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Climate of the Past Discussions

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Interactive Comment

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#1 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.

The abstract is focussed on the common results of the two models. But there are considerable differences in the results, which seem to be avoided. In contrast, they should be linked to the differences in the models themselves to improve understanding.

[Authors]: We added in the abstract information lines related to the major differences between the two models as follows: "...Discrepancies exist in the sea-ice formation zones between the two models. Cooling is simulated by CCSM3 in the Greenland-

Norwegian Seas and near the shelves of Antarctica during DJF but not in LOVECLIM as a result of excessive sea-ice formation." "...Trees and grassland expand north in Sahel/Sahara, more clearly seen in LOVECLIM than in CCSM3 results." "...The interannual SST variability of the tropical Pacific (El-Nino Southern Oscilation) of the last interglacial simulated by CCSM3 shows slightly larger variability and magnitude compared to the PI. However, the SST variability in our LOVECLIM simulations is particularly small due to the overestimated thermocline's depth."

It is good practice to test the statistical significance of the climate anomalies. This may alter some of the conclusions drawn by the authors (e.g, changes in southern ocean temperature consistent with reconstructions, unimportant precipitation changes in mid-latitudes).

[Authors]: We did a t-test for the significance level. We included the result as contour lines on figures 2 (JJA temperature anomaly), 4 (DJF temperature anomaly), 6 (Annual temperature anomaly), 7 (JJA precipitation anomaly) and 12 (DJF precipitation anomaly).

Sea ice and vegetation changes are extensively discussed in the article. What is the role of snow cover changes in the models? This effect is potentially as important as the other two, but not at all adressed in the article.

[Authors]: Sea ice was discussed a bit more in details in order to explain the observed surface temperature discrepancies in the sea-ice formation zones that seem to appear through the whole year. We added discussion in section 3.1 JJA surface temperature anomalies as follows: "Additionally, the reduction of snow cover (not shown) in Greenland and on the islands west of Greenland, is simulated to be up to 8m in LOVECLIM and up to 1m in CCSM3. The strong feedback from the reduction of snow cover over land, next to the external astronomical forcing, could partly explain why Greenland is on average warmer in LOVECLIM (5.3°C) than in CCSM3 (3.4°C)..." In Section 3.2 DJF surface temperature anomalies we discuss the snow cover as follows: "The Arc-

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tic, for 60°N to 90°N, remains warmer in LOVECLIM partly related to the snow cover change, too. In LOVECLIM the anomaly is -0.5m and in CCSM3 it is -0.01m. This is mainly attributed to the melting of snow over Greenland where the role of snow depth is important due to its effect on albedo. A signal from the vegetation feedback could also be related to the simulated warmth in LOVECLIM. LOVECLIM surface temperature in MIS-5e remains higher than in CCSM3 in the areas of expanded vegetation during MIS-5e. However, CCSM3 do not account for the MIS-5e vegetation, hence it will be difficult to assess its effect on surface temperature... "

SpeciïňĄc comments:

pp / ll 5294/21-22 [credit to both models and recostructions] The comparison to reconstructions is discussed in the text, but in a quite hand waving, inaccurate manner. There are no ïňĄgures or tables to support this conclusion, with numbers and error bars on timing, location, and variable.

[Authors]: The focus on the paper is on the qualitative comparison between the two simulations. However, we also give some quantitative comparison with proxy data reported in literature as suggested, in order to determine where features are robust and where uncertainties are large. We added an additional table (Table3) in the manuscript, that includes location, reconstructed temperature anomalies and simulated anomalies using CCSM3 and LOVECLIM for the respective coordinates.

5296/10-14 [127kyr] The authors mention the uncertainties in duration and variability of MIS-5. But you do not give a single reason why 127kyr BP was chosen. What are the particularities of this period?

