Interactive comment on "Climate and African precipitation changes in the mid-Holocene simulated using an Earth System Model MIROC-ESM" by R. Ohgaito et al.

Reply to M. Notaro (Referee #1)

The authors thank the detailed review of the manuscript with constructive suggestions and recommendations. We sincerely consider the reviewer's suggestions and reply all of them below. Our answers are written in blue and boldface.

Main suggestions:

The paper tries to cover too many topics, ranging from global climate to N Africa climate to carbon budget to ocean streamfunctions to salinity and so on. As a result, the text is too long and there is an excessive number of figures (30). The authors should decide what is their primary focus and remove all unnecessary text/figures.

Often changes between 6k and 0k are mentioned but no mechanisms for the changes are described.

The writing needs some improvement.

This is a first full paper using our newly developed Earth System Model, MIROC-ESM applied to 6 ka climate. In order to evaluate the model under a different climatic forcing from the present day, we aimed to overview broad and various aspects of the 6 ka climatic changes in comparison with the previous version of MIROC, MIROC3 and discuss which newly developed components attribute or not attribute to represent the climate changes. Although "African precipitation change" is appeared in the title because it has been one of the most interesting features in 6 ka climate change, the general "climate changes" is also supposed to be overviewed and discussed in the study. Studies on specific features on 6 ka will be discussed in upcoming papers. Therefore, not only the atmospheric changes but also the oceanic responses are overviewed in the text even if they look verbose. However, we agree that necessity of more analyses and insights for the briefly mentioned paragraphs. We'll improve the draft with being aware of conciseness and ask a final check of the writing for a native speaker.

MECHANISMS

At numerous points in the paper, changes in the climate system are reported/mentioned but no mechanisms are offered. Please explore deeper.

For example. . .

On page 3279, explain why the monsoons shift northward.

Although we have omitted most of the detailed explanations in Sect. 1 in order to shorten the text volume of the introduction, we will recover more explanations in the text following the reviewer's suggestion. We modified the sentence at line 14 of page 3279 as
"The seasonal cycle of temperature over land is enhanced in the northern hemisphere. The resulting increased land-sea temperature contrast enhances low-level convergence into the monsoon low over the continents. Therefore the position of the monsoonal precipitation is also affected."

On page 3279, explain the mechanisms for these vegetation feedbacks.

The refereed articles basically suggested the consistency with Charney (1975)'s hypothesis. Charney (1975) proposed the desert surface has higher albedo than the vegetated surface and it works to enhance sinking motion of the atmosphere. Thus the desert has positive feedback to maintain dry condition. This reference and the explanation are added in the text. Thus, the more vegetated land surface would work as the opposite feedback.

On page 3280, why does ocean coupling enhance the monsoons?

We guess the reviewer asked about the sentence at the line 24. The sentence is uncompleted and lacks the context. We jointed it to the previous sentence as
"… 6 ka insolation forcing and reported that the ocean coupling enhanced precipitation over Africa, India, and the Indian Ocean."

On page 3281, how does the ocean play a major role in monsoon change?

The sentence was insufficient. The ocean plays a major role in the Asian monsoon change compared to the vegetation in 6 ka. The sentence is modified.

On page 3282, how does vegetation amplify the monsoon?
See Notaro et al. (2011 J. Climate) for a study of vegetation feedbacks on the global monsoons.

Zeng et al. 1999 claimed that the Sahel rainfall variability is influenced by SST variations and the vegetation feedback is found to increase this variability for longer time scale like inter-decadal time scale. Notaro et al. 2011 investigated the vegetation feedback for the sub-annual climate by reducing the vegetation cover for the global monsoon regions and see how the climate reacts for that forcing. They concluded that the reduction of the vegetation cover influence the damping of

monsoon activities. These references and explanations are added in the text.

On page 3288, why are the monsoons stronger? Due to a warmer mid-high latitude continent? Are they responding to springtime warming of the land (pre-monsoon thermal gradient)?

Here we wrote suddenly "strong monsoon" before going into the analyses. The detail of the summer monsoon change is discussed in Sect. 5. Here we re-worded "strong monsoon" to "enhanced precipitation (Fig. 8)".

On page 3289, why does soil moisture decline over Eurasia/N America? (also, how many soil layers in the model?)

