Anonymous Referee #1 Received and published: 16 June 2020 Review of: Seasonal and Interannual Variability of Melt-Season Albedo at Haig Glacier, Canadian Rocky Mountains Submitted to The Cryosphere by Marshall and Miller.

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The paper uses a long-term observation dataset of surface albedo in the Haig Glacier during the period 2002-2017 to depict the seasonal and Interannual Variability of Melt Season Albedo at Haig Glacier, Canadian Rocky Mountains. It is important to present this valuable dataset for developing any energy or mass balance model to project the evolution of the glacier. The tuning of the MB model is also a nice try. The paper is promising to be finally accepted by the Cryosphere from my point of view. However, before its formal acceptance, I want to address a few concerns here.

Thank you for your time and suggestions. We appreciate your thoughts on how to improve this manuscript. Please see below for our responses, in blue. Page and line numbers refer to the attached track-changes revised manuscript, not the TCD-formatted line numbering.

Specific comments:

1. The first paragraph of the Introduction part seems to describe the target of the work, which is more proper to be moved to the end of this part.

We rewrote this as suggested, and moved some of the specifics of this study (location, objectives) to later in the introduction.

2. Line 3-4. The sentence, “Variations in surface albedo, therefore, exert a strong control on the surface energy balance and available melt energy”, needs a reference. Here is one by Ming et al. (2015) for your information. - Ming, J., et al. (2015). Widespread albedo decreasing and induced melting of Himalayan snow and ice in the early 21st century. PLoS One. 10: e0126235.

This and another reference from Oerlemans have been added here, p.2, l.14.

3. Line 4. “manuscript” -> “work” or “study”.

Changed to “study” as suggested, p.3, l.23.

4. Line 44-51. This paragraph reads to be wordy and not well organized and needs to be rephrased.

We rewrote this to shorten some sentences and moved a bit of content to later in the introduction.

5. Line 44. The word “this” is not clear. Please clarify it.

“this” was deleted and we added “therefore”, p.2, l.24.

6. Line 45-51. These two sentences are too long to read. Please rephrase them to several shorter sentences.

Rewritten; these sentences are now simplified, p.2, ll.25-30.

7. Line 97. Figure 1 had better incorporate a smaller map of the study area from a global perspective so that the readers could know where the study area is in the first sight. It is also beneficial to include the conditions of climatology for this area in the figure.

Sorry for the geographic assumption – we have added a larger map to indicate the area. We did not included climatology though – partly it is not known in the Rocky Mountains (e.g. monthly precipitation data is not really available, except in the valley bottoms where it is about 20% of what we measure on the glacier, based on the depth of the spring snowpack. Figure 1 has been revised to better indicate our study region within North America.

8. Line 97. “Albeta” -> “the Albeta province” or “the Albeta state” or “the Albeta city”?

Clarified: “provinces of British Columbia and Alberta”, p.4, l.8.

9. Line 101-102. “Snow surveys conducted on the glacier each May indicate a mean winter snowpack of 1.35 m water equivalent (w.e.) on the glacier from 2002-2017, with a standard deviation (σ) of 0.24 m w.e. (Table 1).” Is this original from this study or cited from other studies? If it is in the latter case, it needs a reference. I suggest using a simpler expression of 1.35 ± 0.24 m w.e. to replace the long one in the previous form.

Revised as suggested, for the standard deviation, p.4, l.16. We needed to introduce/define this here, so it is a bit wordy. These numbers are newly reported in this study, a slight update from Marshall (2014).

10. Line 105. Could you also add a standard error of the mean of the temperature after the number 5.3 âDˇ C?

Added as suggested, p.4, l.19. Although it is not standard error, but rather the standard deviation (i.e., the interannual variability).

11. Line 111-115. This paragraph ˇ could be incorporated into the measurement section, and the next as well, because two paragraphs are more like introducing the measurement and data collection.

Shifted into Section 2.2 as suggested.

