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## **Review of Colgan and others, "Greenland Geothermal Heat Flow Database and Map (Version 1)" [essd-2021-290]**

Anonymous Referee #1

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Referee comment on "Greenland Geothermal Heat Flow Database and Map (Version 1)" by William Colgan et al., Earth Syst. Sci. Data Discuss., <https://doi.org/10.5194/essd-2021-290-RC1>, 2021

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In this manuscript, the authors describe a newly compiled database for measurements of the geothermal heat flow (GHF) in and around Greenland. Based on these data and additional, geophysical information, they use a machine learning technique to assemble a gridded GHF map for the entire domain at a nominal resolution of 55 km. Several corrections are discussed, and a comparison to other, recently published GHF models is given.

As the authors correctly point out at the end of their summary remarks, increasing the level of understanding of Greenland's GHF is of great scientific relevance. Therefore, the current study is highly welcome. I applaud the enormous effort that went into putting together all this information and the subsequent analyses. However, I would like to raise some issues that should be dealt with.

As for the GHF data, I am a bit confused about which corrections have actually been applied, which ones are just mentioned as caveats, and what the rationale is behind including or excluding the corrections. The ones discussed in Sect. 2.2 are evidently applied. However, things become a bit obscure in Sects. 4.1 and 4.2, where some corrections are explicitly said to be used, whereas others are merely mentioned. This should be separated more clearly, perhaps by moving the explanation of all actually applied corrections to Sect. 2.2, while discussing in Sects. 4.1 and 4.2 only the conceivable corrections that are not applied in this study.

Related to this topic, I am somewhat surprised that the authors do not attempt to impose a paleoclimatic correction for the effect of glacial-interglacial cycles on the basal temperature gradient of the ice at subglacial sites. This is explicitly said in lines 468/469: "Indeed, the 61 +/- 2 mW/m<sup>2</sup> present-day heat flow that we estimate at GRIP is ~20%

greater than the 51 mW/m<sup>2</sup> estimated for that site with paleoclimatic correction by Dahl-Jensen et al. (1998)." [BTW, the study by Greve (2019), which also accounts for the glacial-interglacial correction, gets exactly the same value as Dahl-Jensen et al. (1998).] In a paper by Calov and Hutter (1997, 49(5), 919-962, <https://am.ippt.pan.pl/index.php/am/article/view/v49p919>), the authors demonstrate for Dye 3, Summit (GRIP) and Camp Century that the imbalance due to the time-dependent surface climate can be more than 10 mW/m<sup>2</sup>.

As for the constructed GHF map, I have some doubts whether the decision to omit the large GHF value at NGRIP for the main product was a good one. I understand the argument that a single, outlying value is spurious and may not be representative for a larger region. However, there is some additional evidence from the glaciological side, namely the existence of the North-East Greenland Ice Stream (NEGIS) that originates east of NGRIP and flows generally northeast towards the coast. The fast flow of this extended ice stream requires a continuously temperate base, which is hard to maintain with the 40ish mW/m<sup>2</sup> GHF values in the area that I infer from Fig. 7. The situation is clearly better in Fig. 9, even though the main zone of elevated GHF values lies to the west of the NEGIS area. This issue deserves some further thinking/discussion.

Detailed comments:

Table 1: A bit more information would be helpful. What is "parent" vs. "child"? What is "TC pT"? Others at the authors' discretion. I fully understand that detailed explanations of all these entries are unnecessary, but they should at least be roughly understandable.

Line 92: I suggest adding the main information about EPSG:3413 (polar stereographic projection, parameters).

Lines 130/131, "Heat flow uncertainties are also estimated for all 290 sites, based on the approach described in Section 2.1":

I am not sure to what part of Section 2.1. this statement refers. This should be clarified.

Table 3: "This \_s\_tudy"

Line 168: Reference for the 86°C?

Line 169: Reference for the 2.00 W m<sup>-1</sup> K<sup>-1</sup>?

Table 4: "Previous \_s\_tudy", "This \_s\_tudy"

Equation (1): Units are missing.

Lines 231-237:

Basal melting is not the only problem at subglacial sites with a temperate base ( $T = T_{pmp}$ ). Another one is frictional heating due to basal sliding, which works in the opposite direction: Basal melting consumes sensible heat, while frictional heating produces it. This makes it very difficult to estimate the geothermal heat flux in the underlying rock from the heat flux into the ice sheet ("basal temperature gradient approach").

Lines 296-298:

I find it a bit inconsistent to keep Table 5 in the main text, while outsourcing Figure A1 to the Appendix. Since it is not explained in much detail, what about moving everything to the Appendix, and perhaps giving a bit more detail there to make the paper more self-contained?

Lines 390-392:

Why does the inclusion of NGRIP also produce an island of large GHF values ( $\sim 70$  mW/m<sup>2</sup>) around  $\sim 69^\circ\text{N}$ ,  $43^\circ\text{W}$  (Fig. 9 vs. Fig. 7)?

Line 459, "snowfall rates are comparatively high":  
This statement is quite vague. Compared to what?

Lines 461/462, "convolution of complementary advection and conduction":

In general (exception: ice domes/ridges), strain heating (viscous dissipation) also plays a significant role in the deeper parts of an ice sheet.

Line 473: "This \_study\_ provides"

Line 495: "heat production from radioactive sources can also influence the apparent geothermal gradient":

My understanding is that a significant part of the GHF we see at the Earth's surface is due to radiogenic heat production in the crust. So, it's a normal process rather than merely a perturbation. It should be clarified how to differentiate this normal background from a correction-worthy anomaly.

Lines 525/526: I would find it more logical to swap the order of Tables 6 and 7 (methods

first, results later).

Table 6: "This \_s\_tudy" (2 x)

Line 566: "This \_s\_tudy" (also in the first column of the table body)

Line 979: "of \_t\_his \_s\_tudy"

Figure 5:

Are the two different panels really needed (subaerial + subglacial = on-shore, submarine = off-shore)? They could be combined into a single one by either adding the green curve (on-shore) to the left panel, or dropping the green curve altogether.

Figure 8a:

A nonlinear scale would be better, such that  $O(10 \text{ mW/m}^2)$  differences can also be discerned (especially for the subglacial sites).