Decline of the soil moisture over Eurasia/N. America:
It requires not only further analyses but also re-coding for the specific outputs to clarify the reason, which is beyond the scope of this study. But the change of the seasonality of the water input into the soil must influence the soil moisture. Especially modulation of the timing and amount of melted snow runoff influences the soil moisture during the boreal spring for Eurasia/N. America. The colder spring in 6 ka delays the timing of snow melt and the following summer with stronger insolation works to melt snow more rapidly during shorter time than 0 ka, which can lead higher runoff into river system and eventually the decline of the soil moisture. The explanation is added in the text.

Soil layers:
The soil layers in MIROC3 is five and MIROC-ESM, six. Basically there are no big differences between the codes for the soil in the two models, but the deepest one layer was added to MIROC-ESM, which affects very little on the present day climate representation. The soil layer numbers are added to Table 1.

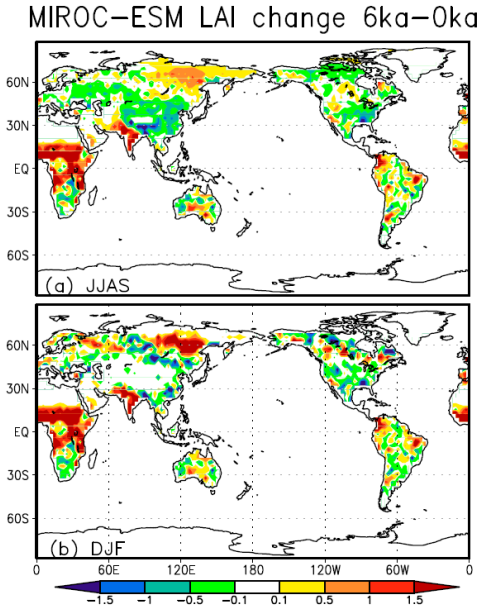
Why doesn't SST increase over the N Pacific/Atlantic in JJAS in Fig. 10, since insolation increases?

Because it is something unexpected, we have explained what had happened in the first paragraph in Sect. 4.2. The seasonal evolution of the SST change in 6 ka over the northern Atlantic Ocean suggest reasonable changes following the radiation change but there is an offset of about –0.5 °C for MIROC-ESM compared with MIROC3 (Fig. 11). As a result, the JJAS change becomes negative. The lower SST in 6 ka compared with the change obtained with MIROC3 is due to differences in the surface radiation budget (Fig. 11). The longwave radiation changes in 6 ka are about 3 W/m^2

less than those obtained with MIROC3 throughout the year. Additionally, the change in shortwave radiation suggests weaker enhancement during the boreal summer associated with the enhancement of low-level cloud cover over this area. These differences in the 6 ka and 0 ka surface radiation changes lead to lower SST during the winter and a hardly positive SST change during the following summer.

On page 3293, did global LAI increase at 6k versus 0k? I recommend plotting LAI to check.

We guess the reviewer meant page 3292 in Section 4.3. line 15. We plotted LAI changes but it was not shown in the manuscript. As the LAI change shown below, important change is not the global averaged LAI because the change of LAI is highly area dependent. Moreover, just looking at the change of the LAI is not enough to examine how it affects the climate because the relationship of the change of LAI to albedo change (which is not simple relationship but having loose but clear correlation) saturates when LAI exceed about 1. It means that there is no big impact for the area where LAI changed from 2 to 3 for example. We have tested the effect of LAI simulated in MIROC-ESM using a set of sensitivity experiments M3Alai in Sect. 5.3.4. The explanation of the LAI changes itself and the above explanations are added in the manuscript.



On page 3294, it doesn't look to me like the model even simulates the North American monsoon at that spatial resolution.

In Kim et al. 2011 (Journal of Climate), the global monsoon domain and the monsoon precipitation index (derived from the slightly different definition from the GMPI in the present study) for the GPCP and the different MIROC models were compared in Fig. 2, in which MIROC3med correspond to our MIROC3 model (not the identical experiment with our 0 ka but no big difference in the mean climate). As the reviewer has pointed out, North American monsoon is not faithfully reproduced in MIROC3. Yet it is better represented in MIROC-ESM (Fig. 16 (a)). We add this in the text.

On page 3298, why is ENSO's amplitude weaker at 6k?

