Reviewer 2

Review in normal type, response in *italic*:

Review of ***The ST22 chronology for the Skytrain Ice Rise ice core – part 2: an age model to the last interglacial and disturbed deep stratigraphy***

Authors: Robert Mulvaney, Eric W. Wolff, et al

General Comments: The manuscript presents the age-scale for the deep section of the Skytrain Ice Rise, below the depths where annual layer counts are evident. The methodology chosen by the authors is robust and is similar to that chosen for other Antarctic ice cores. The manuscript is well written with generally good presentation. Relevant work is properly cited. I recommend publishing pending minor changes.

We thank the reviewer for this overall positive assessment.

- I am not sure of the claim that Skytrain is the only WAIS ice core that extends into MIS5 (the last interglacial period). Siple Dome extends to at least 100 ka (Severinghaus et al, 2009) and maybe to 118 Ka (Dunbar et al, 2011). RICE likely contains ice from ~90 ka. Taylor Glacier, which is on the border between East and West Antarctic similar to Hercules Dome, has been measured for MIS5-4 transition (Menking et al, 2019).

This comment arises from a difference in terminology. The LIG is normally identified as MIS5e, ~110-130 ka, and not as the whole of MIS5 – we make this identification in line 43 of the paper. However we had missed that for Siple Dome some data extended to 100 ka, and we have now corrected our comment on this core and added the Severinghaus reference.

- Beyond establishing the ST22 age scale, the authors hypothesize that ice from the last interglacial period is inherently prone to stratigraphic disturbances (e.g. folding). The Skytrain ice core is poorly suited for testing this hypothesis since this age range is within the bottom 50 m of the core, near the basal interface and stratigraphic disturbances may be expected. The authors do not convincingly demonstrate that the discontinuities observed in the Skytrain chronology are due to processes related to the age of the ice.

We did not mean to sound so definite; the reviewer is correct that we do not have enough evidence to demonstrate the cause of stratigraphic disturbance convincingly. We propose to add a new sentence "We do not have enough evidence to conclude whether the disturbance we see is indeed due to rheoogical contrasts or is just a consequence of investigating ice that is close to the bed." In response to the other reviewer we also changed the final sentence of section 9 from "only plausible" to "most plausible" in describing the cause of our disturbances.

- Several of the figures could be combined into panels such as figures 4-7, all of which show how tie points were matched using reference records, and figures 9-12, which all show CH4 and d18O cross plots.

As also requested by the other reviewer we will combine Figs 8 and 9 into one, and also Figs 10 and 11. We explain in our reply to Rev. 1 exactly the changes made in the figures, as well as our reasoning. We do not think it is very helpful to combine figures 4-7 as they refer to different time periods and follow the sections of the paper sequentially.

Specific Comments:

22 "… Skytrain ice rise ice core." There should be some description of where this ice core is (Greenland vs Antarctica, Ross Sea Basin or Atlantic side of WAIS…)

Done. Proposed text "We present an age model for the 651 m deep ice core from Skytrain Ice Rise ice core, situated inland of the Ronne Ice Shelf, Antarctica."

32 "base of LIG section" is confusing. Please clarify.

We are not really sure what the confusion is here. However we have added "below 628 m" after "LIG section" to avoid any doubt.

38 "Antarctic Ice Sheet" "Ice sheets of Antarctica". "Antarctic Ice Sheet" is a misnomer.

We respectfully disagree. "Antarctic Ice Sheet" is a common and well-understood terminology for the whole ice sheet even if we often refer to component parts such as WAIS. Authorities such as the British Antarctic Survey (https://www.bas.ac.uk/about/antarctica/geography/ice/), National Geographic (https://education.nationalgeographic.org/resource/ice-sheet) and NSIDC (https://nsidc.org/learn/parts-cryosphere/ice-sheets) happily use the term. No change made.

56-57 "The Siple Dome core reached the bed at 1004 m, but again data have only been presented as far back as 90 ka (Brook et al., 2005; Saltzman et al., 2006)" Severinghaus et al (2009) presents d18Oatm data back to 100 ka (973 m)

Thank you for pointing this out. Corrected as above.

58 In Lee et al (2020), there appear to have MIS5 ice near the base as identified by negative d18Oatm that are unique to interglacial periods.

We very much hope that it will be possible to interpret deeper and older ice at RICE. However Lee et al does not provide us with a basis to claim that LIG ice (110-130 ka) is present.

87 "(J. Kingslake, pers. Comm.)" Personal communication is not an acceptable reference. (https://www.climate-of-the-past.net/submission.html#references)

I'm a little surprised at this interpretation of the rules. A pers comm is indeed not a reference, but it is a standard way to acknowledge the provider of information that is used in the paper but that does not warrant an authorship. However to avoid further argument, we will remove the pers comm from the text and instead acknowledge Kingslake in the acknowledgments.

