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The Cryosphere Discussions

Interactive comment on "New ground ice maps for Canada using a paleogeographic modelling approach" *by* H. Brendan O'Neill et al.

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Dear Dr. Allard, Thank you very much for the time and effort put into your review. We appreciate the thoughtful and constructive feedback. We have followed nearly all of your suggestions and responded to each comment individually below.

1. P. 2, L15 " Holocene environmental changes results in reduce ice abundance where treeline advanced during warmer periods". This may not be correct or may need precision. . .

We have indicated on p4, L29 that the ice abundance for each map unit (i.e.) pixel is reported, so the relative abundance is now explicitly stated on a per-area basis.

2. P 4, L5. Delete "data"

Deleted

3. This methodological approach certainly leads to a great improvement in predictive mapping of ground ice occurence and abundance on the Canadian territory. . .

We have added text based on your suggestion. The text explains that the expert-system uses logical deduction and a set of conceptual models (rules), and have given a few examples of the rules.

4. L9 not clear what is meant by "temporal criteria"

We have removed this sentence, as it was not necessary.

5. L28-29, Formation of intra-sedimental massive ground ice. You could refer here to the therorical and modellin work of Konrad (1990) in the proceedinds of the 5th Canadian permafrost conference.

Thanks, we have added this reference to the section.

6. P6, L.5, I appreciate the reference to the original (and often forgotten) Taber Paper on ice segregation

Cheers! Far too often the good fundamental papers don't get cited. . .

7. L 10, Here I suggest adding aggradational ice at the base of active layer in areas where there is surface sedimentation (alluvium, colluvium, aeolian, organic).

We have added this (now p6 line 15)

8. P7, L3-4, I suggest to start the sentence by "Since most of the permafrost in surficial geological materials formed during and after the last glaciation, we model..." Good point, we have edited the sentence accordingly.

9. L 10. Precise: emerged (post-glacially uplifted) marine sediments

We have clarified that the sediments are emerged

10. L11, again precise: “deposited in post-glacial seas” Added 11. L16, I suggest adding a sentence: “Indeed, it can be assumed fine-grained matrix-rich tills are more prone for ice segregation than coarsed-matrix tills”.

We have added: It can be assumed that dominantly fine-grained matrix soils are more frost susceptible than coarse-grained deposits.

12. L17 Precise: “each surficial geology unit”

We have added “each surficial material unit”

13. P8, L9, replace “since” by “but” or by “however” We have added “however” 14. P9, L10, The ice volume is still very high in palsas, this is a decrease of permafrost area but not of % content in the remaining local permafrost. Avoid confusion between ice content in the permafrost in an area and ice content in a map area (see my first comment in the abstract)

We have added a sentence to clarify this: It should be noted that these reductions reflect an overall decrease in ice abundance in the mapping units, though segregated ice content may remain high locally in remnant palsas and lithalsas.

15. L14, I suggest replacing “melt” by “remnants of relict ice preserved: : :”

We have edited this sentence to indicate the model reflects the preservation of buried glacier ice.

16. L15, frost cracking takes place more in mid winter than in late winter We have changed it to “mid to late winter” to be more inclusive. 17. P10, L 17-18 I cannot make sense of the sentence: “Finally, the present-day permafrost distribution is used to the differential melt of ice-wedges. . .” this needs more explanation.

We have added an additional sentence to clarify this

18. P 11. L 1, precise: the modelled distribution of segregated ice (your result is a predictive model) We have added “modelled” to clarify this.

19. L4 replace “the” by “its” Not sure where this is referring to – the only “the” on P11 L4 seems correct.

20. L7 should you not precise “Early Holocene” ?

We do not specify Early Holocene here because there are also small adjustments in the tree line later in the Holocene, though the most obvious changes were earlier.

21. P12, L2, add “in” glacial lake sediments added 22. P13, L 16, spell out the Permafrost Map of Canada (PMC)

We have spelled it out in this paragraph to remind the reader of the acronym.

23. P14, L 26-27 be careful here, fine-grained slopewash material, weathered sedimentary rock and fine-grained regolith may contains significant segregated ice. I have even found segregated ice in sedimentary shales on an Arctic Island.

We have now split colluvial material into coarse/fine grained based on the underlying bedrock (see point 35). Fine-grained colluvium now has higher values for segregated ice and wedge ice grows more readily in the model. As for regolith/shales, we do not dispute that there are areas with ice in them. However, based on the average condition in these units, we must assign a reasonable relative value. Since on average these units are likely less frost-susceptible than marine, lacustrine, fine-grained tills deposits, we assign them a lower relative value.

24. P15, L3-4. I strongly support that the new model better represents distribution of segregated ice in Canada

Thanks, we are very glad of this!

25. L17 watch out. The model may fail in wet plains area, where surface drainage is poor, cracking frequent and water available each spring to feed the growth of ice veins and wedges.

Good to know – though the only published field evidence (that we could find) for the

Great Plain of Koukdjuak indicated only small wedges. However, this point may be part of the reason the model seems to underestimate wedge ice in some areas Hudson Bay Lowlands (we have seen this in imagery). We have added a few sentences into the "conceptual validity" section on this point, and referenced this review.

26. L 19. Incipient

Thanks for noticing this!! Corrected

27. L20-25 again in the case of ice wedges: specify: abundance on ground ice in the model means spatial, i.e. amount by surface area, not at all locations.

We have now addressed this by indicating that abundance is amount per map unit.

28. P16, L12-13 "small units between two larger units were attached to similar adjacent units" incomprehensible technical jargon.

We have simplified this sentence to: "This reduction caused the removal of some small map units and a consequent loss of detail in the surficial geology dataset"

29. P17, L4 add "full" before complexity

Added, thanks

30. L10, add "overly" before simplified Added 31. L26-27 there is another issue with peatlands and permafrost in vast areas where palsas are found: often the minerotrophic peat has accumulated in non-permafrost conditions during warmer early Holocene climate interval. It froze into epigenetic permafrost during Late Holocene (Neoglacial and LIA) cold intervals.

This is a good point. We mention that we cannot address the timing of peat accumulation in our model presently, and that the evolution of peatland terrain is a weakness in the model. I think this is something that could be considered for future improvements in the modelling, but at present is beyond the scope of the discussion to consider in detail.

32. P18, L5 also on some Arctic Island, see Fortier and Allard, The Holocene, on Bylot Island.

We have added reference to this paper in the paragraph

33. P19, L4, replace "may " by shall We replaced with "will" 34. L9 "updated paleoenvironmental information" : among these are treeline migrations during the Holocene which your model does not seem to consider. They are important for the current distribution of ice-rich permafrost in the discontinuous zone.

Treeline migration is accounted for in the different biome distributions, i.e., the boundary between forest tundra and tundra. Though perhaps the treatment of this boundary could be improved in the model as it relates to ice-rich permafrost in the discontinuous zone.

35. Table 1: I Think that low ice content in colluvial deposits is likely an erroneous interpretation. Fine grained ones can be rich in aggradation ice and wedge ice.

We have considered this carefully. The initial rationale for low ice content in colluvial deposits was based on the legend description on Fulton's surficial geology map, which indicates that colluvial units are dominantly coarse grained. However, we fully agree that there are fine-grained ice rich colluvial deposits in places. Our solution has been to split the colluvial units based on the bedrock source, as we did for till. We have increased values for fine-grained colluvial units, which has resulted in higher segregated and wedge ice in areas of Yukon and some Arctic Islands. We think the depiction is more accurate now, and thank you for spurring this change.

36. Figures: they are great.

Thanks!

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