

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

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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 restructured the results section as suggested, separating spatial and temporal analysis. We also added a paragraph highlighting the takeaways of each of the four 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.

Due to the reasons explained in our previous response we decided to leave the information of alternative window lengths out of the discussion. However, we added 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. See the manuscript with tracked changes on page 12, line 3.

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 did introduce figure 7 with an extended explanation right before presenting the absolute Euclidean distance, to clarify the rationale behind this distance choice. See the manuscript with tracked changes on page 12, line 15.

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 revised the whole manuscript and use now 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.

As explained in our previous response we made clear that disconnected regions persist through the years with observations. See the manuscript with tracked changes on page 27, line 9. We did also mention that we will discuss their impact on surface speed in a follow-up paper. See the manuscript with tracked changes on page 36, line 35.

1.2 Specific comments

- L14-P1: “diffusivity” has a typo.

R.

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 did include several reference to well-studied mountain glaciers. See the manuscript with tracked changes on page 2, line 11.

- 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 did 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 did add e.g. and also Fleurian et al. (2018) in a relevant location in the manuscript. See the manuscript with tracked changes on page 3, line 6.

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

R.

We did change it 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 did change the colour scheme to the colorblind-friendly choice suggested and described the acronym OBP in the caption.

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

R.

We did change it to “not”

- L27-P5: the recent paper from Doyle et al. (2021) could be cited here too.
R.
We did cite it as suggested. See the manuscript with tracked changes on page 6, line 6.
- Equation 2: There is an extraneous right parenthesis.
R.
We did 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 did add a sentence pointing to their jaggedness and resemblance to a square signal with a peak position just before dropping to base levels. See the manuscript with tracked changes on page 14, line 5.
- L13-P14: The colour coding for correlated and anti-correlated subclusters could be re-iterated here.
R.
We did add a reiteration of the colour coding of each cluster 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.
As explained in our previous response this was not an error. However, we did rephrase the paragraph preceding Equation 4 to make this clear. See the manuscript with tracked changes on page 19, line 3.
- Figure 10: I think that clarifying between effective or water pressure is needed in the labels here and in other figures.
R.
We did change figure 10 and 17 Y axis label to “Normalized water pressure”. In this last figure, we did 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.
We added a color bar to figure 10, and make it explicit in all caption that figures share the same colour coding for snow cover.
- 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.
We did 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 increased the contrast between lines to make individual records easier to identify.
- L6-P20: It should be “a” not “an”.
R.
We did 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 did rephrase it 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.” See the manuscript with tracked changes on page 20, line 3.
- L15-P20: “through time”.
R.
We did change “trough time” by “through time”.
- L33-P20: Perhaps “in the study area” should be added here.
R.
We did 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 did 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 that there is no hydraulic connection between them.”
- L6-P24: There could be a reference to the section where the probability were introduced here.
R.
We did add a cross-reference to section 2.5 (Spatial patterns in basal hydraulic connectivity).
- L11-P26: Typo in “section”.
R.
We did remove the misplaced space within the word “section”
- L15-P30: “might be able”, “be” is missing.
R.
We did 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 did rephrase to mentioned reductions in volume would be associated with ice creep. See the manuscript with tracked changes on page 32, line 7.
- L11-P32: It should be “boreholes”.
R.
We did replace “holes” by “boreholes”.
- L16-P32: The sentence starting on this line is unclear and should be rephrased.
R.
We did rephrase it 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”. See the manuscript with tracked changes on page 34, line 12.

- L23-P32: “resolution of our data”, “of ” is missing.
R.
We did add the missing “of”
- L31-P32: Shouldn’t it be “assigns”.
R.
We did change it to “assigns”.
- Sup-L33-P2: “reproduce” in place of “reproducing”.
R.
We did change “that does best reproducing” by “that best reproduce”.
- Sup-L34-P2: RIG should be defined here.
R.
We did 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 did replace EOF by “Empirical Orthogonal Functions (EOF),” followed by the reference.
- Sup-L8-P3: SOMs should be defined here.
R.
We did 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.
We did replace all a_1 and b_1 by a_i and b_i respectively.
- Sup-L6-P14: “mechanical”.
R.
We did replace the typo “machanical” by “mechanical”

2 Answers to referee N°2

2.1 General comments

We appreciate your positive comments about our manuscript and the uniqueness of the presented dataset. We were intentionally cautious of not explicitly saying that the dataset is unique and exceptional. However, your comments encourage us to put some of that caution aside. Therefore, we made some changes to the abstract to better communicate the uniqueness of the presented dataset to the reader. See the manuscript with tracked changes on page 1 line 5. We did also emphasize the previous publications discussing this dataset and mention that a follow-up papers are coming to explores the effects of the subglacial drainage evolution on surface speed variations. See the manuscript with tracked changes on page 36, line 35.

