Responses to Reviewers' comments

We are grateful for the careful review and valuable feedback provided by the referees. Below, we provide responses to each of the reviewers' comments and indicate our plans to revise the manuscript. Comments from the referees are marked in *italics*, and our detailed responses to each comment are in blue font. We hope that the revision addresses the referees' concerns.

Reviewer 1

Comment 1: *The work titled "The Effects of Orbital Forcing on the East Asian Summer Monsoon for the Past 450 kyr" is intriguing. The authors have adeptly reviewed previous research progress and provided a detailed and clear explanation of the research methodology in this paper. However, the section discussing their own research findings appears to be rather weak, lacking a comprehensive showcase of the work's novel discoveries. Substantial revisions are necessary to better highlight the new contributions of the study.*

Response to comment 1: We appreciate the reviewer's constructive feedback. We believe the novelty of our study lies in demonstrating the varying impact of solar radiation variability on the East Asian monsoon across different regions. Particularly noteworthy is the discovery that summer precipitation patterns in Japan and China exhibit distinct responses, each governed by different atmospheric circulation mechanisms—the reinforced North Pacific High and sub-high, respectively. Based on your suggestions in Comment 1 and Comment 9, we will revise sections 3 and 4 to underscore the novelty of this study. Additionally, in response to Reviewer 2's suggestion, we will include simulation results beyond summer precipitation and incorporate additional proxy data for comparison in the revised paper. We will include simulated annual precipitation and summer temperature, which will be compared with simulated summer precipitation and proxies (speleothem $\delta^{18}O$, ^{10}Be and pollen records). We will also extend the model-proxy comparison in CLP and JP, by incorporating several other proxies that offer access to variabilities of annual mean temperature (CLP), winter monsoon (CLP) and annual temperature range (JP). These changes will alter Fig.2; additionally, we will add new figures, Fig.4 and Fig.5, as well as a new discussion on model validation and proxy-data comparison. These new figures are at the end of this manuscript.

Comment 2: *The term "calculate and calculation" in the given sentence (Abstract) is not accurate; it should be replaced with "simulated" or "simulation." Please check similar issue thorough the manuscript.*

Response to comment 2: These will be corrected as suggested.

Comment 3: *The initial segment of the abstract is well-structured; however, the latter part, starting from "The calculated change in summer precipitation is dominated by a 20-kyr precession cycle over China, highly consistent with cave d18O records in southeast China," becomes overly generalized. The author delves into various aspects, addressing the periodicity of simulated East Asian Summer Monsoon (EASM) precipitation in connection with forcing cycles. Subsequently, a correlation analysis is presented to establish the relationship between EASM precipitation intensity and solar radiation forcing. This deviates somewhat from the conventional approach of enhancing mechanistic understanding through numerical simulations. Therefore, in this section, I recommend that the author enrich the paper by incorporating more explanations related to climate dynamics*.

Response to comment 3: We thank the referee's constructive comment. Reviewer 2 also suggested rewriting the abstract. Considering the feedback from the two reviewers, we will rework the latter portion of the abstract. Specifically, we will revise the structure and wording to highlight the simulation outcomes: the influence of solar radiation forcing on summer precipitation across each East Asian monsoon region (SEC, CLP, and JP). The description of correlation analyses will be deleted from the abstract. Subsequently, we will delve into the underlying causes of simulated EASM variability from a climate dynamics perspective.

