

Dear Editor and reviewers,

Thank you for your letter and for the reviewer's comments concerning our manuscript entitled "Tracing seasonal signals in dry/wet status for regions with simultaneous rain and heat from Eastern and Central Asia since the Last Glacial Maximum". Thanks very much for giving us such a precious chance. Those comments and suggestions are all valuable and very helpful for revising and improving our paper, as well as the important guiding significance to our research. We have studied all of the comments and suggestions carefully and made corresponding corrections in the manuscript with colored text. A detailed list of revisions against each point of reviewer 1 that is being raised is below.

Reviewer 1

This manuscript presents a comprehensive study of the hydroclimate evolution of the central and eastern Asia region since the Last Glacial Maximum (LGM). The authors analyze the similarities and differences between the spatiotemporal hydroclimate regimes in these regions, at both modern and paleoclimate timescales, using modern climate datasets, modelling data, and a compilation of more than forty paleoclimate records. The manuscript elaborates on the asynchronous nature of short-term and long-term dry/wet patterns in central and eastern Asia. Modern climate regimes in these two regions show a strong anti-phase climate pattern, marked by the westerly-dominated "winter" regime in central Asia and the monsoon-dominated "summer" regime in eastern Asia. However, previous paleoclimate reconstructions suggest that these spatiotemporal differences could have changed during late Pleistocene and the Holocene periods, especially towards the eastern border of central Asia. With their new statistical analyses on modern climate data, summed to an exhaustive revision of published proxy data, the author adds interesting information that complements well with other published studies, proposing that monsoonal precipitation might be key to understanding the evolution of these two climate regimes since the LGM.

However, the article could, in my opinion, be improved in several ways. Here I summarize my suggestions for major changes and several other minor amendments to the text and figures.

Response: We'd like to thank your constructive comments and suggestions on our manuscript. We appreciate the chance to clarify some concepts and have adopted all suggested changes raised by Reviewer 1. In addition, we have scrutinized the text for additional minor errors and to improve clarity and readability, which are also highlighted in the revised version. We sincerely hope this revision meets with your approval.

Conceptualization

I think that the authors do not provide enough information to clearly state why exploring the past and present spatiotemporal changes in the two regions is scientifically relevant. Although differences in the interpretation of paleoclimate data exist, why does this merit to analyze modern climate timeseries and compile such a great number of paleoclimate records? Also, I personally miss an explanation to why combining modern data analysis with paleoclimate records and past climate simulations is a valid avenue to “assessing future hydroclimate changes” (line 403). It would be great if these issues can be addressed in a new version of the introduction.

Response: Thanks very much for your suggestions and carefulness. Firstly, because the concept of simultaneity of rain and heat period is derived from the modern climate, we first start from the modern climate to analyze the impact of simultaneous rain and heat on the differences and linkages in precipitation between CA and EA. We believe this can improve the reliability and scientific for applying this concept to paleoclimate analysis. At the same time, jointly analyzing modern climate characteristics and paleoclimate history can more comprehensively explore the impact of seasonal signals of precipitation on dry/wet status in CA and EA. Secondly, we have deleted the inappropriate description (e.g. assessing future hydroclimate changes in line 403) and the updated sentence is “Model simulations are a valid means to visually study the mechanism of paleoclimate change in EA and CA during the LGM and MH.”.

Also, I found it troubling to understand some concepts used throughout the manuscript. For instance, what does “wet/dry status” mean (e.g., line 74)? In my opinion, the authors should be more careful in placing complex terminology without further explanations.

Response: Thanks very much for your suggestions. We have checked all the complex terminology in the text and added more explanations. The description in line 74 is amended to “In monsoonal EA, a strengthened summer monsoon and humid climate usually occurs in the early and mid Holocene, and a weakened summer monsoon and drier climate prevailed during the late Holocene (Dykoski et al., 2005; Chen et al., 2015). Based on the integration of paleoclimate records, modern meteorological observation data and paleoclimate simulations, Chen et al. (2008, 2009, 2019) revealed that the ‘westerlies-dominated climatic regime’ in arid CA presents dry early Holocene, wetter mid-Holocene, and moderately wet late Holocene, which is out-of-phase or anti-phased with the dry/wet status in the monsoon-dominated regions.”.

