin the gauge samples and the influence of rainfall.
9. Terminus retreat: you need to be consistent when providing data. In the methods, you state terminus change was determined by comparing successive Landsat images and measuring the area of change. Yet Figure 3e and later in the text, you use m per yr, not area! How did you convert area to linear retreat?? There are now standardized methods for doing so to get an average rate of retreat. In Fig. 3e, did you plot all Landsat data or just one from each year? It appears that the terminus advanced in some years. Not unusual, as we see calving of floating tongues in lake systems to be quite episodic, on the scale of years sometimes, see Trussel et al 2013.
10. Velocity data: please show all of your velocity results somewhere, either as vectors on the map or in a table with reference to position. This is important for a reader to assess the validity of your ice flux calculations.
11. Lapse rate: what do you mean "standard lapse rate"? Need a reference.
12. Section 7.2: comparing summer surface melt that takes place below the ELA to calving losses seems to be the crux of your paper. I am having much trouble understanding the data in this section and much more explanation is needed. Furthermore, I do not understand how you arrived at your 85 day retreat area. I also have problems with water depth, flotation and ice thickness.
    a. First of all, you should show all of your velocity results somewhere, either as vectors on the map or in a table with reference to position.
    b. 2cd, just how did you determine the 65 m terminus retreat over the 85 day period? Is this an average? Or can you show schematically the area of retreat?
    c. 3rd, what width did you use to get an area of -0.297 km^2 for the retreat?? You would have to have a width of 4.6 km for a retreat of 65 m in order to get your answer of -0.297 km^2! If I use the width you used for calculating ice flux, 1.055 km, and a retreat of 65 m, that gives me an area of 0.068 km^2, not -0.297 km^2. Or was this a typo and you meant -0.0297 km^2? That would fit with a terminus width of ~ 0.5 km.
13. OK, now for ice flux area.
    a. So where was the velocity = 139 m/yr (0.38 m/d) measured?? Are you assuming plug flow? What about drag from the valley walls? What does the cross-valley velocity profile look like?

b. Where is your “flux gate”, i.e., where on the glacier are you measuring this flux? You state a width of ~ 1 km, so that would put it about a km from the terminus? Please show it on one of your figures!

14. Now for ice thickness: Why are you measuring water depth 500 m from the June 2013 terminus to calculate flotation thickness in 2013?? Aren't the appropriate data the soundings right next to the terminus?? Using 109 m is wrong! From your Fig. 6, maximum depth is about 90 m at the terminus and much shallower on either side of the lobe, so perhaps an average of 80 m or so?
15. Speaking of ice thicknesses of floating tongue: why use equation 13 when you have a highly accurate Lidar DEM? If it is really floating then just use the freeboard to estimate ice thickness. You also have your TLC data to give you floating tongue freeboard. Judging from Fig. 5 photo you may be overestimating the ice thickness. For floating tongues, ice thickness is primarily controlled by the thickness at the grounding line. At Yakutat Glacier, the lake depth was 325 m but ice thickness was about 175 m.
16. Figure 10 and 11. Again the terminology is really confusing. What you are measuring is summer melt below ELA, specifically for 2013, not surface melt, not glacier mass balance. To be accurate, surface melt would include all melting, including snow above the ELA. The confusion comes from thinking in terms of glacier mass balance, where net ice loss (or gain) has a specific meaning, i.e., net accumulation minus net ablation.
17. Figure 11: is never cited in text. I presume it was to be keyed to section 7.3? What are the shaded envelopes? Some sort of estimate of uncertainty? If so, it needs discussion and explaining.
18. Figure 12: these sorts of figures were in vogue a couple of decades ago when researchers were first trying to understand the drivers of calving. I am not sure how useful they are anymore, particularly for floating tongues. Although these figures do point out the difference in calving rates for marine vs. lacustrine glaciers, water depth is clearly not the reason why.
19. Redundancies: the discussions sections contained so much of what was already said, it was hard for me to read through it. Filled with too many generalities.
20. Uncertainties: a section on propagation of all of the uncertainties should be included in Methods.

<u>Some References to check:</u>

Clarke G. K. C., F. S. Anslow, A. H. Jarosch, V. Radić, B. Menounos, T. Bolch and E. Berthier (2012) Ice volume and subglacial topography for western Canadian glaciers from mass balance fields, thinning rates, and a bed stress model. J. Climate, e-View, doi: 10.1175/JCLI-D-12-00513.1 pdf

Radić V. and R. Hock (2011) Regionally differentiated contribution of mountain glaciers and ice caps to future sea-level rise. Nature Geosci., doi:10.1038/NGEO1052. pdf supplementary

Shepherd, A., et al. (2012), A reconciled estimate of ice-sheet mass balance., Science, 935 338 (6111), 1183{9, doi:10.1126/science.1228102.

