Review of manuscript by Sime et al. entitled 'Summer surface air temperature proxies point to near sea-ice-free conditions in the Arctic at 127ka'.

The authors present a well though-out and well written study to study LIG sea-ice changes and simulated relationships between changes in temperature and sea ice. I have only a few comments which are listed below.

Main comment:

To make this work more directly relevant to a larger public and to the understanding of ongoing climate change, it would be useful to compare the presented findings with observational records. In particular, I'm wondering if from observational estimates one can also deduce a relationship between changes in Arctic summer temperatures and sea-ice area, and how such a relationship would compare to the LIG-based estimate. A dSIA of 4.4 mil. km2 for a dSSAT of 3.7, gives dSIA of 1.18 mil. km2 per 1K dSSAT. Potentially, there is a difference because the LIG climate was close to equilibrium while an observational estimate would be based on transient climate change. Another problem could be that the LIG winter forcing was negative, while the present-day GHG-driven winter forcing is positive. Nonetheless, this could be a nice addition to the presented work.

We thank #1 for their kind review of our manuscript.

In answer to their main comment, we agree that comparing our presented findings with observational records is indeed a useful exercise. In accordance with the practice of most recent papers looking at present-day sea ice in the Arctic, we use NSIDC sea ice data and ERA5 SAT data from the satellite-era (1979-2020). The figure below shows the scatter plot of these SAT versus SIA data. The calculated relationship gives an (observational) dSIA of 1.32 mil. Km2 per 1K. This relationship shows slightly higher values for dSIA than LIG one of 1.18 mil. km2 per 1K dSSAT. In accordance with the comment, we will add this comparative present-day observation relationship figure to the manuscript in the supplementary section, and provide the comparative numbers in the main manuscript.

Whilst we agree with the #1 that potentially, there could be difference because the LIG climate was (probably) close to equilibrium while the observational estimate is based on transient climate change, the close agreement between the LIG and present-day relationship tend to support the idea that Arctic sea ice and SAT tend to be both reside in the fast reacting part of the climate, and that slower ocean and vegetation (transient) feedbacks therefore seem to play a lesser role is determining the association between the two.

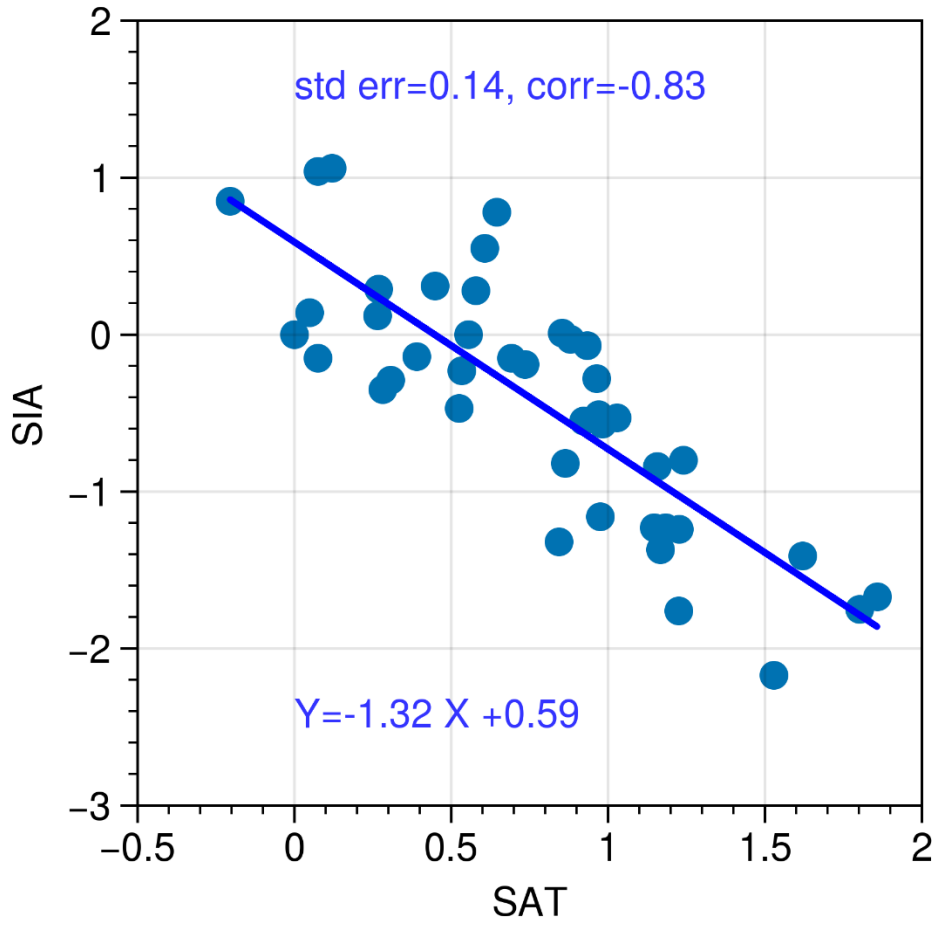

Figure R1: *Scatter plot of SAT versus SIA for current period. JJA surface air temperature versus NH September Sea ice area for each year from 1979-2020. Anomalies computed from year 1979 values. SIA is from NSIDC (https://nsidc.org/data/g02135/versions/3) and Air temperature (area averaged north of 60°N) is from ERA5 reanalysis (Hersbach et al. 2020).*

