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Climate of the Past Discussions

Interactive comment on "Differences between repeated borehole temperature logs in the southern Canadian Prairies-validating borehole climatology" *by* J. Majorowicz et al.

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The two reviews we have received are pointing out several important issues which need to be explained. Many detailed comments will be dealt with in the final version of the paper. We would like to thank reviewers for their work.

Here are some major points in reply to both reviewers discussion of our paper.

We did repeated measurements of temperature-depth profiles for 24 boreholes in the southern Canadian Prairies and calculated difference of temperature with depth. We also show result of the same experiment for the N. Dakota and the results compare very well. We compare those differences vs. differences constructed from SAT (Surface Air Temperature) data that have been projected into the subsurface. Referee 1 is correct

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stating that strictly we are validating the borehole technique over an approximately 20-year period as earliest logs are from the 80th. Considering possible noise in the data and uncertainty in thermal conductivity estimates, the differences in the temperature logs are in general agreement with those from SAT data. The misfits which appear to be important for Referee 1 and which are called by him systematic misfits can in fact be explainable by above. The difference between T logs taken decade-decades apart and observed in Canadian Prairies as well as in N. Dakota are all within decimal to few decimals degree surface temperature change. These agree very well with observed SAT changes in $>$80% of cases. In the paper we only show few examples of good fits between the model based on SAT forcing and the measured T log differences for time span of decade to couple decades.

There is a request from Referee 1 to put the above results into context of older work. In revised version of our manuscript we highlight the result of repeated T logs experiment as a validation of the method for the recent time period for which we have the data. Does this validation means that our reconstructions made for more than decades to a few centuries are valid? We do not imply that as we do not know the history of land changes and pre-observational snow cover changes. On the other hand, we can get a good fit between measured transients from T-z logs and modeled transient as based on the existing 100 year SAT record and assumed pre-observational SAT (Majorowicz and Safanda, 2005, J. Geoph. Eng. v.2, 291-299; in "Special Issue on New and Classical Applications of Heat Flow Studies" ; C. Clauser Ed.). Such validation is not a 100% proof as good fits in such cases depend on the assumed pre-observational history. The current work fits in well with the results of previous work. Both approaches show that we can have a good fit between well constrained by the data model and the observations from T logs.

Our previous works showed that GST warming has been significantly greater than SAT warming in this area. In fact, this finding first published by Majorowicz (1996, PAGEOPH, v. 147, 1-24) and Majorowicz and Skinner (1997, Climatic Change, v. 35,

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485-500) was confirmed in the much larger N. Hemispheric scale from well temperature based reconstructions (Harris and Chapman, 2001, GRL, v. 28, 747-750). It is correct that the new proxy reconstructions of Esper et al.(2001), Moberg et al. (2005), and now Hegerl et al., (in press, Journal of Climate) point to larger variability and larger amplitude of Little Ice Age (LIA) to a recent SAT change. We agree with this. As shown in our previous work (Majorowicz and Safanda, 2005), we can get a good fit to the transients based on SAT data pre-observational SAT level by lowering the recent part of the LIA level.

In explanation to comments of both Referees we explain that in our earlier paper we were using same boreholes as in the southern Prairies analyzed in this paper plus the data from the Northern Canadian Prairie provinces not analyzed here. Here we focus on the data mainly from the southern Prairies covered by grass. Skinner and Majorowicz (1999, Clim. Res. V. 12, 39-52) have argued that air and ground temperatures were showing different warming responses because of land-cover change, and specifically that temperature logs showed greater warming than SAT records. Indeed, this result has gained prominence because it has been used to question the validity of warming estimates based on borehole climatology (e.g. IPCC, 2001; Jones and Mann, 2004) as noticed by Referee 1. Referee 1 asks: “How do the authors reconcile the present results with the differences in trends between SAT and GST records and earlier studies? “ This is good point. We need to remember that land changes and specifically clear cutting resulting in change of forested land to farmland took place mainly in the first part of the century, while the experiment of repeated T logs described in the paper took place in different time frame (from 80th till near present). No land changes occurred in the investigated well site’s areas. The wells are mainly from the grassland province which did not experienced clear cutting like in the northern Alberta. Therefore, there is no conflict between the result of the previous paper and this one.

A better organization of the material as suggested by the Referee 1 and Referee 3 should make the above points more clear. Our study includes two important topics:

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1. changes in surface temperature as inferred from repeat logs, comparing transients between repeat logs and profiles constructed from SAT data; 2. GST histories FSI derived from wells through the study area. Re. topic 2; we show these in Table A1 and Fig.8.

While some aspects of topic 2 have been covered elsewhere we would not agree that it could be deleted without adversely affecting the other topic. The reason is that we have combined Canadian Prairie Provinces data with US Great Plains data and compare these for the first time. We used FSI inversion to get the data listed in Table A1 in Appendix. So, Referee 3 had trouble to find where it was used. We will explain it more explicit in the revised manuscript. In Response to Referee 3; we have used deep wells only and not all of the 24 the wells used in T logs comparison experiment (as shown in Appendix Figure) were used in estimate of the century ground warming. It is apparent what we used as related to topic 1 and topic 2 as the data are in tables. Some of the wells used in repeated logs comparison were to shallow to invert for the century GST history. However, they were deep enough to compare with the last decade-decades SAT changes important in analysis of topic 1. Referee 3 writes that the 2005 logs from TSA1 and TSA6 indicate cooling; yet, Table 1 gives 2.3 and 1.3 degrees warming since 1900. We have misunderstanding here. The inversion of the whole T log based on simultaneous inversion shows warming for the last century which is different from cooling between 2005 and 1995 as shown by repeated logs. These are two different parts of the SAT history influencing different section depth section of T-z.

Comparison of the Canadian and US mid-continental data shows a strong change in warming amplitude from T - depth inverted data. It occurs between Nebraska -S. Dakota wells and N. Dakota wells (Fig.8 of our paper). Important new result of our paper is that Canadian Prairies and N. Dakota well temperature logs show $>$ 2 times higher warming. It is also noticed that it is not related to a pattern of snow cover changes known from the last half a century record. In response to Referee 3 comment we delete Fig.9 as the change in warming is well illustrated by Fig.8. The trend of

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northward increase in GST warming is in fact biased by a strong change occurring between Dakotas as correctly noticed by Referee. The wells in the area north of that border all show similar pattern of very high warming (mainly $>$ 2 C).

In response to comments of Referee 1 and Referee 2 we expanded on the snow cover analysis in relationship to the result shown in Fig.8 (warming patterns). In the revised version of our paper we show additional figure which shows the pattern of snow cover trend through the area analyzed in Fig.8. It is shown that the changes in snow cover's cumulative thickness can not explain the existing patterns of warming based on temperature - depth profiles unless some very different pattern existed before 1955 A.D.

Interactive comment on Clim. Past Discuss., 2, 1075, 2006.