Weaker amplitude of ENSO in 6 ka is known from the paleo-proxy records (Tudhope et al. 2001, McGregor and Gagan 2004, Gagan et al. 2004). Liu et al. 2000 proposed that the intensified Asian monsoon increases the Pacific trade wind through the Walker circulation and it intensifies the equatorial upwelling. The cooling of the equatorial SSTs in the growing season of the El Nino can damp growth of the El Nino. We also have checked what happened to our model outputs and the both of the models show consistent changes with Liu et al. 2000. This explanation is added in the draft.

On page 3300, how do vegetation feedbacks enhance the mid-high latitude warming?

O'ishi and Abe-Ouchi 2011 simulated increases in vegetation in high latitudes which leads reduced albedo during summer, indirect amplification through sea‐ice feedback in autumn and winter and snow albedo feedback in spring.
Although we have not included the oceanic feedback in the sensitivity experiment because they are conducted with the prescribed SSTs, the change in the snow amount and the albedo feedback are consistent with their results.
The explanation is added in the text.

On page 3301, what specifically was learned from comparing the 2 models? It seems the models only slightly differ in climate and their differences are small and can not be attributed in most cases.

What the reviewer has pointed out is one of the conclusions. The coupling of carbon cycle including vegetation and the other model developments has limited impacts on the 6 ka simulation. The text will be modified to clarify this point in Sect. 6.

On page 3301, where are the models going wrong in their inability to spread vegetation deeper into the Sahara at 6k?

Sentences are added at the line 10, page 3280 as

„They suggested the consistency with an early pionnerling study by Charney (1975), in which the desert surface with higher albedo than the vegetated surface enhance sinking motion from the overlying atmosphere. Although many attempts had been carried out to imvestigate precipitation-vegetation feedback over the Sahara desert, the vegetation coverage is almost limited to the desert border and none of the models simulated the state what the proxy records suggested, called „Green Sahara".“

WRITING
The writing needs further editing to improve the grammar and readability.
Some examples:
On page 3278, change "using paleoclimate simulations" to "through paleoclimate simulations".

changed

Also change "by paleoclimate simulations" to "through paleoclimate simulations".

changed

On page 3278, regarding “6 ka precipitation change”, make it clear that you are comparing 6 ka to modern.

done

On page 3279, reword “lake status data”.

Reworded to “lake level”

On page 3280, the discussion of Kutzbach’s paper is unclear.

The description of their study is introduced in further detail as followings
“Kutzbach et al. (1996a) compared the models with and without albedo feedback and suggested that the lowering albedo in the northern high latitudes associated with the expansion of vegetation facilitates the northward expansion of vegetation.”

On page 3281 and elsewhere, avoid saying “warm SST” or “cold SST” (or “warm temperature” etc. . .). It is more accurate to say “anomalously low/high SST”.

changed

On page 3282 and elsewhere, it is better to say “studies” rather than “works” (also change “work” to “study”).

Changed

On page 3282, change “strong monsoon” to “stronger monsoon”.

Changed

On page 3282, explain the global monsoon idea.

(*) Wang et al. (2011) proposed the idea of the global monsoon (GM) and defined the GM domain

as the regions where the local summer-minus-winter precipitation rate exceeds 2.0 mm/day and the local summer precipitation exceeds 55% of the annual total. Here the local summer denotes May through September for NH and November through March for SH. The concept of the GM has proven to be a useful tool in delineating the global monsoon system as a whole, investigating the trend and interannual variability of global water cycle, and examining a numerical model's fidelity (Kim et al., 2011; Wang et al., 2011). This explanation is added in the text.

On page 3283, when you state "differences in MIROC-ESM", do you mean differences between MIROC-ESM and MIROC3?

Yes. The expression is modified.

On page 3283 and elsewhere, add a comma at times when introducing a model name.
For example, use "transportation component, sSPRIANTARS". On page 3284, use "chemistry module, CHASER, is. . . ".

Done

On page 3283, why is the stratosphere coupled to the land surface?

80 vertical atmospheric layers are coupled to the land surface model. The atmosphere includes not only troposphere but also stratosphere. The sentence is modified.

On page 3284, why discuss Table 2 before Table 1?

Tables 1 and 2 are swapped.

Throughout the paper, try to make the text more concise. For example, on page 3284, change "performed sets of simulations in time-slice experiments" to "performed timesliced experiments".

Changed

Also, avoid describing a figure in the text, since that is the job of the figure captions. For example, on page 3285, you mentioned that the change in insolation is shown in Figure 1. The caption states that. In the text, just make your scientific point and then refer to the figure (e.g. at 6k, seasonality is enhanced in the

NH [Fig. 1]).

