Review on

The trajectory of landcover change in peatland complexes with discontinuous permafrost, northwestern Canada

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Short summary

The authors describe a conceptual model of landscape development from a permafrost underlain forest to a treeless wetland and, as last step, an afforested wetland. This conceptual model is underlain with historical and recent aerial photographs and energy and water balance data of one field site to describe the transformation in more detail. The study is motivated by a large scale analysis of the spatial distribution of landcover types in northwestern Canada.

General comments

This study needs more effort on the concept, the analysis, and the writing. My major critique on the **concept** is that the large scale analysis is not linked well with the conceptual model. What does the conceptual model mean at a larger scale? What is the timeframe when we would expect such changes? How big of an area is likely to change when? I am missing the space-for-time substitution that is mentioned in the abstract. This would improve the scientific significance. At the current stage, it is not clear what the new contribution of the study is.

Parts of the **analysis** itself are questionable, sometimes because they are just not well enough described. The statistical analysis with ANOVA cannot be used for autocorrelated data (such as the monthly values in this case); also comparisons should always be limited to the common period as with climate change most variables are certainly not stationary. Changes in permafrost area are mentioned in several places, but it is not clear how the permafrost area was estimated.

The **writing** needs to be more specific on what the authors did for the current study. In multiple places of the paper it is hard to distinguish between their work and other peoples work. The paper would be much easier to read if they used the active voice for everything they did and found out. It is also important that they separate the results from the discussion. That would help a lot to distinguish what the new contribution in this study is as compared to previous understanding and the literature cited. This is something that needs to be highlighted. In the current version, the joined section reads like a literature review in lots of paragraphs. Even the methods section includes parts that should be moved to the discussion or introduction. The description of the methods is, in many places, not clear and for some of the described methods it is not clear to me which results they generated. The complete methods section should be restructured (suggestion below) and the remote sensing methods should be illustrated with a figure. In several parts I am also missing information on why a specific method/dataset was used. The English

25 is fine but the quality of the figures could be improved. The complete paper is much longer than it would need to be to address the objectives; it would be better is it was more concise.

Specific comments

Abstract I waited until the last sentence to learn about the main method of this paper and I find it difficult to extract the main result and the main message from the abstract. I suggest to put the information about the method right after the first topic
30 introduction sentences, be more specific in the results sentences and add a statement about the implication of this work.

18 'This study explores the current trajectory of landcover change across...' this is what I would like to see in the study. However, the large scale analysis is quite disconnected from the rest.

19 Where are you doing a space for time substitution? Mostly, you use a single location (Scotty Creek) as a substitution for a large area and show how it evolved over time.

35 **22–24** This needs to be included in Figure 3.

Key points The key points are all about methods. I suggest to include at least one on your findings.

Introduction The introduction touches on many interesting points. However, I have trouble to follow the introduction as the paragraphs do not seem to have one clear focus each and build on each other. Maybe you could slightly reorder the sentences and start every paragraph with a topic sentence, for example introducing current landscapes, observed changes,
40 implications for the water and energy budget. The current last paragraph is very helpful.

40 Please update this reference to a peer-reviewed paper which also includes the thaw component.

43 What is 'not well understood'? Two sentences later you write that lots of changes have already been documented. Please be more specific on the lack of knowledge.

92–98 This part of the paragraph seems to belong to the second paragraph of the introduction.

45 **Figure 1** All fonts are too small, some are barely readable. Please use vector graphics (such as pdf) for all figures so that the resolution is high and the text does not appear blurry. What does the yellow line mean? Can you indicate with keywords what it separates? How was the border between the permafrost regions determined? Are you using the map by Brown et al.?

Section 2.1.1 One or two pictures (maybe as part of Figure 1) would be good to show the different landscape parts. Please
50 indicate where permafrost can be found.

167–169 Can you specify how much the temperature increased at this site specifically?

179–181 'relatively long record', 'Long-term observations': how many years? Are those continuous measurement series?

Section 2.2 is not very clear to me. The methods could be described more clearly and I would like to read some sentences on why a certain wavelength/dataset/... was selected. The section would also profit a lot from a figure showing a small example area in all the different datasets and computed products. A table would also help, stating the most important properties for each dataset such as spatial coverage, resolution, date of acquisition, categories contained, who created it, citation. This could also be moved to the appendix.

