

AUTHOR RESPONSES TO REFEREE 3 COMMENTARY ON MANUSCRIPT 2022-38

Manuscript ID#: **2022-38**

Title: **Significant underestimation of peatland permafrost along the Labrador Sea coastline**

First Contact: **Yifeng Wang**

Second Contact: **Robert Way**

REFEREE 3 (DR. STEVE KOKELJ)

[Authors' Response]: We thank Dr. Steve Kokelj for taking the time to provide helpful comments on our manuscript and supplemental materials. We have responded to each comment below and have made corresponding changes to the revised manuscript and supplemental materials.

COMMENTS TO THE AUTHORS

The Introduction is reasonably effective at framing the study but should be further strengthened by better linking the state of knowledge with clearly articulated research questions or hypotheses. This will help to better frame the content of the paper, and provide clear logic behind the methods and analyses that are implemented.

[Authors' Response]: We agree and have included a sentence near the end of the Introduction that more clearly outlines the main hypothesis of the study, which is that peatland permafrost landforms are abundant in some areas along the Labrador Sea coastline.

In relation to this point, there is a fair bit of data shown in the Supplementary materials, some of which seem central to the paper, while other figures in the main manuscript host relatively small amounts of information (F1, 2a). Some figure content could be better organized to make more economic use of figure space while highlighting the data that best supports key arguments.

[Authors' Response]: We agree and have rearranged some of the figures between the main manuscript and the supplemental material.

Some minor editorial adjustments and additions to the figures would be helpful to more clearly define the spatial scope of the study. Early in the manuscript, it seemed that the paper developed Labrador-wide datasets, but only later in the manuscript did it become clear that the manuscript was focused on the coastal region as indicated in the title. Also, it would be useful to express whether the inventory was aimed to be exhaustive or whether it is thought to represent a subsample of the total population of the features within the focal area of study.

[Authors' Response]: We agree and have modified Figure 1 to include an outline for the primary study area, corresponding to the area within 100 km of the Labrador Sea coastline. We have also included a Section 2.4 (Inventory extent) that describes the extent of the inventory and the justification for our focus on the coast. We have also included additional details in Section 3 (Methods) that includes mention of the sample nature of the inventory, as opposed to a full census or total population.

I think that the paper would also benefit significantly if the point data could be more effectively linked to some spatial characteristics of the peatlands. In this regard, I suggest three points to consider. First, it would be useful to clearly express the rule-base for decisions of how and where

researchers dropped points to indicate the presence of a (permafrost) peatland complex. In Figure S9 the points seem to represent discrete features, however, it is less apparent why multiple points are dropped in peatland areas in Figure S10. In relation to this point, I think it would add significant value to the paper if the points could be attributed by a size index describing the peatland. This could be through establishing categories based on the area (discrete/small, basin/medium, landscape/large). Alternatively, or in addition, it would be useful to digitize a random subsample of peatlands to show the size distribution of a sample population. This would better contextualize the point dataset giving the inventory more “depth” and providing a better picture of the areal coverage of permafrost peatlands. This data would also provide the Authors with a solid platform for future analyses. It would be useful to include a table showing the data model describing attributes that were collected by the inventory.

[Authors' Response]: We have provided additional information in Section 3.2.1 (Identifying wetlands of interest (WOIs)) on the criteria that were considered when identifying individual WOIs. To support this, we have generated a new figure that shows how the delineation of the WOIs was interpreted, and this figure is included in the supplemental material (Supplement Sect S1).

We have also provided additional information in Section 3.2.1 (Identifying wetlands of interest (WOIs)) on the approximate range in the size of WOIs. While information on the size of the surrounding peatland (discrete/small, basin/medium, landscape/large) is relevant to a wetland mapping initiative, we are worried about an implication that larger peatlands may have more permafrost area when that is not something that we can evaluate at this point. Rather than provide an estimate of the area of each WOI, we have conducted an additional analysis, in which we have classified each likely and possible peatland permafrost complex as palsa, peat plateau, or mixed (palsa and peat plateau). This information has been included in the main manuscript (Figure 6) and will also help provide us with a solid platform for future analyses, especially given the relative permafrost coverage by peat plateaus compared to palsas.

As suggested, we have included a table in the supplemental material (Supplement Sect. S2) that shows the attributes that were collected as part of the inventorying and validation process.

