[Research Article # cp-egusphere-2026-3348]: "Muted orbital-scale Monsoon Variability over the Korean Peninsula" by Sinha et al.

Reply to the comments of reviewers

Please Note:

- **Responses are in blue bold text**
- Manuscript changes are in blue normal text

Referee 1

This manuscript presents a comprehensive and insightful investigation into the orbital-scale hydroclimate variability over the Korean Peninsula, integrating new speleothem $\delta^{18}O$ records with a series of isotope-enabled transient and time-slice model simulations. The authors convincingly demonstrate that the precessional signal in both precipitation and $\delta^{18}Op$ is muted over the Korean Peninsula due to compensating effects between oceanic and continental moisture sources, a finding that aligns with the recently proposed grand dipole pattern of the Asian summer monsoon. The study further highlights the potential utility of deuterium excess (d-excess) as a complementary proxy for capturing precessional moisture-source dynamics in this nodal region.

Overall, I find the analyses to be thorough, the model–data comparison carefully executed, and the interpretation physically coherent. The manuscript is rich in content, well-structured, and makes a valuable contribution to our understanding of pan-Asian monsoon dynamics on orbital timescales. I only have some minor comments.

We sincerely thank the reviewer for the positive and encouraging assessment of our work. We are grateful for the reviewer's constructive comments and have addressed them below.

Abstract: please add 1.2 in the first iCESM.

Reply: Corrected.

Please consistently use the "precession timescales", "precession scales" or "precession scale"

Reply: Thank you for pointing this out. We have ensured that the terms "precessional timescales" or "precessional-scale" are used consistently throughout the manuscript.

"To this end, we consider new and previously published δ18Osp records from two Korean stalagmites: ED1 (Eden Cave, (Jo et al., 2014)) and GE1 (Gwaneum Cave, (Jo et al., 2010)).' This sentence is **ambiguous, please clarify which one is new?**

Reply: We thank the reviewer for pointing out this ambiguity. We have revised the sentence to clearly distinguish between the newly generated and previously published records. Specifically, the Eden Cave (ED1) $\delta^{18}O_c$ record presented in this study is new, whereas the

ED1-$\delta^{13}C_c$ and Gwaneum Cave (GE1) records have been published previously (Jo et al., 2010, 2014).

Text revised. **“**To this end, we consider the Korean stalagmites’ 550,000-year $\delta^{18}O_c$ records (discontinuous), which include a new $\delta^{18}O_c$ record from the Eden Cave stalagmite (ED1) and previously published $\delta^{18}O_c$ records from Gwaneum Cave stalagmite (GE1) (Jo et al., 2010, 2014).**”**

Line 171: realistic ice-sheet forcings. I don’t think it is realistic, as there is no realistic reconstructions before LGM.

Reply: Corrected. “realistic” word removed.

Section S1; Figure S7 is not the source region.

Reply: In the revised version, the source regions are shown in Figure S7.

Line 314: please check the Fig. S3a, d. It’s not WNPSH.

Reply: Corrected. WNPSH is plotted in Fig. S5c and S5f

Fig. 6: coastal line should be black.

Reply: Fig. 6 revised.

