Anonymous Referee #1

We thank the reviewer for his/her comments that help to increase the quality of the paper. We answered them hereafter and took them into account in the revised manuscript in preparation. The referee's original comments are in italic, reply by Loutre et al is in plain text, and text included in the revised manuscript is in bold.

It is not clear to me if albedo changes due to the changes in ice sheet configuration are also taken into account. Please discuss the impact on the simulated temperatures.

As already pointed out in the abstract, when the changes in the NH ice sheet configuration are applied in a simulation, changes of ice sheet extent, ice sheet altitude and ice sheet surface albedo are taken into account. However, we did not perform simulation changing either the extent or the albedo. Therefore we cannot quantify the impact of the albedo of the NH ice sheet on temperature. Answering such question would require further simulations, which is out of the scope of this paper.
This is clarified in the revised version, section 2.3: "**Ice sheet albedo is also applied in this simulation.** "

What calendar is used in the model, a fixed-day (like in Bakker et al., 2013; Lunt et al., 2013; Langebroek and Nisancioglu, 2013) or a fixed-angular calendar? Please discuss.

The model year is divided into 12 months of 30 days. The vernal equinox occurs on 21st of March. We are aware that it would be necessary to use a celestial based calendar to analyse the differences between the two time periods in order to keep a definition of seasons consistent with the insolation forcing in both climates (Joussaume and Braconnot, 1997). However, we preferred to consider monthly means computed with the present-day calendar as usually done with climate models.
Two sentences are added in section 2.2 :" **The model year is divided into 12 months of 30 days. The vernal equinox occurs on 21st of March.** "

How is the scaling of the freshwater fluxes with sea level done? The LR04 stack will give you a global sea level record, not a NH one, or? Please elaborate.

As mentioned in the text: "The total freshwater flux magnitude is scaled to be in line with the total sea level contribution of the NH ice sheets". The glacial-interglacial contrast in NH sea level contribution between the penultimate glaciation and LIG is assumed to be the same as between the LGM and present day, for which a value of 110 m SLE is taken in line with the reference model results of Zweck and Huybrechts (2005). This further description has been added in the revised manuscript.
Zweck, C. and Huybrechts, P.: Modeling of the northern hemisphere ice sheets during the last glacial cycle and glaciological sensitivity, J. Geophys. Res, 110, D07103, 2005.

236.16-17: rewrite sentence, too low compared to reconstructions This is done.

236.21: change to "not depending on changes in surface boundary conditions. . ." This is done.

237 and several other places: "At last" has a different meaning. You probably mean "Lastly" or similar This is done.

239.10-240.15: re-structure. Now it is not clear what is done in transient and what in time slice simulations, and what forcing is applied. Maybe start with Bakker et al (2013) as overview for transient simulations, followed by other transient simulations. In the end discuss the time-slice simulations e.g. Lunt et al. (2013), Langebroek and Nisancioglu (2013).

This section has slightly been modified according the referee's suggestion : "**Langebroek and Nisancioglu (2013) who performed equilibrium simulations at 130 kyr BP, 125 kyr BP, 120 kyr BP and 115 kyr BP with the Norwegian Earth System Model, pointed out the role of the insolation in the seasonal cycle of temperature and the importance of the greenhouse gas forcing in the actual value of temperature. They also showed that temperature is maximum during the early LIG in the NH in JJA and south of 45S in JJA and DJF, while it reaches its maximum late in the LIG in the NH in DJF.**"

240.27: skip "in this framework" This is done.

241.6: "other" instead of "others" This is done.

Section 2.1:- also shortly describe LOCH and AGISM

One sentence has been added : "**The reader is referred to Goosse et al (2010) for a more detailed description of these components, as well as to Mouchet and François (1996) for LOCH and to Huybrechts (2002) for AGISM.**" *- give spatial resolution for T21.* It corresponds to about 5.625°×5.625°(section 2.1)

- Is the PI climate as simulated by LOVECLIM1.3 similar to the PI climate of LOVECLIM1.2? yes. This is added in section 2.1.