2.2 Minor remarks

- page 3, line 18: about the winter measurements, if most boreholes display pressure near overburden pressure for several months, one should expect high or even increasing surface velocity? Do you have observation of surface velocity all around the year that show that? May be this link with the surface velocity measurements (as mentioned in 2.1) even if I understand you don’t have surface velocity in 2015?
R.
As explained in our previous answers. We do have continuous surface velocity records for the whole

studied period, including 2015. However, due to the extent of the manuscript we have intentionally left out the analysis of velocity data in the context of the described temporal evolution of the subglacial drainage system. That will be the main focus of a follow-up paper. We made the rationale explicit in the text and mention that the above paper is in preparation.

- page 3, line 19: which size are expected to be this “water pockets”? The wording make me think to a feature that as similar vertical and horizontal dimensions, whereas I expect more a flat feature? May be “water patches” would be more appropriate here?

R.

Following our previous answer, we now explicitly mention that we do not have constraints on the exact shape and size of these water pockets and explain exactly what we mean when using this terminology. See the manuscript with tracked changes on page 3, line 26.

- page 3, line 20: sometime you are using upper case after a colon, sometime not. Here I would said that a starting a new sentence would work better as the second point is at the beginning of a new sentence (even a new paragraph).

R.

We did check the whole manuscript to make sure there is no capitalization after colons, except for proper nouns and acronyms. In this case, we did start a new sentence and removed the paragraph break before describing the second process.

- Figure 1: cases b, c, d are not steady, in comparison to a that can be steady. May be it should be mentioned in the caption. Also, how long do we expect these unsteady situations to last? Give order of magnitude.

R.

Following our explanation in our previous answer, we did add that a sentence to the caption saying: “Note that (a) is a stable configuration and (d) is unstable, while the stability of (b) and (c) depends on the conditions”.

- page 4, line 3: missing a verb in the last part of the sentence?

R.

We did review the wording.

- page 4, line 12: it is obvious, but may be you should mention here that you are measuring water pressure in these boreholes?

R.

We did add a mention to the fact that what we are actually measuring in the boreholes is water pressure.

- page 11, line 7: how sensitive are your results to this choice of a 6-day time window?

R.

Following on the responses to referee N°1, we will elaborate by mentioning the results obtained with other time windows and how we decided only to discuss the ones resulting from 6-day time windows, which seem to strike the right balance between reliability and temporal resolution. See the manuscript with tracked changes on page 12, line 3.

- Figure 7, caption: for c, you should mention that f is defined in Figs. 10 and 11.

R.

We did add the suggested mention.

- page 16, line 11: Is that that in winter the pressure is not showing any daily variations and more a monotonic signal? Any suggestion how the connection between the different boreholes could anyway be qualified?

R.

Following our previous answer, we did elaborate on how it might be possible to detect connection on such cases. See the manuscript with tracked changes on page 37, line 6.

- page 18, line 20: in this chapter?

R.

We did replace “in this chapter” by “we will present showing”

- page 20, line 6: a small increase

R.

We did change “an small increase” by “a small increase”.

- page 22, lines 12-14: don’t really get the point of this isolated paragraph with the surrounding ones.

R.

We did rephrase it and merge it with the following paragraph. See the manuscript with tracked changes on page 23, line 16.

- page 26, line 11: section 2.6

R.

We did remove the misplaced space within the word “section”

- page 27, line 12: Fig. 5,

R.

We did replace the misplaced comma by a dot.

- page 32, line 23: resolution of our data?

R.

We did add the missing “of”

- page 34, line 35: May be you could conclude by a bit of prospective? Which new measurements could allow a better understanding and complement these measurements? Array of seismometers? What more could still be inferred from this existing dataset?

R.

We did add a paragraph with future work, prospective thoughts and suggestions for new measurements. See the manuscript with tracked changes on page 37, line 3.