



# ***Interactive comment on “A detailed radiostratigraphic data set for the central East Antarctic Plateau spanning the last half million years” by Marie G. P. Cavitte et al.***

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The paper by Cavitte et al. (2021) presents an extensive ice-penetrating radar dataset of internal reflecting horizons (IRHs) traced on both airborne and ground radar data over the Dome C area of East Antarctica. The authors go in length to describe the processing of the data, the uncertainties associated to the radar systems, and their processing steps; as well as the methods used to date (directly at the ice core; indirectly using a 1-D ice flow model) their IRHs. This dataset will be very useful to future modelling studies interested in calculating past accumulation rates, ice-flow speeds, and assess past ice-sheet stability over this sector of East Antarctica; and indeed rep-

resents a strong contribution to the SCAR AntArchitecture initiative. This work is a huge testament to the many people involved in collecting, processing and analysing the radar data and has undoubtedly resulted in many hours of meticulous work.

Overall, I found this manuscript easily readable and the methodologies adequately described, particularly with regards to the processing of the data and its impact on IRH geometry. I also particularly appreciated Figure 2c which shows nicely the difference in IRH geometry between different processing regimes. However, I think some efforts are needed to improve the flow and structure of the results and discussion sections, as well as the overall presentation of the paper. The formatting of the text (including equations) suffers from some LaTeX glitches and some figures need to be reworked to improve clarity and avoid colour clashes. The order of the tables throughout the text also needs attention. Lastly, some inconsistencies in the choice of structure for the published dataset need some clarifications. A list of minor and line-by-line comments can be found below.

I recommend that this manuscript be accepted to ESSD providing that the minor comments with regards to the structure and presentation of the paper/dataset be addressed, and that an alternative to Figure 3 is provided.

Minor comments:

- Section 2.2.1: The processing methods for the HiCARS data presented in this section is important but the order of the sentences and paragraphs is confusing (see my line-by-line comments). Additionally, the order of the table is not sequential and the naming of these tables is not consistent between the text and the actual table numbering. There is also no mention of Table 1 in the text, although as pointed below, the authors could perhaps shift this table to the supplementary materials as it is of lesser importance compared with Table 2.

- Figure 3: Throughout the discussion and the conclusion, the authors mention that the main limitation to the tracing of deep IRHs in the region is impeded by rugged

bedrock that induces dipping geometries and attenuation of the radar return. As this is one of the main argument provided to explain why the authors were unable to extensively trace and directly date IRHs 20-26, it would indeed be useful to provide a direct example of this. However, I'm not convinced that this is adequately shown in the manuscript. The authors refer to Figure 3 as an example of this, but I think a much better example could be provided such as a radar image passing over the Concordia Subglacial Trench, which as the authors mention in the paper is an area where basal processes affect substantially IRH geometry in the area and thus would link well with your main conclusion. With regards to Figure 3 in its current state, is difficult to assess the continuity of the IRHs at depths. As a starting point, it would be much clearer if the authors could replace the continuous lines which result from the picking algorithm for something more subtle like crosses or circles at regular intervals. Additionally and as I show in my comments below, I feel this figure could be much improved, first by replacing the screenshot view for a proper figure with axes. There is a lot of unnecessary information in this figure at the moment, especially the different tools and menus from the Landmark Desktop which complicate unnecessarily the presentation of this figure. In my understanding, the point of this figure is three-fold: 1) Show how IRHs can be intersected with other data at crossover points, 2) the vertical position of each of the 24 IRHs (highlighted those that were dated and those that were not), and 3) the fact that tracing IRHs at depths is impeded by rough topography and radar attenuation. Whilst this figure shows these to some extent (mainly point 1 and 2), it lacks heavily in clarity and simplicity and may confuse easily the reader. I would suggest replacing this for a much more standard radar figure, with perhaps a zoomed-in view of the bottom ~20% of the ice thickness where IRHs become discontinuous. More details on this can be found in my line-by-line comments.

