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Climate of the Past Discussions

Interactive comment on "The last interglacial (Eemian) climate simulated by LOVECLIM and CCSM3" *by* I. Nikolova et al.

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We thank the reviewer#3 for the interesting questions and valuable comments to improve the manuscript. Our point-by-point reply is given hereunder. Please refer to the attached supplement for updated manuscript, references, tables and figures.

Main concern:

Many aspects of the 127ka BP LOVECLIM and CCSM3 simulations have been published by Yin and Berger (2010), Herold et al. (2012) and Lunt et al. (2012). In my opinion Nikolova et al. should focus on those aspects of their study that are new and complementary to previous work: simulated changes in sea-ice covered areas, monsoon regions, vegetation changes and ENSO variability. Moreover, in this way the main

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differences between the two simulations can be detailed which was not possible in the study performed by Lunt et al. (2012) because the large number of simulations in their model inter-comparison. The main concern is thus that the manuscript lacks focus and the authors should pick speciïňĄc aspects of the last interglacial climate to investigate.

[Authors]: In our manuscript, we focus on the simulated surface climates at 127 ka (include surface temperature, precipitation, vegetation and ENSO variability) which could be easily reconstructed from proxy records. Yin and Berger (2010) and Herold et al (2012) focused on the intercomparison between the DIFFERENT INTERGLACIALS with LOVECLIM and CCSM3, respectively. It is therefore necessary to presents in our manuscript a detailed evaluation of two climate model simulations for the Eemian climates as compared to Pre-Industrial. The analysis of Lunt et al. (2012) was made for 2m temperature. We give detailed information on the surface temperature and to explain the differences/similarities between two specific models and to point out possible reasons of the simulated regional differences that are difficult to assess from the ensemble mean of 18 snapshot simulations in Lunt et al. (2012). We have included in section 1 the following: " Lunt et al. (same issue) analyzed 18 snapshot simulations between 125ka and 130ka BP performed by several climate models. They focus on the analysis of near surface temperature pointing out large regional deviations in the ensemble mean and between ensemble mean and proxy data. However, due to the large amount of models, it is difficult to address in details the possible reasons for the simulated regional dissimilarities between the models. Given the increasing interest of the paleoclimate community in the last interglacial climate, detailed information about the simulated climates is needed and the mechanisms responsible for the changes of different climatic variables deserve to be investigated. In this paper, we present a detailed regional and seasonal analysis for the surface climates of MIS-5e relative to the Pre-Industrial (PI) period. We investigate the feedbacks of sea ice, monsoon, vegetation and ENSO in the modeled climate system as plausible explanations for the regional similarities/dissimilarities simulated in both models, making it the first detailed intercomparison between CCSM3 and LOVECLIM models with emphasis on MIS-5e."

Minor comments: (page.line)

1) Title: The title is very general. Maybe the authors could, in line with the focus of the manuscript, make the title more speciïňĄc.

[Authors]: As said above, the focus of our manuscript is on the simulated surface climates which include surface temperature, precipitation, vegetation and ENSO variability. Although these different aspects are not mentioned in the title, they are clearly given in the abstract.

5295.25 Be more precise about the main problems related to last interglacial proxy reconstructions.

[Authors]: We have included in section1 the following: "This is related to the fact that creating a database based on individual records is complicated (Groll et al., 2005) due to the large uncertainties related to difficulties in estimating the duration of MIS-5e (Shackleton et al. 2003)."

5296.1 What about the Holocene thermal maximum?

[Authors]: The sentence has been changed to "The last interglacial (also called the Eemian interglacial and Marine Isotope Stage (MIS) 5e) was a recent warm interglacial during which the Arctic experienced markedly summer warming, accompanied by sea-level rise and reduction in ice sheets (Otto-Bliesner et al., 2006a; Kukla et al., 2002; Bintanja et al., 2005; Jouzel et al., 2007; McKay et al., 2011)."

5296.7 Make it more clear what this manuscript adds to the work of Lunt et al. (2012). Maybe refer to questions which could not be answered in their work but which is feasible in this manuscript because the smaller number of models. 5296.11 Start by describing the mechanisms and feature you would be able to investigate not with the fact that you can present more variables.

