

# ***Interactive comment on “Synergy of the westerly winds and monsoons in lake evolution of global closed basins since the Last Glacial Maximum” by Yu Li and Yuxin Zhang***

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We thank very much for reviewer's comments concerning our manuscript. We use bold font to highlight reviewer's comments and use normal font to mark our reply.

**General Comments** The study combines simulated water balance in closed lake basins and paleoclimate records to distinguish the influence and temporal evolution of monsoon and mid-latitude westerlies on moisture levels. This study is an interesting approach to the influence of both the westerly winds and monsoon on climate changes since the Last Glacial Maximum. While as a whole the study is of good quality and fits within the scope of the journal, there are a number of issues with the manuscript, that I think will need to be taken care of prior to publication.

## **1. The authors present the study as global, but mainly focus on Central and East Asia.**

Thank you very much for your suggestion. According to our original intention, we regard the global closed basins with prominent water resources problem as a carrier to explore the natural driving mechanisms that affect their dry and wet patterns—synergy of the global westerly winds and monsoons. However, most of the global closed basins are located in the Northern Hemisphere and the Eurasian continent has the largest area. Therefore, based on the differentiation of water balance change since the LGM in different latitudes of global closed basins, we focus on the mid-latitudes of the Northern Hemisphere where may be affected by the synergy of the westerly winds and monsoons to retrospect the water balance change since the LGM in the entire region. Then we further pay attention to the Eurasian continent for distinguishing the evolutionary characteristic of water balance in the regions respectively affected by the westerly winds and monsoons. Following your comments, we will revise the title to “Synergy of the westerly winds and monsoons in lake evolution of closed basins since the Last Glacial Maximum and its implication for hydrological change in Central Asia.”

## **2. Some changes in the structure of the manuscript are needed, especially in the results and discussion sections.**

Thank you very much for your suggestion. As you mentioned in Specific comments 6, we will combine sections 3.3 and 3.4 with the discussion to create a results and discussion section with a more readable description.

**3. More details on the method of selection of the paleorecords is needed.**

Thank you very much for your suggestion. As you mentioned in Specific comments 4, we will supplement the number of dating samples and resolution of paleoclimate records in Table 3.

**4. I think the manuscript would greatly benefit from a thorough review of the English. While, the manuscript is comprehensible, there are many sentences that are not properly structured. The verb tense should be standardized, as they are sometimes changing even within a single sentence.**

Thank you very much for your careful examination of the manuscript. We will check the each sentence carefully.

**Specific comments 1. Title I have issues with the title where the authors present the study as global, while in fact it is focusing on the Northern Hemisphere. The authors even provide the reasoning behind the focusing on the Northern Hemisphere in the last paragraph of the introduction. Actually, the study largely focuses on Central Asia and China (17/25 (68%) records from China). I think the title should be modified accordingly.**

Thank you very much for your suggestion. As answered in the General Comments 1, we will revise the title to “Synergy of the westerly winds and monsoons in lake evolution of closed basins since the Last Glacial Maximum and its implication for hydrological change in Central Asia.”

**2. Introduction There is no clearly defined objective. Please clearly state the purpose of the study. What scientific question was this study intended to answer?**

Thank you very much for your suggestion. Global closed basins with prominent water resources problem occupy one-fifth of the terrestrial surface, distributing in both low-latitude monsoon regions and mid-latitude westerlies. As the two important components of global atmospheric circulation, monsoon system and westerly circulation exert different effects on global climate change and interact with each other in the mid-to-low latitudes. We regard the global closed basins as a carrier to explore the synergy of the westerly winds and monsoons in lake evolution since the LGM and its implication for hydrological change in Central Asia. We will modify the introduction for clearly stating the purpose of the study.

**3. Time period partitioning What is the reasoning behind the selection of the PI period in the simulation? The authors mention that the selection of the time periods where subjective, was that 100 years period**

**selected as a reference for the “modern/recent”? Why not choose a more climatically significant period like the Little Ice Age or the late Holocene, for which monsoon reconstruction clearly display a change? The authors mention that the division into those three periods was done to validate the water balance simulations and explore the evolution of the monsoons and westerly winds in the selected basins. Validating the water balance simulations for such a short period of time with records that are generally poorly constrained (see comment on section 2.2 below) for that period might be problematic. Furthermore, the PI period is absent from the discussion on the changes in monsoon and the westerlies.**

Thank you for pointing this out. Due to reduction of CO<sub>2</sub> levels at the LGM, previous studies hypothesize that lake levels of the LGM could map a reverse analog to future hydroclimate changes and verify this hypothesis by comparing hydroclimate change between the LGM and PI (Lowry and Morrill, 2019; Quade and Broecker, 2009). And in our study, PI period is a period with strong influence of modern human activities. In the time slice simulations, the selection of PI period is mainly used to measure the changes in hydroclimate conditions during the LGM and MH periods relative to the modern period, and verify the feasibility of the lake models by comparing the lake level simulation with the lake status records among the three periods. After verification, combining lake models and continuous simulation can be used to track water balance change of the global closed basins and investigate the evolutionary differentiation of the westerly winds and monsoons since the LGM. We agree that the absence of discussion on the changes of westerly winds and monsoons during the PI period is indeed an omission in our study, and we will add it accordingly in the revised version.