- Published dataset: I'm also interested to know why the authors chose to place NaN values in the IRH depth column for each of their IRH in the csv files (data accessible at: <https://www.usap-dc.org/view/dataset/601411>). If there are no values for IRH depth, then why placing these rows in your dataset files? If this because you provide

IRHs at regular 1-km intervals (for mcords and HiCARS) and 250-m for DELORES, then wouldn't it make more sense to provide all the other values (i.e. surface elevation, ice thickness, bed elevation) separately? If your aim is to provide IRH depth (and the values for ice thickness, surface elevation, bed elevation) plus all the ice thickness/surfelev/bedelev values along the flight line, then why not creating two separate csv files, one with all these values along the flight line, and one for when you only have IRH values? Also, I'd suggest to add somewhere in your paper that the IRHs are provided along regular intervals depending on which radar system you used.

Line-by-line comments:

- L06: Could you provide an age range for your IRHs here? You could be more accurate when you say 'beginning of the holocene' and provide the age of your shallowest layer. Perhaps, it would also be useful to provide the percentage depth of your shallowest and deepest IRH in the abstract too. - L27: 'The IRH' should be 'The IRHs' - L34: Extra reference to this methods point is this recently accepted paper on IRH dating over Pine Island and Thwaites glaciers in JGR-Earth Surface by Bodart et al. (2021). Full ref: Bodart, J.A., Bingham, R.G., Ashmore, D.W., Karlsson, N.B., Hein, A.S., and Vaughan, D. G. (2021). Age-Depth Stratigraphy of Pine Island Glacier Inferred from Airborne Radar and Ice-Core Chronology. *Journal of Geophysical Research: Earth Surface*. doi: 10.1029/2020JF005927. - L35: Extra reference to this point: Karlsson et al. (2014) in *Journal of Glaciology*. Full ref: Karlsson, N.B., Bingham, R.G., Rippin, D.M., Hindmarsh, R.C., Corr, H.F. and Vaughan, D.G., 2014. Constraining past accumulation in the central Pine Island Glacier basin, West Antarctica, using radio-echo sounding. *Journal of Glaciology*, 60(221), pp.553-562. doi: 10.3189/2014JoG13J180 - L40-41: Yes, but not only due to its sheer size. Different types of data acquisition methods (e.g. system frequencies, survey objectives), different processing regimes, and the multitude of institutes who collected the data must also be mentioned as a comparison to why it's so much harder to create an Antarctic-wide product like over Greenland. - L49: 'using the AICC2012 chronology'. Suggest adding 'ice-core chronology' as it

is the first time you mention AICC2012 in your paper. - L58: Suggest removing the double parenthesis and 'participants are listed alphabetically' - L75: Could you add on Figure 1 where the Concordia Station is? - Fig 1: Could you switch the colours for the ice divide (purple) and the HiCARS <2016 (black) around? It would be easier to keep all the radar surveys in colour and make the ice divide black. - Fig 1 caption: 'shown as solid lines whose colour is a function of the radar system'. This is an odd phrasing. Maybe replace by 'whose colour is shown in the figure legend'. - L82: The table order in the manuscript is not sequential and does not correspond to the actual tables in the text. The authors refer to Table 2.1 for the radar system characteristics but this is labelled as Table 1 in the main manuscript. Also, is there really a need to have two tables for system characteristics before and after processing in the main text? Table 1 ('ice-penetrating radar system characteristics before focusing and migration') is useful but maybe more suited to the supplementary materials, especially since the authors don't mention it in the main text. The frequency range could be mentioned in the text as this is maybe the most useful information here. Table 2 is much more useful when it comes to quantifying uncertainties in your dataset. - L101: Again, table 2.2.3 does not exist. Please amend this. If you're referring to Table 2 as above, then this suggests again that Table 1 is better suited to the S.I. as it is not mentioned in the text and is relatively less important than Table 2. Also, below this line, you have a reference to Holschuh et al. (2014) in footnotes. I believe this is a glitch from using LaTeX and should be removed. - L106-110: The connection between the two paragraphs is not very clear and leads to misunderstanding. Particularly, the link between L108 and L109 is confusing. I suggest rewording as follows: 'To improve along-track geometries and produce foc 1 and foc2, we use the matched filter-focusing approach of Peters et al. (2007) by interpolating the data to 1 meter records along track and filter out coherent noise. For Foc1, [...] etc.' - L116: I did not understand the beginning of this sentence starting with 'our primary processing approach for IRHs was foc2'. Please rephrase. Again this could be improved using the suggestion above. I think putting this and the previous paragraph together would make more sense here. - L122: Again the