194 How is the warm season defined? How can you exclude moisture variations? I assume that you have different acquisition dates and some may be after a rainfall.

189–198 Did I understand it correctly, that you selected one image per scene based on fewest possible clouds, latest possible year, and month in June/July/August? Maybe you could make the collection criteria more clear. Concerning vegetation development, the beginning of June is quite different as compared to mid of August. Can you justify the 'rendering the images seasonally comparable' a bit better?

198–199 Why did you restrict yourself to those 3 bands? Can you explain why you did not include more?

205–207 I do not know this dataset. Can you describe it briefly (What variables? Continuous or in classes? Spatial resolution? Vector or raster data?) Did you apply thresholds? Please cite a documentation and not only the download link.

207–209 I also do not know this dataset and the reference does not appear in the literature list. Can you describe the dataset briefly (What variables? Continuous or in classes? Spatial resolution? Vector or raster data?) Did you apply thresholds? Please cite a documentation.

203–211 This step seems central to me and it is very abstract. It would be great to see a figure with examples of the datasets in combination with the Landsat imagery and the result of your filtering. One small area in all the different images.

212–214 It is not clear to me what you clustered here. Is it 3-band-Landsat pixels?

215–217 How did you aggregate the classes? Manually based on expert knowledge? What was the advantage of having the unsupervised clustering first, if you targeted the specific classes described?

220 Which map of peatland distribution?

212–221 Can you add the clustering result to the figure I suggested?

228–229 What do you mean by 'This generated a spatially distributed dataset'? I thought you reduced the spatial dimension to a north-south gradient.

Section 2.3 is long and confusing. It should be restructured and some parts should be move to the introduction or discussion. It should contain only references to specific methods/datasets and not general findings on landscape change. I suggest to arrange the complete methods section as follows:

1. The Taiga Plains ecozone

2. The Scotty Creek field site

3. Geomatics methods

4. Water balance data (currently lines 234–237, 252–255, 260–282)

5. Imagery of the Scotty Creek basin (currently lines 283–295, 328–333)

6. Energy balance data (currently lines 299–323)

7. Conceptual model (currently lines 324–328, 333–340, needs more details)

237–252 I do not see how these paragraphs fit into the section 'field based methods'. Please see my general comments.

253 'Interannual': please specify which years.

255–259 This belongs to the discussion not to the methods.

260–262 Please indicate how runoff was measured.

Table 1 The caption sentence 'Both..thaw' should be moved elsewhere (The methods section on Scotty Creek would be a good place). You mention a runoff increase above. For non-stationary processes, it is misleading to calculate residuals
from variables averaged over different time periods. Please use the common period 2013-2016 to calculate residuals. The numbers from the complete datasets can be added as additional columns or rows.

277–278 Table 1 does not show annual values. I think annual values would be interesting to see the variability and showing them would answer to my comment on Table 1. Why do you not show a figure with the time series of annual precipitation, runoff, evapotranspiration, and residual storage which you used for your study.

280–282 Why do you analyse the runoff, evapotranspiration, and storage data for trends but not the precipitation data?

293–295 By you or by the other authors you cite above?

296 – 299 This does not belong in a methods section.

318 Here you mention 'subcanopy' are all measurements below the canopy? Please specify this when you describe the stations.

320–323 What do you test with the ANOVA? What are your responses and drivers? Are you looking for the effect of station
landcover on November reflected shortwave radiation, for example?

328–333 What are these images used for as comparred to the airborne and satellite images described in l. 283–295?

324–328, 333–340 Here you touch on the conceptual model you developed, but it is not clear to me how you did it. The methods section should describe how you did your analysis and why you used a specific method/dataset, but not why you study something in general (this part should be moved to the introduction or maybe partly to the discussion section).
You do not need to mention here which figures you show later.

337–340 Whether or not your results can be extrapolated is a topic for the discussion section, not for the methods.

Figure 2 What did you use the Landsat 8 data for in this map? As far as I understood, it was only used to estimate forest cover and not whether or not the landscape was 'peatland-dominated'. Please make this more clear in your methods! Some fonts are too small.

344–345 Is this a finding, or a part of the original definition of a peatland which you used in the classification?

Figure 3 Please exchange the word 'proportional' with 'fractional'. You are not really showing 'proportional permafrost area', but only the rough classes. Are these from the Brown permafrost map? Do you have more detailed information? If not, please change the caption. The fonts are too small and the whole figure too big for the content. I would be interested to see an additional line for fraction of peatlands.