[Authors]: We added in section 2.3: " It is worthy noting that several dates around the peak of the last interglacial have been used to select the insolation forcing in previous studies (see the summary in Lunt et al, same issue). According to the strategy of Yin and Berger (2010, 2012), insolation at 127 ka BP was used in our MIS-5e experiments of both LOVECLIM and CCSM3. This is because, following the hypothesis that an interglacial is associated with a strong summer insolation in Northern Hemisphere (NH), the insolation was taken at the dates when NH summer occurred at perihelion just preceding the interglacial peak taking into account a few thousands of years of lag between the forcing and climatic response.. . ...”

5296/14-16 [models] The model choice is obviously guided by availability. But a comment on why a comparison between these two models is particularly interesting or why you do it would be useful.

[Authors]: We have added in section 1: “...Yin and Berger (2010, 2012) have simulated the peak climates of the past nine interglacials with LOVECLIM, an Earth system model of intermediate complexity. Using the same boundary conditions, Herold et al. (2012) simulated the climate of five stronger interglacials with CCSM3, a comprehensive Atmosphere-Ocean General Circulation Model. These studies focused on the comparison between different interglacials. Because they used the same climate forcings, these studies provide ideal paired experiments for inter-model comparison, which would be interesting for the modeling community in particular given that LOVECLIM and CCSM3 are often used in climate/paleoclimate modeling and are of different complexity. . . . 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.”

5297 [section 2.1/2.2] The order of the sections on LOVECLIM and CCSM3 should be consistent with the order in the ïňĄgures.

[Authors]: We corrected this accordingly.

5297/15-16 [ice sheets] It is still common practice to prescribe present-day ice sheet topography. But what is the uncertainty introduced by this on the atmospheric circulation and the freshwater input to the North Atlantic? Aren’t these important for some of the results?

[Authors]: Prescribing ice sheets to present conditions is indeed a shortcoming of this study. Few results have been published on the impact of the ice sheets of the last interglacial on the climates, partly due to the uncertain ice-sheet reconstructions during this interglacial (eg. Otto-Bliesner et al, 2006a). Therefore, only a rough estimation could be made based on some sensitivity studies. We added in section 3 the following discussion about the potential role of dynamic ice sheets, as follows: ". In addition to the possible uncertainty in the estimation based on proxy records, one of the reasons might be due to the lack of interactive ice sheets in both models. 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. “

5297/5-5298/1 [resolution] The resolutions of the models, except for vertical resolution of the atmosphere, are not that different for representing two different types of models. Some readers may ïňĄnd that striking.

5298/3-4 [vegetation] I understand CCSM3 is using the same vegetation input as in a conïňĄguration for the PI. Did you ever test what is the effect of using the BIOME4 127k vegetation on temperature? Is the feedback not critical for the dramatic vegetation changes you ïňĄnd?

[Authors]: It is a good idea to test the effect of BIOME 127kyr BP vegetation in CCSM3. We have not done it unfortunately. It could be an interesting topic for future study on the impact of vegetation on the last interglacial climate. The following discussion has been included in our revised manuscript in section 3: “Along with the missing feedback from dynamic ice sheets, the feedback from vegetation could also affect the temperature through albedo change. As we discuss in Section 5, trees expanded deep into the northern high latitudes replacing grassland. The lack of interactive vegetation in CCSM3 could cause unrealistic surface temperature because of the missing response during the replacement. According to Brovkin (2002), climate exerts a major control on the spatial distribution of vegetation types while vegetation influences climate via changes in the physical properties of the land surface such as albedo, biogeophysical mechanisms, roughness and atmospheric gas composition. For example Crucifix and Loutre (2006) show that during boreal winters the albedo of snow in the presence of grass is about 0.8 (contributing to the cooling of the atmosphere). The presence of trees, however, reduces the albedo to 0.4 and consequently increases the temperature in the atmosphere. Denman et al. (2007) claim that “Shorter vegetation with more leaves has the most latent heat flux and the least sensible flux. Replacement of forests with shorter vegetation together with the normally assumed higher albedo could then cool the surface”. Vegetation induced cooling/warming through albedo change is also

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discussed in several other studies (Ganopolski et al., 1998; Claussen, 1998; Claussen et al., 2006; Kubatzki et al., 2000)."