242.18 & 243.3: no need for italic. This will be asked to the production.

Section 2.2: how do the GHG concentrations that you used compare to the ones used in the PMIP3 protocol? "**The atmospheric CO_2, CH_4 and N_2O concentration of the PMIP3 protocol is used from 132 kyr BP to 115 kyr BP.**", i.e. the PMIP3 time interval for the LIG. This sentence is added in section 2.2.

Section 2.4: please describe what the difference is between the reference parameter set (std) and parameter set 22

Parameter set	**λ2 (m)**	**λ4 (m)**	**amplw**	**explw**	**albocef**	**albice**	**avkb**	**CorA**
71	**0.131**	**0.071**	**1.00**	**0.4**	**0.950**	**0.44**	**1.5**	**-0.0850**
22	**0.125**	**0.070**	**1.00**	**0.4**	**0.900**	**0.42**	**1.5**	**-0.0425**

Table: Value of the major parameters involved in the parameter sets (column 1) used in this study. Parameters λ2 and λ4 (columns 2 and 3) are applied in the Rayleigh damping term of the equation of the quasi-geostrophic potential vorticity. The coefficients amplw and explw (columns 4 and 5) are used in the longwave radiative scheme to compute anomaly in humidity. The uncertainties in the albedo of the ocean and sea ice are accounted for through albcoef (column 6) and albice (column 7). The minimum vertical diffusion coefficient in the ocean is scaled according to avkb (column 8). CorA is a correction factor for the distribution of precipitation over the ocean (column 9). More details about these parameters are available in Goosse et al. (2007).
This material is included as supplementary. Indeed, this material was already published in Goosse et al. (2007).

Fig 4: - Please include the corresponding simulated PI Section 3.1 and fig. 5:
- Please include the corresponding simulated and reconstructed (if possible) PI values in Fig. 5

Unfortunately, the quality of the core top does not allow determining the reconstructed PI temperature. The simulated PI values are included in the figure and compared to the LIG values in the main text.