Comment 4: *The Introduction section lacks a recent review of the advancements in the comparison of data and models in East Asian paleomonsoonal dynamics.*

> *Sun, Y., H. Wu, G. Ramstein, B. Liu, Y. Zhao, L. Z. X. Li, X. Y. Yuan, W. C. Zhang, L. J. Li, L. W. Zou, T. J. Zhou. Revisiting the Physical Mechanisms of East Asian Summer Monsoon Precipitation Changes During the Mid-Holocene: A Data–model Comparison. Climate Dynamics 60, 1009–1022 (2023). https://doi.org/10.1007/s00382-022-06359-1.*
>
> *Sun, Y., H. Wu, M. Kageyama, G. Ramstein, L. Z. X. Li, N. Tan, Y. T. Lin, B. Liu, W. P. Zheng, W. C. Zhang, L. W. Zou, T. J. Zhou. 2021. The contrasting effects of thermodynamic and dynamic processes on East Asian summer monsoon precipitation during the Last Glacial Maximum: a data-model comparison. Climate Dynamics. 56, 1303–1316.*
>
> *Sun, Y., G. Ramstein, L. Z. X. Li, C. Contoux, N. Tan, T. J. Zhou. 2018. Quantifying East Asian summer monsoon dynamics in the ECP4.5 scenario with reference to the mid-Piacenzian warm period. Geophysical Research Letters, 45: 12,523–12,533.*

Response to comment 4: We thank the referee for providing information about these papers. We will incorporate them into the introduction.

Comment 5: *I could not agree with the authors statements "Section 4 discusses the possible climate systems that drive EASM variability". As we knew, orbital forcing via solar radiation changes can be attributed fundamental driver of climate changes, here the authors may discuss the possible climate systems associated with EASM variability.*

Response to comment 5: We will revise the phrasing accordingly.

Comment 6: *L86: "due to orbital forcing" needs to put behind the insolation changes*

Response to comment 6: Will be corrected as suggested.

Comment 7: *L131-135 should move to the method section somewhere.*

Response to comment 7: Will be corrected as suggested.

Comment 8: Title in section 3.1 is confusing, if I understand well the authors want to express "simulated……"?

Response to comment 8: Will be corrected.

Comment 9: *I have additional comments on the organization of the results section. In fact, it is not necessary to divide Section 3 into two subsections. The authors intend to focus on one specific task in this section: the model-data comparison of East Asian Summer Monsoon (EASM) precipitation evolution for the last 450,000 years. The current version contains numerous citations, making it challenging for the reader and reviewer to discern the extent of the authors' new findings. Consolidating the section into a single subsection may help clarify the presentation and emphasize the novel contributions of the authors. Please rephase these sections.*

Response to comment 9: As suggested, Section 3 will be combined into one section instead of being divided into subsections and will be modified to emphasize the novelty of this study.

Comment 10: *Figure.4-5-6 can be merged into one new Figure.*

Response to comment 10: Will be modified as suggested.

Comment 11: *L427: please use SEC instead South East China, as the abbreviation has already appeared.*

Response to comment 11: Will be corrected.

Reviewer 2

Comment 1: *This paper presented new results about how orbital forcing influence the East Asian Summer Monsoon by a group of new time-slice simulations. The authors conducted an extensive review of previous research. But more discussion should be added regarding their own results. (1) They only presented summer precipitation changes. But for East Asian summer monsoon, annual precipitation and summer temperature could also be presented and compared with proxy records; (2) They only show three proxy records. More model-proxy comparison should be added.*

Response to comment 1: We appreciate this feedback. Recognizing the significance of enriching the context of our simulation outcomes, we will incorporate additional data and discussion. In response to the concerns raised, we will make the following modifications in the revised manuscript:

(1) We will include the simulation results of annual precipitation and summer temperature variability in the three regions under investigation in our study (SEC, CLP, and JP). The simulation results will be compared with simulated summer precipitation and summer/annual precipitation proxies.
(2) Additionally, we will expand the dataset by incorporating several other proxies in CLP and JP that offer access to variabilities of annual mean temperature (CLP), winter monsoon (CLP), and annual temperature range (JP).

In response to Reviewer 1's suggestion, we will also modify the structure of section 3 and revise the sentences in section 3 and 4 to underscore the novelty of this study. These changes will alter Fig.2, additionally, we will add new figures, Fig.4 and Fig.5. We will also add a new discussion on model validation and proxy-data comparison based on new Fig. 2, Fig.4 and Fig.5. These new figures are at the end of this response file.