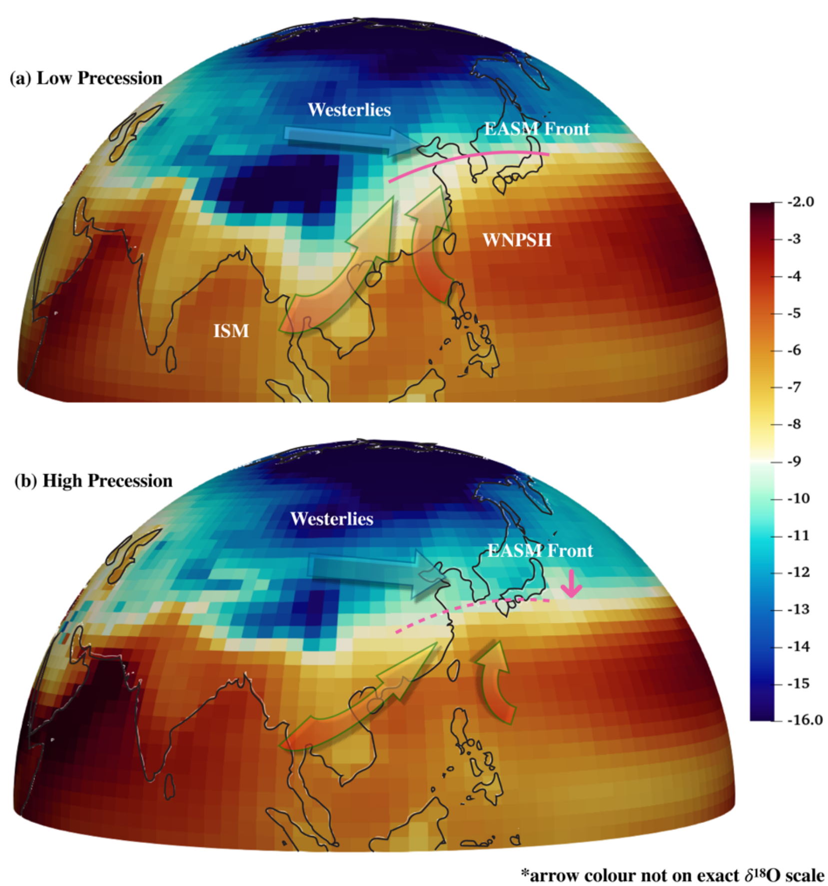


Figure 6: *Schematics of precession effects on summer East Asian monsoon circulation and spatial distribution of precipitation-$\delta^{18}O$ (blue to dark orange: depleted (low $\delta^{18}O$) to enriched (high $\delta^{18}O$) in ^{18}O in relative to low and high precession conditions). The thickness of the arrows represents the strength of the circulation systems. The solid and dashed pink lines indicate the location of the EASM front. (a) In the low precession case, ISM strengthening (a more southerly component), Westerlies (northward), and WNPSH (northwest) result in low (high) $\delta^{18}O_p$ over India to northern China (eastern Asia). The solid pink line indicates the EASM front location. (b) For the high precession case, the combined effects of the weakening of the ISM (more northeast component), the southward migration of the Westerlies, and the eastward movement of the WNPSH result in suppressed transport of Pacific moisture into the eastern domain of the EASM, result in high $\delta^{18}O_p$ across India to East Asia, however leading to relatively low $\delta^{18}O_p$ in eastern Asia. The interactions between two circulation systems (ISM and EASM) and the Westerlies create a nodal zone, which includes the Korean Peninsula (KP).*

Referee 2

The authors have completed a modeling study to look at the response of rainfall, rainfall d18O, deuterium excess, and relative humidity over orbital (precessional) time scales, to test the hypothesis that there should be muted precessional-scale variability over the Korean Peninsula.

Overall, the modeling data are important and provide nice targets for future work, including a look at d-excess in speleothem fluid inclusions.

Where I think the manuscript could be improved is in better making the case that there truly is a dampened precessional-scale d18O response in the calcite speleothems. As written, this is not yet clear and unambiguous. I don't think this is a fatal flaw, however, because most of the paper relies on the model results.

General Remarks:

We agree that the extent to which individual stalagmites faithfully preserve the modeled dampened precessional-scale $\delta^{18}O_p$ signal depends on site-specific cave processes and proxy fidelity.

We thank the reviewer for pointing out this and for the thoughtful views regarding the interpretation of speleothem isotope records. We recognize the importance of more explicitly establishing the model–data correspondence and have therefore strengthened the discussion of the Korean speleothem records and their interpretation in the revised manuscript. In particular, we now provide additional context from previous studies of Korean speleothems, including Jo et al. (2010, 2014, 2017), which have highlighted the importance of considering speleothem-specific characteristics, cave conditions, and the limitations in interpreting speleothem $\delta^{18}O$ records. Accordingly, we have addressed the reviewer's specific comments below.

Detailed comments:

Abstract: not only d-excess, but cap17O, which could be reconstructed from speleothem carbonate in the absence of usable fluid inclusions.

Reply: We agree that oxygen-17 excess (^{17}O-excess) is another promising isotopic tracer that can be reconstructed directly from speleothem carbonate, even in the absence of usable fluid inclusions. However, our proposal regarding d-excess is based on the simulations and analyses performed in this study. We neither simulated ^{17}O-excess nor performed any analysis in the present study. Thus, we have chosen not to include ^{17}O-excess in the Abstract. However, following the reviewer's suggestion, we have revised the "Summary and Concluding Remarks" section to discuss ^{17}O-excess alongside d-excess as an emerging proxy that provides additional constraints on paleo-hydrological conditions and moisture-source processes. The revised text now reads:

"The present study highlights the importance of a multi-proxy approach, utilizing additional speleothem proxies, such as trace elements, $\delta^{13}C$, and growth rate or frequency, in conjunction with fluid inclusion proxies (d-excess). While reconstructions of paleo-water d-excess provide valuable information on past moisture source conditions and evaporation processes, suitable fluid inclusions are not always preserved or available for analysis. In such cases, oxygen-17 excess (^{17}O-excess) measured directly from speleothem calcite, which is not sensitive to temperature variations, offers a promising complementary proxy (Sha et al., 2020, 2023). Future paired measurements of $\delta^{18}O$, d-excess, and ^{17}O-excess in speleothems could therefore provide a powerful framework to further test the circulation and moisture-source mechanisms inferred in this study. In addition, multiproxy speleothem data, along with data from marine and lacustrine archives, may provide further insights into regional hydroclimatic variability in the EASM region, and help reconcile different hydroclimatic records and elucidate their underlying mechanisms."

L35: I would state this as "near equilibrium", because we really don't know exactly what is isotopic equilibrium in carbonate isotopes. You get different answers from really slow-growing calcite (Daëron et al., 2019) than you do from shallow vadose-zone caves (Mickler et al., 2004).

