Response to referee comments

Anonymous Referee #2

We thank Referee #2 for the time they spent reviewing our manuscript, and the helpful comments and feedback they provided. See below our point-by-point response to their comments, with their comments marked in black and our responses marked in blue.

Review of Diamond et al.,

Diamond et al. analyse the processes leading to Arctic sea-ice loss during the Last Interglacial period (LIG) in the HadGEM3 model. The HadGEM3 is the only model simulating an ice-free Arctic in summer at the LIG. The authors analysis suggests that the sea-ice loss is due to thermodynamic processes, and particularly the creation of melt ponds in late spring/early summer. While the HadGEM3 Arctic sea ice LIG results were presented in Guarino et al., 2020, this study looks in more details at the processes at play. As such, this is an interesting study, well suited for TC, however, I find it a bit hard to follow, with many missing links between sentences/paragraphs/sections. I detail a few comments below but encourage the authors to read their manuscripts and improve the flow and links, particularly in the Introduction and the first part of the results.

Following these comments, we have made substantial changes to the structure of the manuscript, which can be seen from the point-by-point response below. Primarily, we have restructured and added context to the Introduction and added a Discussion section, to contrast our results with those of prior publications. We have added further detail in the Methods and Results sections and improved the flow and links.

Section 3.1 (before 3.1.1, as a side note, maybe the structure of the results need to be amended):

- A first short paragraph and Fig. showing a comparison between observed and simulated monthly Arctic sea-ice area would be useful.
  Figures comparing observed and simulated monthly Arctic sea-ice area are shown in Guarino et al. (2020) and Kageyama et al. (2021), which are cited in the Introduction.
- Since the anomalous Arctic sea-ice loss is due to the higher seasonal insolation at the LIG compared to PI, it would be useful to show in Fig. 1 high northern latitude insolation in PI and LIG. The addition of the insolation curve could also lead to a much earlier discussion of the conundrum: i.e. the maximum insolation anomalies are in June while the maximum sea-ice anomalies are reached in August. An earlier statement on that issue could make the flow of the paper easier to understand.
  Figures showing the higher seasonal LIG than PI insolation are shown in Guarino et al. (2020) and Kageyama et al. (2021), which are cited in the Introduction.

Fig. 6 clearly shows the maximum short-wave anomalies in June, yet I find it surprising that during the early years of the spin up (Fig. 5), Aug. and Sept are the ones decreasing sharply and quickly while July (and June) sea-ice decreases less and more slowly.

As for present-day sea-ice, LIG sea-ice had minimum area in August-October. As quasi-equilibrium was reached within the first few years of the LIG spin-up, it should not be surprising that Aug and Sept sea-ice area decreased more than June and July sea-ice area.

As such, I am not so convinced of the usefulness of Fig. 5 (which could be moved to SI?), but wonder if it would make sense to instead show the timeseries of meltpond area in May and June in the spin up (i.e. similar to Fig. 5 but for meltpond area).

This section considers differences between PI and LIG sea-ice and upper ocean. It is important to show the large differences in sea-ice behaviour before introducing melt ponds as a driver of these differences, which we do later in the manuscript.

Another option would be to show sea-ice volume instead of area. Indeed, the July sea-ice area is 50% smaller in LIG than PI, but it is also much thinner, and sparse.

Sea-ice area and volume show similar patterns, but we can make a figure showing sea-ice volume.

It is quite interesting to show the SST and SSS changes in the Arctic, however this is very briefly mentioned and I don't find the flow of the beginning of section 3.1. logical.

It is important to show the simulated SST and SSS changes in the Arctic, as observations of these quantities from proxy records can be used to deduce LIG ice conditions. We include SST and SSS changes in Section 3.1 as they are closely related to the enhanced sea-ice loss that we detail here.

We have modified the introductory paragraph of this section (line 126) to improve the flow:

'Here, we examine the HADGEM3-simulated LIG sea-ice and upper ocean, in order to identify factors that contributed to LIG summer sea-ice loss. We first compare LIG and PI sea-ice area, as well as sea surface temperatures and salinities, which were closely related to sea-ice area in each time period. We then consider the LIG production run and spin-up to determine the primary drivers of LIG sea-ice loss.'

Section 3.1.1: How were the ice volume tendency due to thermodynamics and dynamics calculated (Figs. 7 and 8)?

These were calculated from model output variables, so we have added a sentence describing this.

Section 3.1.2:

There are a lot of Figures (and sub-panel) in the manuscript, and I wonder if all are necessary.

For example, are Figures 10a,b necessary?

Figures 10 a and b are useful to show where melt ponds form in each time period, as readers will not necessarily be familiar with this.

Similarly, wouldn't only fig.12a be sufficient?

Figures 12b and c are useful to compare the initial rates of melt pond formation between LIG and PI, as these are difficult to see in Fig. 12a alone. We can move Figures 12b and c to Supplementary Information.

Maybe only Fig. 13b is necessary.

Fig. 13a is useful to see absolute values of where incoming shortwave radiation is absorbed. Fig. 13c will be moved to the Supplementary Information. Fig. 13d is useful to visualise how Figs 13a and b were computed, but can be moved to the Supplementary Information.

P16, L. 240-255: PI SW as well as albedo differences between LIG and PI are discussed while not shown. Maybe at least the albedo could be shown in Fig. 13 instead.

A subfigure in Fig. 13 showing the albedo climatology for each time period will be added.

Minor points:

P1, L. 20: "affect"

Thank you. Modified.

P1, L. 24: what are you referring to here?

We are referring to surface energy balance differences, as mentioned in previous sentence. We have changed the wording to 'surface energy balance differences'

P3, L. 68: Please add a transition sentence before that section

We have restructured the Introduction so this comment no longer applies.

P4, L. 120 and 122: I doubt the model is "in equilibrium" after 350 years of spin-up. Please modify to "quasi-equilibrium" or "the surface variables have reached a steady state".

We have changed the wording to 'quasi-equilibrium'

P6, L. 151: remove "is"

We have reworded this sentence.

P6, L. 153: "year" or "years"?

'Year', as we briefly discuss sea-ice changes over first 35 years of spin-up (Fig 5), but focus in particular on the first year of spin-up (Figs 5 and 6).

P6, L. 154: "Fig. 5 shows that…"

Thank you. Modified.

P16: Many full stops are missing.
We have corrected this.
P18: Section 3.1. discusses “sea-ice area” whereas section 3.3. discusses “sea-ice extent”. It would be good to only discuss one or the other.
We have changed this so that Section 3.3 also discusses sea-ice area, rather than sea-ice extent.