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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 the reviewer for his thoughtful and constructive comments. We do agree with several points that he/she has made and we shall include his/her suggestions in the revised manuscript.

1. *Borehole sites: In adequately determining if borehole sites are appropriate for use in climate reconstructions, several criteria are required. While the authors have addressed several of the sites and determined they were unsuitable (as presented in Table 2 of the manuscript), information regarding the other sites is not included that would aid a reader in understanding the conditions at the boreholes. For example, no discussion of slope, topography, vegetation or*

surface material is given, although the authors do reference previous studies. A discussion of vegetation and ground cover at the sites would be extremely useful, however, especially considering that the argument that one site (Thierry Mine) may have additional warming due to the removal of vegetation was put forth. Further, some sites are said to be "too shallow" or on the side of steep hills. What exactly is too shallow and steep? Can a quantitative discussion replace the qualitative explanation? Also, are all of the boreholes vertical? At least one site was excluded because it was plunging under a lake. It should be clear.

   We logged the majority of the holes and noted in our log books if terrain conditions appeared to be not suitable. Holes less than 300 m were rejected for being too shallow. Holes were rejected for being near a lake when the mean distance was less than the depth of the hole, or less than 300 m. Holes were deemed too steep and rejected if they had slope of 5% or more over distance comparable to depth. The dip of the holes varies between 55° and 90°. Only two holes, Nielsen Island and Otoskwin, were not inclined. A more detailed description of each site will be provided.

2. *... if the results of the removal of the steady state gradient as shown in Figures 2 and 3 are different if the length (100 m) is modified?*

   Jaupart et al. (2014) and Lévy et al. (2010) have analyzed the heat flow of the majority of the boreholes presented in this manuscript. They varied the length they used to calculate the steady state. Some differences are noted including the heat flow for the Thierry Mine sites differing by 5%. This could be related to the differing lengths used to calculate the steady state. But, inversions were done using the complete profile and no significant differences were noted with those reconstructed from the residual (only the temperature anomaly).

3. *The authors state that only one site has a ground surface temperature (GST) that was affected by the LIA. However, based on the temperature anomalies shown in Figures 2 and 3, it would seem that other sites exhibit cooling at the same depths as Otoskwin. Mussellwhite, TM0608, and CC0713 all have temperature anomalies that indicate cooling at the same general depth. Is this not a LIA signature*

   All the temperature anomalies of the three sites (Musselwhite, TM0608, CC0713) indicate cooling. However, the profiles and anomalies at Musselwhite and TM0608 are noisy, which could mask a clear LIA signal when inverting the sites. Mareschal and Beltrami (1992) showed that resolution decreases when noise and errors must be filtered. Larger singular values are required when dealing with noisy data since they reduce the impact of noise but retain the gross features of the solution. If the LIA signal is too weak in a noisy profile, it will not resolved. The CC0713 temperature anomaly is less noisy and shows a mild cooling signal of $\leq$0.2 K. The site was inverted individually and no LIA signal was observed since it is too small to be resolved. Furthermore, the choice of singular value could impact the ability to reconstruct a LIA signal. A test was run with a 1 K cooling between 1600 and 1800 and varying the singular value cutoff (Figure 1). For noise-free synthetic data, a 1 K cooling signal cannot be resolved with less than 5 singular values.

4. *Also, the anomaly shown in CC0712 (Figure 3, top left) has a very interesting profile. What is the cause?*

   There are discontinuities in the gradient between 100 and 300 m, which could be due to small water flows.

5. *Other questions I have about the results that don't have any explanation or that aren't adequately explained include the assertion that the Thierry Mine signal may be amplified by the clearing of vegetation between 1934 and 1950. However, most of the GST histories show a large increase in temperature at this same time, indicating it may not be vegetation alone. Have the authors done any modeling or do they have any surface temperatures to support this hypothesis*

   The warming at Thierry Mine is greater than the other sites (at least 0.7 K greater than any other site). Figure 2 locates the three Thierry Mine boreholes (0605, 0606, 0608). From the satellite image, the three Thierry Mine sites are $\sim$500 m away from a large clearing. This clearing is associated with the development of the nearby mine in 1934-1950. Furthermore, all three sites are $\sim$300 m from a lake. Lakes disturb a profile if they are at distance less than the depth of the boreholes (Lewis and Wang, 1992). The Thierry Mine boreholes are 530 m or deeper. Therefore, they could be influenced by the presence of the lake. We hypothesize that the greater warming signal is related to the change in vegetation cover and the presence of the nearby lake (Lewis and Wang, 1992, 1998; Lewis, 1998).

6. *Lastly, one site (Eleonore) has warming that began considerably earlier than the other sites. Why might this be?*

   We do not believe that Eleonore shows earlier warming. There is a clear recent warming signal.

7. *...Corvet, which is located on the side of a 30 m hill. However, what is the slope?*

How much of an effect does this have? It is still being used, so the authors must think it isn't significant.

Errors were made in the coordinates of Corvet in the manuscript. Corvet is located at 53°19.072′ N and 73°55.760′ W. Using the elevation of the Google Earth images of the site, we see that topography is less than 5 m. This will be fixed in the manuscript.

