

Answers to comments in The Cryosphere Discussion of preprint Channelised, distributed, and disconnected: Spatial structure and temporal evolution of the subglacial drainage under a valley glacier in the Yukon

Camilo Rada G. and Christian Schoof

August 20, 2022

1 Answers to referee N°1

1.1 General comments

We appreciate your positive comments about the description of the methodology, as well as your constructive feedback regarding the shortcoming of the paper structure and presentation of the results. We will restructure the results section as suggested and add a paragraph highlighting the takeaways of each of the three subsections of the discussion. We will answer your numbered list of general suggestions one by one:

1. Regarding the length of the time window, I wonder if using several different time windows with different length would yield more information when comparing their results in term of clustering?

R.

It would indeed yield more information, but it would make it more challenging to interpret due to the volume of data and its reliability. If we make the time window smaller, we would have a better temporal resolution to capture the rapid structural changes of the drainage system during some periods. However, at the same time, we would reduce the reliability of the detected connections. In the extreme of a one-day time window, our methodology would be useless, and a significantly different approach would be needed. In such a case, our method would assign almost any borehole with diurnal variations to a single cluster. Note also that our methodology doesn't do well when a borehole switch behaviour in the middle of a time window, sometimes failing to assign the borehole to either the initial or the final cluster. Such problems are more common with longer time windows, which, together with the loss of temporal resolution, are the main drawbacks of increasing the window size. Nevertheless, we tried both approaches (12 and 3 days time windows), which yielded additional useful information. However, the benefits of this information for the main points of our analysis were small relative to the increased complexity of the data presentation and discussion. Therefore, we decided to leave that information out of the discussion. We will add a paragraph mentioning that we decided to leave the information derived from longer and shorter time windows out of the discussion. Noting also that such information increased our confidence in interpreting the six-day time window that we found to strike the right balance between reliability and temporal resolution.

2. I feel that the discussion between correlated and anti-correlated series should be made clearer earlier in the manuscript. The process itself is well illustrated in Figure 1, but I feel that the author are missing an opportunity to clarify their workflow when they introduce the equation for the absolute Euclidian distance where the reason for the use of this specific formulation could be reiterated.

R.

We agree with the observation. We will introduce figure 7 on page 11 line 19, right before presenting the absolute Euclidean distance, to clarify the rationale behind this distance choice.

3. At some point in the manuscript, I was not sure if Pressure was designating water pressure or effective pressure, which is a major issue when describing increase or lowering of the pressure. I urge the authors to use either effective pressure or water pressure throughout the manuscript which would help with readability.

R.

We apologize for introducing that ambiguity, and we will revise the whole manuscript to use either “water pressure” or “effective pressure” to avoid any confusion.

4. On the spatial distribution of the disconnected regions, I was wondering if they were appearing consistently in the same region for the different years, and if that is the case, are there any velocity records that they can be compared against?

R.

Yes, permanently disconnected regions seem to persist through the years. We also have surface velocity records that will be analyzed in a follow-up paper. However, the small magnitude of the velocity differences between different areas of the glacier prevented us from directly studying the impact of disconnected regions on surface speed. Nevertheless, the impact could be measured on the stress field. An approach we have not yet attempted. We will make clear that disconnected regions persist through the years with observations. We will also mention that we will discuss their impact on surface speed in a follow-up paper.

1.2 Specific comments

- L14-P1: “diffusivity” has a typo.

R.

Will be fixed

- L7-P2: The references here all refer to ice-sheets velocity, given the fact that the present study treats of a mountain glacier, references pertaining to this type of glaciers might be better suited.

R.

We will include a reference to a well-studied mountain glacier.

- L17-P2: “OBP” is defined here but used only once in the text, perhaps it should be omitted and only described in the caption of Figure 1.

R.

We will remove the OBP acronym and use it only on Figure 1 as suggested,

- L28-P2: The citation of models here is strange, perhaps adding an “e.g” with a shorter list, or a review paper such as de Fleurian et al. (2018); Flowers (2015) would be better suited here.

R.

We will add e.g. and also Fleurian et al. (2018) in a relevant location in the manuscript.

- L18-P3: “water pressure” should be stated here, or effective pressure (see comment 3 above).

R.

We will change to “water pressure”

- Fig 1: Colourblind readers might struggle with the colorscheme of the arrows, perhaps something more contrasted would fit better (gradient of blue to red with black for overburden). In the caption of the figure OBP should be described.

R.

We will change the colour scheme to a colorblind-friendly choice and describe the acronym OBP here (as we will not use it elsewhere).

- L8-P5: It should be “not” not “nor”.

R.