Abstract

With 393 words, the abstract is too long in my opinion and includes not only the most essential results and discussions presented in the manuscript. Phrases such as “The remarkable difference in summer precipitation regime and winter precipitation regime reveal the seasonal signals of precipitation in multi-time scale climate change.” (Lines 17-19) and “In particular, summer and winter precipitation in EA and CA is associated with the Asian monsoon, westerlies, ENSO, NAO, and PDO” (lines 30-32) do not provide any critical information and are too general for an abstract. I would favor a shorter and concise abstract.

Response: Thanks very much for your suggestion. We have shortened the abstract and the updated contents are reproduced below:

“

Abstract

The global monsoon region with the summer precipitation regime and the

Mediterranean climate region with the winter precipitation regime show opposite dry/wet evolution since the Last Glacial Maximum (LGM). Therefore, different precipitation regimes bring about the contradiction in dry/wet status between Eastern and Central Asia (EA and CA). Based on the comprehensive study of modern observation datasets, ensemble simulations of eight climate models from the Paleoclimate Model Intercomparison Project phase 3 (PMIP3), and the compilation of 42 proxy records from EA and CA, here we reveal that seasonal signals of precipitation derived from the simultaneity of rain and heat periods could govern the difference and linkage in dry/wet status from EA and CA. At short-term timescales, EOF analysis results of mean annual precipitation uncover different precipitation regimes in EA and CA. However, EOF results of summer and winter precipitation indicate the similarity between EA and the east of CA, suggesting that seasonal signals of precipitation affected by the Asian monsoon, westerlies, ENSO, NAO, and PDO are the primary factor causing the linkage in dry/wet status. At long-term timescales, proxy records since the LGM in EA and CA reveal parallel dry/wet evolution in EA and the east of CA as well. A visual inspection from PMIP3 multi-model simulations in summer and winter shows that the insolation in different seasons control the intensity of westerlies and summer monsoon and further influence the summer and winter precipitation in EA and CA since the LGM. Overall, we suggest, in addition to the traditional difference caused by different precipitation regimes, that dry/wet status in EA and CA universally have inter-regional connections affected by seasonal signals of precipitation at multi-time scales.”

Results

A visual inspection of Figure 2a (the first EOF mode of mean annual precipitation during historical times) shows a spatial pattern which is quite different from the “simultaneous region of rain and heat periods” revealed in Figure 1. Hence, it is hard to justify that this EOF mode shows a clear “dipole mode” or a “seesaw pattern” as stated in section 3.1. Also, the variance contribution (10.3%) is clearly low, and therefore it is hard to argue that the pattern revealed by this EOF mode is a good representation of variance of the whole dataset. By contrast, a much clearer pattern emerges when this mode is decomposed in their seasonal components (Figure 3), and

when annual and winter-summer differences are analyzed (Figure 4). All this makes me think that Figure 2 is not contributing much to the data analysis. Perhaps a good alternative would be to add this Figure 1 to the supplements.

Response: Thanks very much for your suggestion. This is a good point. We have deleted some controversial descriptions and transferred Figure 2 to Supplemental materials.

Conclusions

The authors mention in the conclusions that “The multi-model simulations of multiple climatic elements explain the climate mechanism of differences and linkage in dry/wet status from EA and CA” (Lines 464-466), however there is no explanation as to what mechanisms they are talking about. Similarly, the conclusion mentions that “A compilation of 42 proxy records with reliable chronologies enables us to reassess the dry/wet status in EA and CA since the LGM.”, but then again there is no mention about what this evolution of the dry/wet status has been. The conclusion does not provide any clear link between the results of the modern “short-term” EOF analysis and the descriptions of paleoclimate trends that comprises the “long-term” analysis. It would be great that the authors are able to address these issues in a new version of the manuscript.