12. Line 116. “The forefield AWS” -> “The AWS in the forefield”? This phrase appears a few times throughout the text.

We think it is permitted to use “forefield” as an adjective, similar to “glacier AWS” or “forefield environment”, but for clarity we have reworded this throughout the manuscript, e.g. p5, l.6.

13. Line 123. Please clarify what “the set of available in situ data” is.

We reworded this as well. We just mean the available data – the 79% of days from 2002-2015 with valid data (N = 1018), p.5, l.13.

14. Line 133-134. Here needs a more detailed description of how to do manual quality control and remove the questionable data, although the authors claimed that the data control had been introduced in Marshall (2014). The current is too simple to understand the method.

We added a few sentences to make this more self-contained, so that readers don’t need to look this up elsewhere – thanks for this suggestion and we hope that it is now more clear, p.5, ll.3-8.

15. Line 135. “concentrates” -> “focuses” or “zooms in”? The usage of “concentrate” here seems to be strange.

Revised to “focuses on”, p.5, l.29.

16. Line 135-136. The intent of the sentence is unclear, and please rephrase it.

Rewritten – we mean simply to define the variables and our notation here, p.5, l.30.

17. Line 136. “pragmatic” -> “virtual”?

Apologies, we have removed this word – it was unnecessary, p.5, l.31.

18. Line 137. “evolution” -> “variation”?

Clarified: seasonal evolution and interannual variation, p.5, l.31.

19. Line 142. “than” -> “from” or put “other” before it.

Revised to “from”, p.5, l.38.

20. Line 150. Please clarify how you calculated out 7%.

Apologies, just from standard propagation of errors, and assuming 5% uncertainty in each of the incoming and outgoing radiation values: for z = x/y and uncertainties (dx, dy, dz),

dz/z = sqrt((dx/x)^2+(dy/y)^2) = sqrt(2*0.05^2) = 0.07

We add a short explanation, p.6, l.8, but don’t include the equation in the text, as it is standard error analysis.

21. Line 157. The last sentence “modelling of potential reflected radiation from valleys walls indicates that this is negligible at our AWS site”. Could you please present evidence of your claim?

This is a fair request. We have done the modelling as part of previous studies (Marshall, 2014; Ebrahimi and Marshall, 2016), but this specific result is not published and is ancillary to the focus of this study, so rather than include a Figure and the equations to explain this point, we have removed this sentence.

22. Line 159. “paper” -> “work”. “repeat” -> “repetitive” or “repeated”.

Revised to “study”; “repeat” deleted, p.6, l.20.

23. Line 161. “Haig Glacier albedo” -> “The albedo of the Haig Glacier”.

Revised as suggested, p.6, ll.22-23.

24. Line 162. “points” (geometric concept) -> “sites” (geographic concept). Check that throughout the context.

Revised to “sites” as suggested. We consider it point data but it’s true, we made multiple measurements over a few m^2, p.6, l.24.

25. Line 166. Was the sensor held manually? If so, how did you avoid the shadow of the body when measuring? Please clarify.

Yes, held manually, at arms length and pointed to the south to avoid shadows, p.6, l.33.

26. Line 167. Please give the detail of presuming a 10% uncertainty.

We added more detail on this. The manufacturer reported 5% accuracy, but we also observed fluctuations of a few 10s of W/m^2 while taking the readings of incoming shortwave radiation. e.g. for a value of 800 W/m^2, the instrument readings would bounce around between values of ~770 to 830 W/m^2. Readings of reflected shortwave radiation were much more stable. We therefore assign an additional 5% uncertainty in the observation itself, and add this to the instrumental accuracy to get what we consider to be a conservative estimate of 10%. Discussed on p.6, ll.34-38.

27. Line 169. "for melting and major ion and organic carbon analyses" -> "for the analysis of major ions and organic carbon". Please provide the source or references of the impurities used in this work.

These are detailed in Miller (2018), as cited. We are preparing a separate manuscript examining the impurities in detail, but with much of this beyond the focus of this study. That said, we recognize the importance of having the essential data that we refer to presented within this study, so we have added these results (Table 5) as well as essential details on the sampling and analysis, p.7, ll.4-14.

