Response to reviewers

We found both reviewers' comments very constructive and helpful. Thank you very much for helping to improve the manuscript! In this document we have compiled our replies to all raised issues and comments. The Referees' texts are in black print, while our responses to each item are in blue and changed text passages are given in green. This pdf file contains our responses in the order of the reviewers' comments. New figures for the manuscript and supporting figures are included at the end of this response.

Response to reviewer #1:

Line 2 – 4: Maybe the second and third sentences of the abstract could be switched around. Then you would first introduce the complexity of the relationship between proglacial lake and ice sheet retreat and then explain the mechanism of that complexity. It would also then lead nicely from the possible regional climate influence -> your attempts to quantify this influence in the fourth sentence. This is not something I have a strong opinion on though, so feel free to ignore.

Good idea, we switched the order to:

While proglacial lakes are commonly regarded as promoting ice-sheet retreat through dynamic interactions with the ice margin, their influence on the climate may instead have acted to stabilize retreat. Sustained by meltwater inflow and iceberg calving, these lakes likely remained cold throughout summer and may have modified the regional climate, potentially reducing ice-sheet melt.

Line 15-47: The first paragraph is quite long and I find myself get lost a little bit in the details. I would
recommend trying to split this into two paragraphs.

We have introduced a split between paragraphs after line 29.

Line 16: "large proglacial lakes (PLs) have evolved along the margins"

corrected

Line 27-29: "For the deglaciation of the Laurentide Ice Sheet, the coupled simulations with an Earth system model of intermediate complexity from Quiquet et al. (2021) suggest that proglacial lakes cause additional mass loss of 3000 Gt per year, which however likely overestimates the dynamic effect

corrected

Line 54: There seems to be an issue with your "ø". I would just make sure when this goes to the copy editing stages that the correct character is used.

corrected

Line 142: Please make "East" lowercase.

corrected

Line 228: The citation of Quiquet et al needs brackets.

corrected

Line 240: “(Dyke, 2004; Margold et al., 2018; Dalton et al., 2020; Norris et al., 2024, e.g.)” Move e.g. to the start of the brackets.
corrected
Line 234-242: This sentence is quite long because of the colon and seems to contain a few different ideas
that make it tricky to follow. I would recommend splitting it:
“However, sensitivity studies also reveal that the strength of the dynamic feedback strongly depends on
complex processes and poorly constrained basal boundary conditions, including basal friction, ice–lake
interactions, glacial isostatic adjustment, and changing lake levels or drainage events (Scherrenberg et
al., 2024; Austermann et al., 2022; Hu and Haseloff, 2025)., which may be another reason why both
These factors may explain why both ice sheets exhibit a more heterogeneous retreat history in geological
reconstructions than in the above simulations with ice-only models or models of intermediate
complexity: The southern Laurentide Ice Sheet exhibits highly variable ice-stream configurations and
periods of stagnation and readvance (Dyke, 2004; Margold et al., 2018; Dalton et al., 2020; Norris et al.,2024, e.g.) and contrasting retreat patterns of the Fennoscandian Ice Sheet between Bølling–Allerød and
Younger Dryas despite a continuous presence of the Baltic Ice Lake (Stroeven et al., 2016).”
This isn’t perfect, but splitting this sentence somewhere
We agree and have split the sentence

Response to reviewer #3:

Main points

Further develop the discussion of the precipitation changes

The manuscript places considerable emphasis on reduced melt, but precipitation changes received only a brief description (alongside figure 2). I found these results some of the more surprising in the paper, and wanted to read more about it! The paper would be strengthened by adding some discussion of the potential physical mechanisms for these changes.

We have added some context regarding the general climate response to the existence of lake at the beginning of the Results section:

Introducing lakes in experiment PL13ka adds substantial heat storage capacity that regionally dampens the seasonal cycle relative to experiment REF, yielding cooler, later-onset summers (Fig. 1) but elevated autumn temperatures (not shown). The cooler lake surfaces increase surface air pressure, which suppress advection of humid air and cloud formation. Consequently we observe a drier climate around the lakes with reduced spring and summer precipitation, while autumn precipitation may be enhanced in some locations. Because summer precipitation dominates the seasonal cycle over North America and Europe (Fig. S6 in the Supplement), this reduction translates into lower annual-mean precipitation along the ice-sheet margins (Fig. 2).

The additional cooling of the lake surface in experiment PL13ka$_{cold}$ further amplifies the effect on summer temperatures and precipitation (Fig. 1 and 2), while suppressing the autumn warming and wetting.
We also provide maps of surface air pressure anomalies in Fig. 1-4 below.
Justify the set up of the cold proglacial lakes
The PL13ka_cold experiment is central to the paper because it enhances all reported effects. The authors acknowledge that the imposed 4C cap is idealised, but the discussion remains qualitative. I'm happy with an idealised approach like this, and you can learn a lot from these experiments, but it would still be useful to consider why 4C is the most appropriate threshold. Can we test how sensitive the results are to that value? Would a seasonally varying cap produce a similar result?
Unfortunately we cannot run any new experiments- but we would expect that the climate response scales linearly with the constrained surface temperature.