Response: Thanks very much for your suggestions. We have added a detailed description for the climate mechanism and the evolution of the dry/wet status. Meanwhile, we have also clearly described the link between the modern “short-term” analysis and the paleoclimate “long-term” analysis. The updated conclusions are reproduced below:

“

Conclusions

The summer precipitation regime in EA and the east of CA and the winter precipitation regime in the core region of CA reveal seasonal signals of precipitation. Using the EOF method, this study analyzes the spatiotemporal variations of precipitation in EA and CA. Results reveal that seasonal signals derived from the

simultaneity of rain and heat periods are important factors linking climate change modes in EA and CA at short-term timescales. A compilation of 42 proxy records with reliable chronologies enables us to reassess the dry/wet status in EA and CA since the LGM. In core regions of CA, dry/wet status is usually characterized by dry EH and wet LH. However, most records in the east of CA with simultaneous rain and heat periods hold the same dry/wet status with EA, i.e., the dry condition during the LGM and the wet climate during the EH and MH. This also reflects another meaning of seasonal signals at long-term timescales, namely the “dry-cold” pattern and “wet-warm” pattern. Concurrently, paleoclimate records reflect seasonal signals triggered by the insolation at long-term timescales. The multi-model ensemble simulations of multiple climatic elements explain the climate mechanism of differences and linkage in dry/wet status from EA and CA since the LGM. Results show that summer insolation influences the meridional temperature gradient and sea level pressure in the summer, changing the intensity of the westerly winds and summer monsoon and further controlling the summer precipitation in EA and the east of CA. Meanwhile, winter insolation contributes to the general warming in EA and the core region of CA, and in turn results in lower relative humidity, which ultimately increases winter precipitation during the LGM.

In general, the seasonal signals of precipitation derived from the simultaneity and non-simultaneity of rain and heat periods on short-term timescales can also affect the dry/wet status on long-term timescales, but their influencing factors are different. Due to the influence of precipitation seasonal signals on multi-time scales, CA with the winter precipitation regime and EA with the summer precipitation regime show traditional anti-phase in the evolution of dry/wet status. However, it is worth noting that in the east of CA with simultaneous rain and heat, there is the same dry/wet evolution as in EA. Therefore, we believe that seasonal signals can provide important insight for analyzing the differences and linkages in climate change between CA and EA on multi-time scales.

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Minor changes

Line 29: "...winter precipitation, suggested seasonal signals...".

I suggest adding "that" between after "suggested".

Response: Thanks very much for your carefulness. Done.

Line 30: I suggest removing the sentence "In particular, summer and winter precipitation in EA and CA is associated with the Asian monsoon, westerlies, ENSO, NAO, and PDO" it is a general sentence that does not provide critical information for an abstract which is -in my opinion- too long.

Response: Thanks very much for your suggestion. We have removed the sentence.

Lines 35-36: "PMIP3 multi-model simulation between the LGM and Mid-Holocene (MH) in summer and winter visually was...".

The word "visually" is not correctly placed in the sentences. Please rewrite (e.g., "A visual inspection...").

Response: Thanks very much for your suggestion. Based on your suggestion, we have rewritten the sentence to "A visual inspection from PMIP3 multi-model simulations in summer and winter shows that the insolation in different seasons control the intensity of westerlies and summer monsoon and relatively humid and further influence the summer and winter precipitation in EA and CA since the LGM.".

Line 63: "Therefore, exploring spatiotemporal climate and environment changes in EA and CA has attracted much research interest."

In my opinion this sentence does not lay the groundwork for the general question posed in its corresponding paragraph, and looks detached from the previous sentences. I suggest changing by "These contrasting climate regimes have attracted much research interest".

Response: Thanks very much for your suggestion. We have made corresponding revisions according to your suggestion.

Line 67: Could you please provide a definition for “multi-time scales”.

Response: Thanks very much for your carefulness. The multi-time scales mentioned here mainly include orbital, millennial, interdecadal and annual timescales, and we have added definitions in the text. We have added the definition in the main text. In addition, the discussion following this sentence provides a detailed review of research on multi-time scales.

Line 75: “...records in part regions of CA..” I suggest changing this text by “...records in some regions of CA”.

Response: Thanks very much for your suggestion. Done.

Line 79: I suggest changing “causing” by “caused”.

Response: Thanks very much for your suggestion. Done.

Lines 84-88: Please consider rewriting this sentence. It is full of technical jargon with no clear meaning.