[Authors]: We have rewritten the paragraph and stressed the contributions of our study as follows: "The MIS-5e simulations provided by these studies and also included in Lunt

CPD
8, C3172–C3185, 2013

et al (same issue), are analyzed here. Lunt et al. (same issue) analyzed 18 snapshot simulations between 125ka and 130ka BP performed by several climate models. They focus on the analysis of near surface temperature pointing out large regional deviations in the ensemble mean and between ensemble mean and proxy data. However, due to the large amount of models, it is difficult to address in details the possible reasons for the simulated regional dissimilarities between the models. Given the increasing interest of the paleoclimate community in the last interglacial climate, detailed information about the simulated climates is needed and the mechanisms responsible for the changes of different climatic variables deserve to be investigated. In this paper, we present a detailed regional and seasonal analysis for the surface climates of MIS-5e relative to the Pre-Industrial (PI) period. We investigate the feedbacks of sea ice, monsoon, vegetation and ENSO in the modeled climate system as plausible explanations for the regional similarities/dissimilarities simulated in both models, making it the first detailed intercomparison between CCSM3 and LOVECLIM models with emphasis on MIS-5e. We also give some quantitative comparison with proxy data reported in literature, in order to determine where features are robust and where uncertainties are large."

5296.13 Why LOVECLIM and CCSM3? Is there a speciïňĄc reason?

[Authors]: Our model choice is mainly driven by availability. With the same climate forcings in both models, LOVECLIM and CCSM3 have been used in our group to simulate the interglacials of the past 800ka (Yin and Berger, 2010; Herold et al 2012). These studies focused on the intercomparison between different interglacials, and provide simulations for studying the last interglacial as an additional effort to PMIP3. Besides, these two models have different complexity and have been used in many climate studies, so it would be interesting to see the differences and similarities in their response to the same forcings.

5296 Please formulate a speciïňĄc research question.

[Authors]: See our answer to 5296.7

CPD

8, C3172–C3185, 2013

5297.17 Is this version of CCSM3 or the boundary conditions different from the one used by Otto-Bliesner et al. (2006)? See also the lines 5300.2

[Authors]: CCSM version 2 was used in Otto-Bliesner et al. (2006). Moreover, the insolation of 130 ka BP was used in Otto-Bliesner et al. (2006) but the one of 127 ka BP was used in our study.

5297.25 It is mentioned that the CLM model includes plant types but on line 3 of page 5298 that in the CCSM3 model framework there is no dynamically coupled vegetation module. Please clarify this apparent contradiction in the manuscript.

[Authors]: The plants are fixed (prescribed to present day) and not changing with the climate. The vegetation in MIS-5e was estimated separately with the offline model BIOME4. We have clarified this in section 2.1.

5298.12 Make clear that the experiments are equilibrium simulations.

[Authors]: We have changed the section title to “Boundary conditions for the equilibrium experiments”

5299.1 Use a header to make clear that the results / results and discussion section starts

[Authors]: We have changed the section title to “Simulated surface temperature anomalies”.

5299-5311 The structure of the results section could be improved. Maybe base the subsections on speciïňAc regions (e.g. sea-ice covered areas, monsoon regions and ENSO regions) instead of the basic climate variables.

[Authors]: Subsections on specific regions would make a big spatial gap in the analysis. For example a section on sea-ice covered areas will focus only on sea, excluding continents. Similarly, a monsoon section will focus on areas between equator and +-30, 40deg , but not between 30 and 60deg. Therefore, we would prefer to keep the

CPD
8, C3172–C3185, 2013

sections based on the variables.

5299-5311 Make more clear in the different result sections what the ïňĄndings from this study are, in which of the models this has been found (or both models), what has been found in earlier model-studies and what has been found in proxy-based reconstructions.

[Authors]: We have discussed more on the findings in the revision.

5299.2 What kind of temperature? Surface? 2-meter? And are these numbers global annual means? Please specify.

[Authors]: It is global annual mean surface temperature. We have specified that.

5299.4 By introducing proxy-data in this section it will be very hard to distinguish between results and discussion.

[Authors]: We have tried to make it clearer when speaking our results by for example adding "simulated". For instance: "The simulated warming for 75.10°N and 42.32°W in CCSM3 is 3.8°C and in LOVECLIM is 6.3°C in line with the warming of about 5°C found in ice-core record (Andersen et al., 2004).