Minor comments:

Line 25: So dSIA corresponds to NH-wide changes in sea ice while dSSAT corresponds to local, proxy location changes in temperature? Reword to make this clear.

We propose that in line 25 (in abstract) "Second, across the 11 models, the averaged ΔSSAT at the 21 proxy locations is inversely correlated with ΔSIA (r = -0.86)" be changed to "Second, across the 11 models, the averaged ΔSSAT at the 21 proxy locations as well the pan Arctic average delta SSAT, is inversely correlated with ΔSIA (r = -0.86 and 0.79 respectively).

Lines 85-88: You make it sound like it is either sea-ice changes or vegetation changes, while in reality they will very likely go hand-in-hand. It is hard to imagine a sea-ice free Arctic that is several degrees warmer in summer, that does not see any changes in vegetation on the surrounding continents. And indeed, these vegetation changes will likely feedback on the temperature and sea-ice changes.

#1 is correct that in reality sea-ice and vegetation changes will go hand in hand. However we do think it is useful to point out that sea-ice change on its own is sufficient to explain the LIG SSAT changes. We thus propose to modify the text so that "In particular, it offers the opportunity to address the questions of whether the Arctic sea ice loss is sufficient to explain LIG summertime temperature observations, or whether the Arctic vegetation changes idea (Lunt et al., 2013; Otto-Bliesner et al., 2013; IPCC, 2013), is still potentially required." becomes instead, "In particular, the existing non-dynamic-vegetation PMIP4 LIG protocol and associated simulations offer the opportunity to address the question of whether the Arctic sea ice loss alone is sufficient to explain LIG summertime temperature observations, or whether active vegetation modelling, and the idea of vegetation feedbacks (Lunt et al., 2013; Otto-Bliesner et al., 2013; IPCC, 2013) are required. This said, we recognize that in reality there must also be LIG Arctic vegetation feedbacks. These should be explored in future modelling work."

Figure 2: why not show the observational sea-ice concentrations on all the maps, or in a separate plot?

The reason we do not do this is that we would be comparing modelled pre-industrial SIA with observed historical SIA data. This is rather confusing, so we prefer not to do this.

Lines 299-302: by using percentage changes, is EC-Earth no longer an outlier as mentioned above, or is it still an outlier?

#1 is correct to point out that using percentage changes EC-Earth is not an outlier (Figure A4).

Figure A4: using this metric is seems HadGEM3-GC31-ll is now an outlier!

Given that HadGEM3 has approximately 100 % summertime sea ice loss during the LIG, it is indeed an outlier: no other model simulates such a complete loss of sea ice. That said, if the amount of sea ice loss and observational agreement is considered HadGEM3 fits ok, being the model with the best LIG SSAT match – but with the largest sea ice loss. This is also pointed out in Kageyama et al (2021) and Diamond et al (2021).

Technical comments:

Line 91: maybe better to use 'reconstructed' instead of 'observed' throughout the text to avoid

Will do.

confusion with recent and present-day observations? Or alternatively, consequently use 'proxy observation' as you do on for instance line 106?

Will do.

Figure 1: the figure and legend shows empty and filled red circles, but they appear both to be SI, IP25. What is the difference between them?

On the F1 open/filled symbols, open symbols correspond to records with uncertain chronology, and filled symbols correspond to records with good chronology, following the Kageyama et al (2021) convention. Apologies that this was not clarified in the caption. We will add this information during revision.

Why are the sea-ice reconstructions shown on this map, are they used in this study?

#1 is correct, these sea ice reconstruction data are shown in Figure 3.

Line 267: remove 'for any model'?

Will do.

Lines 285-287: perhaps reverse the order of 1 and 2 to be coherent with earlier mentioning.

Thank you to #1 for pointing out this. Since the figures follow the order mentioned here, we will reverse the order mentioned in text in lines 194-196 to be consistent with this.

Figure 8: add legend to the figure or mention in the caption that the legend can be found in figure 7.

We will add to the caption that the legend can be found under Figure 7.

Figure A5: indicate what is on the x-axis and y-axis.

Thanks to #1 for also spotting this. We will incorporate this change in the revised version.

Additional 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