Response to reviewer 1

General comments

This is a well-crafted paper that presents new insights on the deglacial chronology of a vast area of the NW LIS and is constrained by a significant number of new surface exposure dates. The paper addresses relevant scientific questions within the scope of TC and is of high scientific quality, and the results are well supported using thorough methods and modelling. Substantial conclusions are reached – namely the authors propose meaningful modifications to ice margin retreat positions in an area clearly lacking dated material, and the results have a significant impact on ice retreat dynamics, the timing of ice-saddle collapse, meltwater delivery to the Arctic Ocean and contribution to sea level rise, and on the idea of an early opening of the IFC for peopling of North America.

The authors give proper credit to related work and clearly indicate their own original contribution. Model outputs and inputs, sensitivity analysis results for different GIA models, and description of model calculations provided in the text and Supplementary materials are complete and precise to allow their reproduction by fellow scientists. The overall presentation is well structured and clear; language is fluent and precise. The number and quality of figures is appropriate. Figure 6C is missing however. The references are generally appropriate. Several references cited in the text or in the figures are missing in the list, and some listed references do not appear in the text.

Overall a very good contribution that requires minor revisions outlined in the comments below. Specifically minor parts of the text and figures should be clarified and/or modified. Technical corrections are required or highly recommended.

Thank you for taking the time to review our manuscript and for the detailed comments. We copy your comments below in black and respond to each of them in red text. When we copy text from the manuscript into the response we 'underline' sections where we have added new text and 'strikethrough' to indicate deleted text.

Specific comments:

45: Clarify timing of persistent IFC from the earlier models. During entire last glaciation?

Yes, this is correct. We have now amended this sentence to:

'At the same time, earlier models suggested a lack of coalescence between the LIS and CIS (Johnston, 1933; Antevs, 1935; Mandryk, 1996), and thus a persistent IFC between these ice sheets <u>during the last glaciation</u>.'

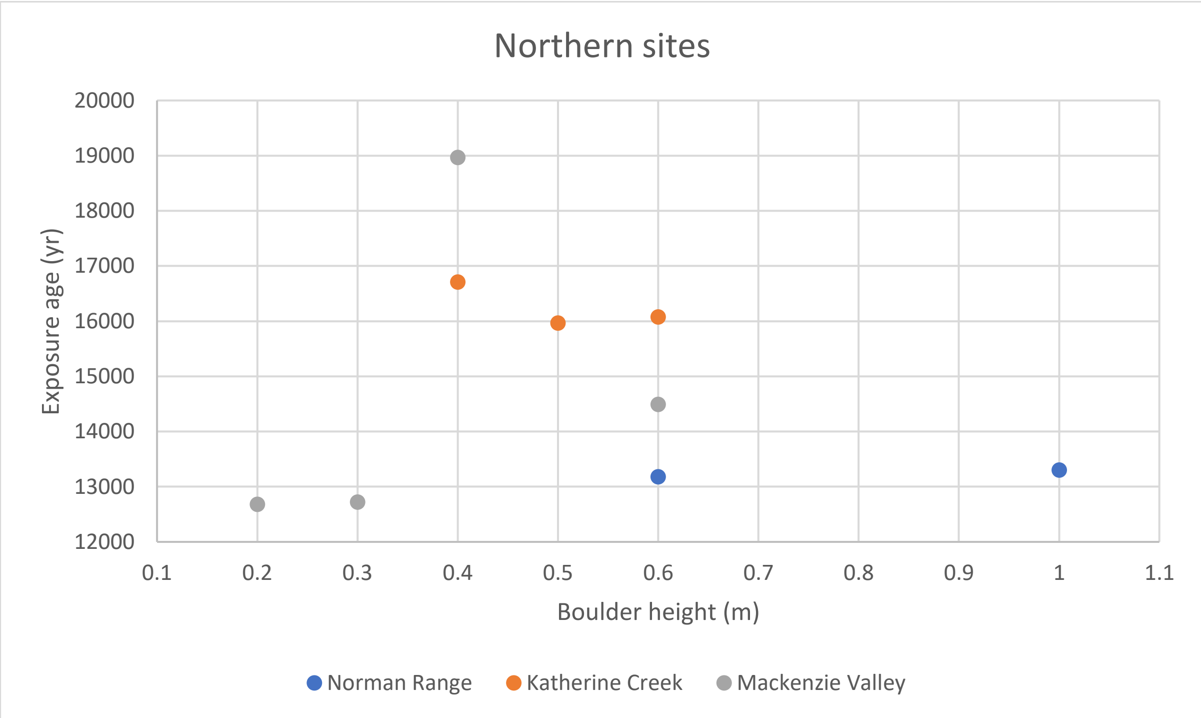
73: Boulders suited for TCN analysis should be large in size (>1 m) and stable. Some boulders from this study appear rather small and/or considerably embedded in sediments on Figure S2. Explain reasoning for choosing such small boulders and if exposure ages may have been affected by movement or exhumation – in methods section or caption of Figure S2.