References:

- Lowry, D. P. and Morrill, C. 2019. Is the Last Glacial Maximum a reverse analog for future hydroclimate changes in the Americas? *Climate Dynamics*, 52: 4407-4427.
- Quade J, Broecker W S. 2009. Dryland hydrology in a warmer world: Lessons from the Last Glacial period. *The European Physical Journal Special Topics*, 176: 21-36.

**4. Section 2.2: Please define what is considered a reliable chronology. . . Did the authors apply a minimum number of dates per thousand years? What about the temporal resolution for the selection of the various records? Did the authors apply a minimum number of the samples per time frame? For example, minimum one sample per 100 or 200 years? I cannot tell for other regions, but to me there are some Chinese high-resolution lake records missing from the list that would be of better quality than some of those included. On the top of my head, I would consider Gonghai lake (Chen et al., 2015 Sci Rep 5), Dali lake (Goldsmith et al., 2017 PNAS 114). They might not be within your simulated closed basins, but they are close enough and high-quality enough to be considered. Finally, for the PI period, as far as I know, many of the records in table 3 do not have any proper chronological control (210Pb or 14C bomb pulse)**

**for the top section of the cores. The 1800-1900AD period can be difficult to narrow down chronologically as  $^{14}\text{C}$  is not very precise during this period and  $^{210}\text{Pb}$  is at its limit.**

Thank you very much for your suggestion. It is our negligence not to specify the number of dating samples and resolution of paleoclimate records in detail, and we will supplement these parts in Table 3 of the revised version. We fail to consider the paleoclimate records of Gonghai lake and Dali lake in our study, and as you suggested, these two high-resolution records will be added in the revised version. In this section, our aim is to reconstruct the regional moisture change by synthesizing the paleoclimate records for verifying the the continuous simulation. Therefore, we do not need to pay special attention to the dry and wet changes in the PI period, but focus on the matching degree of reconstructed results and simulated results throughout the Holocene. Both reconstructed moisture change and simulated water balance fluctuation exhibit a decreased trend since the early-Holocene, giving our confidence that the simulations are useful for investigating the evolutionary characteristics of the millennial westerly winds and monsoons.

**5. In section 3.2, the authors state “Qinghai Lake, Hala Lake, Zhabuye Lake are typical lakes which are located in interactional transition zones between Asian monsoon and westerly winds, probably not following a single climate changing pattern”. I would argue that many of the selected lakes in China, which they consider as being in the monsoon zones (see Fig. 6), were influenced both by the westerlies and the East Asian summer monsoon. Especially since the boundary of the monsoon was not static over time.**

Indeed, due to various internal and external forces, the low-latitude monsoons and the mid-latitude westerly winds produce different intensities over time. The boundary of the East Asian summer monsoon will also be adjusted accordingly with the change of monsoon strength, leading to more complex and diverse evolution of Asian lakes. We will modify this sentence in the revised version as “Since the boundary of the monsoon will be adjusted accordingly with the change of East Asian summer monsoon strength, evolution of Asian lakes on the millennial scale probably not follows a single climate changing pattern.”

**6. Structure of the manuscript Some parts of the result section belong to the discussion. While I understand that the authors must show that the lake simulations are valid and that, to do so, some interpretation is needed. I think that sections 3.3 and 3.4 should at the very least be moved to the discussion as they are focusing on the mechanisms driving the changes in water balance. Actually, I think that, given the nature of the data, this manuscript is a case where it would be beneficial to do a results and discussion section rather than separating them.**

Thank you very much for your suggestion. Your suggestion provides a new perspective for discussing our study

deeply. We will combine sections 3.3 and 3.4 with the discussion to create a results and discussion section with a more readable description.

**7. Terminology** Several times in the manuscript, the authors refer to the Asian monsoon. To me it seems that what they call Asian monsoon is actually the East Asian monsoon. Especially since most of the selected records at the eastern edge of the simulated closed basins in Asia are roughly located at the northern limit of the East Asian summer monsoon (EASM). I think some precision is needed.