123 "as has been observed in other ice core records including those of the LIG in Greenland". See general comments.

We have adjusted the text in section 9 as discussed above to cover the point made here by the reviewer.

145 CFA has not yet been defined.

Now defined here.

154 “discrete samples analysed in Bern” add something like “discussed below” or a reference for the discrete sample system.

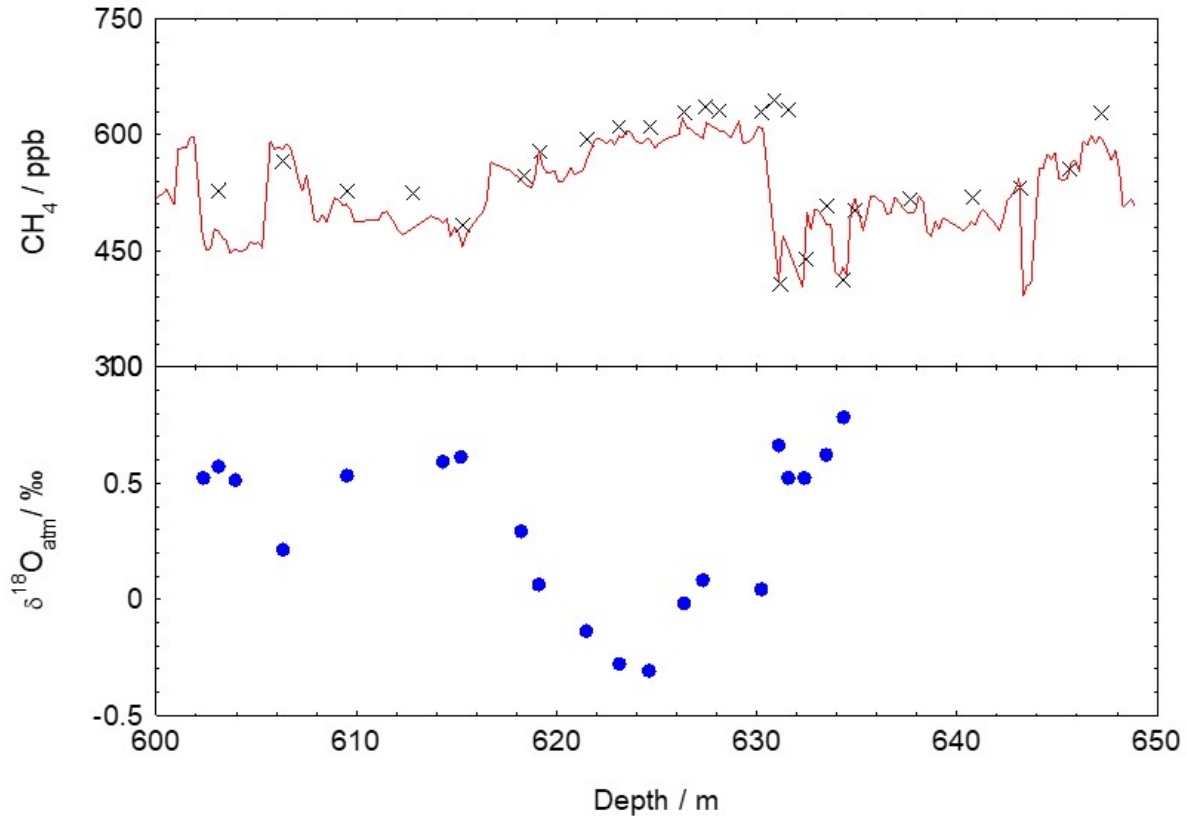
This sentence already refers to section 4.2 where the method in Bern is discussed.

175 “ginput” MATLAB function. This function returns the [x,y] coordinates of a point plotted on a graph. It does not describe a method of identifying and removing outlier data. Do you mean, “manual identification”?

Yes, we will alter to say that.

Fig 3 It is hard to tell how well the CFA and discrete data represent each other. You could try a cross-plot as presented in Chappellaz et al (2013) Figure 6 and 7. Is it possible to “correct” the cfa data as they did for the NEEM record?

The purpose of Fig 3 is to show that the CFA data are generally OK at the LIG, but are not OK between 534 and 545 m, as we suspected. Of course we could use the discrete data to offset the CFA data but this would assume that the offset stays constant and we don’t feel we have enough discrete data to confirm that. We therefore prefer to use the uncorrected CFA data as a pattern match rather than a value match, and then use the few discrete data to value match where they exist. We discuss the offset in section 4.1. To satisfy the request to more easily compare the CFA and discrete methane, we now show a detail of Fig. 3 from 600-650 metres in a new Fig. S1.



212 There should be a reference to a paper describing the system.

The Extier paper referred to later in this paragraph describes the system for 18O_atm analysis.

Fig 4 Why do the well known 5.2 and 8.2 ka methane variations not line up with the reference methane record?

