

Interactive comment on “Permafrost thaw couples slopes with downstream systems and effects propagate through Arctic drainage networks” by Steven V. Kokelj et al.

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Reply to comments by Dr. Ingmar Nitze (R2)

We appreciate the thoughtful input provided by Dr. Nitze and have undertaken several minor modifications to address his suggestions. In particular, constructive critique of several figures has resulted in improvements that have increased their clarity and impact. Dr. Nitze's contribution to improving our manuscript is recognized in the Acknowledgements section. Detailed replies are provided to specific comments below.

General Comments The manuscript “Permafrost thaw couples slopes with downstream

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systems and effects propagate through Arctic drainage networks.” provides a comprehensive overview of the extent and effects of mass wasting processing in NW Canada on its associated drainage networks across different scales. It analyzes different scales from local watersheds to the entire study area of ca. 1 Mkm². The authors used numerous methodologies and data sources were applied for each specific scale and target objective. The authors did a great job. This manuscript is of high quality and very comprehensive with a lot of detail and only needs minor corrections.

Here are some general remarks. Detailed comments are stated below. The analysis of many different aspects, with a plethora of datasets in different scales, makes it sometimes hard to follow. I think it is generally very hard to find the balance between details and the overall story. Perhaps minor improvements, such as adding a table of datasets (see detailed comments) will help the readers to understand the scale, objective and significance of the specific analyses. The quality of figures ranges from very good to “room for improvement”. Please check detailed comments. Geospatial datasets (Shapefiles or KML) of e.g. the slumps, and perhaps other features as well, would be a helpful addition for readers to easily find the locations and cross-check with other data sources. Overall this manuscript will be a great contribution to the permafrost science community.

REPLY. We acknowledge that the paper covers a wide range of scales as our goals are to link processes on slopes, evolving connectivity with downstream environments and propagation of effects across Arctic drainage networks. To help provide readers with great clarity on what datasets were utilized in the paper and what research questions they address we have constructed Table S1. The table indicates main research objectives and identifies and describes the datasets used to address these questions and their source. We have also made several minor adjustments to figures or captions where possible to improve their quality and clarity. Finally, shapefiles will be published with the associated Open Reports that are referenced in Table S1, which have been reviewed and will be released concurrently with paper publication through the Northwest

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Territories Geological Survey Open Report system.

Specific Comments Title: The title is rather complicated, particularly reading it for the first time

REPLY. We have made a slight modification to the title to improve its clarity.

175: It would be good to somehow provide the exact number, especially since you do that in the abstract.

REPLY. Changed as suggested.

201 ff: You used several different datasets, but it is rather hard to follow this part with text only. I suggest to add a table with basic methodologies and datasets and its related objectives. This will help to keep better track of used methods and spatial scales.

REPLY. Table S1 was developed to indicate the datasets utilized, the research question they pertain to, the base data from which interpretations were made, and reference to data sources.

238: Could you provide a little bit more information who exactly digitized the slumps (how many different people, people with field experience, etc.). I personally find it very challenging to consistently digitize thaw slumps, and even more so with several people.

REPLY. The Authors of the paper did all of the digitizations and have field experience in the study area. It should be noted that to address various research questions in this paper, various base-data layers were used, such that delineation rules and resolution of digitized outputs will vary even if the same individual is mapping features. Methodological aspects of slump digitization is beyond scope of this paper, however, co-author Jurjen van der Sluijs is leading a critical assessment of slump delineation and classification within the context of assessing scatter within area-volume relationship functions. The majority of the datasets used in this paper are published as open reports and the Authors of those reports were responsible for digitization. Also, some examples of the base data and slump digitization are provided in new Figure S1.

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258: I think it would make a great supplementary figure to show some examples (e.g. cross sections) of the reconstruction for selected sites. It looks like you provided this in Figure 3e, but did not reference it in the text.

REPLY. Developing these images are of interest but beyond the scope of this paper. The terrain reconstruction methods are explored in a robust manner through a separate methods paper. However, we have added supplementary Figure S1 which shows DTMs of thaw slumps discussed in detail in Sect. 3.1 & 3.2 and the position of topographic profiles shown in Figure 2g

267: Which Sentinel exactly. I suppose you mean Sentinel-2.

REPLY. We have clarified that Sentinel-2 imagery was used in this analysis.

366: "decade": Do you have exact initiation ages or is it rather an estimate? If the former I suggest using a more precise values (year) otherwise it's also fine to leave decade.

REPLY. The feature is present as a very small stream side slump on the 2011 LiDAR (544 m²) suggesting it had initiated only a few years prior to that. We have left the text as is.

369: see decades 369: I suggest writing "2" as a word, as a few words later.

REPLY. Changed as suggested.

376 Table 1: Please use either negative values without direction (W) or positive values with direction for longitudes. E.g. -135.7555° OR 135.7555°W 381:

REPLY. Changed as suggested.

Figure 2: It would be nice to somehow make a more efficient use of this figure in the next version in case this will be a full-page figure, as there is a large blank space on the right. Of course I understand that this version of the manuscript is C2 still a preprint. Figure 2h: This plot is somehow hard to understand at the first glace. XLabel: is not

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initially clear, which distance you mean. I suggest extending it to “Distance from ” (fill with your reference location). The same (to a lesser extent) applies to the Y-Label. I suggest using “Thickness of sediment accumulation” or so.

REPLY. We appreciate the suggestions to improve this figure. We have made the layout more symmetrical and show pictures of slumps across the size continuum. We have also extended the topographic profiles relative to the pre-disturbed surface from the top of the slump headwall to the end of the debris tongue in order to better capture the evolution of slope to stream connectivity associated with enlargement of disturbances. Please note that new Figure S1 shows the digital terrain models, delineations and transect locations of all thaw slumps shown in Figure 2.