I generally like the comparisons between the data generated by this project and the broad-scale spatial products. I think the comparisons are made in a reasonable manner, despite the difficulty of direct comparison with most of these broad-scale datasets because what they represent can be unclear. Some straightforward quantitative comparisons that show the degree of agreement between empirical permafrost peatland observations and grid cell classifications for the datasets portrayed in Figure 5 or S5 would be useful and should be added to the results section. The implications of these results can remain in the discussion.

[Authors' Response]: We have presented quantitative comparisons that show the degree of agreement between our inventory and the datasets portrayed in Figure S1 in Section S4 of the supplemental material. We have modified this section to also include quantitative comparisons that show the degree of agreement between our inventory and four peatland permafrost distribution products. We appreciate the suggestion to include these comparisons as part of the results of the main manuscript, but we have decided to keep them in the supplemental material (Supplement Sect. S4) as our inventory represents only a sample of some of the largest peatland permafrost complexes in coastal Labrador. These comparisons may be more suitable for a future manuscript that considers area-based estimates of peatland permafrost in Labrador.

P1 L10-13. Consider making a clear statement of the general distribution of peatlands across Labrador early in the paper to help frame this study. This added context would help a reader not familiar with the region.

[Authors' Response]: We have provided a statement in Section 2.2 (Physical environment) describing the general distribution of wetlands in Labrador. We have also provided reference to nine wetland or peatland distribution products in the supplemental material (Supplement Sect. S1).

L15 – I think it would be useful to briefly explain what is meant by a wetland and peatland permafrost complex. Does the area of the landform matter?

[Authors' Response]: We have provided additional information in Section 3.2.1 (Identifying wetlands of interest (WOIs)) on the criteria that were considered when identifying individual WOIs and the range in the size of WOIs.

L21 – It is not clear why the presence of “frost susceptible sediments” is important for peatland permafrost to form. Is it that peatlands typically develop in flat, poorly drained environments often characterized by lacustrine or glaciolacustrine deposits, which also happen to be frost susceptible?

[Authors' Response]: We discuss the importance of sediment type, particularly of marine deposits like marine clays and silts, for peatland permafrost distribution in Section 5.1 (Distribution of peatland permafrost in Labrador). The nature of the sediments beneath the peat is very important for peatland permafrost development and persistence given that permafrost extends through the peat and into the underlying sediments. The presence of frost-susceptible materials allows for the development of segregated ice and the formation of an elevated landform that facilitates permafrost persistence (snow scouring).

Consider that total peatland counts are not the best way to highlight the relative importance of the phenomenon over a geographical area. While the totals have value in comparing permafrost vs non-permafrost peatlands, reporting the data as a frequency density (count/unit area) is more useful to understand the relative importance of the phenomenon, it can be portrayed spatially, and it can be compared more readily with data from other regions.

[Authors' Response]: We appreciate this suggestion and have presented the count per area, or density, of likely peatland permafrost complexes in Figure 4B. We agree that counts that are not contextualized by total study area can be difficult to compare with other datasets, but we are cautious about making broad assumptions about the area of peatland permafrost in coastal Labrador from this first inventory. This manuscript is intended to describe a first attempt at mapping peatland permafrost complexes in an understudied region where these kinds of landforms were previously believed to be largely absent. These suggestions will certainly be considered in the next steps of our overarching project, and additional work in modelling the area of peatland permafrost in coastal Labrador is already underway.

L28. Suggested modification. Add “in the form of” palsas (peat mounds...)

[Authors' Response]: We agree and have changed “as” to “in the form of”.

L28-29. Suggested modification for the definition of peat plateau. “variable-sized fields of frozen peat elevated above the general surface of the peatland”

[Authors' Response]: We appreciate the suggestion and have changed the definition to “fields of frozen peat elevated above the general surface of the surrounding peatland”.

P2L44-51. This narrative is good, but it would also be useful to describe the distribution of peatlands in Labrador (and the coast) to better contextualize the study. There are some nice maps in the supplement but those don't get introduced until much later in the paper. If peatland distribution was integrated into a map earlier in the main manuscript it would help contextualize the discussion from L44-51.

[Authors' Response]: We have provided a statement in Section 2.1 (Bioclimatic setting) describing the general distribution of wetlands in Labrador. We have also provided reference to nine wetland or peatland distribution products in the supplemental material (Supplement Sect. S1).

