Response to Reviewer #1

General remarks on the revision and the reviewer's comments:

Dear reviewer,

Thank you very much for all your constructive comments. We have addressed all of them and provide a point-by-point response below (our responses are in italics). You also pointed out a few typographical errors and omissions, which have been corrected in the revised manuscript.

Based on your comments and suggestions, we have addressed the main issues you raise in the following ways:

Main points raised:

i) Ice penetrating radar section can be improved - in particular, several references are missing, and the relevance of the examples to readvance is not clear.

We agree that this section could be improved. We have completely rewritten this section, adding more references, including some recent ones, and providing better explanations for the relevance to detecting retreat-readvance of specific internal ice features we mention. We have also added a paragraph on challenges of collecting and using radar data.

ii) The analytical and logistical limitations and challenges of applying these methods in remote regions could be discussed further, and is notably missing from the subglacial bedrock section.

Thank you for pointing this out - we are keen to make the challenges of accessing subglacial archives clear to readers, and have therefore added brief summaries to each section to highlight the challenges (and limitations where appropriate) for applying each method in Antarctica.

iii) There is no mention of geodetic evidence for readvance.

We originally left this out of the manuscript because we were focusing on glacial-geological archives. However, we appreciate GPS uplift rates could be used as indirect evidence for readvance in the late Holocene. We have therefore added a new section (Section 3.1.4 in the revised manuscript) to discuss this. We have additionally added a geodetic observations panel to Fig. 1.

Point-by-point responses:

Summary:
This article presents a summary of, mostly recent, work focused on investigating the potential readvance of the Antarctic Ice Sheet in the late Holocene. Although it is widely agreed that the ice sheet has retreated since the LGM, its behaviour within the past few thousand years is less certain. The manuscript is structured into four sections; (i)

introduction, (ii) summary of the concept of readvance, (iii) methods and results for evidence of readvance, and (iv) conclusion.

The largest section is dedicated to geological and glaciological methods for investigating readvance; subglacial bedrock and sediments, marine sediment cores, relative sea-level records, ice-penetrating radar and ice cores. The authors identify subglacial bedrock and sediments as providing direct evidence of past grounding line position, while the other methods providing indirect evidence.

In large part, the article is mainly focused on methods and their potential use to investigate readvance. There is less focus on formulating a conclusion from the existing evidence, but rather a central takeaway is; although evidence exists that the ice sheet was smaller than present during the late Holocene, further work is needed to provide a more comprehensive picture and to better understand the drivers of this change. The authors conclude that improvements in our understanding are most likely to result from a multi-discipline approach.

The manuscript is well structured and well written. I believe it will be of interest to many within the cryospheric community and surrounding fields. It will be of particularly interest to students and those new to the topic of ice sheet history, and as such, I believe it will be well cited.

I have a number of fairly minor comments which I list below. I also include an attached PDF with line-by-line comments.

Main Comments:

My most critical comments are in relation to the ice-penetrating radar section (3.3.1), which I believe can be significantly improved:

- Firstly it is important to specify that the internal structure of the ice sheet is the cumulative result of accumulation, flow and ablation (surface or basal). In order to use the englacial structure to interpret ice-sheet history each of this processes should be accounted for.
- The use of references is limited, with many possible relevant citations missing. (see attached PDF)
- Lines 317-321: It is unclear how this information relates to ice-sheet readvance.
- Lines 342-344: Again it is unclear how this information relates to readvance. This needs to be more clearly justified.
- Line 354: More recent references to ice-divide studies are missing.
- Lines 355-356: “For example, significant thinning followed by readvance and ice thickening might produce an unconformity visible within radar stratigraphy” – see Kingslake et al., 2018 and Wearing et al., 2019 for an example of this.

We have rewritten the radar section for the revised manuscript, taking into account all of these comments, and adding in more detail and references as requested. In the first two paragraphs of Section 3.3.1, we have now explained that there are multiple processes that must be accounted for when using englacial ice structure to interpret ice sheet history. For the text originally in lines 317-321, we relocated these sentences to the penultimate paragraph of this section, in which we stress the challenges of determining the timing of

observed events from radar data. For the information originally in lines 342-344, we removed this sentence to improve clarity, but have instead provided more discussion about the use of radar data in the Weddell Sea sector in the third paragraph.

Discussing the analytical and logistical limitations and challenges is identified as one of the key outputs of this work. However, this doesn't seem to be included in some sections. It is most visible in the subglacial bedrock section. It would be good to mention in the summary that challenges that apply to all methods include logistical access to remote locations, presence of suitable sites (i.e. bedrock close to ice surface) and the difficulty in surveying large areas (with the possible exception of radar).
We have added details about analytical and logistical limitations and challenges to all sections in the revised manuscript. We have also highlighted the logistical challenges common to all approaches by adding a couple of sentences to the summary.

