

## ***Interactive comment on “Geothermal heat flux and basal melt rate in the DomeC region inferred from radar reflectivity and thermal modelling” by Olivier Passalacqua et al.***

**Anonymous Referee #2**

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### SUMMARY / MAIN CONCERNS

The authors do a nice job leveraging available data sets and modeling capabilities to provide constraints on the basal melt rate near Dome C. The methods applied seem reasonable and the results seem to advance how to choose a site that is most likely to have preserved more than million-year-old ice. While this is good work, the way the manuscript is written makes it hard to follow, and I think that it does not communicate results in a way that they can be readily used in the broader community effort in the search for an “oldest” ice site. I hope that the authors can both restructure and reword much of the paper in order to make this work more accessible. I do not know exactly how this should be done but will provide some suggestions and identify as many of the

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grammar mistakes and typos that I can – unfortunately there were many. I recommend starting with reordering and reconfiguring the sections to make sure that each header offers something logical to understand the work, and that text in each section is complete. I recommend that all the authors carefully review the revised manuscript before publication.

I strongly recommend that the authors change the terminology from “geothermal heat flux” to “heat flux” or “geothermal flux”; geothermal heat flux is redundant. (In the same way that “thermal heat model” would be redundant.) I know the chosen term is often used but hope that stating what is meant more directly will also help the flow of the paper since the term is used throughout the paper.

Introduction to heat-flux estimates from Antarctica doesn’t differentiate between east and west, which is confusing the way it is written.

Section 2.1.2 header is misleading when referring to “water circulation”, and I am not sure that it is only finding a new word that is needed – is there really a chance of a significant basal hydrological system here? If so, even if a basal spot has not water evident is there a way to constrain that water was not routed through this region?

I wonder if “emulator” is the right word. If you keep it, make sure it is really clear at the start of section where this is introduced what you are doing. Since you are trying to simply approximate the solution to physical equations maybe “approximation” or “parameterization” is a better word?

If you can find a location that has experienced no basal melting that is obviously ideal, but it seems like some melting at some time in the past million years may have occurred and what you really want to make sure is that very old ice is still at the bottom. If there was no melting how old could the deepest ice be? And, for continuity of the record is it critical that no melting has occurred? There needs to be more context on how your results inform the search for very-old ice and how good your results have to be before picking a site. Only at the end it is stated that this work may inform other modeling

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efforts – I might have missed it but this should be stated more clearly up front. It would really help to put this work in better context with the larger effort to find a drill site. Of course we won't know what is there until we drill, but I didn't know if your results have really helped to target a site or provided additional information that has to be weighed with all else.

Is the kriged product what would be used in follow-on 3-D modeling? Is this good enough? It seems like the validation you can do for point locations doesn't hold across this whole area in a kriged result, but maybe this interpolated map is the product you need to provide? That wasn't very clear.

If there was more radar data could you do this a lot better? Where is the community at with respect to drilling for oldest ice – will more data be available that you can use in a follow-on study? As a general approach it seems that you already have a lot more data than you might have compared to most places. But, is more needed to really pick the best drill site?

Is there no chance for accretion? Or, have you already ruled out spots where that may have occurred?

#### MINOR COMMENTS

Line 5: "climate forcing lagged by thick ice" – you mean lag in heat transfer through thick ice, right?

"Temperate" isn't the wrong word, but maybe you want to keep the distinction between "frozen" and "melting"?

Line 29: While the measurement at subglacial Lake Whillans is an important one, I think that it requires some assumptions about the thermal stratification of the lake in order to back out heat flux. I am not an expert in this area but more generally I would make sure that this section fits with your paper. How is this estimate from west Antarctica relevant to Dome C?

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Line 37: Statement is about measurements but aren't the references to modeling efforts?

Line 49: should be "increase" instead of "increasing"

I would suggest using "infer", instead of deduce (this occurred in multiple places)

Lines 51-54: I didn't understand this sentence that talks about water routing models – not only was I unsure about how it related scientifically but I'm just not sure what point was being expressed. Perhaps a problem is also that it was a long sentence broken up by citations.

Line 54: Who is "They"? I don't know what study is referred to

Line 57: "significant" should be "significant"

Line 57: I am weary about making a point that uncertainties at a given level are a significant improvement – how uncertain are these uncertainty estimates

Line 58: I would restate to be something like "... but is still too large when trying to find a location that may preserve very old ice"

Line 60-62: Doesn't add much to the reader, either be specific about how what you are doing is or is not similar to previous work or I suggest taking it out

Line 67: Suggest finding another word than "triggered"

I'm not sure it is clear here what you mean by "interesting" – state directly that the glaciology (not glaciologist) community is interested in sites where it has remained cold at the base without melting

Line 88: Again, I would state clearly what you are trying to do and somehow "... this paper primarily aims to assess the risk of past temperate conditions at places known to be cold today" doesn't quite get it across. Perhaps something more like "This work constrains sites where basal melting is less likely to have occurred over the past 800

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ka, even if they are frozen today, so that very old ice has the best chance of being preserved at that site”

Line 90-94: A little bit of introduction isn't always helpful if the reader doesn't really have a good sense of what is coming. Consider expanding this to be more direct about what it means to do this in “forward mode” and “inverse model”

It may be more clear to talk about this as “running a forward model” and “solving an inverse problem”?