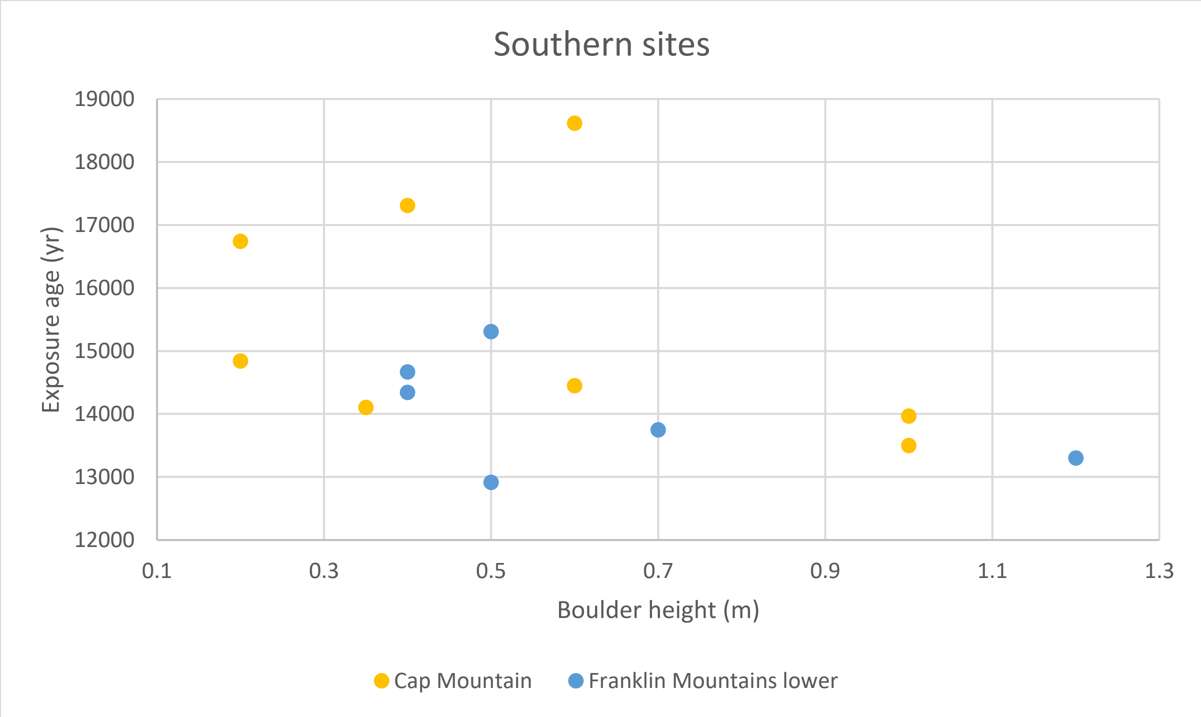
We have now expanded upon the methods section to highlight the potential issues of sampling smaller boulders. It now reads:

'In particular, we preferentially sampled the surface of erratic boulders which: were situated on stable ground away from steep slopes (Heyman et al., 2011), display a rounded shape suggesting a longer transport history by the ice sheet, exhibited limited evidence of surface weathering (Balco, 2011), and were large and well exposed above the ground surface (Heyman et al., 2016). <u>Sampled boulders for TCN exposure dating should be exposed >1m above the ground where possible. Limited</u>

boulder availability meant that some smaller boulders were sampled. These smaller boulders are more likely to be impacted by shielding from snow cover or to have been exhumed following the denudation of surface till cover, resulting in an exposure age which underestimates the true deglaciation age (Heyman et al., 2016). In our sampling area, the annual precipitation rates are very low (average snow depth of less than 30cm; Government of Canada, 2019), meaning that snow cover is unlikely to be an issue. The majority of our samples were taken from high elevation sites with very limited till cover, meaning the sampled boulders are unlikely have been covered in till after deposition.'

