The Cryosphere Discuss.,
doi:10.5194/tc-2017-23-RC1, 2017

The Cryosphere Discussions

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 #1

Received and published: 1 April 2017

REVIEW OF "GEOTHERMAL HEAT FLUX AND BASAL MELT RATE IN THE DOME C REGION INFERRED FROM RADAR REFLECTIVITY AND THERMAL MODELLING " By Passalacqua et al., submitted to TCD.

SUMMARY

The paper presents a new method for estimating the geothermal heat flux in regions of slow flowing ice. The authors apply the method to the Dome C region. The study makes use of a combination of radar data to infer wet/dry conditions, the one-dimensional heat equation and inverse methods. The authors first construct a time-dependent, one-dimensional heat model including vertical advection of ice. The model is forced

with past temperature and accumulation rates reconstructed from a deep ice core. The geothermal heat flux is initially assessed at ten spots, where the bed is known to change from wet to dry conditions from radar measurements. The geothermal heat flux is estimated by calculating a critical ice thickness necessary for basal melt, and then applying an inverse method to get the most likely geothermal heat flux. These values are interpolated to the entire region. The heat flux field is then used to calculate melt rates and the authors then arrive at a parameterisation for the melt rate that depend on geothermal heat flux, ice thickness and ice-flow parameter p. This parameterisation is used to calculate the melt rate over time in the region.

MAIN CONCERNS

Overall, the scientific method is sound and it is a nice combination of radar observations, simple ice-flow assumptions and inverse methods. The use of rational assumptions such as negligible variation of the geothermal heat flux on small spatial scales is a good example of how a complicated and under-measured parameter may be simplified. However, I found the structure of the manuscript rather confusing to a point where it detracts from the scientific content. I have listed some of my main points of concern below but overall the manuscript would greatly benefit from a critical revision by the authors with regards to structure, presentation and grammar.

1. Introduction: It is never explicitly mentioned what "old-ice" is. I assume it refers to the on-going international effort of locating ice that is more than 1.2mio years old but the manuscript does not state this nor is the reader told why this is important. Instead the introduction jumps between general statements about geothermal heat and radar data processing, and specific descriptions of a dataset from the region. It is only at the end of p. 3 that the reader is told what the aim of the study is. I suggest splitting the introduction into three sections: i) A general introduction to why "old ice" is important etc. including the general effect of geothermal heat flux and ice thickness on basal melting, ii) an overview of past studies of radar data processing and what have been achieved so far with this technique, and

iii) an introduction to the study region and the specific dataset that this study uses. The authors are of course free to use a different structure but I strongly recommend rewriting the introduction in one way or another. Finally, a figure with a context map would be very helpful. For example, the introduction mentions studies from Thwaites Glacier, West Antarctica, but the Dome C region is in the central part of East Antarctica. A map could prevent confusion as to why the geothermal heat flux values differ significantly between the two sites.

2. Heat model: This section consists of several short subsections that not always follow each other in a logical order. For example, the one-dimensionality of the heat equation is presented first as a model assumption in section 2.1.1., then expanded on in section 2.2 and the reader is presented with the equations in 2.3 and 2.4, while the values of the parameters in the equations are mentioned in sections 2.5 and 2.6. It would greatly improve the readability of this section if the heat model is described first in its entirety, then the velocity model and then the assumptions about geothermal heat flux and water circulation.

3. Basal melt rate emulator: What is the advantage of the "emulator" (I assume this is the same as a parameterisation)? The model is run for the whole domain over the period of 800kyr so why is the parameterisation needed? Can't the model be applied directly to the different scenarios? Is it too computationally expensive?

4. Discussion: Again, I find the order of the sections confusing. The model assumptions and sensitivity tests are followed by a comparison to other studies and then a discussion of the geothermal heat pattern followed by a section titled "Interpretation" (interpretation of what?). I suggest having a separate section with comparison between this study and previous studies, then the discussion section that could start with the overall interpretation and then the discussion of sensitivity tests etc. in the context of the interpretation.

MINOR COMMENTS

There are several small typos e.g. "southest", "explicitely", "conlude", "flown" instead of "flowed", "extend" instead of "extent", "additionnal" that need to fixed. In addition, I have the following comments
Line 5-7: there is a word missing
Line 19: which ice core?
Line 56: What are internal layers? Presumably radar layers but this need to specified and explained why they can be used.
Line 60: How can the method of Carter et al. be used in this study without using the internal layers?
Line 74: "amplitude difference" – is that the same as the difference in returned signal strength?
Line 105: the heat balanace is assumed to be only vertically dependent.
Line 140: Need a few more details here. What are these tabulated parameters? What is the uncertainty in the method? How well do the results compare to those of a 3D model?
Line 143: Missing a word? Coordinate?
Line 160: what is the physical meaning of the parameter p? Is higher values equivalent to more/less basal sliding? What is appropriate for a dome region.
Line 174: The density of the firn layer from Dome C? or from somewhere else?
Line 180: This paragraph seems to contain some information that is irrelevant.
Lines 191-193: These sentences are very confusing. What is too low for what?
Line 209: Odd to use the value 1/6.04 instead of 1.656.
Line 261: Reference to Monte Carlo method missing (e.g. Tarantola, 2005 "Inverse Problem Theory and Methods for Model Parameter Estimation"). Also, from the description of the inversion it does not sound like a Monte Carlo approach but rather like a search of the parameter space. Is it a random parameter space exploration? And how is this done?
Line 274: This is the first mention of potential drill sites. Why C6 and H1?
Line 285: Where is E4 and E6? Which figure is referred to here?

Line 311-317: There should be a reference to Fig. 7 somewhere in this paragraph. Generally, this paragraph is not very clear. E.g. in line 315: How do you assign values to some of the variables? Equations (15) and (16) do not help the reader nor do the several almost identical symbols for different GHF.
Line 323: Point N8 in Fig. 1.
Line 361-373: This is another paragraph that is not clear. For example, what is meant by “much of the map is quite well assigned”? or “well described”. Does this mean that the model agrees with the observations? Line 389: “. . . realistic transport of cold...” Cold snow?
Line 391-385: How does this affect the conclusions?
Line 414-419: Is the accumulation rate influencing the results? That question is raised by not answered in this paragraph.
Line 447: Is it truly Occam’s razor or just a lack of good quality data inhibiting model validiation?
Line 482: What clue? Please clarify.
Line 495: The amplitude analysis was not performed in this study but from the sentence it sounds like it was.

FIGURES:
None of the map have an indication of scale. Presumably the axis are in metres but it is not stated anywhere. Figs. 1 and 9 are very busy and could be split up into several maps. Additionally, The combination of magenta/orange and red/blue in Fig. 9 makes it difficult to read.
Fig. 2 is a very nice schematic of the assumptions on this study.

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