Sakakibara, D., and S. Sugiyama (2014), Ice-front variations and speed changes of calving glaciers in the Southern Patagonia Ice field from 1984 to 2011, J. Geophys. Res. Earth Surf., 119 (11), 2541{2554, doi:10.1002/2014JF003148.

Sakakibara, D., S. Sugiyama, T. Sawagaki, S. Marinsek, and P. Skvarca (2013), Rapid retreat, acceleration and thinning of Glaciar Upsala, Southern Patagonia Icefield, initiated in 2008, Ann. Glaciol., 54 (63), 131{138, doi:10.3189/2013AoG63A236.

Warren, C., D. Benn, V. Winchester, and S. Harrison (2001), Buoyancy-driven lacustrine calving, Glaciar Nef, Chilean Patagonia, J. Glaciol., 47 (156), 135-146,doi:10.3189/172756501781832403.

Krimmel, R.M. and L.A. Rasmussen.1986. Using sequential photography to estimate ice velocity at the terminus of Columbia Glacier, Alaska. Ann. Glaciol., 8,117-123.

Harrison,W.D., K.A. Echelmeyer, D.M. Cosgrove and C. F. Raymond. 1992.The determination of glacier speed by time-lapse photography under unfavourable conditions. J. Glaciol., 38(129), 257-265.

Trüssel, B. L. , R. J. Motyka, M. Truffer, C. F. Larsen, 2013. Rapid thinning of lake calving Yakutat Glacier and the collapse of the Yakutat Icefield, Southeast Alaska. Journal of Glaciology, 59(213), 149-161.

TRÜSSEL, B.L., M. TRUFFER, R. HOCK, R.J. MOTYKA, M HUSS, J. ZHANG, 2015, Runaway thinning of the low-elevation Yakutat Glacier, Alaska, and its sensitivity to climate change. Journal of Glaciology, 61(225), 2015 doi: 10.3189/2015JoG14J125

Larsen, CF, RJ Motyka, AA Arendt, KA Echelmeyer, and PE Geissler, 2007. Glacier changes in southeast Alaska and northern British Columbia and contribution to sea level rise. J. Geophys.Res., Earth Surface. 112, F01007, doi:10.1029/2006JF000586.

Bodvarsson G (1955) On the flow of ice-sheets and glaciers. Jo¨ kull,5, 1–8

Text Comments:

Title: This title is confusing to me because I think of ice loss in the context of glacier mass balance. Here, you are not looking at overall mass loss or gain (positive or negative mass balance) (accumulation - ablation) but instead simply comparing summer surface melt below ELA to frontal ablation (calving losses).

P1

L 7: “surface melt”: This implies across entire glacier, whereas you are only measuring below ELA?

L11: What do you mean by summer balance? You do not have info on accumulation to make a glacier wide assessment.

L 23: Include more modern references: Shepperd et al. 2013, Radic and Hock 2011, Also see Clarke et al. 2012.

P2

L 4: Include Radic and Hock 2011, Shepard et al 2013

L 18: see also Larsen et al 2007

L 23- 25: Again ignoring more recent work of Japanese in Patagonia on Upsala and other glaciers. See ref. list for Sakakibara et al 2013 and 2014 and also Warren et al 2001 for Glaciar Nef in Chile. Also for Alaska, see Larsen et al 2007, Truessel et al 2013 and 2015.

P4

L 13-15: rewrite this confusing sentence.

L 19: Cite Fig. 1 here.

P5

L 7: 1972? Fig. 2 starts with 1985.

L 13, Fig. 3e: How is terminus position defined? Is an average? How measured? Advanced in some years??

L 15: Why would Vancouver be representative of this mountainous region, which you previously said was under a mixture of climate influences? You need to defend or find a closer index.

L 17 -20: Rewrite, too confusing.

L 22-23: OK, once again mixing apples and oranges. Your study is not measuring surface mass balance so you don't really know what the annual ice loss is!

L 26: reference the model being used.

P6

L 10 – 14: To really check the model, you need ablation measurements at higher altitudes too.

L 19 – 20: This is confusing. Were 74 pts measured or interpolated between measurements?