Below, we provide two charts showing sample exposure age against boulder height. In these charts, there is no clear relationship between boulder height and exposure age which would suggest that the exposure age was influenced by snow cover or denudation of a surface till layer. We will include these charts in the supplementary material.





134-135: Provide range of % change of the minimal impact of changes in atmospheric mass distribution on the exposure age from cited studies.

In the cited studies, the impact of atmospheric mass distribution changes on the calculated exposure ages is over an order of magnitude less than that of GIA impacts. In Cuzzone et al. (2016), the calculation for atmospheric changes was about 4% of the GIA correction, resulting in ages ~1% younger. In Ullman et al. (2016), the atmospheric correction ranged from 1 – 5 % of the GIA correction for their sample sites. In Dulfer et al. (2021), the atmospheric correction was ~1% of the GIA correction. We now include these values in the main text.

299 and Fig. 8: The two clusters of ages at the Cap Mountain summit site are not obvious on Fig. 8 and S6. They appear more like a spread. Clarify.

Thank you for the comment. You are correct that spread is a more appropriate term to describe the exposure age distribution. We have now changed the description to 'spread' instead of 'cluster' when referring to this site.

308: Is the change in the retreat pattern and style provided by the new TCN ages also supported by ice marginal landforms and/or changes in the glacial erosional record?

There is geomorphological evidence in the record of glacial lineations of the shift from SE-NW ice flow to a more E-W oriented ice flow in the central Mackenzie Valley region around the Norman Range and Franklin Mountains. Currently, we have a Journal of Maps publication in review which documents this geomorphic evidence. Surficial maps from the region also document these changes in ice flow, but the past ice flow dynamics have not yet been properly reconstructed for the NW LIS. Currently, our ice margin reconstruction is drawn based purely on tracing the elevation from our TCN exposure dating sites and drawing glaciologically plausible ice margins. We accept that this leads to a very simplified ice margin reconstruction that may not be completely accurate, but we believe this is appropriate at the broad-scale of our ice margin reconstructions. A higher resolution reconstruction of the ice margin retreat and past changes in ice flow based on empirical geomorphological data is planned in a future manuscript.

335: Provide reference for given radiocarbon dates (13.4 ± 0.17 cal ka BP).

Done.

447: It is difficult to see the ice lowering of 116-157 m versus 19-47 m on Fig. 5A. Can you point to these drops on the figure?

We have now colour coded the model simulations and indicated the time periods we refer to using a shaded area. We believe it now clearly shows that an early saddle collapse, during MWP-1a, only occurs in the model simulations where surface lowering starts before the Bølling-Allerød.

478-481: Consider adding underlined text for clarification: … is an earlier retreat of the NW LIS by about 1000 years around 63N in the central Mackenzie Mountains...

Done.

Figure 2: Outline of Fig. 7 represents Fig. 9; clarify if ages besides the red outlines represent mean values of various samples; grey lines difficult to differentiate from drainage; also where does the LGM (21.1 cal) limit appear – difference with "local LGM limit at 18.0 cal"?; consider adding "(two sigma range)" after "deglaciation ages".

We have made the suggested changes.

The ages beside the red outlines are the three oldest ages within the cluster of ages. We chose to group the dates within the red outlines due to the high density of ages in some areas, which makes the map very cluttered if we present all the ages. We now clarify this in the figure caption.

The ice margin pattern and chronology in this sector of the ice sheet are not very well constrained in the past reconstructions. The ice margin is in a very similar position at 21.1 cal. ka and at 18.0 cal. ka, but do not align very well. This means that including the 21.1 cal. ka margin to this figure results in overlap with the existing margins and a very confusing, cluttered figure. We chose the margin timesteps presented in Figure 2 as they cover the full time period from the local maximum ice sheet extent to complete deglaciation, but are easily interpreted in a single figure panel. We have provided an example of the figure below including the 21.1 cal. ka margin as a solid black line below.