5299.7 Please specify what you expect that ice-sheets would change.

[Authors]: Melting of ice sheets would induce additional warming. We included a short discussion on this topic in the beginning of section 3 as follows: "Holden et al. (2010) investigated the effect of warming in Antarctica when accounting for dynamic ice sheets. They found that the surface temperature in East Antarctica increased from 1.4 (Dome C) and 2.2°C (Dome F) to 5 (Dome C) and 4.9°C (Dome F) caused by the retreat and meltwater of the West Antarctic Ice Sheet (WAIS). In NH, according to Otto-Bliesner et al (2006a), when Greenland ice sheet is completely removed, there is an additional summer warming of several to more than 10°C localized over Greenland, and the freshwater forcing of inserting 0.1 sverdrup of water in the North Atlantic over 100 years yields to an annual cooling of 1.5°C south of Greenland. In spite of this fresh water induced cooling, the summer temperature anomalies over Greenland remain positive. Lunt et al (2004) also found that the effect of melted Greenland is local for temperature (directly related to changes in altitude and albedo of the surface), precipitation and more widespread for circulation (response to changed orography) but the "principal effect of removing the Greenland ice-sheet is relatively localised". They show that December-January-February (DJF) surface temperature decreases over Barents Sea (2°C for 2m height temperature) as a result of changes in the near-surface meridional wind speed. In the case of melted Greenland, cold air from the pole is advected to the south. This cooling along with the freshening of the North Atlantic increases the sea-ice formation and retains sea ice in June-July-August (JJA) as mentioned by Lunt et al (2004). However, all these sensitivity studies are for a complete melting of Greenland ice sheet, therefore the effects of the MIS-5e Greenland melting would be much smaller and would be important mainly for the regions over and around Greenland. Nevertheless, the shortcoming of prescribing ice sheet to present should be kept in mind when model-proxy comparison is made."

5301.4 At several places in the manuscript the authors discuss model biases described in previous work. Please clarify how a model bias in the simulated pre-industrial climate affects the presented last interglacial anomalies relative to pre-industrial.

[Authors]: The biases in the modeled variables give an indication of how realistic the obtained model results are in comparison with present day observations, i.e it is indicative of the error we introduce in the system. For example if Arctic is too warm, this would mean that there is less sea ice/snow and less feedback or less model sensitivity in high latitudes regions. This kind of weaknesses identification is helping to quantify the reliability of simulations for the past or the future.

5302.13 Explain why these differences are found.

[Authors]: The possible reasons are now presented first, followed by a comparison with the proxy data of Bauch et al. ,1999. "Discrepancy on the sign of the anomalies be-

CPD
8, C3172–C3185, 2013

tween the two models happens in the area of Svalbard archipelago from 74° to 81°N and from 10° to 35°E. CCSM3 simulates a large cooling of -4.5°C while LOVECLIM simulates a warming of 6.4°C, mirrored also in the sea-ice concentration in Figure 5. CCSM3 shows a sea-ice expansion with its maximum positive anomaly (more than 20%) during DJF. Herold et al. (2012) first point the appearance of such intensified sea-ice expansion after a 800 years run. Possible reason for this sea-ice expansion could be related to the freshening and cooling of the North Atlantic Current. This would induce two effects: a sea-ice increase at around 45°N and 60°W and a transport of fresh and cold waters to the Greenland and Norwegian seas resulting in an increased sea-ice formation. The decrease in salinity in CCSM3 and LOVECLIM as a result of sea-ice melting during boreal summer indicates a freshening that is consistent with the weakening of the Atlantic Meridional Overturning Circulation (AMOC) simulated in both models during MIS-5e relative to PI. For example, in LOVECLIM, the much higher NH summer insolation during MIS-5e reduces significantly the NH sea-ice concentration and increases the temperature of the source region of North Atlantic deep water all year round, leading to a weaker North Atlantic deep water formation during MIS-5e than PI (Yin, 2013). Oppo et al. (2001) discuss that changes in latitudinal temperature gradients may induce changes in large-scale wind fields with “far-reaching influences”. Such influences include, for example, changes in the strength and/or position of the Atlantic Meridional Overturning Circulation (Hodell et al., 2009), changes in temperature and salinity in areas of deep water formation, etc. Bauch et al. (1999) investigated the sea-surface temperature in the area of Iceland, Norwegian and Greenland Seas based on proxy records of planktonic foraminiferal assemblages, CaCO3 content, oxygen isotopes of foraminifera and iceberg-rafted debris. . ..”

5305 When presenting the simulated changes in the monsoon systems, the ïňĄndings should be compared with earlier work by for instance Bosman et al. (2012).

