Review on: How well can satellite altimetry and firn models resolve Antarctic firn thickness variations?

by Kappelsberger et al 2023

This study combines firn model data and altimetry data to study the spatial and temporal variations in firn thickness over Antarctica. To make this new dataset they use two firn models, and altimetry data from multiple missions, both radar and laser. They do a thorough statistical analysis to validate the new data set. This is a really interesting study and research question. However, I do think major changes are needed before this paper can be published, there are too many grammar errors and overall it is very long and difficult to read and keep track of all the introduced symbols. Below are some more specific comments.

Major comments:

Overall this paper is very dense/wordy, it reads more like a report than a scientific paper. Some sentences and paragraphs seem to just be added as filling without a clear purpose. I suggest heavily cutting the text, especially in the introduction and data section. See some specific suggestions further down.

There are a lot of sentences where you use a full stop rather than a comma. Furthermore, there are a lot of grammar errors, like Line 94/95 "*Nevertheless, discrepancies still remain. (See Section 2.3 for further details on comparisons between altimetry and firn models.)*" It is not grammatically correct to start a new sentence with a paraphrase. All these things are disrupting the reading flow. This paper could really benefit from a proofread!
See some specific suggestions further down.

There are a lot of inconsistencies in the figures, especially with the colour bars (spatial plots). It seems random if the colour bars have a min or max arrow extension, or both arrow extensions. These colour bar inconsistencies are seen throughout the paper. Also, in Figure S13 red is negative and blue is positive, just below in Figure S14 purple/blue is negative and brown/red is positive. Please go through them all and double-check if all the colour bars are correct.

Snow and firn are mentioned many times but the terms are not well defined here. The manuscript could benefit from a clear distinction between snow and firn. Further, sometimes it says snow/firn layers in plural and sometimes the layer is singular, and firn pack is also used. It seems like the terms are used interchangeably, please make sure to be consistent, as they have different meanings.

Minor comments:

In section 2.4 it seems like you start to present and discuss results (Fig. 1 and 2), this feels out of place in the method sections.

In Section 2.1 you refer to the two altimetry datasets as "TUD altimetry" and "JPL altimetry" in lines 124-126. But in the section, you also call them "TUD" and "JPL", or "TUD product" and "JPL product", or "Schröder et al. (2019a)" and "Nilsson et al. (2022)". When you make a definition in the beginning you should consistently use that.
Likewise in section 2.2, you refer to the two firn models as IMAU firn model and GSFC firn model, within the same section you call them "IMAU", "IMAU model", "GSFC", and "GSFC model". When you make a definition in the beginning you should consistently use that.

In the caption of Figure 2, you write "Color" which is American English other places you write "metre" which is British English. Please choose one way and be consistent.

Specific comments:

L21: The references " (Horwath et al., 2022; IPCC, 2021)" are here in alphabetical order, the rest of the references are in timely order oldest first.

L33: "in the snow and firn layer" This reads like there is no difference between snow and firn

L44: "statistically significant trends in the Antarctic (surface) mass balance" this statement needs a reference.

L52-53: "Earth system models have recently caught up in this regard (Lenaerts et al., 2019)". Is this sentences relevant? ESMs are not mentioned anymore.

L53: Suggest change "They are forced" to "They can be forced", because not all RCMs use reanalysis data.

L54: "data from 1979 onwards" I guess you refer to ERA-interim put we have ERA5 now starting in 1950 (Hersbach, et al 2020)

L58: "However, spatial variations in SMB show a poorer agreement. On a basin scale, the largest…" remove the full stop after "agreement" use a comma instead as the following sentence is a continuation.

L57-63: This could be written much shorter, it is not a review in Mottram et al 2021.

L64-70: Again this could be written much shorter, it is not a review in Verjans et al 2021. I do not think all the numbers are necessary

L71-79: In my opinion, this paragraph could be removed, as gravimetric mass balance is not the topic of this paper.

L80: Remove "By contrast"

L81: "They" who?

L83: Change "utilise(d)" to utilise

L84: Change "(ICESat-2)" to (ICESat), as your time period ends in 2017 and ICESat-2 was first launched in 2018.

L86: "laser signals are reflected at or near the ice sheet surface". I think you mean "laser signals are reflected at or near the surface".

L87: Here you have snow/firn layers in plural in L33 the layer is singular.

L87: "If elevation changes due to changing ice flow can either be neglected or subtracted…" Please argue where or when they can be neglected.

L94: "Nevertheless, discrepancies still remain. (See Section 2.3 for further details on comparisons between altimetry and firn models.)" Incorrect grammar, suggest rewriting to: Nevertheless, discrepancies between altimetry and firn models still remain and are discussed.

L98-99: "The reason likely lies in errors in the involved altimetry and modelling results" Is that not always the case? either the errors are from the altimetry or the model.

L99: "Therefore" what?

L99: What is meant by a "Steady-state" density model?

L102: I suggest merging sections 1.2 and 1.3 and removing the text about gravimetry in Sec. 1.3

L104: Remove "(Section 1.2)"

L111: I suggest also merging sections 1.2, and 1,4 and then writing the "purpose part" in the last paragraph in Sec. 1.2.

L113: Remove "(Section 1.1)"

L118-119: "For the first time, the entire spatial information present in both the altimetry products and modelling outputs, together with the high (monthly) temporal resolution of gridded altimetry products, is jointly exploited." This is a convoluted sentence, e.g "altimetry products" is mentioned twice, please rewrite.

L131-132: Suggest changing the full stop to a comma between "differs. Thus,"

L140: Here you write firn pack and firn layer as earlier.