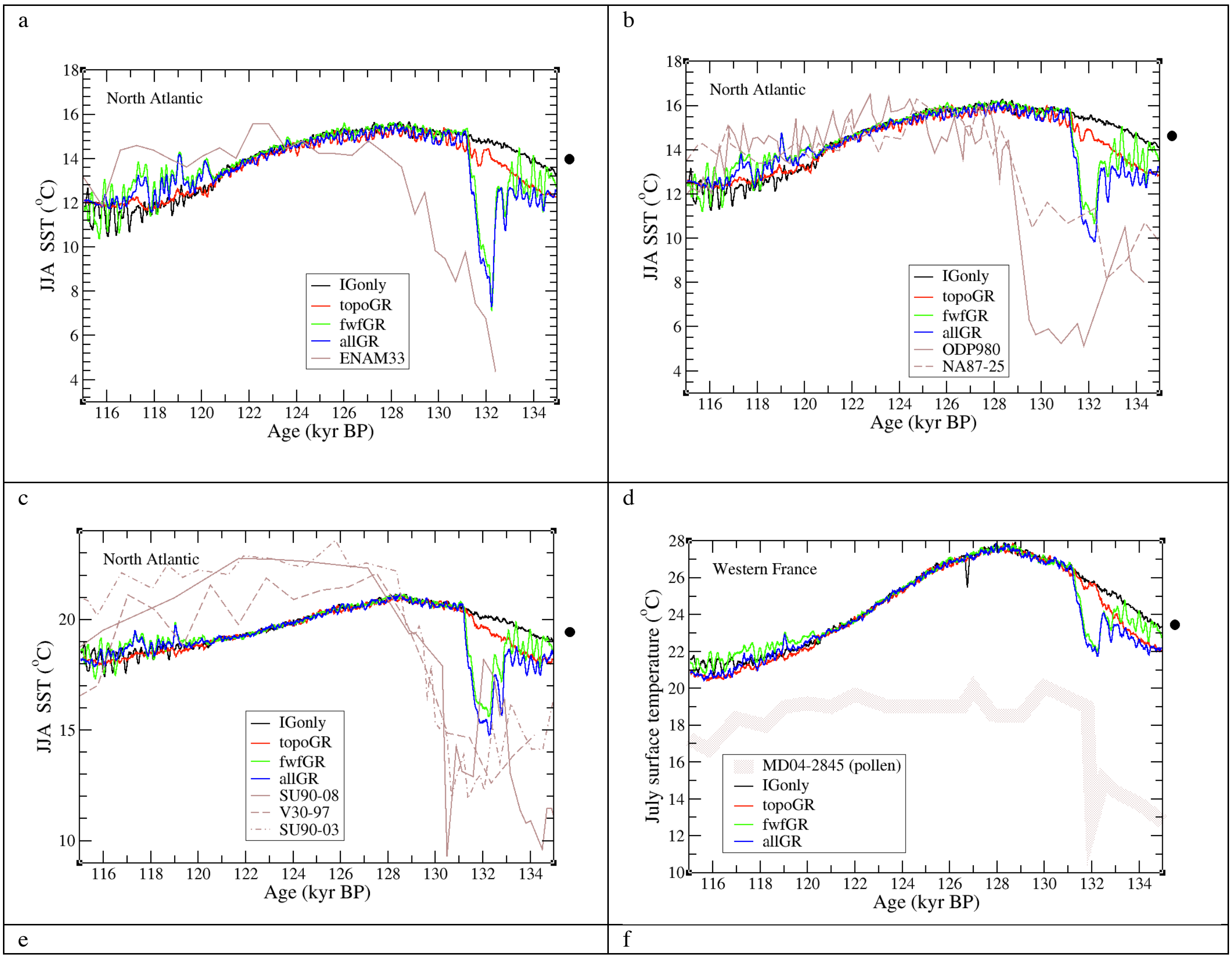
- Change the yellow lines to a different colour, as they are difficult to read- Fig 5c: is this JJA (as said in title y-axis) or annual mean (as said in figure caption).