Response: Thanks very much for your suggestion. We have rewritten this sentence, mainly splitting it up and removing some meaningless descriptions. The updated sentence is “The seasonal signals of precipitation, derived from the simultaneity of rain and heat periods, is an important climate phenomenon at the multi-time scale. It behaves as that the summer half-year at short-term timescales and warm period at long-term timescales get more precipitation than the winter half-year and cold period respectively.”.

Lines 97-100: In this long sentence the authors define the limits of the central Asia region, providing a reference to Figure 1. However, there is no mention where central Asia is in the figure. Particularly useful would be to add to the map where eastern central Asia is located as well. Then again in lines 110-111 the author refers to Figure 1 to mention the central and eastern Asia regions, but no references are in the map.

Response: Thanks very much for your suggestions. We have added a clear depiction

of Eastern Asia, Central Asia, the core region of CA, and the east of CA in Figure 1. Meanwhile, boundaries of CA and EA are added to all images in the study. The updated figure is reproduced below:

“

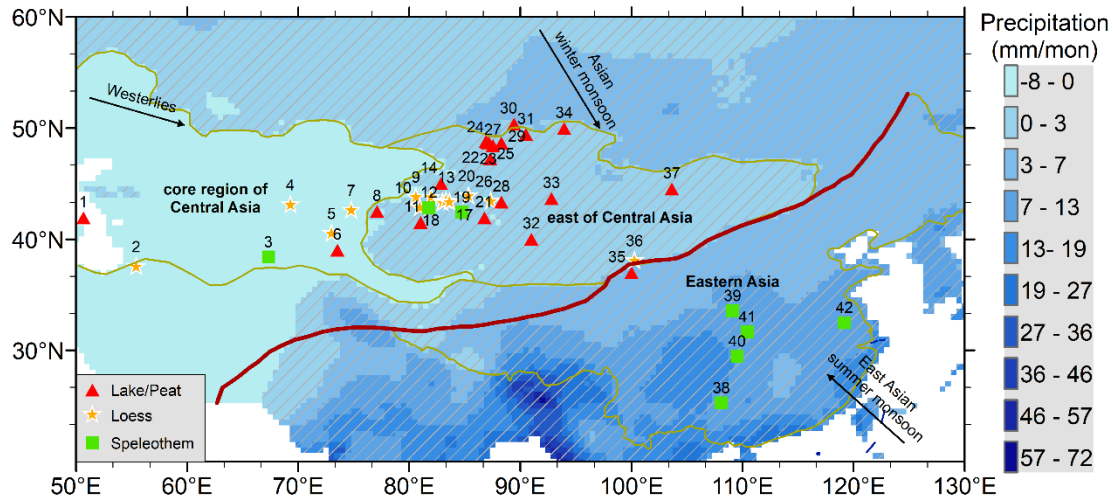


Figure. 1 Overview map showing the paleoclimate record sites selected in this study from EA and CA, the difference between summer and winter precipitation over 1965-2014 (shade), and the dominant circulation systems, including the westerlies, Asian winter monsoon and East Asian summer monsoon. The modern Asian summer monsoon limit (red solid line) is summarized by Chen et al. (2008, 2019). The gray slash represents the simultaneous region of the rain and heat periods. The brown solid line represents the range of CA, the core region of CA, the east of CA, and EA as defined in this study.

”

Lines 101-102: monsoon China” Please provide another term for this expression (e.g., The chinese monsoon”)

Response: Thanks very much for the comment. According to your suggestion, we amended the description to “we viewed Chinese monsoon region in the east and south of the modern Asian summer monsoon limit in China as EA.”.

Line 132: “The high-resolution monthly averaged data high resolution...”. Please remove “high resolution” as it is written twice.

Response: Thanks very much for the suggestion. Done.

Lines 149-151: “We used the Hurrell NAO index (station-based) to investigate the impact factor of midlatitude westerlies (Hurrell, 1995; Hurrell and Deser, 2009)”. What does “impact factor of midlatitude westerlies” mean? I would suggest adding a short definition of this concept in the main text.

Response: Thanks very much for your suggestion and reminder. Our original intention is to express the influence of NAO on mid-latitude westerlies. Thus, we have amended the sentence to “We used the Hurrell NAO index (station-based) to investigate the impact of NAO on midlatitude westerlies (Hurrell, 1995; Hurrell and Deser, 2009).”.

Line 162: Consider changing “index” by “indexes” or “indices”.

