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The Cryosphere Discussions

Interactive comment on "Multi-year Evaluation of Airborne Geodetic Surveys to Estimate Seasonal Mass Balance, Columbia and Rocky Mountains, Canada" *by* Ben M. Pelto et al.

Anonymous Referee #1

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General comments This paper uses data collected from repeat airborne laser altimetry surveys to determine seasonal mass balance of 6 glaciers in the Columbia and Rocky mountains. Results indicate strong agreement between the geodetic estimations of mass balance and in situ observations. Technically, the paper is quite strong as it includes validation with in situ measurement and a rigorous analysis of the geodetic measurement error, however I found in many cases the writing was unclear (see comments below). In encourage to authors to carefully re-read the manuscript in order to address the many grammatical errors, improper/over use of hyphens and custom terminology throughout. Results from this work however do contribute scientifically to methods and knowledge pertaining to mass balance of Canada's western glaciers of

which are an important but diminishing source of freshwater at the head of several major watersheds. I recommend this paper for publication after addressing the comments below.

Specific comments âĂć The meaning of 'Glacier-wise' is unclear, but unfortunately used quite oftern throughout the paper. Please change to a more intuitive term.

âĂć Use 'our glaciers' should be changed to something less possessive like, 'glaciers in this study'.

âĂć 279: Assuming that the exposed old firn occurs in the ablation zone, can you please provide an explanation as to how the overlying snow/firn/ice has ablated away without filling up the available pore space of the 'old firn' and leading to more internal accumulation than is accounted for in this study? this needs to be addressed as it also applies to your discussion on internal accumulation (L415-419) where it is similarly dismissed as insignificant.

âĂć Introduction doesn't justify this work well enough. Need to elaborate on the recent trends experienced by glaciers in western Canada as per menounous et al, 2018., and the potential impacts of declining contributions to stream flow post ∼2040ish as per Clarke et al, 2015. Contributions from glacier melt to sea level rise are of secondary importance from this region as it is poorly quantified as to how much actually makes it to tidewater and how much is taken up enroute through groundwater storage and human usage.

âĂć L28-29 re: 'Measurement of seasonal mass change provides...' - I assume your talking about in situ mass balance measurements? if so, then should be specific about it - seasonal balances can be derived from more than just in situ meausrmeents –as you indicate below.

âĂć L37-41: poorly written paragraph.

âĂć L50-51. "The climate of the Columbia Mountains is transitional between maritime

and continental (Demarchi, 2011), with a strong maritime influence (Hägeli and McClung, 2003)." - So its more maritime then than continental? Would inner montane better describe the climate type here?

âĂć L55-56: Please give average snowfall rates and specify the source and what elevations they were measured at. This is probably the aspect of the climate that is the most important for this study. âĂć L64-65: please quantify differences - ie. average temp, snow precip, total precip, etc. describing the differences between climate regimes as "colder and drier.." is not very informative.

âĂć L68-71: please link glaciers to the Columbia and Rocky mountain ranges (described above) more clearly. An outline or some indication of the extent of each of the major mountain ranges in Figure 1 would be useful

âĂć L77: indicate swath widths for each instrument/altitude.

âĂć L81: is there a systematic bias in error of the laser shots as a function of off-nadir angle? Ie., does accuracy of z degrade towards the swath margins?

âĂć L119: It would be helpful to add a sentence or 2 here to describe what 'snow course' data is.

âĂć L282-283: ' Excluding this site, the remaining study glaciers in the Columbia Mountains had an AAR of 0.45 with 0.15 exposed multi-year firn cover and 0.40 bare glacier ice.' - The way this is written it implies Haig is in the Columbia mtns, it is not.

âĂć L282: I presume you mean the average AAR of the remaining glaciers in the Columbia mtns? If so, please edit.

âĂć Line 279-283: Line 279-280 indicates firn/glacier ice extents as percentages (13% and 49%) while the same are expressed as ratios on 281 – 282. Need to be consistent.
âĂć L373: 'In western Canada, onset of snow melt is occurring earlier on average relative to 1970-2006'. Please clarify for what period the onset of earlier snow melt is occurring.

âĂć L387-389: the statement 'We also chose not to apply a firn correction since it requires glaciological measurements that we purposely withheld in order to evaluate the feasibility of measuring seasonal balance without surface observations from the glaciers.' Is vague. Please be more specific.

âĂć L407-409: Re: 'Our field operations have been impacted by the melting out of crevasses: as strongly negative years are becoming the norm, and glacier flux is likely decreasing, crevasses are exposed for longer periods of time, and slower to close.

âĂć L408: ' Please define the 'melting out of crevasses'.

âĂć L408: What are you basing the assumption that flux is decreasing? Decreasing velocity or surface mass balance? Or both? If these assumptions are based on velocity changes, please indicate the sources used.

âĂć L409-411: re: 'This means that the total void area of crevasses is increasing due to ablation, which we have observed on Conrad, Zillmer, Nordic, and Haig glaciers, which could possibly increase their influence on Bw.'

o Can you expand on how this was observed? Was it measured? If so, how was it measured and over what period of time?

âĂć L415-419: Methods to measure internal accumulation include repeat shallow ice cores and ground penetrating radar (Bezeau et al., 2013; Gascon et al., 2013). As the issue of internal accumulation has not properly been addressed in western Canada, particularly over the larger icefields where this process has potential to be significant, it is worth highlighting as an important knowledge gap concerning glacier mass balance in this region.

âĂć L426-427: re: 'Our glaciological measurement densities ranged from 0.5 to 18.5 points km-2 (Table2), whereas our ALS data had around one million points km-2.' This is an unfair concluding statement as the datasets have different limitations that are not fully discussed.

âĂć L433-434 specify, ‘ as the melt season progresses. . .’ ice layers may form as internal storage ‘within the snowpack’

Technical corrections âĂć Questionable use of hyphens throughout the paper.

âĂć L281: lower accumulation, no hyphen.

âĂć L282: 0.06 add ‘ km2’

âĂć Figures: text is of variable font and size – this should be standardized for all figures. Text is so small it is unreadable on figures 7 and 4

References: Bezeau, P, Sharp M, Burgess D, and Gascon G (2013) Firn profile changes in response to extreme 21st century melting at Devon Ice Cap, Nunavut, Canada, J. Glaciol., 59(217), 981-991 (doi:10.3189/2013JoG12J208).

Gascon G, Sharp, M, Burgess D, Bezeau P, and Bush ABG (2013) Changes in accumulation-area firn stratigraphy and meltwater flow during a period of climate warming: Devon Ice Cap, Nunavut, Canada. J. Geophys. Res.-Earth, 118, 2380-2391

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