Thank you very much for your suggestion. We will modify the “Asian monsoon” mentioned in this manuscript to the “East Asian summer monsoon” in the revised version.

**8. Discussion - Westerlies-monsoon interactions** While studies have shown that trends in moisture changes in Westerly dominated arid Central Asia generally differ from those in EASM regions, owing to the fact that EASM rainfall does not reach this region, the opposite is not necessarily true. Records well into the region that the authors would consider as the East Asian monsoon region suggest an influence of the westerlies on moisture levels. The authors briefly discuss the interactions between the westerlies and the East Asian monsoon. However, I think the discussion would benefit from a more in-depth discussion of the relationship between the Westerly Jet and the EASM. For example, there are increasing evidence for a control of the Westerly Jet on the northward extent and timing of the EASM rainfall in East Asia (see for example: Chiang et al., 2015 QSR 108: 11-129; Herzsuh et al., 2019 Nat Comm 10; Nagashima et al., 2013 (Geochem Geophys Geosys 14: 5041-5053).

Thank you very much for your suggestion. The information you provided about the influence of the orientation and position of the westerly jet on the EASM rainfall give us a lot of help. Previous studies mostly focus on the complexity of climate change in the transition zone between the westerlies and Asian monsoon, and investigate the interplay of two global atmospheric circulation on the millennial scale. However, the impact of the seasonal progression of the westerly jet on the EASM rainfall has not been thoroughly discussed. We will supplement this issue in the results and discussion section.

**9. Speleothems** The close similarity of the PCA1 time series with the speleothem records from Gongge and Hulu caves suggest it is a record of the East Asian summer monsoon. There is a long-standing debate about what the  $\delta^{18}\text{O}$  speleothem records from China represents. One view interprets the oxygen isotopic

**record from Chinese cave deposits as reflecting real rainfall changes and hence reflecting changes in the EASM. The other main view suggests that these the oxygen records (depending where they are located) reflect changes in the moisture source (Indian monsoon vs EASM) and that they do not directly represent changes in EASM. What can the present study contribute to that debate? I think it could be an interesting addition to this manuscript.**

Thank you very much for your suggestion. The climatic significance of the  $\delta^{18}\text{O}_c$  in the Asian speleothem records is always a long-standing debate, and some influential hypotheses regard  $\delta^{18}\text{O}_c$  of the monsoon regions as a proxy for “Asian monsoon intensity”, “Indian monsoon intensity”, “summer monsoon rainfall amount”, “circulation conditions”, etc. Although the climatic significance is controversial, it is well-accepted that  $\delta^{18}\text{O}_c$  changes should bear the imprint of variations in the oxygen isotopic composition of precipitation ( $\delta^{18}\text{O}_p$ ) (Cheng et al., 2012; Chen et al., 2016). In addition, a conclusion that the evolution of the EASM is generally controlled by summer insolation in the Northern Hemisphere is also widely recognized (Yuan et al., 2004; Chen et al., 2006; An et al., 2015). We therefore not only compare the PCA1 with the stalagmite records of Dongge Cave with controversial climatic significance, but also with the summer solar radiation at low-latitudes in the Northern Hemisphere. However, the contribution of our results to the paleoclimate research of Chinese stalagmites is not discussed in-depth in the article, and we will make corresponding supplement in the results and discussion section.

#### References:

- Cheng H, Sinha A, Wang X, Cruz F W, Edwards R L. 2012. The global paleomonsoon as seen through speleothem records from Asia and the Americas. *Climate Dynamics*, 39: 1045-1062.
- Chen J H, Rao Z G, Liu J B, Huang W, Feng S, Dong G H, Hu Y, Xu Q H, Chen F H. 2016. On the timing of the East Asian summer monsoon maximum during the Holocene—Does the speleothem oxygen isotope record reflect monsoon rainfall variability? *Science China Earth Sciences*, 59: 2328-2338.
- Yuan D, Cheng H Y, Edwards R L, Dykoski C A, Kelly M J, Zhang M. 2004. Timing, Duration, and Transitions of the Last Interglacial Asian Monsoon. *Science*, 304: 575-578.
- Chen F H, Huang X Z, Yang M L, Yang X L, Fan Y X, Zhao H. 2006. Westerly dominated Holocene climate model in arid central Asia—Case study on Bosten lake, Xinjiang, China. *Quaternary Sciences*, 26: 881-887.
- An Z S, Wu G X, Li J P, Sun Y B, Liu Y M, Zhou W J, Cai Y J, Duan A M, Li L, Mao J Y, Cheng H, Shi Z G, Tan L C, Yan H, Ao H, Chang H, Feng J. 2015 Global Monsoon Dynamics and Climate Change. *Annual Review of Earth and Planetary Sciences*, 43: 2.1-2.49.

