Response to Referee#2

Main comments

1 - This study is presented as a theoretical work aimed at better understanding the relative role of insolation and CO2 in the triggering of glacial inception, with the objective to better predict "future glaciations and the effect that anthropogenic CO2 emissions might have on them". This paper is indeed fully relevant in this respect. It complements a previous study (Ganopolski et al. 2016) made with a simpler model. But in contrast to this previous paper based on CLIMBER-2, CLIMBER-X appears to be a rather new model. In particular, it is not clear how well it can simulate the actual glacial inceptions observed during the Quaternary. The authors are citing a preprint (Willeit et al. 2023b) concerning the last glacial inception, but it is difficult to evaluate how well this new model configuration behaves on the other inceptions. I would appreciate some discussions or comments on this point, for instance by building on improvements made versus CLIMBER-2, or by discussing a bit more the simulations corresponding to the actual last 4 inceptions, among the 19 simulations performed. It would strengthen the paper to put these results against observations, even if they are not fully comparable.

The reviewer is perfectly right – CLIMBER-X is a brand-new model, superior to CLIMBER-2 in all respects. CLIMBER-X was extensively evaluated against observational data and results of more complex models. The successful simulation of the past glacial inception (Willeit et al. 2023b) is also part of such validation. In addition, similar to Ganopolski et al. (2016), the model's parameters were selected to meet two clearly defined empirical constraints: the model should not simulate glacial inception at the end of the Holocene but simulate glacial inception at the end of MIS11. Since the critical CO2-insolation relationship obtained in this study is very similar to that in Ganopolski et al. (2016), the fig 3b from the 2016 paper shows that CLIMBER-X should simulate all previous glacial inceptions since they are located below the critical CO2-Insolation line. The question of how realistically the model can simulate previous glacial inceptions is not possible to address because prior to MIS5, the only empirical information which could be used to compare with modelling results is the global sea level or ice volume (e.g. Elderfield et al. 2012; Grant. et al. 2014; Rohling et al., 2014; Spratt and Lisiecki, 2016; Waelbroeck et al. 2002), but these reconstructions strongly disagree with each other, in particular during glacial inceptions. This fact makes simulations of previous glacial inception of little use for model validation.

2 - It is not discussed if climate sensitivity is different, or very similar, in CLIMBER-X versus CLIMBER-2 (I suspect the latter), if the radiative code is identical or not. Such information would be critical to assess such statements as (line 155): "values for alpha and beta might not be strongly model-dependent". This would likely not hold with very different climate sensitivity to CO2 forcing. A few lines of information on CLIMBER-X in this respect would be useful.

Although CLIMBER-2 and CLIMBER-X are very different models, they do have similar equilibrium climate sensitivities close to the "IPCC best guess" of 3K. The reviewer is right - climate sensitivity should affect the slope of the critical insolation-CO2 relationship. In any case, modelling results are always model-dependent. This is why we will change the statement of model-dependence "values for α and β might not be strongly model dependent" to "values for α and β might not be as uncertain as it was assumed in Talento and Ganopolski (2021)". Note, that in this publication, we considered as "acceptable" all values of the parameter α in the range from -150 to 0 W m-2.

3a - Line 89-90: biais correction on temperature. It is all right to use such a procedure, but it would be necessary to have some discussion on possible impacts on the final results. The hidden assumption is that the biaises should remain constant, whatever the climate and the ice-sheet evolution. Is it realistic?

The assumption about constant temperature biases is not so problematic for the given study, where we are only interested in the initial phase of ice sheet growth. Obviously, such an assumption would be much less justified for modelling the entire glacial cycles. As shown in Fig. 8, glacial inception in different experiments happened under conditions that are rather similar to modern summer temperature conditions. This is not surprising since PI climate was already very close to glacial inception. Thus, prior to the appearance of large ice sheets, summer temperature biases are not expected to be very different for different combinations of orbital parameters and CO2. Since glacial inception is diagnosed by the growing of additional ice by less than 10 msl, such ice sheets are by order of magnitude smaller (both in area and volume) than the LGM-size ice sheets and their impact on atmospheric circulation is expected to be rather small. Since the main cause for summer temperature biases over North America is a bias in simulated atmospheric circulation, there is no reason to expect that a small Northern American ice sheet would have an appreciable influence on climate biases. This issue will be discussed in more detail in Willeit et al., 2023b.