Although we see many papers describing figures in their texts, the reviewer's suggestion would be useful to sophisticate and shorten the text part. The figure explanation parts are modified.

On page 3285, change "In MIROC3 simulation" to "In the MIROC3 simulation".

changed

On page 3285, reword "prescribed SSTs, which are the climatologies. . . ".

Reworded as
"M3Amiroc3 is the experiment sets (0 ka and 6 ka) of the MIROC3 AGCM with prescribed SSTs. The SSTs are taken from the climatologies of the MIROC3 experiments for 0 ka and 6 ka."

On page 3286, exactly how long are the sensitivity runs? If 15-20 years, are they long enough given decadal variability?

There are various timescales of the variability affecting the tropospheric climate. If we consider the climate shorter than the order of 100 years, the variability with the longest timescale is the decadal variability coming from ocean. The sensitivity experiments we used here is the AGCM experiment with prescribed SSTs, which means that the oceanic variability is neglected. In this type of experiments, the variability coming from the atmosphere should be concerned which is something less than a year. Previous studies using an AGCM with prescribed SSTs are often performed like 10 years or so and the first 2 to 3 years are discarded (Vettretti and Peltier 1998 JC, Masson and Joussaume 1997 JC, Hall and Valdes 1997 JC). The length of the integration and the analyses for our sensitivity experiments are listed below.

M3Amiroc3 0 ka: the last 45 years are used from 50 years integration
6 ka: the last 20 years are used from 30 years integration
M3Aesm 0 ka: the last 18 years are used from 35 years integration
6 ka: the last 24 years are used from 39 years integration
M3Aesmofs: the last 25 years are used from 40 years integration
M3Alai 0 ka: the last 16 years are used from 25 years integration
6 ka: 16 years are used from 31 years integration

For being more confident of the analyses period, we extended the analyses years for M3Alai experiments to 21 and 24 years for 0 ka and 6 ka, respectively. The conclusions are not affected

with this change. The associated texts and the figures are modified.

On page 3287, either use scientific notation for all carbon #s or for none of them. The model #s use scientific notation and the observations do not.

Changed to use scientific notation

On page 3288, regarding "less warming over North America", is that less warming compared to what?

Less warming in MIROC-ESM compared to MIROC3. The sentence is modified.

On page 3288, regarding "slightly lower net temperature changes", these changes in temperature are lower than what?

Lower than 0 ka. The sentence is modified.

On page 3288, change "recoreds" to "records".

changed

On page 3288, regarding "changes in the meridional heat transport", is that 6k vs 0k?
Throughout the paper, the authors begin discussing changes in different variables without any introduction on why they are now focused on that variable. For example, on page 3288, meridional heat transport is suddenly discussed with no explanation on why they are considering it.

In Sect. 4, we are going to overview the global changes. We included the meridional heat transport change because the global and meridional changes are investigated in an early work using an AOGCM (Braconnot et al. 2000). However, it is true that the Sect. 4.1 is basically dedicated to atmospheric change and the meridional heat transport changes from atmosphere and ocean are not a relevant issue to this subsection. We deleted this paragraph and the figure. (***)

On page 3289, change "to Walker circulation" to "to the Walker circulation".

changed

On page 3289, change "divergences" and "convergences" to singular.

changed

On page 3289, make it clear that you are looking at “peak latitudes of precipitation” as an indicator of the ITCZ.

Cleared

On page 3290, reword “cooler change”.