There is no mention of GPS uplift rates as a method for investigating readvance, such as the study from Bradley et al., (2015). Uplift and GIA are mentioned in relation to relative sea level, but not in this context. There is also no mention of how the less viscous mantle underlying West Antarctica potentially makes it more susceptible to GIA induced uplift (and readvance) in comparison with East Antarctica
This is a good point, and a highly-relevant new paper (King et al., 2022) has been published about this topic since we submitted our manuscript. Therefore to fix this omission, we have added a new section (Section 3.1.4) and a new panel to Fig. 1 in the revised version of the manuscript.

Lines 102-103: "Retreat of the grounding line would be accompanied by dynamic thinning upstream, assuming reasonable limits on surface mass balance changes." This point is key when interpreting exposure age data as thickness change is being used as a measure of grounding line retreat/readvance. However, these properties (grounding line position and ice thickness) cannot be directly compared, thinning is likely to vary throughout the catchment and may adjust over many years. There's potentially a need to consider ice-sheet modelling to interpret these processes. (Similar point can be made when interpreting other indirect evidence (radar, ice cores, etc).).
The purpose of this sentence is to simply point out that ice thickness in regions near the grounding line is, in general terms, a proxy for grounding line position, and we want to make this point in a concise way that does not interrupt the flow of the text too much. We agree with the reviewer. However, since we discuss this in more detail later in the paper, we have decided not to amend the text at this point.

Line 176: "Slowing rates of change" can you be more specific here? Do you mean a reduction in the rate of sea level rise or fall?
We added text here to specify that it is a reduction in the rate of RSL fall.

References:
Bradley, S. L., Hindmarsh, R. C. A., Whitehouse, P. L., Bentley, M. J., & King, M. A. (2015). Low post-glacial rebound rates in the Weddell Sea due to Late Holocene ice-sheet readvance. Earth and Planetary Science Letters, 413, 79–89. https://doi.org/10.1016/j.epsl.2014.12.039

Kingslake, J., Scherer, R. P., Albrecht, T., Coenen, J., Powell, R. D., Reese, R., Stansell, N. D., Tulaczyk, S., Wearing, M. G., & Whitehouse, P. L. (2018). Extensive retreat and re-advance of the West Antarctic Ice Sheet during the Holocene. Nature, 558(7710), 430–434. https://doi.org/10.1038/s41586-018-0208-x

Wearing, M. G., & Kingslake, J. (2019). Holocene Formation of Henry Ice Rise, West Antarctica, Inferred From IceâPenetrating Radar. Journal of Geophysical Research: Earth Surface, 124(8), 2224–2240. https://doi.org/10.1029/2018JF004988

Response to other comments from Reviewer 1 on the attached pdf:

Section 1: Maybe mention here how in some locations we're missing dating constraints from the past few thousand years, but have many/more constraints dated to before then?
This observation is already discussed in detail in Section 3.1.1., therefore we chose not to provide more explanation in this introductory section.

Section 2: Comment referring to "(cf. figure 3, Whitehouse et al., 2012)": Is it possible to include a figure that demonstrates this? It would be good to include a figure that highlights this.
We considered adding this to Fig. 4, but decided that it would make the figure too "busy" and would detract from the point we are trying to illustrate by showing the RSL data plots. We therefore prefer to refer readers to Whitehouse et al., 2012 and the discussion and figures therein.

Section 3.1.3. Line 2: "rise or fall?"
We have amended this to "fall".

Section 3.1.3. Penultimate line, second paragraph: "land or marine-terminating? [glaciers]"
We chose not to change this because present-day glaciers could change from land to marine terminating (or vice-versa) if uplift occurs, and regardless, this does not matter for the point of our sentence.

Section 3.1.3., last paragraph: Interaction between glacier and ocean - transition from marine to land terminating would imply ice retreat.
This is not necessarily the case, because rebound could have this effect without resulting in any further glacier retreat. We therefore chose not to make any changes to the text here.

Section 3.2.1.: referring to "last marine incursion": "which was?"
We agree this was ambiguous, and have amended the text to make it clearer.

Section 3.2.2., second paragraph, referring to "background levels": How long does it take to return to background levels after exposure?
Since we discuss this in the following paragraph of the text, we chose not to make any changes here.

Section 3.2.2., end of third paragraph: Erosion due to abrasion from ice flow or due to a weathering type process?
The mechanism of erosion does not matter for this process. The key point here is that erosion happens, regardless of the mechanism. We therefore decided not to add anything about the mechanism.