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Climate of the Past Discussions

Interactive comment on "Late Weichselian thermal state at the base of the Scandinavian Ice Sheet" *by* Dmitry Y. Demezhko et al.

Anonymous Referee #3

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This study seeks to use borehole paleo-temperatures – whereby measured borehole temperature profiles are inverted to yield surface temperature histories – to infer whether or not certain boreholes were beneath the Scandinavian Ice Sheet during the Late Weichselian (25 to 12 kaBP). While the concept is interesting, the study has two significant issues. Firstly, the inversion methodology is far from a "gold standard" approach and is not sufficiently described to be reproducible. Secondly, the interpretation and discussion of the Scandinavian Ice Sheet extent and thickness is entirely disconnected from increasingly reliable numerical simulations of paleo ice-sheet configuration; important discrepancies and alternative explanations from such simulations are ignored. For these reasons, the usefulness of the present study is restricted to the point that it will likely negatively impact the journal's citation rate.

Page 1 Line 30: Arguing against peer-reviewed published studies with non-peer-reviewed conference proceedings is not good practice.

Page 2 Line 4: Modelling Insight: In light of substantial numerical modelling efforts, it is no longer acceptable to argue that the Scandinavian Ice Sheet was actually “scattered glacial domes”. All available evidence suggests that the Scandinavian Ice Sheet was contiguous. See Nu et al. (2019: https://doi.org/10.1017/jog.2019.42) for the most recent PMIP simulations of the Scandinavian Ice Sheet since Last Glacial Maximum.

Page 2 Line 20: Methodological Concern: For any chance of reproducibility, the original borehole temperature profiles should also be shown, in addition to the derived surface temperature time series, for each site.

Page 2 Line 20: Methodological Concern: Given that borehole inversion is an ill-posed problem, whereby an infinite number of surface temperature histories can result in the observed borehole temperature profile, most studies now adopt a Monte Carlo approach to provide uncertainty envelopes on surface temperature histories (See: Muto et al, 2011; https://doi.org/10.1029/2011GL048086). Additionally, in this study, the “mean” profile is being taken at Outokumpu (Page 3 Line 13), while the “median” profile is being presented at Olkiluoto (Page 3 Line 20). These are not the same inversion product of a borehole temperature profile. More broadly, it seems that different inversion methods have been applied to each site.

Page 3 Line 4: Modelling Insight: It can be problematic to entirely attribute anomalously low geothermal flux – relative to the regional mean geothermal flux – to inter-glacial climate change. Significantly spatial variability in geothermal flux beneath the Scandinavian Ice Sheet has been described by other mechanisms in models (See: Naslund et al., 2005; https://doi.org/10.3189/172756405781813582). For example, the local topographic corrections to geothermal flux can be important in ice-sheet settings (See: van der Veen et al., 2007; https://doi.org/10.1029/2007GL030046).

Page 4 Line 5: Methodological Concern: I am confused how a 1000 m deep borehole at Forsmark, can be used to reconstruct surface temperature history back to 85 kaBP in Figure 2. With most reasonable assumptions of thermal diffusivity, the deepest borehole temperatures should respond on a much shorter time-scale, and thus reflect more recent temperatures. I have admittedly not done detailed calculations myself, but the graph presented does not convince me that a diffusive temperature waves takes more than 10 ka to propagate 1000 m.

Page 4 Line 23: It is not immediately clear how surface temperatures of -8 to -18C must infer that no ice sheet was present at the borehole location, when such basal ice temperatures are found within the Greenland ice sheet today (MacGregor et al., 2016; https://doi.org/10.1002/2015JF003803). It is also very speculative to discuss presence or absence of meltwater at the base of the Scandinavian Ice Sheet – as well as its influence on ice flow – in the absence of a thermodynamic ice flow model.

Page 5 Line 25: Modelling Insight: This results interpretation seems to assume that every ground-point beneath the Scandinavian Ice Sheet only had one temperature value during the Last Glacial Period. Modelling suggests that ice-sheet may have limit cycles, whereby they thicken and warm, then flow fasters, thin and cool, and then start to thicken and warm again. This means that basal ice temperatures can flicker between warm and cold conditions. Payne, 1995 (https://doi.org/10.1029/94JB02778) mentions the Scandinavian Ice Sheet.

Page 5 Line 30: Methodological Concern: The inversions are consistently described as inferred "surface heat flux (SHF)", but in practice the derived variable is surface temperature. Precise terminology is important here, as a flux – in J/s – is a type II (prescribed flux) boundary condition while a temperature – in K – is a type I (prescribed state) boundary condition. It is unclear whether Type I or II inversion models are being applied at each borehole location.

Page 6 Line 14: The discussion of "climate sensitivity" as a parameter – "that determines how much of the additional energy incoming to the upper boundary of the atmosphere due to the variations of the Earth's orbital parameters was finally spent to change the ground surface temperature" – seems steeped in self-citation. I am personally unaware of this parameter being widely adopted as a useful paleo climate index, but if it has been, it should be so demonstrated as being adopted beyond the author group.

Table 2: Methodological Concern: It is unclear how this modelled "amplitude of Pleistocene/Holocene warming" – which is generally approximately 20C across all sites – relates to the <10C temperature changes depicted in Figure 2. Similarly, the graphical depiction of these isotherms in Figure 3 seems to imply that Norway and Sweden have warmed in excess of 24C since the Last Glacial Period. This is significantly warmer than most previously published reconstructions.

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