L 23-24: OK but in results, you state 65 m retreat not area.

L 26: ?? what rgeos?

L 28: TLC 1.5 km east: Location not shown in Fig.1.

P7

L2: References on how this is done? E.g., Krimmel or Harrison? See ref. list.

L 10 – 11: These velocity vectors should be plotted on one of your maps along with magnitude. This should be part of your results! Also, what is ice surface elevation of both your ablation stakes and your velocity markers? Please state somewhere!

L 13 – 15: What is the date of the Lidar?? Reference here and in Fig. 1. Lidar is usually very accurate so you should know surface elevations quite well.

L 15 – 20: You are ignoring the Bodvarsson effect.

L 16 – 18: Sentence as written is confusing.

P8

L 10 - 14: This is totally confusing. Snow is ice! Total ice loss during summer implies melt from above snowline too! Basically what you are measuring is specific balances on exposed ice below the snowline.

P12

L 2: Reference for lapse rate. How do you know whether it applies to Bridge?

P13

L 19: Why are you using this equation? If you know ice surface elevation above lake and you believe it is floating, then way not use free board estimate??

P14

L 1- 2: I would be really dubious about this assertion. Ice thickness of floating tongue is more likely established at grounding line.

L 2: There are two red arrows in the Fig. 5. Which is which?

L 8: Is this average speed, max speed or what? What is the gradient across glacier? Makes a difference when computing fluxes.

L 21-22: Poor coverage ?? Not according to your Fig. 6.

L 24: ?? You are not measuring mass balance are you? So how do you know about long-term mass loss?

L 26: What makes you think summer specific balance is linear with altitude?

L 26: What are the terms in the equation? Define them! Is this a specific mass balance measurement?

L 27: This again mixes apples and oranges. It may be equal to summer ablation but not glacier ice loss.

L 27: Is hypsometry from Lidar?

P15

L 9 – 10: ?? Why not use elevation from Lidar?

L 10 - 16: How do you know hypsometry for prior years? What about Bodvarsson effect? Also, you are measuring seasonal melt not overall ice loss. The latter is mass balance. This gets really confusing!

L 19 – 22: I think it would be good to have a table of hypsometry vs. ice loss. Reminder, you are modeling specific balances. Also, by definition, shouldn't your summer specific balance at the ELA be zero?

P16

L 1-8: What are the elevations of your stakes? From your figure, they all appear to be clustered at between 1500 and 1600 m. How far apart are they?   Also, that's great that it works at your terminus ablation stakes but you have no upglacier control. Also, I believe you said earlier that stakes were 3 m long? But you are measuring ablation on the order of 4 - 5 m?

L 9 – 16: Where did you measure this width? First of all, you should show your velocity results somewhere, either as vectors on the map or in a table with reference to position. 2cd, just how did you determine the change in terminus area over the 85 day period? 3rd, what width did you use to get -0.297 km2?? You would have to have a width of 4.6 km to get your answer! If I use your width of 1.055 km and a retreat of 65 m, that gives me an area of 0.068 km2. You need to show where on the glacier is your flux gate and also show just how you computed the 85 day loss in terminus area. Finally, I don't understand why you are using a position 500 m downstream of the terminus!

Sect 7.3: Totally ignores changes in surface elevation (Bodvarsson effect).

P18

L 1-2: Hmm! This is all very obvious, does it need stating?

L 13-14: ?? How did water depths increase? Did the lake level rise somehow?

L 16: ??? Water depth at terminus looks deeper to me during 2004-2012.

L 19 -22: What's this all about? How do you get thinning rates from Landsat images? Where is this data published??

P19

L 1: Why would glacier thicken? Positive net balance? Floating tongue thickness probably set at grounding line.

L 8-11: !!! Again, you need to be clear on what is being compared! Annual ice loss (or gain) usually refers to glacier-wide mass balance. Here, you mean summer ablation below ELA!

P20:

L 13: OK where did 281 m yr come from?

P24

L 28: published in 2002 not 2003.

P28 Fig. 1: State source of contours (DEM) and date acquired. Show location of 2cd TLC.

P30 Fig. 3: See previous comments about using Vancouver. 3e: explain somewhere how linear rates were determined.

P32 Fig. 5: There are two red arrows. Which is which and what does the 2cd one signify?

P33 Fig. 6: Show here or on Fig. 1 the velocity vectors. Also state the date for the terminus outline.

P37-38 Figs. 10 and 11: see specific comments number 16 and 17.

P39 Fig. 12: See comment number 18.