Comment 2: *The abstract is a bit confusing and should be rewritten.*

Response to comment 2: The abstract will be revised accordingly. Reviewer 1 also recommended revising the abstract. Taking into consideration the feedback from the reviewers, we will rewrite the latter portion of the abstract to enrich the explanation from the standpoint of climate dynamics and accentuate the novel facets of this study.

Comment 3: *Line 18 'Calculated' should be 'Simulated'. Similar expressions throughout the text need to be modified.*

Response to comment 3: These will be corrected as suggested.

Comment 4: *Line 41 23 kyr periodicity should be 23-kyr periodicity. Similar expressions throughout the text need to be modified, e,g. line 43.*

Response to comment 4: Will be corrected as suggested.

Comment 5: *Line 34 Reference should be (An et al., 2015)*

Response to comment 5: Will be corrected as suggested.

Comment 6: *Line 46 Logic question. How does 'EASM varies in phase with orbital cycles' suggest 'the EASM is affected by changes in ice volume'? The author seems to confuse '100-kyr cycle' and 'eccentricity cycle'.*

Response to comment 6: In this sentence we assumed that the eccentricity cycle is the underlying cause of the 100-kyr glacial-interglacial cycle, as written in Line 42−45. In response to the comment raised, we will rewrite the sentence in the revised manuscript, to avoid confusion between '100-kyr cycle' that exist in ice-volume, which can be a direct forcing factor for EASM, and the orbital 'eccentricity cycle':

> "Geological records indicate that the EASM is affected by changes in insolation or ice volume, or both (e.g., Cheng et al., 2016; Clemens et al., 2018; G. Liu et al., 2020; Sun et al., 2006, 2015, 2019) "

In the revised sentence we erased "the EASM varies in phase with orbital cycles," from the original sentence. As we address the periodicity of each geological record and corresponding possible climatic forcings in the following sentences, removing the phrase will not change our overall conclusions.

Comment 7: *Line 52 Rewrite the sentence.*

Response to comment 7: Thank you for the feedback. The sentence will be rewritten.

Comment 8: *Line 61 Rewrite the sentence.*

Response to comment 8: Thank you for the feedback. The sentence will be rewritten.

Comment 9: *Line 20 I do not agree that the results can come to the conclusion ... the importance of other forcing (e.g. ice sheet). Besides external forcings, the internal feedback should also be considered.*

Response to comment 9: We thank the referee for bringing this to our attention. It was not our intention to disregard the potential effects of internal feedback mechanisms. We acknowledge the significance of considering both external forcing and internal feedback in interpreting geological records. This sentence will be revised.

Comment 10: *Line 97 This model comprises an atmospheric general circulation model (AGCM) and a global ocean general circulation model (OGCM). This sentence could be deleted because everyone knows that a coupled GCM consists of AGCM and OGCM.*

Reply to comment 10: Will be corrected as suggested.