3b - There is no mention of "biais correction" on precipitation. I read through Willeit et al. (2023b) Appendix B but found no information on this point. I had a look at Willeit et al. (2022) but could not really evaluate precipitations at high latitude. Are precipitations from SESAM good enough?

Present-day annual precipitation simulated by CLIMBER-X over the region where ice sheets were growing during glacial inceptions is in reasonable agreement with reality (see figure below), and typical biases do not exceed 200 mm/yr. At the same time, the effect of +1°C summer temperature biases on annual snowmelt can be estimated using the classical PDD approach to be 200-500 mm/yr (the low bound corresponds to the melt season duration of two months and parameter α=3 mm/(°C day), while the upper corresponds to the melt season duration of three months and α=5). Since simulated summer temperature biases in this region are about 3-5°C (Fig. 2a in Willeit et al., 2023b), temperature biases are much more important than precipitation biases. This is why we only corrected the temperature. We will discuss this issue in the revised manuscript.

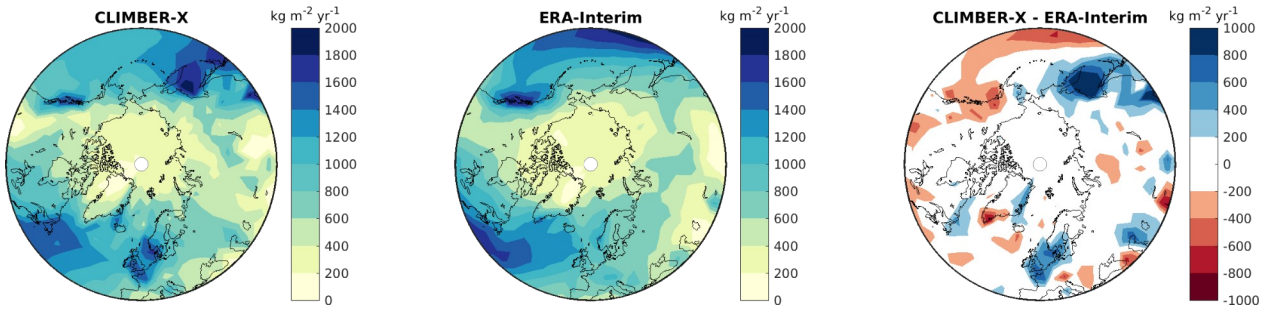

Fig. 1. Simulated present-day annual precipitation (left), reanalysis data (middle), difference between model and data (right).

These two points may be critical for instance in the discussion of Hsmx65_LCO2_Fixice (cold) versus Lsmx65_HCO2_Fixice (snowy).

The main difference between Hsmx65_LCO2 and Lsmx65_HCO2 is in temperatures, not in precipitation. In North America, summer temperature differences between these two experiments are rather small (fig. 8) and, as a result, ice sheet configurations are essentially identical (Fig. 4). In Hsmx65_LCO2 Scandinavia is much colder (partly due to a weak AMOC) and as a result, an ice sheet is growing over Scandinavia in Hsmx65_LCO2 although precipitation in these experiments is lower here than in the Lsmx65_HCO2 run (Fig. 8d and f).

Minor comments

4 - (line 96): "sea level (which affects land-sea mask)". I guess this concerns the atmospheric model, but not the ocean model (bathymetry)? Or does the ocean have a bathymetry which adapt to ice-sheet induced changes?

Yes, the ocean bathymetry, as well as the land elevation above sea level and river routing scheme, are updated every 10 years : "Changes in sea level, and therefore ocean volume, are additionally accounted for by scaling the thicknesses of the ocean layers below a depth of 1000m to match the actual ocean volume derived from the high-resolution topography and provided as input to the ocean model. Total tracer inventories in the ocean are conserved in this process". (Willeit et al. 2023, p. 5912)

5 - (line 170, legend Fig 2) CLIMEBR -> CLIMBER

Will be fixed, thanks.

6 - (line 241) understating -> understanding

Will be fixed, thanks

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