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Climate of the Past Discussions

Interactive comment on "Impact of postglacial warming on borehole reconstructions of last millennium temperatures" *by* V. Rath et al.

Anonymous Referee #2

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Summary

In this study, the authors identify a distortion in the inferred steady-state geothermal gradient of borehole temperature profiles (BTPs) which arises from glacial-interglacial temperature changes. They show that the resulting error has a significant effect on ground surface temperature history (GSTH) inversions, but that even a crude knowledge of a rapid past warming signal can substantially improve these estimated histories, correcting for the bias created by long BTP memory of the last glacial termination. This paper provides a clear explanation of this important effect, and gives useful examples of the problem and how it may be mitigated.

I recommend the manuscript for publication with minor clarifications either in the form

of a brief response, or if appropriate by the addition of a few sentences in the text of the manuscript.

Discussion

To a certain extent, what is identified here is that temperature variability on timescales longer than the sampling interval will introduce a spurious change in the inferred steady state geothermal gradient. This is an intuitive notion, because reduced temperatures are usually obtained by simply subtracting the linear gradient of temperature outside of the near-surface region – and yet we suspect that there must be long-timescale temperature variability that should affect the gradient at all depths of the profile.

The observation made by this paper is that the bias is strong but correctable for the termination. It would be ultimately very useful to extend this type of analysis to encompass the *general* effects of long-timescale temperature variability on inferred steady state geothermal gradients. Long ice core paleothermometer records (such as the Vostok record used in this paper) suggest that climate exhibits power-law variability (i.e., temperature changing more on long-term than short-term timescales). One can then expect some of this variance to penetrate deep into the profile, and then diffuse back upwards on different timescales. That being said, I think that the authors have chosen the correct level of complexity to include in their GSTH model. The choice of a single, simple step function allows them to produce Monte Carlo synthetic GSTHs with a well-defined depth-temperature bias that can be understood and corrected.

Specific Comments

I have a few specific comments, suggestions, and questions.

1. **Glacial-Interglacial Temperature Change:** The choice of a glacial-interglacial

temperature transition (text and Fig. 1) is a good one in that it is simple and therefore isolates the effect of this transition. However I do question why the glacial temperature should be held constant, and why the pre-100kyr temperature is held at the mean quaternary value rather than allowing for additional (periodic or quasiperiodic) glacial cycles (granted, the effect of the older variability is probably minor and well-approximated by a constant value). To me, the simplest temperature history would actually be a sawtooth glaciation (~130 kyr ago to ~21 kyr ago), followed by a step function temperature-increase during the termination. Would the authors expect such a change in the model to alter the results appreciably?

2. **Sensitivity to Transition Duration:** It would be comforting to have some mention of whether it is important that the glacial-interglacial transition is represented as a step function. There is of course some transition time, τ, perhaps on the order of ~2-8 kyr depending on location. Because it seems as though the induced gradient perturbation may depend on the abruptness of the signal (in addition to the time at which it begins), it would be useful to know whether the result (perhaps just for Fig. 2) is expected to change significantly for reasonable values of τ. No additional plot would be necessary, just perhaps a mention in the paper of what the expected effect is (if there is one).

3. **Section 4:** The purpose/conclusion of Section 4 is unclear to me. Atmosphere-ocean global climate models (AOGCMs – this should be defined in the text) are initialized with approximately equilibrated conditions, but will still typically require $\mathcal{O}(5\ \mathrm{yr})$ (atmosphere only, with ocean SSTs specified) or $\mathcal{O}(500\ \mathrm{yr})$ (fully coupled ocean) to spin up to statistical equilibrium. In NCAR's community land model, for example, 15 layers are all initialized at $T = 274$ K. These layers then equilibrate via radiative and sensible heat fluxes, and a zero-flux boundary condition is applied at the lowest layer. Thus, because the AOGCM isn't sensitive to temperatures below this shallow modeled soil, it's not clear to me how the SAT boundary condition presents a problem in comparison with BTPs. Perhaps a sentence or

two could be added to clarify the idea here, what the issue is, and how the bias correction presented here can help to solve the problem. It may be that a close reading of the cited paper by Stevens *et al*. (2008) would clear this up, but since AOGCM-BTP comparisons comprise an entire section of the manuscript it should be somewhat self-explanatory. I suggest either revising or omitting section 4.

Apart from these minor questions and comments, I find the manuscript to be an excellent, clear study of what appears to be an important bias. It is noteworthy that the authors have taken the additional (big) step of showing that this bias can be corrected. As long as Section 4 is clarified or omitted, my recommendation is for publication.

Typographical

I also have a few typographical/grammatical suggestions:

1. 3326–24: "there *are* still"
2. 3327–3: "One such"
3. 3327–13: "Since the time of"
4. 3327–29: "This allows *us* to"
5. 3329–19: "its true *steady state* value"
6. 3329–25: "allow *for* targeting *of* changes"
7. 3331–4: "For *this reason/these reasons*, increasing the depth"
8. 3331–11: "and to *a lesser* extent on rock properties"
9. 3331–17: "GSTH*s*"

10. 3331–19: remove comma after here.

11. 3331–20: “As *with* many other”

12. 3333–6: “carrying *information* from times”

13. 3334–6: “depths of several *km* for numerical reasons”

14. Table 1: $\Delta t_1, \Delta t_2 \rightarrow t_1,\ t_2$ since these are absolute ages and written without Δ elsewhere in the manuscript.

15. Figs. 3 and 7: What is the regularization parameter, ϵ, used for the the BTP correction test (Fig. 3) and the sensitivity experiment (Fig. 7)?

Interactive comment on Clim. Past Discuss., 7, 3325, 2011.