[Authors]: During MIS-5e, there was more summer insolation on the Northern Hemisphere than today, which intensified the meridional temperature and pressure gradients. We also found a weakened African Easterly jet but strengthened Tropical Easterly Jet (TEJ) with north and westward extensions. Therefore, strong TEJ could be a dominating factor for stronger monsoon over Indian and African region. Similar results (for Mid-Holocene) are found in Bosman et al. (2012). We added the following discussion in section 4.1: "We found that TEJ was stronger and shifted northward from its mean position during MIS-5e, consistent with the strong rainfall over the convergence zone between the wind of the southern and northern hemispheres, known as the monsoon trough (Zeng and Guo, 1982). Similarly, Bosman et al. (2012) found a weakened African Easterly jet but strengthened TEJ with north and westward extensions. Therefore, strong TEJ could be a dominating factor for stronger monsoon over Indian and African region."

5303.15 Please make clear what has been found and presented in previous studies (and which therefore does not have to be detailed in this study!) and what is new in this work.

[Authors]: We have rephrased this paragraph.

5306.17 Please refer to the ïňĄgures in which these aspects of the changes in the monsoon can be seen.

[Authors]: Figure is not shown here.

5306.27 Discuss in some more detail what the IMI index is and what it adds to the results.

[Authors]: Indian Monsoon Index (Wang and Fan 1999) is calculated by the JJA 850 hPa zonal wind averaged over (5°N-15 °N and 40°E-80 °E) minus that averaged over (20°N-30 °N and 70°E-90°E). The Indian summer monsoon component plays dominating role in over all performance of Asian summer monsoon. When IMI is positive and strong then Indian summer monsoon precipitation as well as low level monsoon flow would be strong. IMI is highly and positively correlated with all India summer monsoon

CPD
8, C3172–C3185, 2013

Interactive Comment

Full Screen / Esc
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Interactive Discussion
Discussion Paper

rainfall. Positive IMI in MIS-5e is well representing the change in precipitation over Indian region. We have added details on IMI in section 4.1.

5311.4 Mention if the 'poor' representation of ENSO in the LOVECLIM model has been discussed before in the literature.

[Authors]: We cited the publication of Goosse et al. (2010).

5312.3 Conclusion: In line with earlier comments, focus on those aspect of this study which are new and complementary to previous work.

[Authors]: Section Conclusions is revised. We stress on the following findings: " ... Discrepancies between the two models mainly occur in the polar areas, closely related to the differences in sea-ice concentration where CCSM3 simulates more sea ice in MIS-5e and lower surface temperatures than LOVECLIM. In addition, the reduction in snow cover in LOVECLIM is much larger than in CCSM3, contributing to the larger Arctic warming in LOVECLIM. " ... "Trees and grassland flourish in Sahel/Sahara, trees being more abundant in LOVECLIM simulation than in BIOME4. Simulated mid-latitude trees are also more abundant in LOVECLIM. " ... " CCSM3 simulates larger tropical Pacific SST for MIS-5e than for PI. We suggest this is related to the change in the SST annual cycle next to smaller effects through increased east-west temperature gradient and less-steep thermocline. The SST variability in our LOVECLIM simulations is particularly small due to the overestimated thermocline's depth."

Technical comments: (page.line)

Please carefully check the spelling and word order in the whole manuscript. 5296.13 through 5296.25 Model descriptions 5298.22 simulations are 5299.11 (2010) 5305.2 Be consistent in the use of JJA or June-July-August

[Authors]: All mentioned above technical comments are taking into account.

Reference to Lunt et al. (2012) is missing.

CPD
8, C3172–C3185, 2013

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper

[Authors]: We added the reference to the list.

The references to Anderson et al. (2006) and to CAPE (2006) are the same articles

[Authors]: Thank you for pointing this out. CAPE (2006) is removed from the list.

Tables and ïňĄgures:

Be more precise and uniform in the captions and layout of the tables and ïňĄgures: Some ïňĄgures centred around 0E and other at 180E. Some include gridlines while others don't.

[Authors]: We centered the figures for surface temperature and precipitation at 0E.

Table 2: are the temperatures mean 'global' temperatures?

[Authors]: Yes. We added this in the caption.

Figure 1: What are the month's corresponding to the true longitudes of the sun?

[Authors]: 0° and 180° are for the spring and fall equinoxes; 90° and 270° are for the summer and winter solstices. We have explained this in the figure caption.

Figure 2: Is the contrast in Antarctic temperatures between CCSM3 and LOVECLIM discussed?

[Authors]: Yes, we did discuss the differences for the sea-ice concentration in both models.

