

## ***Interactive comment on “Proglacial icings as records of winter hydrological processes” by Anna Chesnokova et al.***

**Tim Ensom (Referee)**

enso5730@mylaurier.ca

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### 1) Overall Quality

In my opinion the manuscript by Chesnokova et al. is a valuable contribution to mountain and winter hydrology, and to general methodology for winter hydrological investigations in cold regions. I think it is a good fit for The Cryosphere. The title and abstract represent the manuscript well. The work includes a substantial review primarily of North American literature in its Introduction and Discussion. The purpose of the work as I understand – to improve understanding of winter hydrological connectivity in a glaciated mountain catchment in order to improve projections of hydrological response with continued climate change – is well articulated. While the approach of geochemical

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sampling and analysis of aufeis is not new, to my knowledge there are few examples in the literature of this approach in high-altitude glaciated catchments.

There is an opportunity for greater detail in the description of how samples were obtained from the icings and the extent to which they might represent all ice layers. I think that the thresholds for classifying water sources as contributing to the icings or not, on the basis of the distance between their samples and those of the icings in co-isotope plots, might be too restrictive and not fully consider isotope fractionation. The authors might be able to expand on the rationale for this approach, as it could be based on isotope work that I am not aware of. I think that the conclusions are substantial in relation to the type of hydrological system being investigated, and can help guide the design of catchment-scale studies in other cold regions.

The specific comments and technical suggestions below provide ideas for minor improvements in language.

## 2) Specific Comments

Line 124: Would it be possible to replace the term "drastically" with a word that would quantify how limited the changes in chemical and isotopic properties can be, based on the Beylich and Laute reference?

Line 142: It would be helpful for me if the opposite principal was briefly described. I think the opposite principal might be that similarities in the composition of an icing and a potential water source according to multiple tracers would suggest that the water source was indeed parent water for the icing, but I could be incorrect.

Line 295: I don't have extensive experience in isotope geochemistry, but it seems to me that there could be a greater separation in co-isotope space (in the  $^{18}\text{O}$  vs. D figure) between an icing sample and its source than the distance between Glacier B and Icing PF. Because of cryogenic fractionation, if Icing PF was a closed system icing it could be up to about 2.75 per mil  $^{18}\text{O}$  higher than the source glacier. Are the samples of Icing

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PF expected to represent each icing layer and provide an approximate mean value for the  $\delta^{18}\text{O}$  of the icing? The 2011 paper by Lacelle ( DOI: 10.1002/ppp.712 ) might be helpful, and seeing it has also helped me in my work.

Line 329: I can't distinguish these events/activities based on looking at the top panel of Figure 7. All blue points are identified as Duke Glacier. Could labels be added?

Section 5.2: I'm not sure that the distance obtained in a co-isotope plot for watershed B has really been established well as the basis for ruling out potential sources.

Section 5.3: I find this analysis more convincing than the approach with isotopes, due to the uncertainty I have over the fixed distance between the icing sample and potential source considered to be necessary in the isotope diagrams. I may have misunderstood part of the rationale for applying the fixed distance in co-isotope space as a threshold.

Section 6.1.2: I think that the indirect methods actually provide the most convincing evidence of the sources for the icings, and that the TLC images mainly provide information about the timing of icing growth.

Lines 472-487 (paragraph): Interesting and informative discussion.

### 3) Technical Suggestions

Line 39: Would it be correct to say "trends in winter discharge are observed in areas with and without permafrost"?

Line 43: Suggest saying "in cold regions, testing the hypothesis about" Lines 84, 85: Does the reference also provide ranges for mean annual air temperature and mean annual total precipitation? If a range is given instead of a single value for a mean, it might make readers wonder if there is more information to explain what the lower and higher numbers refer to.

Line 94: Arctic should be capitalized.

Line 104: "as it flows downstream" could be removed if the manuscript needs to be

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shortened.

Line 105: Consider saying "two areas", consider removing "actual"

Line 107: Is "pronounced" used to refer to steep? If so, it might be more clear to say "less steep, vegetated slopes".

Line 112: I suggest "icing formation" instead of "icings formation", with icing being plural in this case.

Line 115: Suggest "TLC coverage, however, is limited in its range, is vulnerable"

Line 130: Would it be better to say "The same phenomenon can affect the relation"

Line 132: "because there is a link between stable"

Line 135: Can you clarify what limits are being referred to?

Line 139: It's still not clear to me what limitations have been mentioned recently in the text. Is the limitation the fact that icings can't contain things that their source waters don't contain?

Line 141: Would it be better to say "given source for a unique tracer do not mean that the source is a parent water"

Line 141: I suggest saying "between icings" instead of "between icing"

Line 149: I suggest "...oriented to target icing formations..."

Line 163: "southwest shore" might be more descriptive than "right shore".

Line 166: I suggest: "During the field campaign of June 2016 four icing remnants within the Duke riverbed (Figure 1a and c) and two in Watershed B (Figure 1a and b) were observed and sampled". This removes the first person from the sentence, and is conventional for describing methods.

Line 172-173: Do you mean bubble-rich? Line 190: It may help readers if locations

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were described using east/west instead of right and left. There are a few other instances of left/right in the paper that might be reviewed.

Line 199: Might be better to state "Rainwater samples were also collected during the field campaign."

Line 226: "We measured the anion concentrations in the samples"

Line 276: Suggest "of November, icing formation was observed on the (west/east/north/south) side of the proglacial field."

Line 280: Comma may not be needed after "16 February"

Line 302: Could a definition be included of SC+ and SA- ? If I understand correctly these would be the sum of cations or sum of anions.

Line 316: Could say instead: "The sampled solids are therefore most likely sediments carried out by parent waters."

Line 318: I think it would be fine to remove the portion of the sentence "On the other hand".

Line 330: I suggest "appear to be contributing". Can there be a more detailed description of the evidence that suggests that they are contributing? What was observed in the TLC images?

Line 367-370: This sentence might benefit from being broken into two. A reference might be important to include if a statement is being made that high DOC has been associated with suprapermafrost water in other research.

The heading beside 6.1 could be changed to "Icing formation parent source identification"

Line 394: I suggest "water sources for each of the icings that were in the cameras' fields of vision." Line 396-397: Might be better to say "contribute to the formation of

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Icings 3 and 4."

Line 401: Perhaps say systems instead of set-ups.

Line 406: Check parentheses and adjust or add comma.

The sentence starting with "These results", spanning lines 423 to 425, isn't clear to me.

Line 440. Might be good to change "as" to ", and" after the word watersheds, but just a suggestion. The use of indirect methods would have been informative (in my opinion) even if they had contradicted TLC findings.

Line 454: responsible for icing formation (leave out the s)

Line 515: I suggest saying "have been used to chronicle winter hydrological"

Line 517: I suggest saying "natural-tracer-based analysis"

Line 518: Could say that samples were analysed/investigated/explored. "exploited" doesn't seem like the correct term

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