425 Figure 3: a-c: I suggest using a more appropriate colorbar and visual scaling with a distinct break at 0 (zero). E.g. greenish/blueish colors for accumulation and orange/reddish colors for erosion. (e.g. <https://colorbrewer2.org/#type=diverging&scheme=RdBu&n=9> or something similar) a-d: What is the source and timing of the hillshade? e: (very gentle) gridlines may help to better read the proportions of the plot. However, I am not sure if this add too much information to this plot. The intersection of “(e)” and the lines may need some improvement.

REPLY. We appreciate the suggestions and have adjusted the color scheme to improve clarity of the zero breakpoints. Timing of the hill-shade is indicated in the caption and a slight tweak to the placement of annotations was implemented to decrease clutter.

434: Please specify what exactly you mean with thaw-slump indices. Volume, area, . . . ? (I found them in 443). I suggest using them here.

REPLY. Minor editorial modification was made to clarify the text.

434 ff: You are providing slump related statistics, but it is unclear which total area you analyzed with this dataset or how many features/slumps you detected. At least I cannot

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find them here in this paragraph.

REPLY. Method Section (2.3) describing the region from which these slumps were selected, how they were subsampled from the entire population, and the base data from which they were digitized is now referenced.

465: I suggest using “Scatter plots” instead of only “Scatter” (if you mean scatter plots)

REPLY. We clarify by indicating that we refer to “variation in the residuals, or (scatter)”.

543 Figure5: an Inset: The numbers are hard to read especially in the dark grey part. The order in 1986 is reversed (2 bottom) compared to the other years. Technically you could include the same information into the large bars, though the focus shifts to absolute numbers rather than relative to 100%. b-c/d-e: As the information from b & c as well as d & e are highly correlated, using only area or volume might be appropriate. However, this is a “soft” recommendation, but might be ok if you leave it. Perhaps shifting f to position d makes sense to have area and volume in one column.

REPLY. We appreciate the advice and have removed the inset from Figure 5a and present the connectivity by shading on the large bars to portray by count. We have left the remaining figure as it is so a reader can assess both cumulative effects of increasing slump numbers as well as changes in the size distribution of the population.

551 Figure 6: Please check the numbering (a-c) of the insets. The main map does not have a letter. There are duplicate b and c. Main map: Just out of curiosity, which projection is it? The maps seems to be slightly rotated (clock-wise). The grid shows the rotation but the north arrow does not. Please adapt the north arrow, as I suppose the rotation was made to fit the watershed into the figure. I like the accumulated scar C3 area visualization.

REPLY. We have adjusted panels so that they are indicated sequentially. Caption has also been adjusted. The orientation of the North arrow has been adjusted.

567: Sentinel-2?

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REPLY. Minor edit implemented to clarify the text.

596 Figure 7: The data itself are very interesting but the visualization should be improved. I suggest using colors instead of black and white only. Furthermore please make sure that data is not occluded, particularly in a, b and d. Using colors and semi-transparent markers should help. Is a/b already semi-transparent and the grey part the intersection area? If yes, using colors will help to better see that this might be the intersecting area, as this color is not visible in the legend. Perhaps, you could remove the fill color for the bars at all and use only edge colors. b/c: These plots look good, but it's quite challenging to understand what they mean. Particularly c it is not clear to me what the Cumulative disturbance in relation to the catchment area means. I see that there are changes over time (Peel), but the specific data behind it are puzzling to me.

REPLY. Adjustment of the color scheme and use of semi-transparency was implemented to improve Figure 7a, b. We have slightly adjusted the text to clarify what the data on Figure 7c portray and its significance.

641 Figure 8: Awesome Figure What does NHN mean in the legend?

REPLY. We appreciate the feedback! We have clarified in the caption that NHN refers to National Hydro Network. The dataset and acronym are also provided in the methods section and now in the new Table S1.

859: I think it will help to have a list of publically available datasets in this section have a direct and comprehensive overview of these datasets instead of crawling through the text and references. Access to your datasets, e.g. delineated thaw slumps or aggregated spatial statistics, will be of great benefit to other researchers, particularly for large scale remote sensing and model applications.

REPLY. We appreciate the comment and have addressed this in large part through providing a summary of the datasets in Table S1.

Supplement Figure S1: I suggest using colors for nicer visualization. Please add (a,b,c)

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to each subplot. A horizontal alignment of plots would be nice, even if the plot size needs to be slightly reduced.

REPLY. Minor adjustments were made to improve the figure (now Figure S2).

Figure S3 iii: Here it would be great if you'd add an arrow/marker to the slide. With a lot of experience it's possible to find it, but without it can be hard. Please mention (and visually indicate) the dam/blockage.

REPLY. Caption adjusted to clarify location of the slide and damming of the river. Photographs have also been added so readers can visualize the magnitude of this landslide. Similar adjustments were implemented to Figure S3ii. Please note this is now Figure S4.

384: bottom of Table S3: Perhaps it is rather nitpicky, but using ISO format of dates would be nicer (e.g. 1986_07_07 → 1986-07-07)

REPLY. Minor adjustment implemented.

444: Perhaps you should cite <https://jstnbraaten.shinyapps.io/snazzy-ee-ts-gif/> as well, which is the second step to create these animations.

REPLY. The URL is now provided.

C4 Technical Comments Supplement 381 Table S3 caption: typo in: ". . . could free Landsat . . ."

REPLY. Adjusted through minor modification to the text.