

Interactive comment on “Comparison of observed borehole temperatures in Antarctica with simulations using a forward model driven by climate model outputs covering the past millennium” by Zhiqiang Lyu et al.

Anonymous Referee #2

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The paper compares temperature observations from 4 Antarctic boreholes with climate model surface temperatures over the last millennium or so. The standard approach to do this is to reconstruct the temperature record from the borehole temperature using a model and compare it with climatic models. The main difficulty is that the thermal diffusivity of ice damps the temperature variations with time and details of the signal are lost: The farther back in time or deeper in the borehole we go, more details are lost. To help the analysis, the authors suggest comparing borehole temperatures with simulated borehole temperatures driven by the climate models using a thermal model. The

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authors identify a set of key features in the temperature records from the data: Cooling at WAIS over the last millennium, nineteenth century cooling at Antarctica Peninsula and Antarctic warming over the last 50 years or so. Interestingly, the existing climate models do not reproduce these results. They propose to use these key observations as a metric to test the next generation of climate models.

The paper is in general clear and well written. I have some suggestions for the authors below but I can anticipate that any paper that encourages climate modellers to use data has my full support.

General comments

The borehole distribution is scarce. I know it will always be but I wonder how representative these 4 borehole records are. Inspecting Figure 1, I miss data in the interior of East Antarctica, perhaps Dronning Maud Land; and the coastal area of West Antarctica, Amundsen and Weddell Seas. My view is that a few more sites could improve considerably the benchmark for models.

A detailed description of the climate models, thermal model and borehole temperature data is in other papers. This is understandable but a few short descriptions here and there will improve the clarity of the manuscript considerably. This is of particular importance as the methods used in the manuscript are tapping on different scientific areas. To me, for example, Section 2.2 says nothing as I don't know what PMIP3-CMIP5 experiments are, or why they are discontinuous in 1850. I have several suggestions below in the specific comments.

Specific Comments

Title: This is minor point but I think that title is very specific and not easy to digest. What about something like 'Comparing temperature reconstructions from climate models with observed borehole temperature in Antarctica over the last millennium'?

L12-13 In this paper there are two types of 'models': climate and temperature models.

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I found data-model confusing here as often papers will compare borehole temperature with modelled temperature. The novelty of this paper is that is comparing 'climate models' temperature with observations. Figure 1. The Temperature vs depth plots don't show the full temperature profile, from surface to bedrock. I assume that the authors are only showing the fraction for the depth that affects the time of interests in the study. This should be made clear. L129 The Tikhonov regularization is a regularization not an inversion method. It doesn't make sense to compare it with the least squares algorithm in Orsi et al 2012.

Section 2.2 I am not a climate modeller, I simply don't understand this paragraph. What are all these acronyms? What is PMIP3-CMIP5 and why are you using the output? What is the discontinuity in 1850? A gentler introduction to the models used in the paper would be welcomed for CP readers.

Section 2.2. Do these models provide surface mass balance as well as temperature? Has the surface accumulation provided by the models been compared with the one observed and used in the temperature model?

Equation 1 I may have missed this but I can't find a description of what is the vertical velocity that the authors are using. I imagine is connected to the surface accumulation but how? How does it vary with depth?

L156 In addition to explaining how accumulation is used in the model, does it vary with time?

L158 The authors are working with shallow temperature, most likely in the firn area. I would like more explanation about how heat capacity and diffusivity depend of density and if density is assumed constant with time.

L158 Heating term in a heat equation is not specific enough. I assume that the authors refer to the internal or strain heating due to flow deformation. How is that calculated? I don't have access to Cuffey and Paterson but I assume that the term depends on the

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strain-rates. What components are the authors considering? I am assuming that the term is small but this point requires clarification.

L160 The reasons to apply null heat gradient at Mill Island and explained later and this is confusing. I suggest a clear paragraph describing boundary conditions for Equation 1.

L165-166 How recent is the 'recent annual average'? How does it compare with time-steps?

Equation (2). Is 't' the time in years?

L179 It is not clear to me what this means. Is that 10% variation of boundary and initial conditions? I am assuming that in Larissa the temperature gradient refers to the sensitivity to the bottom boundary condition. Why not in Styx or Mill Island, are they not also frozen to the bed with Neumann boundary conditions? Why some of the sites study more parameters than others? All this should be explained.

L183 'if' should be 'in'

L264-266. I don't understand this paragraph. What is internal variability or a profound disagreement?

Figure 6. I can't see the circles in most of the figures. Perhaps that is good but I would suggest a selection of figures, so that they are bigger or add an edge to the circle.

4.2 Compared with the other sections 'cooling at Larisa' sounds very specific. I suggest 'cooling at AP'.

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