A limited analysis of the physical drivers of the cooling response
The manuscript reports cooling cover and around the lakes, but it would benefit from more diagnosis of the atmospheric processes producing that cooling. Is it coming from sensible and latent heat flux changes, clouds, something else? For me this is the most significant weaknessof the manuscript in its current form; there are really interesting results here but I want to understand "why" more than I do at the moment.
The climate response is consistent with the positive surface air pressure summer anomaly over the colder lake surface. See our reply to your first main point.

Specific points
5: "in combination *with* an ice sheet surface"?
corrected
17: Comparable in size or comparable in some other way?
Comparable refers to the directly preciding word area
35: "Even though…" onwards, this sentence is a little long, and I needed a second read to follow it properly.
We have split the sentence: Sensitivity studies have shown that proglacial lakes can lead to colder summer temperatures over adjacent ice sheets (Hostetler …), potentially resulting in a substantial increase in surface mass balance (SMB). However, to our knowledge, no studies have quantified the resulting negative SMB feedback for the Laurentide Ice Sheet.
74: "during *a* fundamental climate transition"?
corrected
73: "somewhat hybrid setup appears to be appropriate". I agree, but it would better to briefly justify why here.
We have added: appears to be appropriate for a first sensitivity study which primarily considers response to changes in the land surface
105: Should "overall" be in bold?
We have renamed it to "General climate response"
144: "5 % (2 %) in PL13kacold (PL13ka)" would be clearer as "5% in PL13kacold and 2% in PL13ka"
corrected
179: "There empirical method(s) are grounded"
corrected
228: Quiquet reference should be in brackets?

corrected

Figure 1: Something to give a more accurate sense of the geography of these plots would be helpful. Something like a graticule, scale bar, or contemporary coastline? This is true for other plots.

The model coastline is given- however a modern coastline would be misleading, as this would mean that the modern Baltic Sea would be represented.

Figure 4: Please change the colour map on figure 1 to a colourblind friendly choice. I wouldn't be sure until the paper is properly typeset, but fonts etc look a bit small at the moment.

changed

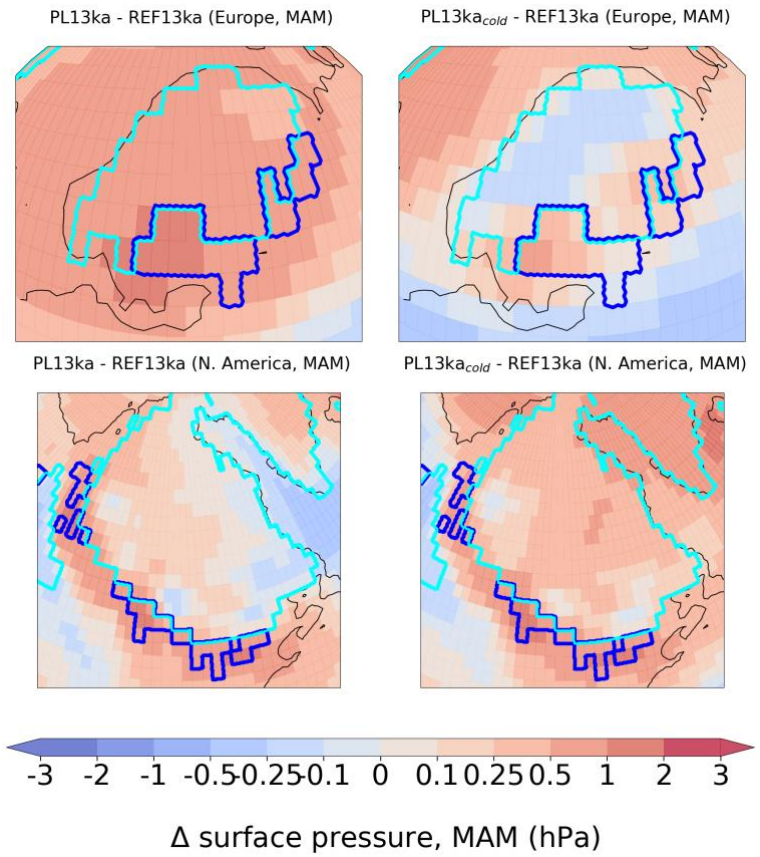


Fig. 1: Seasonal surface air pressure anomalies for spring (MAM) over FIS (upper row) and LIS (bottom row) for experiments PL13ka-REF13ka (left) and PL13ka$_{cold}$ – REF13ka (right)