Figure 3: Is this sea-ice 'coverage'? Why are there no LOVECLIM results in ïňĄgure 3?

[Authors]: We have included the sea-ice concentration anomaly for LOVECLIM, too. Both figures have the same color scale to make the comparison between seasons more clear.

Figure 5: What does the grey shading indicate and why not present in both panels?

[Authors]: The figure is updated and have the same color scale as Figure 3. Grey shading indicated zero anomaly but this is now replaced by white in Figure 3 and Figure 5.

Figure 7: Reverse colours, red=drier and blue=wetter.

[Authors]: This is considered in the new plots for precipitation anomalies.

Figure 9: The caption reads 'Tropical Easterly Jet anomaly' but the ïňĄgure depicts the whole globe. And what is the height of the wind vectors shown in this ïňĄgure?

[Authors]: The wind is at 200hPa. We have given this information in the caption of figure 9 and figure has been revised as follows: "Figure 9. Tropical Easterly Jet (m/s) anomaly at 200hPa (10°S-50°N and 0-160°E) in a) CCSM3 and b) LOVECLIM."

Figure 10: Are the values averages or values for a single latitude?

[Authors]: This is meridionally averaged (Equator to 40 degN) vertical velocity. Figure is updated and caption reads "Figure 10. Vertical velocity (Pa/s) anomaly at 400mb for region 0-40°N and 0-360°E, simulated in CCSM3.

Figures 12 and 13: Are the values longitudinal averages? Is there a way to compare these two ïňĄgures since they present vegetation changes in different ways? Figure 12c: is the difference around 20N discussed? Is this related to feedbacks in the Sahara?

[Authors]: What we did to make the comparison more clear is to select all type of forest in one plot (this include the following vegetation: Tropical evergreen forest, Tropical semi-deciduous forest, Tropical deciduous forest/woodland, Temperate deciduous forest, Temperate conifer forest, Warm mixed forest, Cool mixed forest, Cool conifer forest, Cold mixed forest, Evegreen taiga/montane forest, Deciduous taiga/montane forest, Tropical savanna, Temperate broadleaved savanna, Open conifer woodland, Temperate sclerophyll woodland). Then we did the same for all types of grassland including in this category moses, lichen and forbs (Tropical xerophytic shrubland, Temper-

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ate xerophytic shrubland, Tropical grassland, Temperate grassland, Boreal parkland, Steppe tundra, Shrub tundra, Dwarf shrub tundra, Prostrate shrub tundra, Cushion-forbs, Lichen and moss). Desert, Barren and Land ice are presented in one category. The sum of all three types gives 100%. Hence the comparison between the two models is more evident. We show the longitudinal averages. The large difference in vegetation type at 20degN comes from the availability of resources required to sustain a certain type of vegetation. The overestimation of precipitation in LOVECLIM at these latitudes is such a resource. This is discussed in the text as follows: "Over Africa (between the Equator and 30°N), the increase of tree fraction during MIS-5e as compared to PI is larger in LOVECLIM than in BIOME4 (Figure 13a, d). Grassland simulated in BIOME4 (Figure 13b) occupies about 80% of the land at 20°N while LOVECLIM simulates about 50%, the rest being mainly trees (Figure 13e). On one hand, this difference between the two models could be related to the fact that the vegetation-climate feedbacks are missing in CCSM3 due to the lack of a dynamic vegetation model. On the other hand, it could be related to the fact that LOVECLIM tends to overestimate the precipitation around 30°N and the temperature in the tropics (Goosse et al., 2010) and therefore to amplify the vegetation response. . . . The expansion of the vegetated area during MIS-5e in Sahel/Sahara in LOVECLIM, which results from the northward shift of the ITCZ and moisture advection, is in line with proxy records showing wetter, more green and vegetated Sahel/Sahara (Jolly et al., 1998)."

Figure 14: Specify latitude or region over which average is taken.

[Authors]: We have added this information in the caption of the figure as follows: "Figure 14. CCSM3 and LOVECLIM simulations averaged over 5°S-5°N between 150-275°E of a) SST (°C), b) wind stress (Pa) and c) depth of the thermocline (m). "

Please also note the supplement to this comment:
http://www.clim-past-discuss.net/8/C3172/2013/cpd-8-C3172-2013-supplement.pdf

CPD
8, C3172–C3185, 2013

Interactive Comment

Interactive comment on Clim. Past Discuss., 8, 5293, 2012.

CPD
8, C3172–C3185, 2013