Response: Thanks very much for your carefulness. Done.

Lines 243-244: “...we conducted the EOF analysis on the seasonal precipitation in spring...”. I suggest replacing this sentence with “We conducted EOF analysis on spring precipitation data”.

Response: Thanks very much for your suggestion. Done.

Line 391: It would be desirable to add a statement indicating where the Tarim basin is.

Response: Thanks very much for your suggestion. Done.

Line 404: I would suggest replacing “linkage” by “similarities”.

Response: Thanks very much for your suggestion. Done.

Lines 448-449: “With recent global warming, some recent work also points out increasing summer precipitation in arid CA”. The word “recent” is written twice in the same sentence, please revise.

Response: Thanks very much for your suggestion. We have deleted the first “recent”.

Figures and tables

Figure 1. It would be great if the first image provided a clear depiction of eastern Asia and central Asia. This will be very useful since there is reference of these regions all throughout the text.

Response: Thanks very much for your suggestion. We have added a clear depiction of Eastern Asia, Central Asia, the core region of CA, and the east of CA in Figure 1. The updated figure is reproduced below:

“

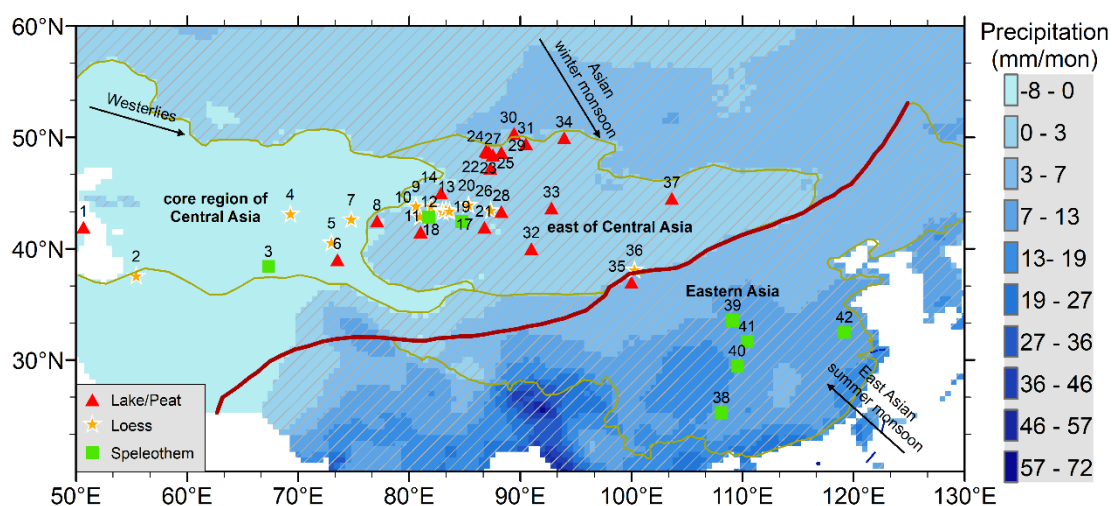


Figure. 1 Overview map showing the paleoclimate record sites selected in this study from EA and CA, the difference between summer and winter precipitation over 1965-2014 (shade), and the dominant circulation systems, including the westerlies, Asian winter monsoon and East Asian summer monsoon. The modern Asian summer monsoon limit (red solid line) is summarized by Chen et al. (2008, 2019). The gray slash represents the simultaneous region of the rain and heat periods. The brown solid line represents the range of CA, the core region of CA, the east of CA, and EA as defined in this study.

”

Table 1. is in my opinion too long, as it covers 4 pages of the main text. The location of the sites is also denoted in Figure 1. I may suggest adding this long table to the Supplements.

Response: Thanks very much for your suggestion. We have transferred Table 1 to the Supplement materials.

Figure 7. This should be Figure 5

Response: Thanks very much for your carefulness. We have checked the citation of figures throughout the text.

Figure 8. Figure 8 should be labeled “Figure 6”.

Response: Thanks very much for your carefulness. We have checked the citation of figures throughout the text.

Figure 5 should be labeled “Figure 7”.

Response: Thanks very much for your carefulness. We have checked the citation of figures throughout the text.