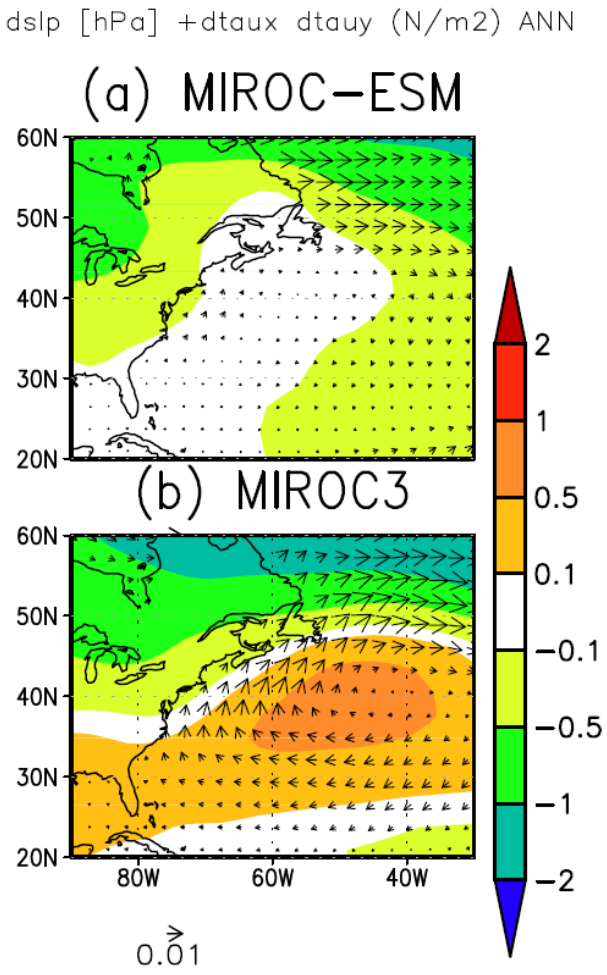
Reworded to “lower SST in 6 ka”

On page 3290, when you state “are generally slightly cooler”, do you mean the mean SST state is cooler, or there is a larger decline in SST?

The SST changes for DJF show large negative values in MIROC-ESM than MIROC3.
The following sentence explains better. We deleted this sentence and modified the next sentence as In DJF, the degree of cooling is higher for MIROC-ESM compared to MIROC3, especially over northern high latitudes.

Adding wind vector anomalies onto Figure 12 might help make the point of the wind driving the ocean anomalies.

When the wind vector anomalies were added onto Figure 12, it became too busy figure. So we explained it in the text. We attach a figure below plotting the net surface wind stress anomalies over ocean in vectors and the sea level pressure changes in color to show the difference between (a) MIROC-ESM and (b) MIROC3. The values of the surface wind stress anomalies are written in the text.



On page 3291, what is meant by "sea ice expansions and convection sites. . . in 0 ka"? Please reword.

We wanted to explain the sea ice extent and formation sites of the Atlantic Meridonal Overturning Circulation are reasonably reproduced in 0 ka. The sentence is changed.

On page 3292, what is the observed strength of the Atlantic meridional overturning?

Smethie and Fine 2001 estimated 17.2Sv and Talley et al. 2003, 18Sv with 3-5 Sv error. Because it is an issue on the 0 ka representation of the models for an oceanic variable, the explaining sentences are added in Sect. 3.2.

On page 3292, please reword "flip-flop".

The sentence is changed to

The grids having no dominant vegetation type (>50%) in the 0 ka and 6 ka MIROC-ESM simulations are white in Fig. 13.

On page 3293, which months are meant by "local summer"?

Now it is explained in (*).

On page 3293, some statements are unnecessarily vague/lack confidence. For example, the monsoon "seems a little earlier" (is it earlier?) and the difference in wind "may lead to more moisture convergence" (does it?). These things can be verified with the model output.

The vagueness is fixed.

On page 3298, change "El nino" to "El Niño" and change "nino3 indexes" to "Niño3 indices".

changed

On page 3299, can a statistical test be applied to statistically compare the strength of 2 correlations to show if they are really different?

t-test is applied to the correlations for 0 ka and 6 ka for the area of concern. The results always suggest that the two correlations between 0 ka and 6 ka are significantly different (30 % for the Sahara and tropics, 70 % for the Sahel). The text is modified following this test.

On page 3299, can you quantify how much of enhancement that the change in LAI causes?

We have performed a statistical test (t-test) for the difference between (a) and (b) of Fig. 29 but the result suggested that almost all difference between (a) and (b) is insignificant in 95 % confidence level. This is added in the text.

On page 3300, how specifically does N Australian precipitation change?

The area averaged (120 to 150 E, 10-20 S) enhancement (M3Alai-M3Amiroc3) of the precipitation change (6ka-0ka) in DJF is 1.7 mm/day. But we must say that the amount could be exaggerated from the prescribed LAI in the sensitivity experiments. The interactive coupling of LAI may work

to damp the precipitation change. Further analyses would lead another study but it is beyond the scope of this study. The explanation is added in the text.

In Table 1, why doesn't MIROC3 have any physics listed?

