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Climate of the Past Discussions



# *Interactive comment on* "Borehole paleoclimatology – the effect of deep lakes and "heat islands"on temperature profiles" *by* V. T. Balobaev et al.

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Interactive Comment

# Can temperature depth profiles be corrected for borehole paleoclimatology?

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**Abstract**

This paper presents a method to account for steady state perturbations in temperature depth profiles due to the non homogeneous surface boundary conditions. It essentially consists of approximating the surface of the lake by a circle, and using the analytic formulas for the downward continuation of the the surface temperature perturbation. The method is straightforward, and can easily be implemented with standard software available on a laptop computer (e.g. MATLAB), but these analytic formulas are not new. I doubt that these formulas are useful and relevant to borehole climatology. Moreover, these corrections do not apply for transient perturbations such as the “heat islands".

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Interactive Discussion

Discussion Paper

# 1 Discussion

Whether this paper will be useful in borehole climatology is an entirely open question. My opinion is that it will not be.

It is exact that the data set of temperature depth profiles compiled by the international heat flow commission (IHFC) for paleoclimatic studies contains less than 10% of all the continental heat flow measurements. This low number is because these temperature depth profiles are the only ones that were contributed by researchers for the IHFC archive. The IHFC did not verify that these profiles are suitable for paleoclimatic studies, nor does it provide any documentation on the surface conditions at the location where these profiles were measured. Many, if not most, of the temperature depth profiles included in the IHFC compilation are in fact contaminated by non-climatic perturbations. For instance, at the request of the IHFC, we have contributed all the temperature profiles deeper than 250m that we measured in Canada before 2004. Most of these profiles are not suitable for paleo-climate studies. These include the many sites in Manitoba and Saskatchewan that we rejected when we inverted the ground surface temperature history for central Canada guillou1998. If the IHFC compilation were to include only well documented measurement sites, the data base would include less than 1% of all the continental heat flow measurements. For many of the sites, the information was simply not recorded when the measurements were made. For most of the measurements, made before the GPS system, the location of the holes is not sufficiently accurate to estimate the perturbations with the help of satellite images. Unfortunately, there is absolutely no chance that the data base of the IHFC can be enlarged with reliable data, or that corrections can be made to the profiles already in the data base. In addition, most of the boreholes that have been used in heat flow and paleoclimatic studies were drilled for mining exploration and they are usually dipping at any angle between 25 and 90 degres. The correction must thus also account for the dip and azimuth of the hole. Again this information is not available in the IHFC data base. Without such information, it will be impossible to make corrections.



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Also, the proposed correction is not applicable for the heat island effect, as suggested by the authors. Deforestation, urbanization are recent perturbations of the surface boundary condition and thus a time dependent correction is required. Transient corrections could be performed. For instance, [*Rolandone et al.*(2002)] have calculated the effect of lateral changes in temperature on the post glacial corrections. When such corrections are needed, they can easily be calculated numerically, or using Fourier transforms. But again, the information in the IHFC data base is insufficient to undertake time dependent corrections.

On the other hand, there is no need to worry about the stability of the lake against seasonal overturn. These cyclic perturbations do not affect the temperature over more than a few meters.

A final point concerns the method of correction itself. It consists of approximating the surface of the lake by a circle of radius $R = \sqrt{S/\pi}$, with $S$ the area of the lake. This maybe adequate when the drillhole is located at some distance from the lake, but I have seen many drillholes extremely close to the lake shore. If the suggested procedure is strictly followed, we may have the effective radius of the lake $R$ larger than the distance of the hole to the center. It may be sufficient to reduce the effective radius accordingly, but one may then wonder whether very simple approximations will not yield a correction with comparable accuracy. For example, we can very easily downward continue in 2-D a surface temperature perturbation $\Delta T$ between $x = 0$ and $x = -a$

$$T(x,z) = \frac{\Delta T}{\pi}(\tan^{-1}\frac{x}{z} - \tan^{-1}\frac{x+a}{z}) \quad (1)$$

where x is the distance to the lake shore.

As an example, I have used this formula to model a temperature profile that we have measured at the Mystic Lake site in Saskatchewan[1] [*Rolandone et al.*(2002)]. An al-

[1]This profile can be found on the Canadian geothermal data base at http://www.unites.uqam.ca/geotop/geophysique/flux/prof98-03.htm



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most perfect fit to the data is obtained assuming that the ground surface temperature is 2.2 $^{o}$C, the hole is 50m away from the Lake shore, and the average lake temperature is 6$^{o}$C. The correction is straightforward. I doubt that a much better fit would be obtained by using the cylindrically symmetric solution. The parameters of the model were selected to obtain a good fit to the temperature profile, because we do not know what is the mean annual lake bottom temperature. It is thus likely that this profile also included a climatic signal that the correction has erased because of insufficient information. Incidentally, the IHFC data base includes the Mystic Lake site (identified as CA-9803) with a proposed climatic interpretation ($\approx$ 3K cooling since 1500). After the correction made here to account for the lake effect, the temperature profile indicates neither warming or cooling. Had a larger lake correction been made, the profile would indicate warming. Clearly, information is needed to make the proper correction and identify the climatic perturbations. On regional scale, it seems that the climatic history can be still be estimated by averaging temperature profiles, although my preference is to retain only the reliable profiles whenever possible. [Chouinard and Mareschal(2007)] have shown that the best resolution in the climate reconstruction is obtained by selecting only noise free profiles. In any case, correcting the temperature profiles will only add to the uncertainty of the climate reconstruction.

Simple corrections could be made to temperature profiles to account for non homogeneous surface boundary conditions. Such corrections require extremely accurate information on surface conditions at the measurements sites. This information is almost never available. It will not be possible to retrieve the climatic perturbations from the temperature depth profiles measured for heat flow studies, including those profiles compiled by the IHFC.



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