365 'wetland features, including collapse scar bogs, are most prevalent' - This would be interesting to show in Figure 3

Section 3.2 It is not clear to me what the new part in this study is as compared to previous understanding and the literature cited.

396–401 Is this something you found out, or is it described in literature? Please cite one or more relevant articles and explain why you adopted/changed the phases.

418 You mention, that the transition is very fast (40 years). Please discuss speed in a bit more detail. Are there other studies? It would be good to add a rough timeframe in your Figure 4. The work of Claire Treat may be relevant here, e.g. *Treat CC, Jones MC. Near-surface permafrost aggradation in Northern Hemisphere peatlands shows regional and global trends during the past 6000 years. The Holocene. 2018;28(6):998-1010. doi:10.1177/0959683617752858* (maybe other papers of her are even more interesting). She includes afforested peatlands in her work, but the timescales for forest recovery were more like 450 – 1500 years.

419–423 What makes you think it is unlikely? I would like to see more discussion here.

Figure 4 Fonts are much too small. Why does incoming shortwave radiation change? Is it measured below canopy? In this case please rename this variable. I do not understand why storage changes across the gradient. As I understand it, storage is not a flux (like runoff and evapotranspiration) and the storage change (which would be a flux as your other two variables) should be close to zero on a multiannual timescale. You do not mention the timeframe here.

459–460 'at the expense of permafrost' - how do you know? You do not describe soil temperature or ice content anywhere. Please be more specific when you talk about permafrost.

Section 2.2.2 Please change your statistical analysis to incorporate autocorrelation and to use only the common period of all measurements. Please also do not provide exact p values but restrict yourself to $p < 0.05$ (or whatever threshold you use).

519–520 Is this measured above or below canopy? Is there shading on the sensors? I do not see why (given the small distance) incoming radiation should be different. I suggest to show albedo instead. It is more interesting and has more implications on the energy partitioning within the vegetation. This comment of course also applies at your statistical analysis and Figure 5.

529–531 It is not statistically sound to use ANOVA on a timeseries (of monthly values in this case). The reason is, that the values are highly autocorrelated. Therefore, you get a 'fake confidence' and the p values are wrong. Either (I) remove your statistical analysis including all p values, (II) use an appropriate methods to include autocorrelation, or (III) use data with no (or at least little) autocorrelation, such as annual values. You could also analyse all mean June values in one analysis, as June 1999 should not be correlated to June 2000. This would give you one p value per month.

Figure 5 As described, your p values are wrong. However, if you fix the analysis, please anyway only write $p < 0.05$ (or whatever threshold you use), not p=.... This gives false confidence. Please consider changing to W/m^2, which is used more often than $MJ/m^2/day$. Please use only the common measurement period as the fluxes are likely not stationary. Fonts too small (use the caption font as an indicator of an appropriate size). Did you check what the low values of longwave radiation represent (10–$15\,MJ/m^2/day$)? Are these real observations or issues with the instruments?

545–563 Given the small distance between the sites, incoming radiation is not very interesting. Please analyse albedo instead. It would also be interesting to estimate snowmelt timing at the different sites and analyse that. In particular as you discuss albedo later.

Section 3.2.3 Do you have new numbers or results to add to this literature review? What do you mean by 'runoff', only in streams/rivers or also as groundwater?

617–620 How about mosses?

666–667 Does landcover depend on climate or climate on landcover?

667–669 Did you really show how the changes were initiated?

675–678 Where exactly can I find these results?

681–684 Here again you mention that your research was on permafrost distribution. However, you did not analyse permafrost distribution. If you prefer to keep the statements on permafrost, you need to make it more clear how you measure or estimate permafrost distribution.

Specific comments

* It would have been more convenient if you used hyperlinks so I could click on the references.

183 'which are not only found extensively': the studies or the collapse scars? Maybe rephrase the sentence.

221 Start a new paragraph for this new thought.

170 **238** describe**s**

237–244 These two sentences are very long and complicated. Please split them into more sentences.

251 With 'this study', do you mean your current paper, or Quinton 2019?

252–253 Sentence a bit confusing. How about 'We used precipitation data of the years ... to ... collected by the SCRS.'

569 The word 'plotted' here and at lot of places in the manuscript irritates me. Try to omit it.