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Climate of the Past Discussions

Interactive comment on "Climate trends in northern Ontario and Quebec from borehole temperature profiles" *by* C. Pickler et al.

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We thank R.Way for his comment and would like to address several points that he brought up.

1. *The authors incorrectly state that their sample sites are all located within the sporadic (10-50% of the land surface) to extensive discontinuous zones (50-90% of the land surface). In nearly every case the sampled sites are located within the isolated patches permafrost zone (<10% of land surface) according to maps produced by Heginbottom et al (1995), Payette (2001) and recent spatial numerical modelling of permafrost distribution for Labrador-Ungava (Way and Lewkowicz, 2016). Considering the more realistic permafrost extent, there is no discrepancy between the borehole observations and existing permafrost maps.*

We thank Mr Way for pointing out that the permafrost map that we used is inaccurate. We agree that, based on the permafrost map of the Geological Survey of Canada, we must qualify our conclusions. In Quebec, we cover a region classified as having only isolated patches of permafrost. We did not find permafrost at any site but our statistics is not sufficient to draw any conclusion. In northern Ontario, one site (4 holes) is near the southern edge of a region with extensive discontinuous permafrost (50-90%). Using the low frequency of 50%, the probability that not one of 4 holes meets permafrost is low: 1/16 or 6.25%. The other sites in Ontario are indeed irrelevant to permafrost.

In Manitoba, we had sampled a region of sporadic discontinuous permafrost (10-50%) between the towns of Flin Flon, Thompson, and Lynn Lake, but we found that only 1 hole in more than 60 was blocked, as described and discussed by Guillou-Frottier et al. (1998). Using the lowest value of 10% permafrost coverage, the probability that only one hole out of 60 encounters permafrost is only $0.1 \times 0.9^{59} \times 60$ or 1.20%; for the 50% frequency, the probability is only 5.2×10^{-17}!

2. *A further point on a similar subject is that the temperature sampling methodology here is at too coarse a resolution (depth) to detect thin permafrost bodies if they were to exist. In the southern end of the discontinuous zone you would be more likely to find thinner permafrost bodies therefore this is a serious limitation of the study.*

We disagree. To avoid repetition of the measurement procedure, we did not sufficiently emphasize the obvious fact that the temperature measurements in boreholes must be performed a long time after drilling when the ground has returned to thermal equilibrium. Should permafrost be present, the hole would be frozen and we would not be able to lower the probe in it to measure temperature. There is no permafrost in the holes that we measured regardless of the depth sampling interval. A second point is that thin permafrost bodies are very unlikely to be present for simple reasons of thermodynamics. The second law of

thermodynamics implies that any temperature oscillation decays with time, and it follows that in steady state the vertical temperature profile can have no maximum or minimum, implying that the existence of a thin frozen layer is impossible in steady state. A frozen underground layer could exist but only as a transient. The life time of such a layer depends on its thickness. For standard values of thermal diffusivity, a 1m thick layer would last less than 1 year.

3. *The article also does not present any indication of the land cover types encountered in the study area and correspondingly, does not consider how permafrost is distributed across the landscape (e.g. Shur and Jorgenson, 2007; Jorgenson et al., 2010). In northern Ontario and Québec, permafrost is largely absent from forested areas at the southern end of the discontinuous zones where snow accumulates while concurrently being present on wind exposed mountaintops (Brown, 1979; Ives, 1979; Allard and Séguin, 1987; Granberg, 1989; Ou et al. 2016a,b; Way and Lewkowicz, 2016). Ignoring these critical variables makes it untenable to draw large-scale conclusions on permafrost from the provided data.*

   It is correct that we did not consider the landscape in these studies. The main reason being that we use holes of opportunity that were drilled for mining exploration in any surface environment. They represent thus a random unbiased sampling of the landscape. Outside Quebec, the study area is in lowlands without “mountaintops". The topography near our sites on the Quebec side is more marked but remains low. Most likely, disagreements arise from the inconsistent and poor quality of the permafrost data because of insufficient sampling and the extreme spatial variability of the land surface.

4. *In general, I believe that the discussion of permafrost in this article should be removed in its entirety as the methodology, discussion and interpretations presented are not appropriate for the analysis of permafrost distribution and history. Finally, the lack of consideration of the literature on permafrost in western Québec and northern Ontario must be addressed.*

We appreciate the comment but must disagree. The methodology is sound, and our reconstruction of past temperature histories is based on very simple physics. As much as we understand the need for considering the literature on permafrost, we believe that permafrost studies would gain to be confronted with physical models. A dialogue would be more beneficial than outright dismissal!

References

Guillou-Frottier, L., Mareschal, J. C., and Musset, J.: Ground surface temperature history in central Canada inferred from 10 selected borehole temperature profiles, Journal of Geophysical Research, 103, 7385–7397, 10.1029/98JB00021, 1998.

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