

**Manuscript:** Dynamic interaction of lakes, climate and vegetation over northern Africa during the mid-Holocene

### **Response to Reviewer 1**

*This is a well-written manuscript addressing a question which is certainly relevant to the scope of CP. It presents a new dynamic lake model implemented to address a pertinent question – the effect of lakes on the mid-Holocene northern African climate. To the best of my knowledge, this is a novel contribution, and it does lead to interesting new insights regarding the synergistic effect between vegetation and lakes as well as regarding the effect of lake depth. I do not have the required expertise to assess the HD and DEL models deeply; on the surface they appear to be reasonably formulated. Overall, I found the manuscript thoughtfully written and would recommend it for publication after addressing some issues.*

**We would like to thank the reviewer for reading the manuscript carefully and for writing this valuable and constructive feedback. We are pleased to hear that the reviewer thinks the manuscript is thoughtfully written and recommends it for publication. In the following, we address the reviewer's comments point by point. We respond with “Ok.” in case we would correct the manuscript exactly as suggested.**

#### ***Specific comments:***

*Line 265: I'm not sure if the lake and vegetation cover can be claimed to have reached a “close-to-equilibrium state” at 400 years into the simulation. Looking at Figure 5, the choices of last 100 years or the last 400 years as evaluation period seem more logical to me, compared to last 150 years which starts with a declining peak in both covers. The peak in lake cover at the beginning of the evaluation period is around 10,000 km<sup>2</sup> and that doesn't seem trivial to me. Either the authors could explain the quantitative basis behind this choice of evaluation period, or remove the phrase “close-to-equilibrium state” and simply mention that the last 150 years were used as evaluation period. Does the precipitation over northern Africa change significantly if the last 400 years are used instead?*

**We will remove the phrase “close-to-equilibrium state” and simply mention that the last 150 years were used as evaluation period. But we will check whether it makes a large difference when using the last 400 years instead of 150 years.**

*Figure 5: Please mention in the caption what the horizontal dashed lines in subplot a) represent.*

**We will add the information that the blue and green dashed line in figure 5 a) represents the mean lake area and mean vegetation cover averaged over the last 150 years.**

*Lines 270 – 273: I appreciate this example to put the 18.8% deviation in context.*

#### **Thank you!**

*Line 303: Some newer work has indicated that precipitation could be even higher than that indicated by Bartlein et al. (2011) (which is also the proxy dataset that Braconnot et al., 2012 refer to). For example, Hely et al. (2014) show that Sudanian taxa were present up to 25 N, which would require 500-1500 mm/yr of rainfall, and Guineo-Congolian taxa (requiring >1500 mm/yr) potentially reached 20 N. More “extreme” examples are also provided by Tierney et al. (2017) and Sha et al. (2019). Hence, I suggest changing “seems to underestimate” to “underestimates” since that is a clear and significant under-estimation of precipitation.*

**We will add the suggested citations to the results part and changes the term “seems to underestimate” to “underestimates”.**

*Line 312: Braconnot et al. (2012) discussed PMIP1 and PMIP2 model results. Brierley et al. (2020) might be a better reference for state-of-the-art climate models. However, in my understanding, biases are usually discussed in terms of simulation of present day climate, and not while discussing (MH-PI, or similar) anomalies.*

**Thank you for the suggestion. We will include Brierly et al. (2020) in our text.**

*Line 328: Could the authors expand a bit on why lake expansion leads to higher precipitation south of Megalake Chad?*

**We will add the following information at line 325: “The dynamic vegetation alone causes a local precipitation increase in regions where the vegetation expands over northern Africa (Fig. 6c; Fig. 7b). This precipitation increase is likely caused by an enhanced local moisture recycling (citation). In contrast, Lake Chad not only enhances precipitation locally above its water surface, but also to its southern side around 5 °N (Fig. 6b; Fig. 7c). This precipitation increase is associated with winds that blow from the cool lake towards its warmer surrounding, where it converges with the monsoon westerly wind to the south of Lake Chad. The resulting moisture convergences to the south of Lake Chad enhances moist convection and, thus, the formation of precipitation in this region, which again enhances the inflow of monsoon westerly winds. The related mechanism is described later in the results part.”**

*Line 390: I think a plot similar to Figure 7 but for mean annual temperature would help visualize this point. Additionally, could the authors provide estimates for changes in albedo due to vegetation and lakes? What exactly causes the change in the meridional temperature gradient?*

**We will compute a factor analysis for temperature and albedo changes and see if it helps to visualize that „the simulated mid-Holocene vegetation cools the land surface stronger than the simulated mid-Holocene Lake Chad“. We will add this plot to the appendix if applicable. Another, more simple, approach would be to add the meridional mean changes in the albedo to plot 9 at the bottom, where the surface temperature changes of mHdV dL – mHdV are already displayed.**

**We will also provide the information that the lake albedo is set constant to 0.07 and the range in the albedo for the vegetation in the model.**