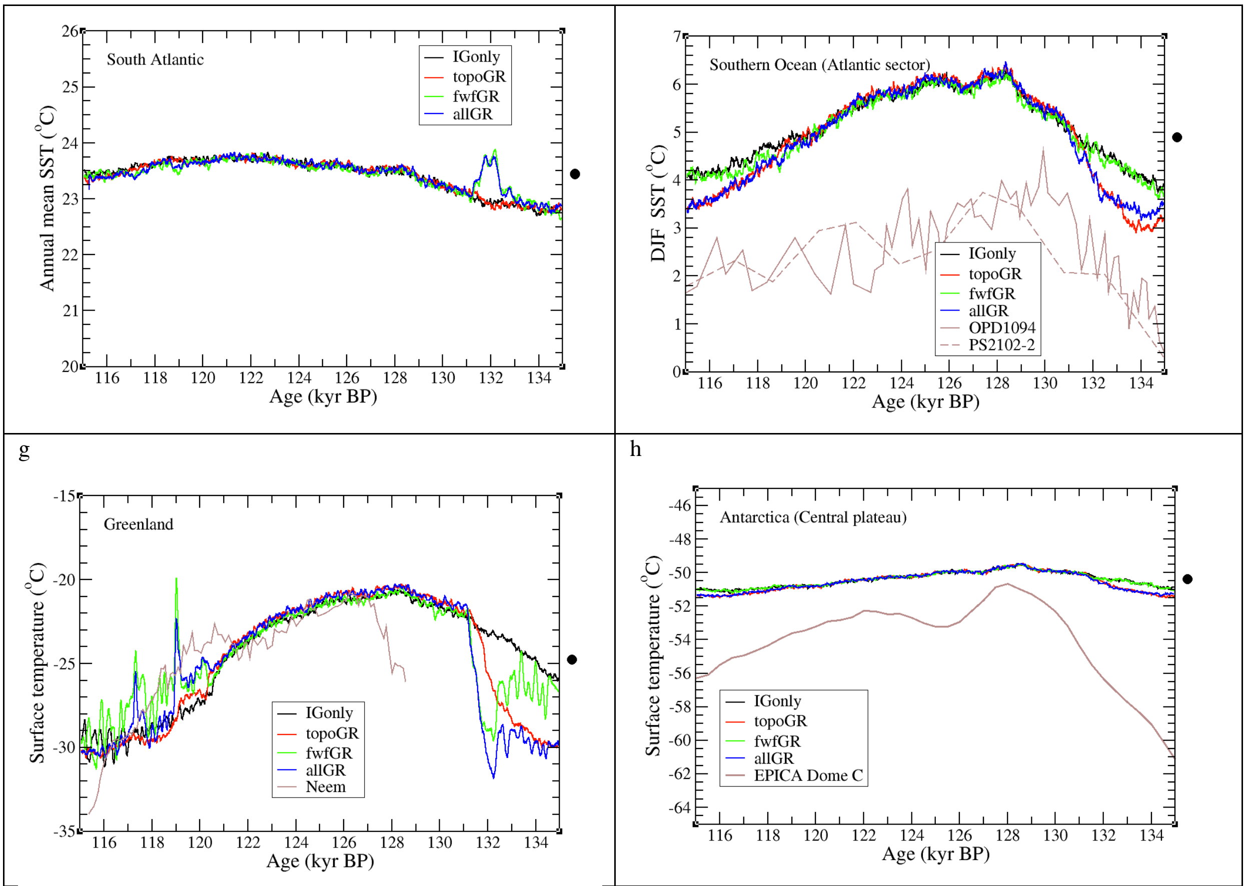
It is indeed summer SST. Thank you for pointing out the mistake.

- Change first sentence of figure caption to "Comparison of reconstructed and simu- lated temperatures in different regions" This is done.

- Add a title to every subplot stating the location/region for clarity

Revised figures are proposed to take into account the referee's comments.





Comparison of reconstructed and simulated temperatures in different regions using different boundary conditions (see text and Table 1). (a) North Atlantic summer SST (°C) (ENAM33: 61.27°N, 11.16°W, Rasmussen et al., 2003b); (b) NE Atlantic summer SST (°C) (ODP980: 55.8°N, 14.11°W, Oppo et al., 2006 ; NA87-25 : 55.57°N, 14.75°W, Cortijo et al., 1994); (c) NE Atlantic summer SST (°C) (SU90-08: 43.35°N, 30.41°W, Cortijo, 1995; V30-97: 41°N, 32.93°W, Mix and Fairbanks, 1985; SU90-03: 40.51°N, 32.05°W, Chapman and Shackleton, 1998); (d) July surface temperature over western France (MD04-2845: 45°N, 5°W, Sánchez Goñi et al., 2012) ; (e) South Atlantic annual mean SST (21°S, 10°E) ; (f) South Atlantic summer SST (°C) (ODP1094: 53.18°S, 5.13°E, Hodell et al., 2003, Kleiven et al., 2003; PS2102-2: 53.07°S, 4.98°W, Zielinski et al., 1998) (g) precipitation-weighted temperature reconstruction corrected for elevation change at the NEEM site, Greenland (77.45°N, 51.06°W, NEEM community members, 2013), and (h) local surface temperature reconstruction at the EPICA Dome C site in Antarctica (75.1°S, 123.35°E, Masson-Delmotte et al., 2011). The study sites are located on the map (see figure below). The simulated series are smoothed using a moving average over 100 years and averaged over four adjacent grid cells. The black dot on the right hand side of the figures provides the corresponding simulated pre-industrial value. Note that a coherent temporal framework has been recently constructed for the ENAM33, ODP980, NA87-25, SU90-08, SU90-03, V30-97, NEEM and EDC records, and they are all displayed here on the recent AICC2012 chronology (Capron et al., 2014; Bazin et al. 2013).