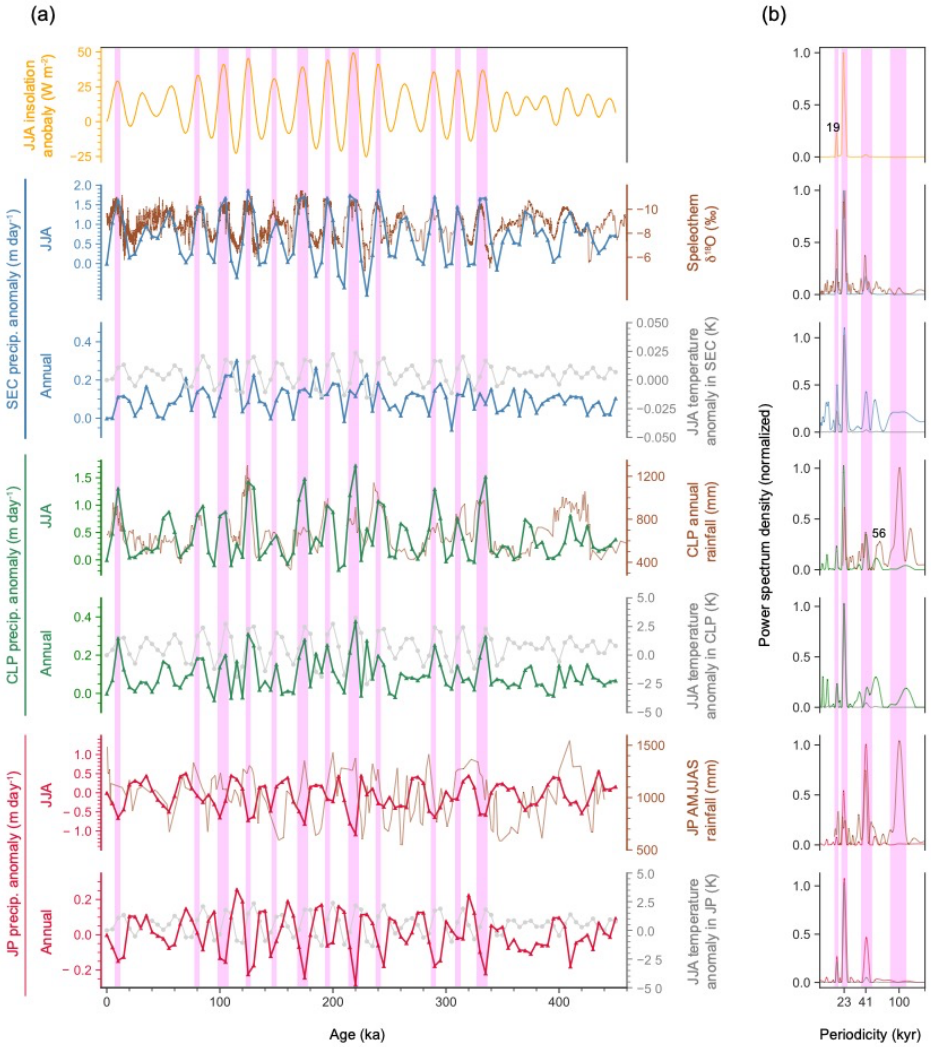
Comment 11: *More introduction on the model should be added, e,g, if there is ice-sheet model.*

Response to comment 11: We will provide additional elaboration on the land model and the sea ice simulation, specifically addressing the treatment of the ice sheet.

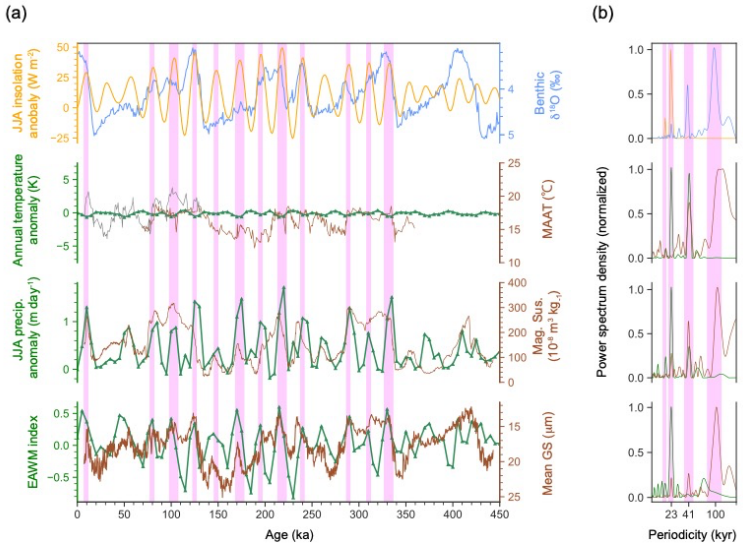
Comment 12: *Line 171 Why is the 100-kyr band from eccentricity? Why not ice volume?*

Response to comment 12: As clarified in our response to comment 6, this presupposes that the eccentricity cycle is responsible for the 100-kyr glacial-interglacial cycle. We will revise the sentence to prevent confusion between eccentricity cycle and ice-volume variability.