We will change it to “not”

- L27-P5: the recent paper from Doyle et al. (2021) could be cited here too.
R.
We will cite it as suggested.
- Equation 2: There is an extraneous right parenthesis.
R.
We will remove the misplaced parenthesis
- L8-P13: It would be nice to have a quick description of the shapes of the pressure record for each cluster here.
R.
We will add a sentence pointing to their jaggedness and resemblance to a square signal with a peak position just before dropping to base levels.
- L13-P14: The colour coding for correlated and anti-correlated subclusters could be re-iterated here.
R.
We will add the colour coding of each cluster type to that sentence.
- Equation 4: Subscript i is used both for time and the number of valid sample M_i which should be fixed.
R.
The number of valid samples is also a function of time, therefore, the subscript i is correct in both cases. M_i corresponds, in other words, to the number of boreholes with valid data for time i . For example, if we are averaging ten boreholes, in the first time step, maybe only 6 of them have data ($M_1=6$), then at time step 7, two additional boreholes might have data, then $M_7=8$. At the final time step, maybe most boreholes have ceased to produce data, and only three are still working, then $M_N=3$. We will rephrase the paragraph preceding Equation 4 to make this clear.
- Figure 10: I think that clarifying between effective or water pressure is needed in the labels here and in other figures.
R.
While in most cases it was specified in the caption, we agree that adding that information to axes labels would be beneficial. We will change figure 10 Y axis label to “Normalized water pressure”, Figure 13 to “Water pressure”, and Figure 17 to “Normalized water pressure”. In this last figure, we will change also “averaged mean pressure” by “averaged mean water pressure” in the caption.
- Figure 10: I expect that the light blue shading is darker when there is snow cover but that should be clarified
R.
Your interpretation is correct; we will make it explicit in the caption.
- L4-P19: It should be specified that “the formation of a well developed subglacial drainage system, something that does not occur every year” on this specific site.
R.
Good point. We will change the wording to note that this is a feature particular to South Glacier.
- L5-P20: I have a hard time identifying individual borehole records on Figure 10, perhaps splitting panel a with correlated and anti-correlated borehole in a different panel would help?
R.
In this figure, we wanted to show the overall pattern of borehole behaviours by type more than providing a good display of individual borehole records. However, this concern is valid, and we will look for a way to make individual records easier to identify. Either by splitting into two panels as suggested or increasing the contrast between lines.

- L6-P20: It should be “a” not “an”.
R.
We will change “an small increase” by “a small increase”.
- L8-P20: The sentence starting on this line is hard to read and should be rephrased.
R.
We will rephrase to: “Such pressure drop would reduce the total normal stress supported by connected areas. Therefore, this unsupported load is transferred to the surrounding unconnected areas where the anti-correlated boreholes are located.”
- L15-P20: “through time”.
R.
We will change “trough time” by “through time”.
- L33-P20: Perhaps “in the study area” should be added here.
R.
We will change “that incorporated all the connected sections of the bed.” by “that incorporated all the connected sections of the bed under the study area.”
- L15-P23: I add to look for the meaning of “straddle” perhaps “intersect” would be better, or am I missing some of the subtleties of the wording?
R.
We will change “seem to straddle the one on panel f”, by “seem to intersect the one on panel f. In a two-dimensional drainage system, such a condition would imply a hydraulic connection between these intersecting clusters. However, the differences in their pressure records suggest no hydraulic connection.”
- L6-P24: There could be a reference to the section where the probability were introduced here.
R.
We will add a cross-reference to section 2.5 (Spatial patterns in basal hydraulic connectivity).
- L11-P26: Typo in “section”.
R.
We will remove the misplaced space within the word “section”
- L15-P30: “might be able”, “be” is missing.
R.
We will add the missing “be”.
- L24-P30: I am not sure why the discussion on creep that is made below is not stated here.
R.
We will rephrase that the mentioned reductions in volume would be associated with ice creep.
- L11-P32: It should be “boreholes”.
R.
We will replace “holes” by “boreholes”.
- L16-P32: The sentence starting on this line is unclear and should be rephrased.
R.
We will rephrase as: “Such a hydraulic head difference implies that water will flow between two hydraulically connected boreholes. In such a case, we would expect differences in the hydraulic head when significant water storage exists along the flow path. These differences would take the form of oscillations with attenuated amplitude and phase lag”.

- L23-P32: “resolution of our data”, “of ” is missing.
R.
We will add the missing “of”
- L31-P32: Shouldn’t it be “assigns”.
R.
Indeed, we will change it to “assigns”.
- Sup-L33-P2: “reproduce” in place of “reproducing”.
R.
We will change “that does best reproducing” by “that best reproduce”.
- Sup-L34-P2: RIG should be defined here.
R.
We will replace RIG by “Relative Information Gain (RIG)” followed by the reference to the section that describe this concept in depth.
- Sup-L7-P3: EOF should be defined here.
R.
We will replace EOF by “Empirical Orthogonal Functions (EOF),” followed by the reference.
- Sup-L8-P3: SOMs should be defined here.
R.
We will replace SOMs by “Self-Organizing Maps (SOMs),” followed by the reference.
- Equation S7 to 9: Shouldn’t it be a_i in place of a_1
R.
Yes, indeed. We will replace all a_1 and b_1 by a_i and b_i respectively.
- Sup-L6-P14: “mechanical”.
R.
We will replace the typo “machanical” by “mechanical”