authors are referring to Table 2.2.3 which does not exist. Please amend all the other mentions of this table and others as well. - L123: This is confusing. You mentioned Pic1, foc1 and foc2 but only used Pic1 and Foc2. Why did you not use foc1 and is it worth mentioning it here if you did not use it at all? - L126: Please rephrase this sentence as it is confusing. - Table 2: The 2nd reference for DELORES in the table (i.e. Lindsey 1989) is obscure. Perhaps King et al. (2016) is more appropriate for this dataset and the processing methods are well described in this paper. Full reference: King, E.C., Pritchard, H.D. and Smith, A.M., 2016. Subglacial landforms beneath Rutford Ice Stream, Antarctica: detailed bed topography from ice-penetrating radar. Earth System Science Data, 8(1), pp.151-158. doi: 10.5194/essd-8-151-2016 - L150: The abbreviation of two-way travel time (i.e. TWTT) needs to be in capital letters and consistent throughout the text and figures. - L168-170: I'm not certain these sentences are appropriate for this section as they sound similar to L157 where a similar issue is mentioned. I suggest removing sentences on L168-170 and combining with section 2.3. Section 2.4.1. could then start with 'One of the HiCARS survey line [...] etc.' - L170: Please improve the formatting of the equations. There is a weird line (linked to LaTeX formatting) which needs to be removed and a footnote in the middle of the text which also needs to be removed. - L171: "with a gap of 94 m between the ice core site and the point of closest approach" – in the description of your dataset on the USAP portal (<https://www.usap-dc.org/view/dataset/601411>; see abstract and 'read\_me' files), you state that the distance between the ice-core and the radar transect is 110 m: "Ice core ages are transferred onto the IRHs on radar transect MCM/JKB1a/EDMC01a at distance = 110.153 m along the transect." Please amend whichever value is erroneous. - Fig 3: This figure is poor. It looks (is) like a screenshot of the Landmark desktop with quick annotations on it. I am not convinced that this choice of presentation helps support any particular point made in the text. I think showing crossovers and the ticks representing the depth of a same IRH across crossovers is very useful, but I don't see why this has to be presented in its current form as a screenshot of the desktop. I suggest re-working this figure substantially (see minor point above), starting with adding

a depth axis in meters as opposed to the TWTT on the left hand-side of radargram and moving from a screenshot to an actual figure showing a crossover point and the depth of your IRHs at this point. It would be good to have coordinates on the map to the left and a clearer choice of colours (I can't see the yellow marking on the white background). It is also not clear why some IRHs are red and marked as (isochrones) and some are yellow and marked as (horizons) until you read the caption. Also, nothing tells you that the yellow IRHs are not isochronous, so why are they called differently? If this is due to the fact they are undated, then it would make more sense to change the annotations to: IRHs (dated) in red and IRHs (undated) in yellow. - L184-188: You state that the IRHs that cannot be traced all the way to your radar transect remain undated. But you do date them using the 1-D model. They might not be directly dated at the ice-core, but you still attempt to date them. Since this sub-chapter is titled Age attribution, I'd expect that you include the information on the 1-D modelling here too. Currently, this section implies you have several undated IRHs. . . but you do date them (although indirectly)! Some details on the 1D model would therefore be useful here. - L219: Could you provide an approximate figure for the amount of snowfall in the 10 years of data collection? Even though this can be neglected as it will like be of the order of a few meters and much smaller than the maximum uncertainty from the radar systems, it would be good to state this here for sake of transparency. - Table 3: I think this table would be better placed under 2.5.2 as you haven't yet explained how you calculate age uncertainties. Also, would it not be more accurate to round the depth and depth uncertainties to the nearest meter? The uncertainties in IRH depth from the radar are unlikely to be of sub-meter accuracy, particularly with the older radar datasets used here. This is also particularly true for the much deeper IRHs (see Table 4) - L232: Again, be careful with the order of your tables. You state the age uncertainties for each IRH is summarized in Table 2.5.1. Do you mean Table 3? - L237-238: This is fairly wordy. Do you mean that you normalised the depth of your IRHs? - L238: The transition between the sentences above and this paragraph is not very clear. Could you make anything below L238 a separate sub-chapter? As it describes IRH stratigraphy, perhaps you could name this