8. *The authors discuss what the LIA surface signal should be for the region, but do not see a ground signal. Perhaps a simple forward model of driving into the ground a surface temperature time series with the appropriate LIA signal and making a comparison to the boreholes would be appropriate? Then, the authors could argue whether the signal is strong enough to actually be observed, or whether it is not seen due to snow or something else. This is similar to the arm waving argument used to interpret a possible ground warming due to longer/deeper snow cover in the region, but it seems that other authors have performed some analysis that may provide quantitative support to their arguments (perhaps Bartlett et al., 2005?)*

   The appropriate LIA signal for the region is unknown. Pollen has reconstructed a LIA signal of $\sim$0.3°C (Gajewski, 1988; Viau and Gajewski, 2009; Viau, 2012). Figure 1 shows than an LIA signal of less than 1 K in a noise free environment cannot be resolved with less than 5 singular values. As discussed above, noisy data requires larger cutoffs to decrease the impact of noise on the solution. This illustrates that a weak LIA signal cannot be resolved in a noisy environment.

9. *I did notice that on page 11 in the reference section that Jaupart and Mareschal,*

2011 was published in Cambridge, not Cabridge; also, the next two references following the previous reference are of Jaupart et al., 2014 and are a duplicate.

   This will be fixed in the manuscript.

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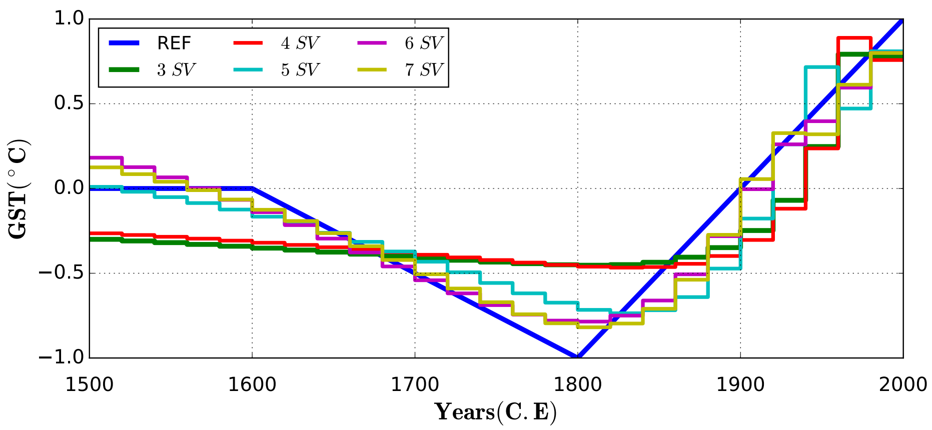

Fig. 1. GST reconstruction of a synthetic noise-free1 K cooling signal between 1600 and 1800 with varying singular values.

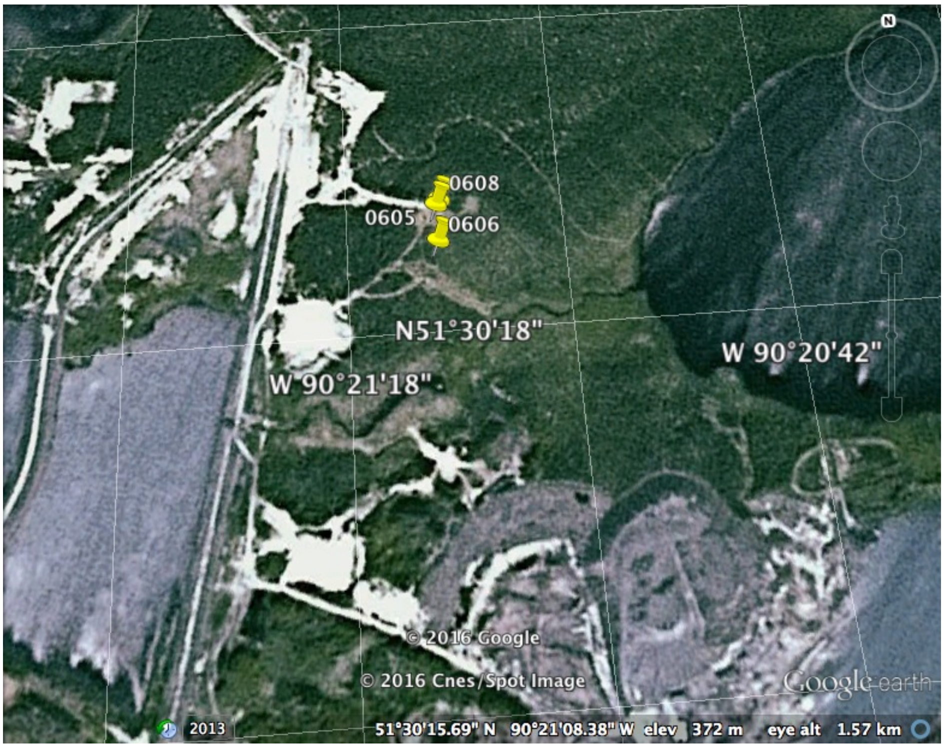

Fig. 2. Location of Thierry Mine boreholes on a satellite image.