

Statistically parameterizing and evaluating a positive degree-day model to estimate surface melt in Antarctica from 1979 to 2022

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The authors made a great deal of changes to the manuscript from its original version and I commend them for all the work they did. A few more concerns remain for me, particularly with regard to the utility of the PDD model. Can you show that it's better than already existing models? Can it really be used into the future? Additionally, I still think that the results section should be condensed and clarified. It is fairly wordy which makes it sometimes unclear. Hopefully my comments can be helpful in guiding the future direction of this manuscript. Once my more major concerns are addressed, I am happy for the paper to be accepted in the Cryosphere.

Major comments

My biggest concern is with the applicability of the PDD model to periods outside 1979-2022 (for which melt estimates are already available from satellite observations or RCMs. The authors mention in the conclusion (lines 467-469) the PDD model may be used "to explore Antarctic surface melt in a longer-term context into the future and over periods of the geological past when neither satellite observations nor SEB components are available." However, I worry that the PDD model is too parameterized to the specific observations/RACMO melt estimates from 1979-2022 to have much applicability outside this time, and especially into the future with expected warming. I understand that the authors attempt to address this in section 4.2.2 but I am not entirely convinced by this work, especially as the PDD cumulative melt seems to get worse compared to observations/RACMO from Member 1 to 3. I think it would be more convincing if the authors parameterize 2 different models: 1) using the full 1979-2022 period and 2) using only data from 1979-1989 and compared PDD-derived melt (spatially) from 2012-2022 for these two different models. I'm afraid that if spatial maps of PDD-derived melt look substantially different between these two models then the applicability of this PDD is extremely limited. I think some more work needs to be done to prove that this model, which is highly parameterized, can be applied to future periods.

I am also still missing a quantified justification for calculating spatially varying parameters for your PDD. For example, it would be really interesting to see how figures 4, 5, and 6 differ if you do not determine spatially varying parameters and use the same parameters for each grid cell (or use an older PDD). If you can show that melt estimates improve when you utilize spatially varying PDD parameters, this would help justify your method.

Minor comments

In general, I would not recommend starting sentences with "That". For example (L232): "That the dominant number of cells show a negative sign indicates that using $T_0 = 0$ °C as a melt threshold may significantly underestimate melt events" can be changed to "The majority of cells have a negative T_0 , indicating that using $T_0 = 0$ °C as a melt threshold may substantially underestimate melt events..." I would recommend re-wording other places with this issue as well (L236, L257, L273, L295, L323, L407)

Also, I am slightly confused by the use of the term "mismatches" used throughout. Is this essentially the bias in each grid cell? For example, is Figure 5d showing a probability distribution of the bias between

the PDD and satellite CMS for all the grid cells? If this is the case, I recommend using the word “bias” as it likely much more familiar and intuitive for the reader. If not, please explain what exactly is meant by “mismatches”

L5/6 – “current understanding of surface melt in Antarctica remains limited”. This statement is a bit too vague... Please specify what aspect of surface melt has limited understanding.

Introduction – I think it is important to still mention the potential impact meltwater has on ice-shelf stability (e.g. hydrofracture, ice-shelf disintegration), just perhaps not as extensively as you did in lines 29-46 of the previous version.

L26 – “However, *these* currently less understood...” Please specify what *these* refers to.

L27 – Please be more specific with regards to how meltwater will become an “increasingly important player to the Antarctic environment”.

L29 – 35 – I’m sorry but I really have no clue what the point of this paragraph is! It jumps around from the Antarctic Peninsula to the melt-albedo feedback to the potential impact of clouds and atmospheric rivers. Please provide a clarified version of this paragraph with the point you are trying to make.

L51-53: “Topographic influences, such as... (Hock 2005)”. This sentence should be reworded for clarity. Perhaps something like: “Spatial and temporal variability in DDF can result from topographic variation, such as the gradient of elevation which affects albedo and direct input solar radiation (Hock, 2003), and seasonal variations in radiation.”

L158 – Perhaps I am missing something but what are the “three satellite products”? I thought there was one product from SMMR and SSM/I and another one from AMSR-E and AMSR-2?

Figure 2 – please describe in the caption how panel a) and b) are different.

Section 3.3.2 – do you average the results from the 3 different folds or look at each fold individually?