'Characteristics of Internal Stratigraphy'? - Fig 4: I can't easily distinguish between the magenta colour representing the IRH and the pink vertical bounds that represent the IRH age uncertainties. Instead of a colour, could you maybe change the linestyle to '- -' or something similar? Also could you add the units in the caption for  $\delta D$ ? - L267: 'Interest' should be 'of interest' - L274: 'some 500 km away' is vague. Can you be more accurate? - L278-282: Please rephrase these sentences and add some examples of what you mean as it is vague. You say that modelling efforts have brought to light the influence of basal processes on internal stratigraphy. Can you be more specific? You state that these effects can be seen on Figure 3, but it's not very clear what you mean. I think a new figure highlighting these different processes would be useful here, as I showed earlier. Especially as you go further in depth in the next sentences and provide an example over the Concordia Subglacial Trench. This figure would also link up well with L238-242. - Fig 5: It is relatively hard to see the percentage depth of each IRH. Could you make it bold and bigger? Also the star representing the EDC ice-core site is fairly difficult to see; it's very small and color navy is too dark for the background. - Fig 6: I think it would help if you had a consistent naming for all your IRHs. Throughout the text and in Figure 5, you use the word IRH or ISO but then in Figure 6 you use the abbreviation H (=horizon?). It would be clearer if you kept the naming convention you've used in Figure 5 and name the IRHs on Figure 6 as ISO20 to ISO 26. This point could also be said of Figure 7 and Table 4 where different abbreviations are used to refer to the same sets of IRHs. - L290: Remove the indent before 'In using' - L292: 'tractable'. Can you be more specific? - L299: 'very good one-to-one match'. I'm not sure this figure shows a 'very good' match. This is perhaps pedantic but 'a good match' is probably more accurate. - Fig 8: I'm not sure why this figure is in the conclusion. Can you move it up in the results or discussion section? It would also be useful if you could provide the location of where these crossovers are (e.g. in Figure 1). If you didn't know they were crossing each other, you could easily assume they are from different locations (i.e. the layers on the DELORES radargram don't always look exactly like the layers on the OIA radargram even considering system resolutions; especially the



bottom two). It would also perhaps be useful to remove the continuous lines from the automatic tracker as they mask the true layer, and instead show the layer as circles or crosses (see similar comment for Figure 3). - L307: You could add a reference to Bodart et al. (2021) here too. - L318-319: I don't think that the arguments provided in the paper show that this is the case so I think this sentence should be removed. Nothing tells you that the 10% of the ice column contain 1.5 m year old ice based on your analysis. You even state above that the fact the 1-D model does not account for stagnant ice could lead to the modelled ages being off but you remain vague on how much this could be. Thus there is no real evidence that you could find 1.5 M ice there. We assume this is the case, but your results don't show that clearly. - L320-323: Data Availability: I think it would be useful if you could provide links to where the readers can access the CReSIS, HiCARS and DELORES data. Are the last two stored in an open repository?

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