L162-163: Why mention the Shepherd et al 2019 data when you are not using it? I suggest removing these lines.

L172-173: you write "In accordance with the altimetry data, we involve firn thickness changes from the grounded AIS excluding the Antarctic Peninsula and the period May 1992 to December 2017" This sentence says that you exclude the AP and the period 1992-2017, it should likely say that you use the period 1992-2017

L177-178: In SMB components you are missing refreeze/runoff

L179: "dynamically downscaled with RACMO2.3p2" does that mean that you have run the RACMO model?

L182: "firn layer" singular

L192: " Medley et al. (2022a) built a new model" should it not say parameterisation instead of model?

L198: Suggest to delete this line, it sounds like a rapport.

L199: Again "TUD, JPL"

L201: Missing reference to ERA-Interim.

L204: Define the sign of rates, is a positive rate making the surface go up?

L206: Remove "section 2.2"

L207:"more positive" does that mean thicker firn or a faster thickness rate?

L208: "less negative" slower thickness rate, or slower thinning rate?

L210: Do you mean the average ice sheet-wide seasonal amplitude in firn thickness? Or are you talking about ice sheet seasonal amplitude?

L211-213: It is unclear what these numbers are, Are they seasonal differences in firn thickness? Are they integrated over the entire ground AIS?

L215: Remove " In this section" it sounds like a rapport.

L215: Which basin definition?

L219: ". (For the JPL altimetry, h A2, and the GSFC firn model, f Mb, similar time series are shown in Fig. S1.)" using the parentheses is incorrect grammar.

L220: "Agreement between hA1 and fMa is generally good on interannual scales. Differences appear in the long-term trends." these are two very short sentences, I suggest removing the full stop.

L225: Here you say the entire period is 1993-2017, does it not start in 1992?

L230: put s on "model" since you are referring to both models.

L230-231: Using the parentheses is incorrect grammar.

L247: ". It is explained in Section 3.1.1" maybe change to ", this is explained in Section 3.1.1"

L262: Replace full stop after regression with comma

L284-286: "Comprehensive and general references…." this feels like it is a bit misplaced perhaps to put in the references after "respectively"

L305: Suggest to merge section 3.1.1 and 3.1.2 as sec. 3.1.2 is very short.

L306: Suggest remove " ('R squared')"

L311: Label eq 5a er 6 instead. It is a bit strange to have Eq 5 followed by eq 5a

L328: Shouldn't you also refer to fvE1?

L330: "These alternative variations are called scaled firn thickness variations. We refer to them by fvE2", replace full stop with a comma.

L332: "These alternative variations are called modified adjusted firn thickness variations. We refer to them by fvE3", replace full stop with a comma.

L345-355: Please add references for the Kolmogorov-Smirnov test

L360-361: ". (For example, power-law with $\kappa = -1$ and $\kappa = -2$ represents flicker and random walk noise, respectively.)" using the parentheses is incorrect grammar

L365-366: ". (Note that the residuals may additionally contain signals related to variations in ice flow dynamics or subglacial hydrology.)" using the parentheses is incorrect grammar

L398: "standard deviation" => std, the abbreviation is already introduced.

L402:"(In the case of data gaps in the altimetry time series, this equality holds approximately.)."

L409: Remove "(Section 3.1)"

L431: "(The rms of all versions of fvA and fvM is illustrated in Fig. S17a–d and Fig. S18a, b, respectively.)"

L441:"(Corresponding rms maps of differences are displayed in Fig. S17–S19)."

L448: Section 4.2.4, you already have a section with the same title, this is confusing.

L456-457: "(Fig. S20 and Fig. S21 further shows maps of the residuals rms and of R2 for different versions of regression and both time periods. Table S1 lists basin averages of R2 for the period before 2003.)

L472: "(Basin-mean time series of all regression results and versions are presented in Fig. S22–S24.)"

L478-479: "(For the larger subset of selected grid points, Fig. S25 and S26 display the psd of the regression results from A1a and A2a, respectively.)"

L485-486: "(HECTOR only yields numerical stable results for -3.)"

L495: "(For all versions and both PCA, the original and rescaled patterns are illustrated in Fig. S27–S29)."

L507: "power spectral density (psd)" => psd, the abbreviation is already introduced.

L510-511: "(Unlike our analysis, they did not co-estimate a quadratic or seasonal term.)"

L548-549:"(The histograms and cumulative histograms for all basins are shown in Fig. S30 and S31, respectively.)

L556-557: "(See also Table 2 for an overview of the various differences in firn thickness variations fv and their description.)"

L595: "also high" please put a number on that.

L610: What is meant by " measurement noise"?

L731: Changes the full stop between noted and By to a comma, as it is the same sentence

Figures:
Fig1: I suggest to refer to Fig3 in the caption for basin locations.

Fig3: I suggest that you put all the areas/regions which you mention in the text

Fig3 caption: you write ". Drainage basins of the EAIS and WAIS used in this study (thick black lines) following Rignot et al. (2011a, b)." but then in L298-299 you talk about regions and multiple Rignot basins forming one basin. Please clarify when you talk about Rignot basins, "your" basins or other regions

Fig9 caption: Replace full stop with and "Histograms. Vertical"

Fig10: The left colour bar has only max extend while the right has both min and max extend. Also are there even Coefficients of determination for the regression that are negative, like the min extend suggests?

Fig11: Shouldn't there be a min extension on the colour bar?

Fig A1: Shouldn't there be a min extension on the colour bar?

References:
Hersbach, H, Bell, B, Berrisford, P, et al. The ERA5 global reanalysis. *Q J R Meteorol Soc*. 2020; 146: 1999–2049. https://doi.org/10.1002/qj.3803