5299/4-7 [underestimated warming] Why do static ice sheets lead to an underestimation of warming? Can you quantify the effect?

[Authors]: Please, see our answer above to the comment 5297/15-16 [ice sheets].

5299/13-15 [cold N/S] Can this explain the smaller warming? Are the temperature related feedback less important?

[Authors]: Polar regions in CCSM3 are much colder than present day temperature observations due to the bias in the model. In the case of Africa (west coast), CCSM3 underestimates the SST by 3.5°C (present day) (Collins et al, 2006, The Community Climate System Model Version 3 (CCSM3). J. Climate, 19, pp. 2122-2143). Temperature related feedback from the interaction atmopshere-ocean appears in the annual anomalies in the African and Indian monsoon bands and in the Nordic Seas. Actually, the cooling in the Greenland and Norwegian Seas during DJF is so strong (more than 5degC difference between MIS-5 and PI) that consistently appears in JJA and annual anomalies. In that respect the feedback is important. We added the potential role of the feedbacks in section 3.

5303/17-19 [AMOC] What is the effect on AMOC in your models?

[Authors]: In both models AMOC is weaker in MIS-5 than PI. As it would require another independent study for the oceanic processes during the last interglacial, we mentioned only briefly the AMOC behavior in our revised manuscript in section 3.2: "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

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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)..”

5304/3-6 [Atarctic] The authors mention the ice core based temperature anomaly estimates, but these need to be compared to a model estimate - visual interpretation from the ïňAgure is difïňAcult and not precise enough. Why don’t you mention, for example, the anomaly at the closest model grid point?

[Authors]: We have added the information in table 3 as suggested in the beginning of the review with reconstructed and simulated temperatures.

5306/14-17 [TEJ] What is the mean change (over the relevant region)? What is it in LOVECLIM?

[Authors]: Mean change (MIS-5e minus PI) over relevant region (5N-20N; 30W-150E) is 1.06 m/s in CCSM3 and -0.91 m/s in LOVECLIM. This has been mentioned in the revised version.

5306/28-29 [IMI] What is the mean change? Is it signiïňAcant?

[Authors]: IMI mean change (MIS-5e minus PI) for 100 years is 0.13 and it is statistically significant. These have been mentioned in the revised manuscript as follows: “The Indian Monsoon Index (IMI) is defined by the difference between the 850 hPa zonal wind averaged over the region of 5°N-15°N and 40°E-80°E and that averaged over the region of 20°N-30°N and 70°E-90°E (Wang and Fan, 1999). The simulated JJA IMI is definitely stronger, by 0.13 in the 100-year mean in CCSM3, during MIS-5e (Figure 10) than PI. This change is statistically significant and well represents the change in precipitation over the Indian region.”

5307/24-26 [data] I get the impression further data is as much needed in the NH as in the SH.

[Authors]: We mentioned SH because DJF precipitation (SH summer) is discussed in this section. However, we find that the last five lines of page 5307 are not necessary, so we have replaced them by “Therefore, both model simulations and proxy data show a weakened monsoon precipitation in the SH during MIS-5e compared to PI.”

5308/6-8 [Mid-Holocene] Why is this relevant for this study? Needs to be explained.

[Authors]: In fact, Braconnot et al. (2007) for the mid-Holocene was cited in order to explain the higher tropical tree fraction in LOVECLIM than CCSM3. We have reworded the relevant lines for clarity: “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). 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. This has also been reflected in the inter-model comparison for the mid-Holocene climate (Braconnot et al. 2007).”

5309/10-12 [Chinese vegetation] What is the vegetation type on the plateau in your models for MIS-5?

[Authors]: We took the area between latitudes 23.77 and 35.9degN and longitude 102.53 and 109.48degE. We discussed the vegetation on the plateau as follows: “Consistently, the simulation of BIOME4 shows temperate deciduous forest, temperate conifer forest and warm mixed forest in the south and central part of the loess plateau, and cool mixed forest, shrubland and grassland in the northwestern part. The simulation of LOVECLIM shows that trees are mainly developed in the south region (>50%) while grass occupies more space in the northwestern part.”