The table is modified as below

model name	MIROC-ESM	MIROC3
reference	Watanabe et al. 2011	K-1 Model developers 2004
model type	Earth System Model	AOGCM
contributed IPCC	planned for AR5	AR4 (as miroc-medres)
resolution :atmosphere	T42 L80	T42 L20
resolution :ocean	~1degree L44	~1degree L44
soil layers	6	5
top level of the atmosphere	0.003hPa	10hPa
radiation	updated version of MSTRN	MSTRN
vegetation	SEIB-DGVM, MATSIRO	MATSIRO
ocean carbon cycle	yes	no
aerosol	SPRINTARS	simplified SPRINTARS

In Tables 1-2, sometimes the first letters are capitalized and other times, they are not.

They are all uncapitalized.

In Table 3, "0 ka + 6000. . . " is confusing.

We eliminated table 3 because the experimental setup is described in the text and eventually we did not use the experiment names in table 3.

In Figure 7, correct the spelling of "positions" in the title.

The title is modified to be more precise as "peak latitude of prec.".

In Figure 10a, is sea ice playing a role off NE Asia?

Arctic sea ice doesn't go farther south in the boreal summer both 0ka and 6ka. One candidate of

the reason of the cooling in MIROC-ESM off NE Asia is the change in the position of Kuroshio-extension. But Fig. 12 suggests that both of MIROC-ESM and MIROC3 show similar and small changes in Kuroshio-extension. The more cooling in Kuroshio-extension area in MIROC-ESM comes from the same reason with the Atlantic, like what Fig. 11 shows, i.e., the change in the low level cloud and the resulting radiation change play a role on this cooling. This explanation is added in the text.

For figure 18, you are plotting "vertical motion", not "convective activity".
For all difference plots (e.g. Fig. 18), t-tests should be applied.

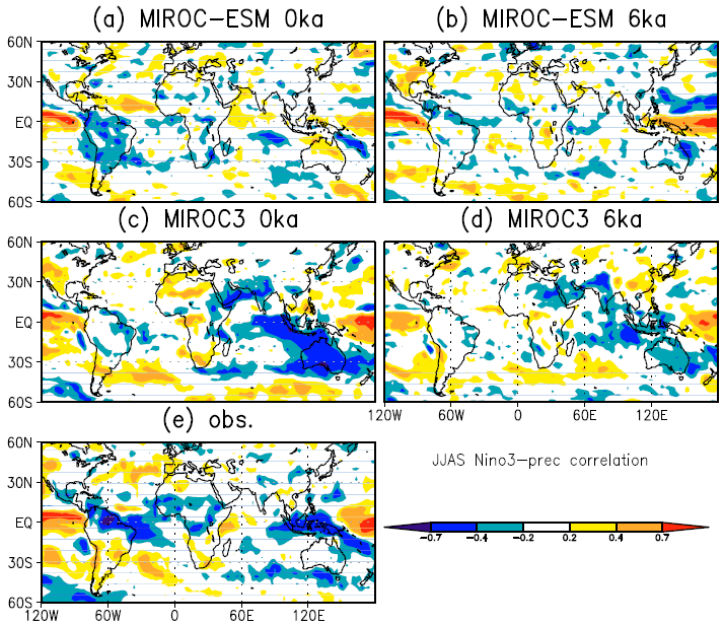
The figure caption is modified. T-test is applied and plotted in the figure. Then, the wind vector is eliminated because the figure became too busy. Besides, the vectors are already included in Figure 17.

For figure 19, you are showing a percentage, not a ratio as the caption implies.

The caption is changed to percentage.

For figure 26, I would remove the contours, which make it noisy, and perhaps start the color bar at +/- 0.1. Why not include an observed map? Why in MIROC3 at 6k is the local correlation between tropical E Pacific SST and precip in the same area not stronger?

Following the reviewer's suggestions, the figure is modified and improved (see below). The observed map is also added in (e). The analyses years are changed to the same year length with (e), 28 years, which is the period taken arbitrary from the analyses years. Compared to the observational data, it is obvious that the negative correlation over the African monsoon area is not well represented in the 0 ka simulations of the two models. Improvements of the control simulations may affect the simulated change under 6 ka forcing. We added this in the text.