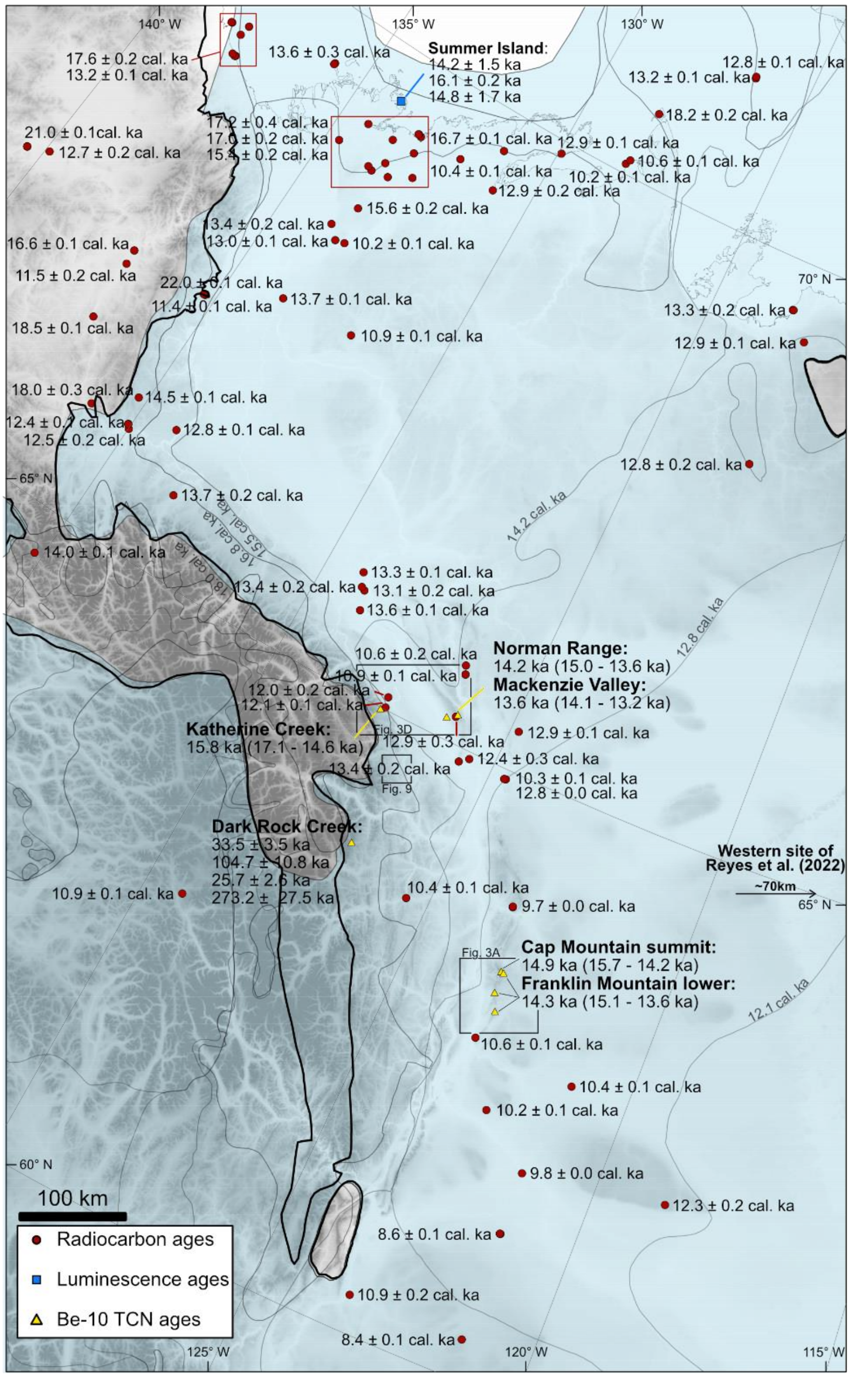


Figure 3: Consider adding reference for ArcticDEM from Polar Geospatial Center.

Done.

Figure 4: Consider indicating location of Mackenzie Valley or River and locations of 6 studied sites.

Done.