L213 – it is unclear to me what you mean by “biases in satellite products are likely due to frequent equipment replacements”. Has this been reported in other studies? Or do the biases mostly come from some process in the development of the satellite products?

L164/165 – Perhaps combine these two sentences to something like: “The DDF is a scaling parameter that controls the meltwater production and is related to all terms of the SEB...”. I am a bit thrown off by the usage of “lumped parameter” in L164.

L234-237: I think these lines can be summed up by something like “The probability distribution of T_0 across all grid cells is approximately normal.”.

L238: Instead of saying “less than 5% probability”, I think it is more intuitive to say something like “more than X standard deviations lower than the mean”. I’m left wondering “less than 5% probability than what?”

L243: Replace “optimal DDFs identified by the minimal RMSE from 291 DDF experiments on each computing cell” with “optimal DDFs identified for each computing cell”.

L256: Do you mean right-skewed?

L272: This phrase is a bit confusing (and misleading): “are either in a good agreement on estimating surface melt days or amount”

Figure 5c (and 6c): It would be helpful to provide some statistics for this scatter plot. For example, RMSE, R2, slope of the line of best fit.

Figure 5 e-f (and 6e-f): Please put a border around the ice shelves as well as it is difficult to see the ice-shelf edge in some places (e.g. Ross, Ronne-Filchner). Additionally, please more explicitly define what the “difference” represents: is it observations – PDD or PDD – observations? Finally, I wonder if it would also be helpful to show relative difference maps. The largest bias appears to be on the Antarctic peninsula (which is in contradiction to Figure 4 and lines 273-275) and I imagine this is just because more melt occurs on the peninsula than elsewhere and thus the bias naturally appears greater.

Figure 5 h/i (and 6 h/i): These figure panels are quite small and have a lot going on in a relatively small area. I would recommend making them bigger or perhaps making them their own figure and moving to the Supplemental material.

L329-330: What changed to cause a greater difference between the PDD and RACMO melt amounts before 1990 than after?

L336: “There are less than 5% computing cells with mismatches in the mean of lower than -15 mm w.e. or larger than +15 mm w.e. (Figure 6h).” – What do you mean by this? Is it “Less than 5% of all computing cells are 15 mm w.e. below or above the mean”?

L349-351 “The disagreement in trends, therefore, is actually between the satellite/RACMO2.3p2 and ERA5 2-m temperature, rather than between the satellite/RACMO2.3p2 and the PDD model itself.” Can you create a figure to demonstrate this?

L355-367: I think this paragraph needs to be simplified and condensed. Essentially, you train on two folds to determine the optimal PDD parameters and test on the third by comparing PDD melt with observations/RACMO, correct? I think shortening this section to would help clarify and make it easier for the reader to follow.

Figure 7g-l: The histograms are not super helpful for me here. Is there a better way to visualize this? The colors for each subpanel are a bit hard to distinguish.

Figure 7s-x: It would be helpful to include other statistics for these scatter plots (RMSE, average bias, slope of line of best fit).

Figure 7o and r: I am confused why the CONTROL line is so different from RACMO2.3p2. Should this not look the same as the PDD line in Figure 5 and 6b? Maybe I am misunderstanding what the CONTROL is.

Technical corrections

L6 – Add “grid” before “cell-level”

L10 – delete “to” in “independently of to the time window...”

L39 – add “better” before “suited”. Also make sure your spelling of “therefor” is consistent throughout the paper. In L54 you use “therefore”.

L58: change “the spatial variability of PDD parameters are rarely considered” to “the spatial variability of PDD parameters *is* rarely considered”.

L68: Change “varying” to “our spatially varying”

L129: change “most used” to “most commonly used”

L161 – Change “multi” to “multiple”

L164 – Change “the amount of melt” to “meltwater production”. (perhaps do this elsewhere too).

L169 – Change “address” to “determine”

L186 – Add either “melt volume” or “meltwater production” after RACMO2.3p2

L190 – I think you can delete “has been developed since the 20th century (Stone, 1974) and”

L205 – change “foldis” to “fold is”

L232 – replace “dominant number” with “majority”

L234: Change “statistics of T_0s ” to “ T_0 statistics across all grid cells”

L280: Add “the” before “two CMS time series” and change “are in a generally” to “are generally in”

L287: Change “symmetrically to the mean” to “symmetrically *around* the mean”

L288: There are two “the”s before “PDD model”