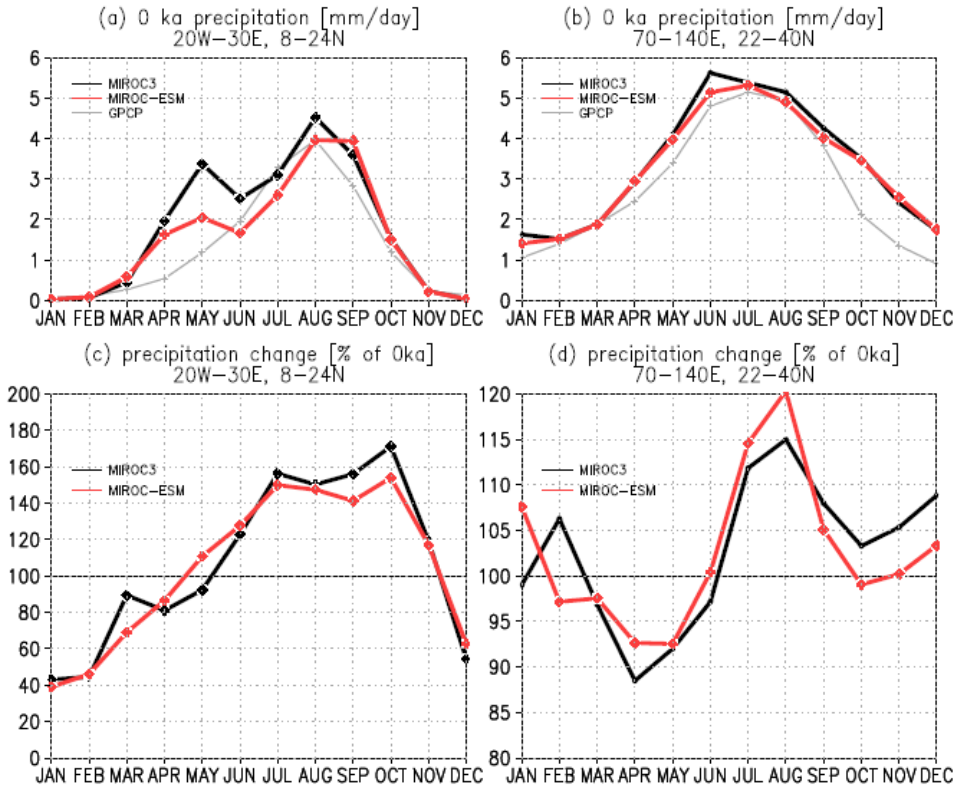
ADDITIONAL

On page 3286, what reanalysis product is being used? It is not sufficient to evaluate a GCM's temperature/precipitation against a reanalysis product. One should use a gridded observational dataset (CRU, Univ. of Delaware, etc. . .). Reanalysis precipitation is model-derived. Also, the model's performance (e.g. mean climatology, correlations with NINO3, etc. . .) should be shown in the figures so the reader knows the strengths/weaknesses of the model. How well does it simulate the seasonal cycle of N African precip for example?

However the use of the different observational data does not undermine the robustness of the present study, we have compared the 0 ka climates with the observational datasets used in Watanabe et al. 2011 Fig. 6 (Jones et al. 1999, Adler et al. 2003). Regarding the model's basic performance, Watanabe et al. 2011 fully described the fidelity of the mean state and its variability reproduced in the model. In this work, we add some explanations that the very basic variables are reasonably well represented. The sentences in the draft are modified following the reviewer's suggestions.

On the other hand, it is a good idea to show the seasonal cycle of N. African precipitation which is one of the foci of this study. We have added the seasonality of the 0 ka precipitation and an observational precipitation in Fig. 19 as shown below. (**) The seasonality of the African and Asian precipitation is generally well represented in the 0 ka simulations except excessive precipitation in April and May over the Africa. The overestimation in MIROC3 is reduced in MIROC-ESM. There is a possibility that the enhanced early summer precipitation over the Sahara region under the 6 ka

simulation in MIROC-ESM may be affected by the improvement of the representation of the 0 ka precipitation. The explanation is added in the text.



The paper text is quite lengthy. You should remove discussions that are not critical to the focus topic. For example, is the discussion of salinity or carbon budgets on page 3287 needed? On page 3291, streamfunction is suddenly discussed with no explanation why you are looking at it. Is it critical to the study or can it be removed to shorten the paper? Same issue with salinity on page 3291. Perhaps remove section 5.3.1.