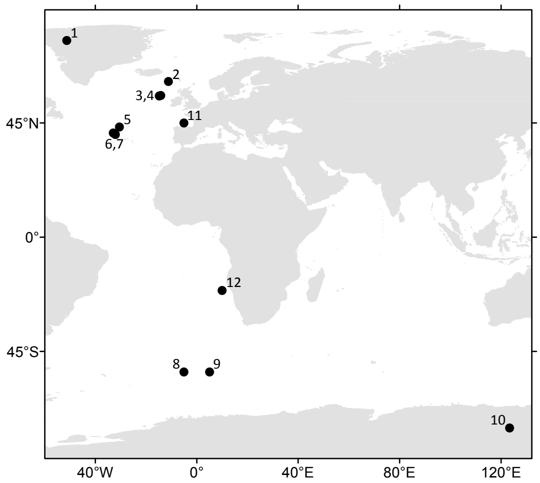


Figure : location of the study sites, including marine and ice core sites. (1) NEEM, (2) ENAM33, (3) ODP980, (4) NA87-25, (5) SU90-08, (6) V30-97, (7) SU90-03, (8) PS2102-2, (9) OPD1094, (10) EDC, (11) MD04-2845. Site (12) corresponds to an unpublished marine core for which only the simulated temperature is available. Details about the cores and related proxy data are provided in the text as well as in Capron et al. (2014).

Section 3.2: - Until page 249.12 this is not a comparison, but rather a description of the proxy data, and should have its own section. Preferable located already before the start of Section 3.

- include a comparison of the simulated and reconstructed SSTs of Fig. 5a-c. Langebroek and Nisancioglu (2013) also show too small amplitudes in the simulated North Atlantic SSTs compared to the reconstructions.

Section 3.2 has been reorganised and is now subdivided into two sections. The first one presents the data and the second one discusses the comparison between model and data. The purpose of the paper is not put on the data. Therefore, we preferred to keep their short description closely related to the comparison with the model.

The temperature increase over Greenland (NEEM site; fig 5g) during the early LIG takes place earlier (~5 kyr) in the simulation than in the reconstructions and the maximum of annual mean surface temperature is reached earlier (~2 kyr) in the simulation than in the data. However, the slow cooling after the peak of the LIG is in good agreement between both the simulation and reconstructions from 126 kyr BP until about 119 kyr BP. Although the maximum of summer temperature is slightly delayed compared to the annual mean value, the general behaviour of the evolution of the simulated summer surface temperature at NEEM is not much different from the annual evolution and cannot explain the difference with the reconstructed values. In Antarctica, the model indicates a warming in annual mean of less than 2°C for the Vostok and Dome C sites from 135 kyr BP to the peak of the LIG, while the data suggest up to 10°C at Dome C and 7°C at Vostok. The maximum of annual surface temperature simulated at Dome C site at ~128 kyr BP (fig5h), virtually simultaneous to the reconstructed one, is followed by an almost monotonous decrease, but the simulated cooling is much smaller