Be consistent with “heat model” or “thermal model” – used interchangeably in title, section headings, and text – but since they mean the same thing just pick one

Line 96: I think you mean “relationships” instead of “relations”

Line 104: “Characteristic” is more often used than “typical”

Line 117: “flown” should be “flowed”, or better yet “been transported by ice flow”

Line 121: “permanently” seems too strong

Section 2.1.3 doesn't add much – why is this a section and why does this get mentioned in this order? It seems like you want to introduce the model equations first, then talk about caveats!

Line 138: typo should be “which”

Again, “emulates” seems like the wrong word. Here, maybe “simulates” or “approximates”?

Line 145: Is D dimensionless? Is K a function of reduced depth? (don't think so)

Equation 2: These might be equivalent or just defined differently, but this equation is not the same as in Parrenin et al. (2007; equation 3) – check to make sure no typos between  $\zeta$  and  $(1-\zeta)$

Section 2.6 header – suggest stating as “Basal boundary conditions”

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Line 87: Why is this an unusual choice?

Line 202: paleotemperatures aren't “known”, they are still estimates

Line 209: Why is this represented as  $1/6.04K$  – if report this way make sure to have typed as actual fraction since as it is now with inline slash it could be confusing

Section 2.8 – Do you concentrate grid cells near the base, and is vertical spacing good enough? Also, are 1000 year timesteps good enough? Can you say anything about uncertainties related to your solution grid? The current statement mentions there was a tradeoff between accuracy and speed, how much was compromised?

Everywhere you use “till” should be changed to “until”

Section 3 heading is a bit confusing since it isn't yet clear what is being measured, and it is definitely not heat flux! I would change that to something more clearly related to your data analysis. In general, I suggest coming up with another term for “measurement spots”.

Suggest in the text to remind readers what p is. Same for any variable that was introduced awhile back in the text

Line 269: Is there a short justification for the heat flux range of  $40-70 \text{ mW/m}^2$ ?

Line 272: Suggest that “inferred” is better term than “derived”

Line 286: “do not mismatch” – do not match? Or, mismatch?

Line 299: I would put your estimated relationship between heat flux and ice thickness in words and remind the reader that this is for the explored range of heat flux values, or does it hold for any heat flux (any melt rate)? Then, the relationship between heat flux and melt rate must correspond to a specific ice thickness, right?

I lost the details around equations 15-16 and suggest adding more text to explain what this means and how it was derived.

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Line 337: what do you mean by “at the opposite” here?

Line 351: Again, not sure how to take this point about an “unusual choice” and why it was chosen that way to begin with

Line 354: Why is “order of magnitude” good enough?

Line 357: The leading sentence doesn’t seem to relate to the second sentence and I had to read back to see if I understood what was coming and has already been done. Suggest better lead-in to this section.

Line 365: “build” should be “built”, and really do you mean “calculated”?

Line 368: What small-scale structures are these E, G, H, I, L locations referring to?

Line 369: Should be “non-melting”

Line 371: Need to rephrase part about “. . . is however often respected . . .”

“undoubtly” should be “undoubtedly”

Line 373: What do you mean by “local gap”?

Line 375: Should be “dependent”

Section 6.1, maybe “Method validation”? There is no lead in, which may be fine but as is now it isn’t clear how come you need to have overarching section 6.1

Line 399: What do you mean “the surface slope is the source of motion”?

Talking about clues isn’t very precise – is there a better word?

Paragraph around lines 415-420: Not sure I understood the point of this paragraph, if this is just too hard to constrain state that directly. If it needs to be considered somehow and will significantly affect uncertainty estimate state that directly too. I can’t tell if this is something that really could matters.

Line 422: Not sure what you mean with “litmus”

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Section 6.1.4 – by “structure” do you mean “spatial variation”

#### FIGURES AND TABLES

Would be worth defining input parameters in Table 2. I don’t quite understand what “total on m” represents.

Figure 2: I might have missed it but check that critical ice thickness is defined in the text to this point, or add to caption

Figure 4: Not sure it was discussed in the text how the 10 spots were chosen?

Figure 6: A lot of overlapping lines. How many discrete values of m are represented?

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