As explained in the abstract, the object of this study is not only to discuss the African precipitation changes but also to explain the difference and/or similarity of the modeled global climatic changes in comparison with the previous AOGCM experiments. Therefore, we also include oceanic variability in the analyses. Moreover, the salinity change is highly related to the precipitation and evaporation changes, which is closely related to the topic of the present study. However, as the reviewer pointed out, carbon cycle is appeared only in ESM and not possible to compared to AOGCM runs. We removed the sections related to carbon cycle.

Because we'd like to describe what is seen for the Saharan precipitation in MIROC-ESM and MIROC3 experiments before going to the sensitivity experiments, we would like to keep Sect. 5.3.1.

When comparing two patterns, it is a good idea to include a spatial correlation. For example, on page 3289, rather than just saying that the two maps have a "general resemblance", you can perform a spatial correlation and quantify the comparison. On page 3290, rather than just saying the "pattern of cooling is similar", quantify with a spatial correlation. Also true for the "patterns of change are common" on page 3291.

The spatial correlation coefficient for the precipitation change (page 3289) is 0.69 in JJAS and 0.64 in DJF. Similarly, the SST patterns in page 3290 are 0.65 for JJAS and 0.56 for DJF. The pattern of the change of the stream function for the Atlantic Ocean is 0.69 and 0.49 for the Pacific. These values are added in the texts.

There is an excess of figures in the article, some of which are discussed by only a couple of sentences (e.g. Figure 17. . . minimal discussion of the wind changes shown here). I recommend removing probably 10 figures:
Remove figure 2. . . the text description of the spinup is sufficient.

If it is sufficient with the description in the text to present the reasonability of the experimental setting, it is no problem to remove Figure 2. Figure 1 is also eliminated because it can be seen in Figure 1 of Ohgaito and Abe-Ouchi 2007. It is explained in the text.

For figure 6. . . what are the units? Is this figure needed?

Figure 6 was removed. Please also see our reply in (***).

For figure 12. . . is this annual? Is this figure needed?

Figure 12 shows the annual change. In this subsection, we have shown the oceanic change. The primary driver of the SST change is the radiation budget at the sea surface. But this figure suggests that the difference of the north Atlantic SST change between MIROC-ESM and MIROC3 arises also from the difference of the oceanic circulation change in 6 ka. In contrast, such difference was not seen in the Pacific.

Remove figure 14. . . the text description and also figure 13 suffice.

What is shown in Figure 13 and Figure 14 are different. Figure 14 is necessary because it shows more detailed information than Figure 13 on the red grids in Figure 13, where the most frequent

vegetation type is desert. Figure 14 shows permanent desert and sporadic desert within the red grids in Figure 13. It clearly shows the spatial distribution of the sporadic desert than the text description.

For figure 15. . . .the DJF is never discussed, so either remove or discuss the NAO/AO implications.

Removed

Remove figure 19. . . figure 20 shows the same info.

Figure 19 shows the seasonal evolution of the areal averaged precipitation change compared to the 0ka precipitation, whereas Figure 20 shows the latitudinal change of the seasonal evolution of the zonally averaged precipitation in the African and Asian regions. Although Figure 19 shows simpler information, it shows how MIROC3 and MIROC-ESM simulate similar seasonality of the precipitation change for 6 ka. We also added the seasonality of the 0 ka precipitation to represent the model ability following the reviewer's suggestion in (**). So we'd like to keep Figure 19, too.

Remove figure 22. . . figure 19 shows the same info.

We'd like to keep Figure 22 because it can reveal the areal distribution of the precipitation changes over the northern Africa and also if the change is significant or not for the early and late summer.

Regarding figure 25, I would either state the #s in the text and eliminate the figure, or replace the figure with something else, like a histogram. Does the frequency of ENSO events change? (check with power spectrum).

We eliminate the figure following the reviewer's suggestion because we are not going to investigate the ENSO variability in detail in this study. The values are stated in the text.

For many figures, including Figure 28, if the 2 models generally agree, it is sufficient to show 0k and 6k from just one model (especially if your discussion is focused on 6k versus 0k and not MIROC3 versus MIROC-ESM for that particular figure).

We intend not only to discuss the differences of the two models, but also to present how the two different models did not affect the results of the 6 ka simulations. Therefore, we would like to include the most of the figures even if they are verbose and don't look very sophisticated. However,

we agree that Figure 28 includes excess of panels and the discussion is focus on the difference between 6 ka and 0 ka. We eliminated lower half of the panels following the reviewer's suggestion.