The 8.2 ka event lines up quite well in Fig 4, but we thank the reviewer for pointing out that there is a small mismatch. This arose from an incorrect entry of a tie point (the tie listed as 8226 should be at 8166). This will be corrected in the new version. A second incorrect tie point at 362.2 m also pulled the features around 6 ka slightly away from the reference data, and this is fixed in the new version. Table 3 and of course the age model are adjusted, and the figures affected will be replotted.

Fig 5 Why are there such large age offsets between when nssMg is observed to increase in Skytrain at 90 and 105ka compared to EDML?

We assume the reviewer means Fig 7 here. We did not use the nssMg in this region to create any tie points, because we did not want to place undue reliance on subtle features like this. The offset is therefore within reasonable uncertainty given that the nearest gas tie points are some way away and that delta-age is unconstrained.

355-356 "…with some thousands of years potentially missing from our record" Are they missing or smoothed out? The reference record show d18Oatm approaching values of -0.4 permil at the peak of MIS5e. Based on the compressed age scale at this part of the core, a sample of 5-10 cm length could represent a significant amount of time. 5-10 cm is the length of typical discrete CH4 samples (Schmidley et al 2020) and 5-6 cm was typical system response of CFA CH4 (Rhodes 2017). This smoothing is on top of uncertainty of interpolation caused by measuring d18Oatm on adjacent samples, not on identical depths. Basically, I question whether uncertainty in age horizons are properly handled and suggest that the authors provide more discussion.

The discrete samples we provided were generally 4 cm for 18O_atm adjacent to 3 cm for methane. In the lower dated section of the LIG 1 metre is about 1300 years so the combined samples for an 18O_atm/methane pair cover about a century. The uncertainties we put on tie points using 18O_atm/methane are larger than this. However as discussed in the response to rev 1 we have increased the uncertainty on some of the methane ties around 70-100 ka where low data quality from the CFA mean that pinpointing the exact tie points in observed features is difficult, and our original picks were too tightly constrained.

Figure 9 This should probably show the cross-plot for age range 60-140 ka as the authors need to prove that the ice is not just folded duplicates of MIS3, 4, 5a.

What was Fig. 9 will now be provided as a pair with Fig 8, and covering the entire period 0-200 ka. We have included the Skytrain data points for the part we date as being at the main part of the LIG so the reader can see their position on the crossplot in the longer context.

Figure 13 This would be nice to also show age uncertainty (as is output by ICECHRONO) and annual layer thickness as is provided in Buiron et al. 2011, Lee et al 2020). These are important metrics in understanding an ice core chronology.

We plan to add, in Fig. 13, a panel showing the age uncertainty. We will also add a new supplementary figure with annual layer thickness.

515 Were there d15N-N2 measurements made in parallel to the d18Oatm? Wouldn't this give you some idea of the accumulation rate?

We do have some 15N data although the analysts of these samples were not very happy with the reproducibility of the 15N data. We assume the reviewer is asking if we have any very low values indicating a hiatus in accumulation. None of the values we have around the LIG are unusual in the context of the shallower ice.

518 "bubble-free ice" could be confused with clathrated ice.

Skytrain is not deep enough for clathrate formation to cause bubble-free ice. But the reviewer is of course correct that clathrated ice might be mistaken for bubble-free ice due to melt. Since our resut is negative (no bubble-free ice) though, this is not an issue for us.

Add'l References:

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Chappellaz, J., Stowasser, C., Blunier, T., Baslev-Clausen, D., Brook, E. J., Dallmayr, R., Faïn, X., Lee, J. E., Mitchell, L. E., Pascual, O., Romanini, D., Rosen, J., and Schüpbach, S.: High-resolution glacial and deglacial record of atmospheric methane by continuous-flow and laser spectrometer analysis along the NEEM ice core, Clim. Past, 9, 2579–2593, https://doi.org/10.5194/cp-9-2579-2013, 2013.

Dunbar, Nelia W., and Andrei V. Kurbatov. "Tephrochronology of the Siple Dome ice core, West Antarctica: correlations and sources." Quaternary Science Reviews 30.13-14 (2011): 1602-1614.

Menking, J. A., Brook, E. J., Shackleton, S. A., Severinghaus, J. P., Dyonisius, M. N., Petrenko, V., McConnell, J. R., Rhodes, R. H., Bauska, T. K., Baggenstos, D., Marcott, S., and Barker, S.: Spatial pattern of accumulation at Taylor Dome during Marine Isotope Stage 4: stratigraphic constraints from Taylor Glacier, Clim. Past, 15, 1537–1556, https://doi.org/10.5194/cp-15-1537-2019, 2019.

Severinghaus, Jeffrey P., et al. "Oxygen-18 of O2 records the impact of abrupt climate change on the terrestrial biosphere." Science 324.5933 (2009): 1431-1434.