5311/19-26 [ENSO amplitude] Is ENSO indeed stronger? Needs to be more clear. What is the change in the amplitude (e.g., in the difference betwwen 10th and 90th percentile)?

[Authors]: The largest peak of the power spectrum in MIS-5 has shorter period compared to the one in PI and its magnitude is slightly larger (∼10 %).

5311/28-5312/2 [correlation to SST variability] This is very vague. Did you compute a correlation coefiňĄcient?

[Authors]: We did not compute a correlation coefficient. This section has been revised.

Figure 2,4,6 Are these differences statistically signiïňĄcant? When comparing to reconstructions, marking the relevant zones in the ïňĄgures would be very useful.

[Authors]: These differences and their significance have been shown on the figures as contour lines. We did a t-test significance test with 99% confidence level and updated the figures and the text. With regard to the model-proxy comparison, a table with the locations of reconstructions and the corresponding model results has been provided.

Figure 3 A plot for LOVECLIM should be added for completeness. The color scale should be common with Figure 5 and centered at 0.

[Authors]: We have prepared the sea-ice plot for LOVECLIM, too. The color scale is common between Figure 5 and Figure 3 and centered at 0 as suggested.

Figure 7 Are these differences statistically signiïňĄcant?

[Authors]: Similarly to Figures 2,4,6, we did a significance test with 99% confidence level and updated the figures and the text. The precipitation anomalies are significant.

Figure 8/9 Give LOVECLIM results as well. Any differences? In Fig.9, mention the model level in the caption.

[Authors]: We have included LOVECLIM result in Figure 8 and Figure 9. For Figure 9 the model level is 200 hPa. South westerly surface wind over India, cross equatorial flow over Indian ocean and anticyclonic circulation over western north Pacific ocean are stronger in CCSM3 than in LOVECLIM.

Figure 10 The caption needs to be more precise. Is this the MIS-5 anomaly or mean MIS-5? Bad quality plot. Wouldn't all the be contained in a line plot at 400 hPa?

[Authors]: This is MIS-5e anomaly (MIS-5e minus PI). We have revised the figure, showing the anomaly at 400 hPa. The figure's caption is updated as follows: "Figure 10. Vertical velocity (Pa/s) anomaly at 400mb for region 0-40°N and 0-360°E, simulated in CCSM3."

Figure 11 Several points are not in the plot window. I wonder how much information can be drawn from this plot. Wouldn't a histogram in comparison to PI be a better ïňĄgure to show?

[Authors]: We have prepared a histogram plot which indeed is a better way to represent the information.

Figure 12/13 Would it not be better to show both models in a same ïňĄgure with the same scale and on the models resolution, maybe with a second, more detailed plot for BIOME4? Where does the huge fraction of boreal forest in the southern hemisphere come from in BIOME4?

[Authors]: The vegetation in the Southern Hemisphere comes from the southern tip of South America. In the revised manuscript, 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, Temperate 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.

Minor comments:

5294/13-15 [El Nino] Needs to be rephrased. 5294/16 ... and on the Arabian Peninsula 5295/4 [IPCC] proper citation should be used. 5295/11-12 to general. 5295/17-19 unclear. 5296/1 [last time] The Arctic received considerable warming last summer. Needs to be more precise. 5300/16 [Exceptionally] doesn't work here. 5303/11 (up to -2 and -3 g/kg, respectively) 5304/20-22 Hard to uderstand what the authors mean exactly. Needs to be rephrased. 5308/3-4 [Similarities] Which similarities? 5310/3 The mean annual cycles (?) 5313/1-2 on the one hand

[Authors]: All minor comments are taken into account and the manuscript is revised accordingly.

Please also note the supplement to this comment:
http://www.clim-past-discuss.net/8/C3147/2013/cpd-8-C3147-2013-supplement.pdf

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