**The surface temperature and, thus, its meridional gradient are influenced mainly by the albedo (net radiation) and turbulent heat fluxes (latent and sensible heat flux).**

*Line 430: I’m not sure the results of this study strictly “contradict” the previous studies, since none of the previous studies discussed the synergistic effect, but only the net effect of vegetation and lakes. If I’ve understood correctly, the drying response is only due to the synergistic effect, and this study agrees with previous ones regarding the net effect.*

**We agree on this comment and will rephrase this sentence as the following: “ This drying response is an unexpected result, since former simulation studies show a general precipitation increase in response to a mid-Holocene extent of Lake Chad prescribed from reconstructions (Coe and Bonan, 1997; Broström et al., 1998; Carrington et al., 2001; Krinner et al., 2012; Chandan and Peltier, 2020; Specht et al., 2022; Li et al., 2023).“**

Line 456: It seems to me that one of the main conclusions of the study (overturning circulation over Megalake Chad, and associated changes) is sensitive to the choice of the lake surface albedo. How much would this change with the use of a dynamic lake albedo? For example, what could be a plausible albedo range for Megalake Chad if a dynamic scheme were to be used?

**Thank you very much for this suggestion. We will add some information from observation estimates about the possible albedo range of lakes i.e. “The values of lake albedo in the study area ranged from 0 to 0.45, with an average value of 0.14.” (Du et al. 2023)**

**Du, Jia, et al. "Retrieval of lake water surface albedo from Sentinel-2 remote sensing imagery." *Journal of Hydrology* 617 (2023): 128904.**

*Line 460-463: The switch from surface warming to surface cooling due to lakes is confusing.*

**We are not sure, if we understand this comment right. We would suggest to rephrase the sentence starting at line 460 as the following: „Since the depth of the lakes is likely underestimated, the surface cooling by the simulated mid-Holocene lakes is likely underestimated, too.“**

***Technical comments:***

*The authors should consider merging Figures 2 and 3 into one figure with the differences highlighted. Results should be moved into a separate section (Section 2.4  $\diamond$  Section 3), moving Conclusions forward (Section 3  $\diamond$  Section 4). The authors could consider moving Figure 11 into the Supplementary Information.*

**We will show Figures 2 and 3 side by side and highlight the differences. Something must have gone wrong in the LaTeX template we used. we will number the individual chapters as follows: 1. introduction, 2. methods, 3. results and 4. conclusions. We will put Figure 11 – as suggested - in the appendix, as this figure is only briefly mentioned in the results.**

*Lastly, I found some grammatical/typographical errors which should be corrected:*

*Line 21: warms  $\rightarrow$  warm*

**Ok.**

*Line 67: In the following section?*

**Ok.**

*Lines 79-81: Consider replacing the phrase “a too” with “overly” or “unrealistically”*

**We will replace “a too” with “an unrealistically”**

*Line 89: albedo scheme represents changes*

**Ok.**

*Line 91: over the northern Africa  $\rightarrow$  over northern Africa*

**Ok.**

*Line 110: on the climate variables e.g. the precipitation?*

**Ok.**

Line 142: thr → the

Ok.

Figure 1 caption: In the last sentence – endorheic catchments were generated in a way that (remove "it") suits

Ok.

Line 214: represented by → represented as a

Ok.

Line 245: shirk → shrink?

Ok.

Line 263: different → difference

Ok.

Figure 5 caption: In the first sentence – northern. Last sentence – subplot c) or d)?

**In the first sentence, we will change “norther” to “northern” and in the last sentence we will correct “c)” to “d)”.**

Line 264: 550 years

Ok.

Line 273: Considering this → such large changes?

**We will change “Considering this” to “Considering such large changes”**

Line 290: orbit → orbital

Ok.

Lines 334, 341: predominately → predominantly

Ok.

Line 340: note the different → difference in the scaling

Ok.

Lines 345, 348: meridonal → meridional

Ok.

Lines 348 onwards: please check all references to various subplots of Figure 9

**There appears to be a systematic error in the reference to Figure 9 b), which is incorrectly referenced as 9 c). We apologize for the mistake. We will correct the following:**

- Line 348 “(Fig. 9c: arrows)” to “(Fig. 9b: arrows)”
- Line 352 “(Fig. 9c: orange shades)” to “(Fig. 9b: orange shades)”
- Line 353 “(Fig. 9c: arrows)” to “(Fig. 9b: arrows)”
- Line 255 “(Fig. 9c: arrows)” to “(Fig. 9b: arrows)”

- **Line 257 “(Fig. 9c: arrows)” to “(Fig. 9b: arrows)”**

*Line 358: is → in the Sahel*

**We will change “is” to “in”**

*Line 410: transitional → transient?*

**Ok.**

*Line 424: for → in*

**Ok.**

*Line 466: the effect of exorheic lakes*

**Ok.**

*I appreciate the work put in by the authors and hope they find these comments helpful. I thank Prof. Buizert for considering me for this review.*

**Thank you again for reviewing this manuscript.**