28. Line 176. "data" -> "temperature" and "precipitation"? Please specify them.

It is an energy balance model, so the full suite of meteorological data as described earlier. We now list this explicitly, p.4, ll.31-33.

29. Line 177. Please check the use of articles throughout the context. "forefield AWS data" -> "the data from the AWS in the forefield".

We deleted this part as it was redundant from the QC and gap-filling explanation in Section 2.2.

30. Line 191. What do you mean "the net energy goes to melting"? Please rephrase it.

We rephrased this as requested, p.7, l.35 – we mean that the energy is directed to melting.

31. Line 195. Give out the exact value of Lf (334 J g−1).

We don't systematically note the values of all of the established constants that are used in the energy balance model, but for clarity we added this here, as well as the density of water, p.7, l.39. Both values are standard but this does not distract too much from the flow of the narrative.

32. Line 240. Please clarify the definitions of a and b, respectively.

Regression coefficients – now defined, p.9, l.9.

33. Line 430. The first sentence needs to be rephrased. Do you mean "the impact of fresh snow on albedo"?

Rephrased for clarity, p.15, ll.18-20.

34. Line 450. "forced" –> "driven".

We see these as interchangeable in common usage, but revised to "driven" as suggested, p.16, l.7.

35. Table 1. Please clarify the definitions of summer and winter for this study in the caption or context.

This is now added to the text in Section 3.1, as the caption is already long and wordy. Our definitions are conventional for mid-latitude glaciers: winter accumulation is from the end of the previous melt season to the subsequent spring (i.e. the start of the next melt season), so roughly October to May at our site. Summer, glaciologically, refers to the melt season, roughly May to September at our site. The exact days vary from year-to-year and over the glacier.

36. Figure 2. Why didn't the authors use the lines of means with shaded area indicating the error?

We think the reviewer is asking for a plot that includes the standard deviation of the measurements? We have added this in Figure 2a, but will leave Figure 2b as is to avoid clutter. Our intent with this plot was not to show the errors but rather then mean and minimum values associated with the 14-year observational record. i.e. the minimum here is not an error, but the lowest daily mean value recorded for that day over the 14 years. We have retained that, as it gives a clear indication of the "bare ice" season. But the inclusion of a shaded region for $\pm 1\sigma$ is useful additional information. Note that if the reviewer was actually requesting error bars, this is not what we have added here. These are very small for the average daily values: with an uncertainty of 7% in the mean daily albedo, the average over 14 years has an associated uncertainty of about 2%. (i.e. Or to be explicit from the quadrature rule for error propagation, for an example with $\alpha_s = 0.60 \pm 0.04$, we have $d\alpha_s = 0.04$ and N = 14. The error in the mean is $d\alpha_s/\sqrt{N} = 0.01$.)

37. Figure 7. The blue points denoting the snowpits are blur.

Thank you – we revised this to make them clear.

38. Figure 8. What about the significances between the observed and modelled?

It is inappropriate to compare the daily modelled vs. observed time series statistically, e.g. for correlation or R^2, as the stochastic model does not attempt to resolve the exact timing of specific snow events. This is a bit like weather vs. climate modelling. Our aim is not to represent a specific day, but rather the mean summer albedo value and the general seasonal evolution. The mean values can be compared through a standard t-test, and the observed vs. modelled variance can be compared with Bartlett's test. The statistical tests indicate that the mean and variance are statistically equivalent ($p > 0.001$). We now report this, p.16, ll.21-25.

39. Figure 9. The same issue as that in Figure 8. Significance?

We now add the R^2 value and note the significance of the linear relation, p.17, ll.23-25. Good suggestion, thank you.

40. The language of the context needs a thorough check for grammar and misused words, such as articles, the function word "of", ambiguous statements, etc.

We have read and edited carefully and believe that the text is in proper and clear English, but we welcome any additional specific comments where our writing is ambiguous.