P2-3L64-65. It would be useful to more clearly indicate the spatial scope of the study. It is implied in P2 L63-65 but should be clarified and shown in Figure 1.

[Authors' Response]: We agree and have modified Figure 1 to include an outline for the study area, corresponding to the area within 100 km of the Labrador Sea coastline. We have also included a Section 2.4 entitled "Inventory extent" which describes the extent of the inventory and the justification for our focus on the coast.

P3L66. Overall, the introduction is well-constructed and the need for research into peatland permafrost is apparent. Still, the final paragraph could be improved by clarifying the research questions or main hypotheses.

[Authors' Response]: We agree and have included a sentence near the end of the Introduction that more clearly outlines the main hypothesis of the study, which is that peatland permafrost landforms are abundant along the Labrador Sea coastline.

L86-93. To support this text it would be useful to show the relative proportion of different terrain types in one of the maps.

[Authors' Response]: We agree that it would be useful to provide information on the different terrain types and surficial deposits. Unfortunately, surficial materials information for the entirety of Labrador is currently only available at the 1:1,000,000 scale, with some information at the 1:50,000 scale in scattered locations. Our ability to provide this information is unfortunately limited by the availability of surficial materials products at an appropriate scale and will not be possible until significant advances are made in this area by partner institutions or governments. We have included additional information in Section 5.2 (Implications for peatland permafrost and permafrost distribution in northeastern Canada) describing the lack of available surficial materials data at a suitable scale for all of Labrador.

P4L95-109.

I find this section to be well-written and informative. It highlights data gaps and provides a nice context for your study. Some of this narrative could be situated in the introduction section to help establish the relevance of your work and to frame clear research questions.

[Authors' Response]: Thank you! We have included some of this information in the Introduction.

It would be useful to define the study area up front and show it in a figure early in the main manuscript.

[Authors' Response]: We agree and have modified Figure 1 to include an outline for the study area, corresponding to the area within 100 km of the Labrador Sea coastline. We have also

included a Section 2.4 entitled “Inventory extent” which describes the extent of the inventory and the justification for our focus on the coast.

It would be useful to elaborate on the description of Peatland permafrost complexes in the study area with reference to figures early on.

[Authors’ Response]: We have provided additional information in Section 3.2.1 (Identifying wetlands of interest (WOIs)) on the criteria that were considered when identifying individual WOIs and have generated a figure that shows how the delineation of the WOIs was interpreted and this figure is included as Figure 2 in the main manuscript.

On P7 L149-154 you could clarify that variation in elevation was used to assess permafrost presence.

[Authors’ Response]: We agree and have clarified that evident shadows indicative of elevated landform edges relative to the surrounding peatland was used to assess permafrost presence.

P7. Upon inspecting some of the supplementary materials the Authors should clarify what comprises a WOI, or a point. Was there a rule base that indicates how a researcher identified a discrete “complex”, and when one vs. two points were dropped? For example, the identification of discrete wetlands seems clear on FS9, but the distinction is less obvious on FS10.

[Authors’ Response]: We have provided additional information in Section 3.2.1 (Identifying wetlands of interest (WOIs)) on the criteria that were considered when identifying individual WOIs and have generated a figure that shows how the delineation of the WOIs was interpreted. This figure is included as Figure 2 in the main manuscript.

P8. With respect to utilizing the DJI Mini 2 as explained in the methods, I would caution promoting a “best practice” since Canadian regulations require maintaining a visual line of sight.

Source: <https://www.gazette.gc.ca/rp-pr/p2/2019/2019-01-09/html/sor-dors11-eng.html>

Visual line of sight see 901.11; also see definitions of VLOS.

[Authors’ Response]: We acknowledge the reviewer’s concerns; however, since the DJI Mini 2 microdrone weighs less than 250 g, it is exempt from Transport Canada regulations regarding small remotely piloted aircrafts (250 g to 1 kg) and can legally be flown beyond visual line of sight. To avoid promoting a best practice of operating larger remotely piloted aircrafts beyond visual line of sight, we have removed this sentence from the text.

Figure S3. It would be useful to show all of the survey points and the flight line.

[Authors’ Response]: We have included a figure in the supplemental material (Supplement Sect. S2, Figure S3) that shows the helicopter survey line and all WOIs that were validated via this method.