than the reconstructed one. In other words, the magnitude of the changes in temperature in Antarctica is much smaller in the simulation than in the reconstructions. Moreover, the reconstructed temperatures are lower than the simulated ones.
The pollen data from MD04-2845 indicates a summer warming of up to 7°C in western France from 135 kyr BP to the peak of the LIG, but it is less than 5°C in the model (fig5d). The short and abrupt cooling event at ~132 kyr BP documented in the pollen data is also simulated. However, the simulated climate optimum occurs later in the model than in the data. Moreover, the western France is warmer in the simulation than in the reconstruction during the warmest period of the LIG.
The magnitude of summer SST change during the LIG is smaller in the model than in the proxy data reconstructions for several regions around the globe (fig5abc; Capron et al., 2014; Lunt et al., 2013). This is particularly the case in the North Atlantic Ocean where the difference between model and reconstructions can reach several degrees. This is consistent with Langebroek and Nisancioglu (2013) who also show too small amplitudes in the simulated North Atlantic SSTs compared to the reconstructions. Many sites in the North Atlantic experience with a cooling event of a few degree magnitude in the model during the termination. This feature is also identified in the reconstructions. The climate optimum in the North Atlantic is simulated earlier than the reconstructed one. The summer SST difference between model and reconstructions is smaller for many regions in the Southern Hemisphere than in the North Atlantic Ocean (not shown).

- change the word "profiles" to "time series" This is done.

- It is tricky to compare model results to the temperatures reconstructed from NEEM during the early LIG, due to the large uncertainties in the bottom of this ice core. Mention and discuss. This is added in section 7.3 :" **The ice below 2206.7m from the NEEM ice core, corresponding to 108 kyr BP, is disturbed and folded (NEEM community members, 2013). Relevant information is extracted from comparison between NEEM and other ice cores for several variables. This process may lead to significant uncertainties.** "

249.25-28: rewrite: comparing simulated to simulated temperatures? This is done.

250.9-12: rewrite: are these values giving the timing of the insolation or temperature maxima? The sentence has been modified : "**The NH and SH mean July surface temperatures reach a maximum at ~128 kyr BP, simultaneously with the maximum of NH/SH June insolation.**"

250.13: are you sure MWT means Maximum Warmth Temperature? Not the T for timing? It is corrected.

250.23-25: Don't the tropical oceans show a much later (more than 2-3 kyrs) peak temperature? It is corrected.

Fig 6: - Maybe order the subplots according to mentioning in text (e.g. first c, then b&a) This is done.

251.6-7:Why is the Southern Ocean January MWT different? Maybe see Langebroek and Nisancioglu (2013) as they find the same. A reference to Langebroek and Nisancioglu (2013) has been added here : "**Langebroek and Nisancioglu (2013) suggested that the early**

occurrence of the MWT in the Southern Ocean is due to the integrating and damping effect of the ocean."

252.19: repeat that fwfGR does include freshwater forcing resulting from changes in ice volume This is done.

253.4: change "climate" to "AMOC" 255.8: change to "lack of input of freshwater . . ." 255.12: skip "taking into account" 255.14-15: change "reduced the difference. . . and" to "improves the fit to the" This is done.

Section 4.4: Is this section really necessary for the manuscript? If kept, please explain better what it means if the synergism is positive or negative.

The separation factor method is a very convenient method for quantifying the role of two factors as well as their joint effect, which is reflected in either the enhancement or the reduction of their cumulated impact. Therefore, we decided to keep the section. An explanation about the synergism is added: "**The synergism between two factors corresponds to their joint effect that is reflected in either the enhancement or the reduction of their cumulated impact.**"

*256.26: explain what allLR entails. allLR is similar to allGR except for the NH reconstructions (extent, albedo, freshwater). This is now explained in more detail : "***The impact on the simulated climate of a later NH ice sheet melting and glacial inception is analysed here through the use of two NH ice sheet reconstructions for the LIG simulation (allGR and allLR, respectively). Simulations allGR and allLR differ only from the NH ice sheet configuration and freshwater flux.**"

257.11: change "significant" to "large"257.12: change "virtually perfect" to "good"257.16: change "agued" to "argued" This is done.

Section 5 misses a final statement/conclusion

The section has been rewritten in order to highlight the final statement. It now reads: "**Compared to the GR scenario, the LR scenario induces a delayed warming, mostly over Europe and the North Atlantic, at the beginning of the simulation. This delay induces large differences in surface temperature between the simulations using either GR or LR scenario. The difference reaches almost 10°C over Greenland, 5°C locally over the North Atlantic and almost 4°C over western France. The comparison with proxy data shows that the LR scenario for the evolution of the ice sheets leads to a better agreement between modelled and reconstructed climates than the GR scenario.**"

258.7: skip "[135-115 kyr BP]" This is done.