**Technical/minor comments Fig 3: Please provide letters to refer to each section of the figure both in the figure caption and the figure itself. I would also suggest putting both EOF figures on the left side and the PCA curves above the speleothem records. It would make the comparison of the curve easier.**

Thank you very much for your suggestion. We will modify the Figure 3 in the revised version.

**Fig 5: please provide letters the refer to each time series, especially since the font size is quite small. If possible, increase the font size of the time series.**

Thank you for pointing this out, we will provide letters the refer to each time series and increase the font size of the time series.

**Section 3.3 and 3.4: EOF is not defined anywhere in the manuscript.**

Thank you for pointing this out, we will add section 2.3 to describe the mathematical methods.

**Line 29: indicate rather than indicated. I would also remove monsoon after Australian and East African.**

Thank you very much for your careful examination of the manuscript. We will modify this.

**Line 30: Remove the And at the start of the sentence.**

Thank you very much for your careful examination of the manuscript. We will modify this.

**Lines 32-33. That sentence needs to be rephrased to something like “. . . the seasonal migration of the (ITCZ) profoundly influences the seasonality of the global monsoons.”**

Thank you very much for your suggestion. We will rephrase this sentence in the revised version.

**Line 36: Please define LGM. This is the first time you mention it in the main body of the manuscript.**

Thank you very much for your careful examination of the manuscript. We will add the full name of LGM.

**Line 36: . . . southern regions of THE North American continent. . .**

Thank you very much for your careful examination of the manuscript. We will modify this.

**Line 51: Please define MH. This is the first time you mention it in the main body of the manuscript.**

Thank you very much for your careful examination of the manuscript. We will add the full name of MH.

**Line 51: remove one space between and and Pre-Industrial**

Thank you very much for your careful examination of the manuscript. We will modify this.

**Line 51: remove and at the start of the sentence.**

Thank you very much for your suggestion. We will modify this.

**Line 58: Capital letter for last**

Thank you very much for your careful examination of the manuscript. We will modify this.

**Line 70: please define P-E. It is mentioned for the first time in the manuscript.**

Thank you very much for your careful examination of the manuscript. We will add the full name of P-E.

**Line 75: either remove And at the start of the sentence or combine with the previous one by for example writing: “(Peltier, 2004), while the vegetation. . .”**

Thank you very much for your suggestion. We will modify this.

**Line 82: IN each grid cell not at**

Thank you very much for your suggestion. We will modify this.

**Line91: assumed rather than supposed**

Thank you very much for your suggestion. We will modify this.

**Lines 135-136: However, there are exceptions that lakes. . . Replace that by where**

Thank you very much for your suggestion. We will modify this.

**Lines 148-149: this sentence need to be rephrased, for example: “ Comparing the simulations with the records, most simulations coincide with the upward. . .”**

Thank you very much for your suggestion. We will modify this.

**Line 135 “For better validating simulated results, reviewed and summarized the millennial-scale changing patterns in lake level of the closed basins since the LGM are particularly important.”**

Thank you very much for your careful examination of the manuscript. We will modify this.

**Line 164: East Asian summer monsoon not East summer Asian. . .**

Thank you very much for your careful examination of the manuscript. We will modify this.

**Line 173: suggested change to: “According to. . . basins in the Northern Hemisphere, affected both by low-latitude monsoon and mid-latitude westerly winds, are ideal region. . .”**

Thank you very much for your suggestion. We will modify this.



**Line 179: “from A humid climate IN the early-mid Holocene to AN arid climate IN the late Holocene” not “from humid climate of the early-mid Holocene to arid climate of the late Holocene”.**

Thank you very much for your careful examination of the manuscript. We will modify this.

**Line 185: “in THE early-mid Holocene”**

Thank you very much for your careful examination of the manuscript. We will modify this.

**Lines 187-188: That sentence need to be rewritten.**

Thank you very much for your suggestion. We will reword this sentence.

**Lines 188-190: Do you still refer to Yu et al. (2000) there or to Fig. 5. This is not clear.**

Thank you for pointing this out, lines 188-190 describe Fig. 5 and we will clarify it.

**Line 190: reaches A maximum not the**

Thank you very much for your suggestion. We will modify this.

**Line 221: experienced not experiences**

Thank you very much for your suggestion. We will modify this.

**Line 255-256: suggest edit: “Winter precipitations account for a large proportion of annual precipitations in these regions.”**

Thank you very much for your suggestion. We will reword this sentence.