3.3 Validation: It would be useful to describe the data model that guided the collection of the inventory information.

[Authors’ Response]: We have provided additional details in Section 3.3. (Validation of subset of WOI database) on the selection criteria for WOIs to be validated via field visits.

Figure 2. Please indicate the study area that bounded the extent of the inventory. Also, please adjust the contrast of the “Not Permafrost Peatland” symbol to improve their visibility.

[Authors' Response]: As suggested, we have included the primary inventory study area and adjusted the symbology for the "Not Peatland Permafrost" locations in Figure 3.

P9 L208-211. Section 4.1 is very brief without much supporting analyses or graphics. Consider integrating this section with the next section.

[Authors' Response]: We appreciate the suggestion but have decided to keep the text as is to help structure the results according to the different stages of the inventorying process.

Supplement Sect. S3. Can the Authors indicate all of the points showing the different WOI categories?

[Authors' Response]: Following previous suggestions, we have defined our study area more clearly as the area of Labrador and adjacent parts of Quebec that fall within 100 km of the Labrador Sea coastline. We have described in Section 2.4 (Inventory extent) our justification for our focus on the coast, so we have removed this figure from the supplemental material as it is no longer necessary.

The data in Figure 4 is good and the descriptions are clear. Consider paired plots that normalize the distribution against available terrain within that class. Also, it would be interesting to see a plot of the distribution of peatlands without evidence of permafrost.

[Authors' Response]: We appreciate the suggestion and have provided histograms characterizing the complexes that were classified as unlikely to contain peatland permafrost in the supplemental material (Supplement Sect. S3).

P14 L278. Permafrost peatlands can also develop in flat sandy areas so that while ice segregation is commonly associated with peatland permafrost it is not a prerequisite. Here I would also suggest referencing the primary literature to support this point rather than a national-scale rule-based model.

[Authors' Response]: We have reworded the sentence to clarify that it is specifically palsas and peat plateaus that form from the epigenetic development of segregated ice and have included additional references to better support this phrase.

P15-17. Figure 5 and S5 host a large amount of spatial data and the Discussion narrative compares and contrasts this study with modeled outputs of related variables. Systematic comparisons of these data sets should be presented as results and the implications can then be addressed more qualitatively in the Discussion. The comparisons are interesting and should be expressed as a study objective given that Figures 5, and S5 present 13 maps with significant amounts of data aimed at comparing new results from this study with existing mapping data.

[Authors' Response]: We have provided quantitative comparisons that show the degree of agreement between our inventory and the datasets portrayed in Figure 6 and Figure S1 in Section S4 of the supplemental material. We have modified this section to also include quantitative comparisons that show the degree of agreement between our inventory and four peatland permafrost distribution products, three of which are already presented in the main manuscript. We appreciate the suggestion to include these comparisons as part of the results of the main manuscript, but we have decided to keep them in the supplemental material (Supplement Sect. S4) to keep the manuscript as compact as possible and to avoid deterring the focus of the manuscript away from its intent of describing an abundance of palsas and peat plateaus in an understudied region where permafrost was previously believed to be largely absent. Further, as our inventory

represents only a sample of some of the largest peatland permafrost complexes in coastal Labrador, these comparisons may be more suitable for a future manuscript that considers area-based estimates of peatland permafrost in Labrador.

To reiterate a previous point, I think it is also helpful to present results as a count per area because reporting total numbers of peatland occurrences does not provide a great sense of their spatial coverage or regional importance. Furthermore, counts that are not contextualized by total study area are difficult to compare with other datasets.

[Authors' Response]: We appreciate this suggestion and have presented the count per area, or density, of likely peatland permafrost complexes in Figure 4B. We agree that counts that are not contextualized by total study area can be difficult to compare with other datasets, but we are cautious about making broad assumptions about the total area of peatland permafrost in coastal Labrador from this first inventory. We have made some progress towards area-based analyses and estimates of peatland permafrost coverage in Labrador, and we have included some of these steps as part of the main manuscript. For example, we have conducted and included an additional analysis, in which we have classified each likely and possible peatland permafrost complex type as palsa, peat plateau, or mixed (palsa and peat plateau). This information has been included in the main manuscript (Figure 6) and provides interesting insights into the extent of permafrost in areas that are dominated by peat plateaus versus palsas. We appreciate the reviewer's suggestions, and they will certainly be considered in the next steps of our overarching project to study the distribution and sensitivity of peatland permafrost in coastal Labrador.