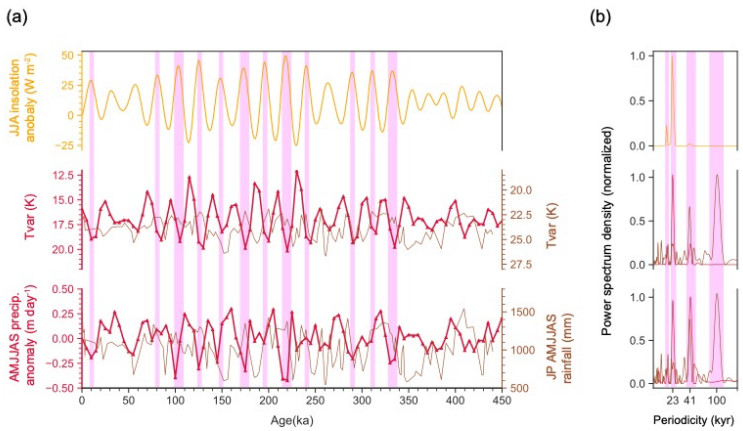
Figures



New Fig. 2 (a) Temporal variation in simulated JJA insolation anomaly (orange, W m-2), precipitation anomaly in SEC (blue), CLP (green), and JP (red). Insolation was averaged over 20° N–40° N. The precipitation anomaly unit is mm day$^{-1.}$ Brown lines indicate proxy records: Speleothem $\delta^{18}O$ over SEC (‰, Cheng et al., 2016), ^{10}Be-based annual rainfall over CLP (mm, Beck et al., 2018), and pollen-based AMJJAS rainfall variability in Lake Biwa in JP (K, Nakagawa et al., 2008). Grey lines indicate simulated annual temperature anomaly (K) in each region. Vertical pink bars in (a) denote strong periods (SP). (b) Normalized power spectrum density of (a) (kyr). Vertical pink bars in (b) denote the main orbital cycles (precession, obliquity, and eccentricity).



New Fig. 4 Model-proxy comparison in CLP. (a) Temporal variation in simulated JJA insolation anomaly (orange, W m^{-2}), benthic $\delta^{18}O$ stack (light blue, ‰, Lisiecki and Raymo, 2005), annual temperature (K) and JJA precipitation (mm day^{-1}) anomaly in CLP (green), East Asian Winter Monsoon index based on Wang and Cheng (2014). Insolation was averaged over 20° N–40° N. Brown lines indicate proxy records: Mean Annual Air Temperature reconstructed from brGDGT (℃), Magnetic Susceptibility (10^{-8} m^3 kg^{-1}), and Mean Grain Size (μm) (Thomas et al. 2016). Vertical pink bars in (a) denote strong periods (SP) as in Fig. 2. (b) Normalized power spectrum density of (a) (kyr). Vertical pink bars in (b) denote the main orbital cycles (precession, obliquity, and eccentricity).



New Fig. 5 Model-proxy comparison in Japan (JP). (a) Temporal variation in simulated JJA insolation anomaly (orange, W m^{-2}), annual temperature range Tvar (K) and AMJJAS precipitation (mm day^{-1}) anomaly in CLP (red). Insolation was averaged over 20° N–40° N. Brown lines indicate proxy records: Tvar (℃) and AMJJAS rainfall (mm). Vertical pink bars in (a) denote strong periods (SP) as in Fig. 2 and Fig. 4. (b) Normalized power spectrum density of (a) (kyr). Vertical pink bars in (b) denote the main orbital cycles (precession, obliquity, and eccentricity).