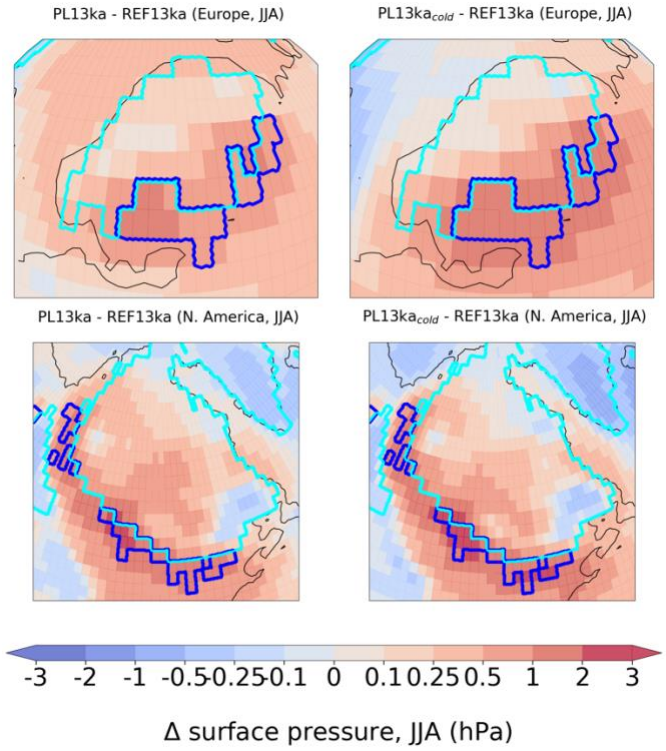


Fig. 2 Same as Fig. 1, but for summer (JJA)

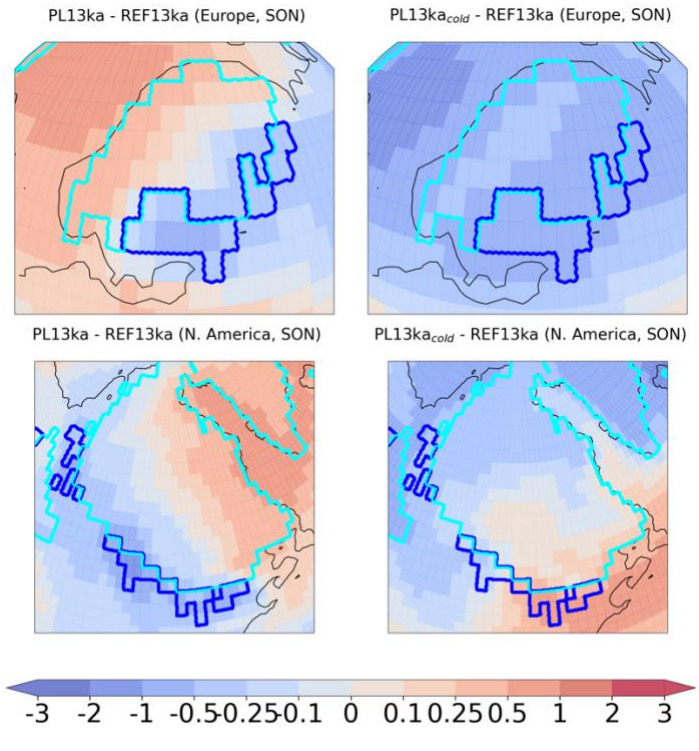


Fig. 3 Same as Fig. 1, but for autumn (SON)

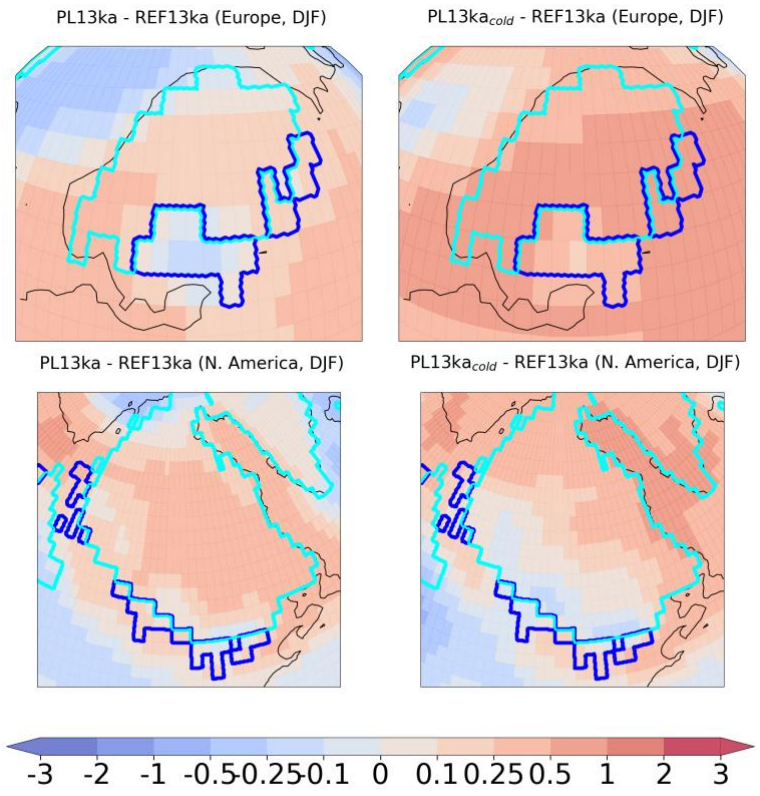


Fig. 4 Same as Fig. 1, but for winter (DJF)