Figure 5: Mention what are the red dots as well.

The red dots indicate our southern sampling site for TCN exposure dating in the Franklin Mountains.

Figure 6: The 10Be versus elevation plot is entirely missing in C; add what are B-A and YD and the two vertical blue dashed lines.

Done.

Figure 7: Replace “points” by “lines” in caption of (A).

Done.

Figure 8: Delete one of the repeated “using the modelled age distribution output of” in caption.

Done.

Supplementary Document #1

- 14.2 cal ka: In fact, the ice margin north of ~65°N does not replicate that of Dalton et al. (2020). Explain the slight changes proposed.

This was a typo. It should read ‘… north of ~66°N…’ We have now changed this. The changes around 65°N are justified by the TCN exposure ages from the Mackenzie Valley and Norman Range, with an ice margin then extrapolated north, based on the local topography.

- 13.5 cal ka: What is the basis for the changes of the ice margin position north of 65°N? Geomorphology, elevation, TCN dates?

We have drawn the ice margin position to the north of 65°N based on our TCN exposure dates and then tracing an ice margin along the local topography. This results in the LIS being constrained to the Great Bear Basin at this time. We have rewritten the text to better describe this.

Technical corrections:

46-47: In addition to what? There needs to be a link to previous sentence here.

We have removed these connecting words.

60: Although Consider replacing by “However”.

Done.

62: Reference should be Dyke et al 2003 (as in list).

Done.

64: Consider adding “(Fig. 2)” after 65°N.

Done.

137: effect

Done.

142: Missing Jones et al., 2017 in reference list. Unless it should be Jones et al. 2019.

You are correct, it should be Jones et al. 2019. We have now corrected this.

162-163: Missing Small et al., 2020 in reference list.

This should have been Small et al. 2019. We have now corrected this.

184: Consider referring to Table S2 at the end of sentence.

Done.

186: Should be Table S2 and not S3 here.

Done.

190: Consider adding “at the Summer Island site” after located.

Done.

201: Consider adding “we” in …and so we do not refer…

Done.

211: Move bracket before “see” (see Gregoire et al., 2016)

Done.

284: Add “was” after Mackenzie Valley floor.

Done.

305: Add reference to Fig. 2 at end of sentence.

Done.

306: Figure 4 does not appear in order as cited in the text. First time this figure is mentioned.

We have removed the earlier mention of Figure 5 from the ‘Methods’ section and moved this citation to the ‘Results’ section as this is more appropriate. All figures now appear in order.

388-89-90: Rephrase – difficult to grasp.

We have rephrased this to:

~~‘While~~ Using the ‘primary’ production rate (Borchers et al., 2016) produces mean site ages which are ~8% younger than mean site ages calculated using the Arctic production rate. ~~dates.~~ The ~~results in a~~ deglacial chronology calculated using the ‘primary’ production rate ~~that~~ is more compatible with the existing geo~~morphological~~chronological constraints (Fig. 7 and 8).’

393: Consider adding “(Fig. 6)” at the end of the sentence (2016).

Done.

453: Add “in” after deglaciation.

Done.

460: Missing (Menounos et al., 2017; Corbett et al., 2019) references in list.

Added.

463: Missing Ivanovic et al 2017 and 2018 references in list.

Added.

465: in

Deleted.

521-22: Delete repeated reference.

Done.

528-29: Reference not found in text.

Deleted.

562: After Barbett, P.J., consider adding “and others”.

Done.

622-23: Reference not found in text.

We have added the reference to the text.

660-663: Reference not found in text.

We have added the reference to the text.

708-709: Delete repeated reference.

Done.

739: Incomplete reference?

This is the suggested citation provided by the Geological Survey of Canada in the original document.

Table 1: Missing Berto et al (2022) reference in list.

Done.

Figure S1: Add references for each named model in caption: Peltier et al., 2015; Lambeck et al., 2017; Gowan et al., 2021.

Done.

Figure S2: Provide size of chisel(s).

Done.

Figure S3: Borchers et al., 2015 is given as 2016 in list of references. Verify.

Borchers et al. 2016 is the correct citation. We have amended this throughout the text.

Table S1: Provide Peltier’s reference instead of ICE-6G in the headers (to be consistent with others); add “age” to all headers.

Done.