258,14-19: rewrite: are you talking about changes in the difference? This section has been modified to compare allGR and parGR only. The comparison between parLR and parGR has been removed for clarity.

Section 7.1 first 2 sections: you are discussing IGonly and topoGR (both without freshwater forcing), but then continue discussing freshwater forcing. Not making sense to me.

The abrupt change discussed in this section occurs without any additional freshwater forcing. Studies with other models suggest that such behaviour can be obtained with a small additional freshwater forcing in the Hudson Bay or because of an internal variability related to salinity change in the Hudson Bay. However, this is not the case in this study. Only FAMOUS and CLIMBER-2 are kept as examples because they do not assume any additional freshwater flux. Moreover, we insist in the manuscript that no additional freshwater flux is involved in this section.

Friedrich et al. (2009), using LOVECLIM, suggested that such rapid changes may be due to a flush of freshwater from the Hudson Bay to the Labrador Sea due to change in wind. Therefore, they are not related to any additional freshwater flux but rather to internal variability.

259.27: skip ", compared to a . . ."260.7: change "strong caution" into "care"261.7: change "divergences" to "differences"261.19: "these changes" – which changes? Pleas rewrite 261.24: skip "Before 130 kyr BP"261.25: change "speed" to "rate"262.10-12: change to "timing and magnitude"262.14: In contrast

Fig 10: Add a title to every subplot stating the location/region The figures have been redrawn.

Summary and conclusions: Very vague, please rewrite. Including the effect of the different forcings on the timing and magnitude of the resulting LIG temperatures (and not only the uncertainties) would largely improve the summary.

This section has been amended:

"**The magnitude of summer SST change during the LIG is smaller in the model than in the proxy data reconstructions for several regions around the globe (Capron et al., 2014; Lunt et al., 2013). This is particularly the case in the North Atlantic Ocean where the difference between model and reconstructions can reach several degrees although taking into account the evolution of the NH ice sheets reduces the discrepancy. The July MWT occurs almost all over the globe at 128 kyr BP and the January MWT is characterised by a late occurrence everywhere, except in the Southern Ocean. This is in disagreement with the data showing a late warming in the NH compared to the SH. Orbital and GHG forcings are responsible for most of the climate changes between 131 kyr BP and 121kyr BP. Moreover, the evolution of the ice sheets prior 131 kyr BP has a negligible impact on the simulated climate between 131 kyr BP and 121kyr BP. In other words, there is no strong climate memory at that time.**

The evolution of the NH ice sheets greatly increases the amplitude of the climate changes before 131 kyr BP. The additional freshwater flux (FWF) from the melting NH ice sheets is responsible for the major contribution, while the changes in the configuration (extent and albedo) of the NH ice sheets only slightly impact the simulated climate. The evolution of the ice sheet is critical in the timing of the warming at the beginning of the LIG, mostly over Europe and the North Atlantic. The uncertainty on the MWT can reach several thousand years depending on the scenario of evolution of the ice sheets. Therefore, the scenario of the NH ice sheet evolution, in particular its timing, is essential for an accurate simulation of the surface temperature, in particular in the North Atlantic region. Further modifications of the climate response can be expected when models of the Greenland and Antarctic ice sheets are interactively coupled within LOVECLIM as

has been done for future projections (e.g. Huybrechts et al. 2011, Goelzer et al. 2012a) and is in preparation for the LIG period in a forthcoming publication."

262.23-25: skip "It is quantified . . . parameter set)." This is done.

263.13-14: which event? An event like the one discussed in section 7.1. This is now specified.

References: The reference to Capron et al. (2014) is quite essential to this manuscript. It would be nice (and maybe necessary?) to have this at least submitted to a journal.