Reply: We thank the reviewer for this important point and for the helpful references. We have revised "under equilibrium" to "under near-equilibrium" in the manuscript.

L35: I don't like the nomenclature "d18Osp". Speleothems are cave deposits that could be comprised of different minerals (gypsum, aragonite, calcite, etc.). What you are referring to is $\delta^{18}O$ in calcite, so $\delta^{18}O_c$ makes more sense, particularly because each mineral has a different temperature-dependent fractionation factor (alluded to in L35).

Reply: We thank the reviewer for this helpful suggestion. Accordingly, we have replaced $\delta^{18}O_{sp}$ with $\delta^{18}O_c$ throughout the manuscript and the figures to improve clarity and maintain consistency with the terminology used for the calcite-based speleothem records.

L74: I think you need to be more specific here: what about "recorded changes in the EASM"? Monsoon intensity, moisture source, changes in $\delta^{18}O$ without changes in rainfall amount, local rainfall amount, upstream rainout, etc? Many of the debates about the EASM arise from the specific interpretations of controlling factors, and you can be more precise when describing the meaning of the $\delta^{18}O_p$. I think it would be helpful to clearly state the authors' interpretation of the records and where they do and do not align (e.g., EASM $\delta^{18}O$ in calcite versus the loess plateau records).

Reply: We agree that our original wording ("recorded changes in the EASM") was too broad and did not clearly distinguish among the different hydroclimatic signals that may be recorded in the Chinese speleothem $\delta^{18}O_c$ proxy.

We have revised the text accordingly:

"On precessional timescales, a significant correlation exists between variability in Asian speleothem $\delta^{18}O_c$ records and NHSI, indicating that the latter primarily controls the large-scale circulation of the Asian summer monsoon and its associated moisture transport. Chinese speleothem $\delta^{18}O_c$ has commonly been interpreted as reflecting changes in large-scale monsoon circulation, integrated moisture transport, and upstream rainout processes, rather than local precipitation amount alone (Cai et al., 2015; Cheng et al., 2016; Kathayat et al., 2016; Wang et al., 2001). The interpretation of Chinese speleothem $\delta^{18}O_c$ as a proxy for local precipitation amount remains debated because independent precipitation-sensitive proxies from East Asia, such as loess magnetic susceptibility and reconstructed seawater $\delta^{18}O$ (Beck et al., 2018; Clemens et al., 2018; Sun et al., 2006; Zheng et al., 2022), show only a weak correspondence with the precessional cycle.**"**

L100: I think the writing style is really good, but more specifics will help the reader understand the issues at hand. What did the authors specifically elucidate about the mechanisms?

Reply: We have revised the text to provide more specific details on the mechanisms identified by Wen et al. (2024). They emphasize that large-scale circulation adjustments redistribute precipitation, producing an antiphase precipitation pattern between South Asia and Japan. Further, the $\delta^{18}O_p$ dipole is not simply an amount effect but also reflects shifts in moisture transport pathways and source contributions. The text is revised to:

"A recent study elucidated the mechanisms by which the precession-driven insolation forcing reorganizes the large-scale Asian summer monsoon circulation, including the strength of the southwesterly monsoon flow, the position of the upper-level westerly jet, and the position and strength of WNPSH, thereby altering regional precipitation and the relative contributions of remote and nearby moisture sources to $\delta^{18}O_p$ (Wen et al., 2024). These processes produce a grand dipole pattern of precipitation and $\delta^{18}O_p$ variability across the Asian monsoon region, characterized by an antiphase precipitation pattern between South Asia and Japan. This pattern suggests that precipitation variability on precessional timescales may be weaker over nodal regions such as the Korean Peninsula (KP).**"**

L108: "…determined by moisture sources" in what way, and how does $\delta^{18}O_p$ respond? The way this paragraph is written suggests that changes in moisture source control $\delta^{18}O_p$. But how can that be? Isn't it the differences in rainout history (i.e., the fraction remaining after rainout in Rayleigh distillation) that controls $\delta^{18}O_p$? Each air mass has a history, and the differences in $\delta^{18}O_p$ do not arise from their geographic sources, but rather from their histories prior to reaching the cave site.

Reply: Our intention was not to imply that the moisture source alone determines $\delta^{18}O_p$. Rather, in Eastern Asia, seasonal shifts in atmospheric circulation alter the dominant moisture-source regions and associated transport pathways, which in turn shape the upstream rainout history of air masses and influence the isotopic composition of precipitation. We have therefore revised the text for clarification:

"Under present-day conditions, precipitation isotope compositions over these regions are influenced by seasonal shifts in atmospheric circulation that alter moisture source regions, moisture transport pathways, and the associated upstream rainout history during transport (Araguás-Araguás et al., 1998; Jung et al., 2022; Kim et al., 2019; Zhu et al., 2023).**"**

L111: what processes control d-excess? Again, it isn't geographic origin that is the control, it is a climatic control through some combination of relative humidity at the evaporation source, condensation temperature, rain drop evaporation, etc. Try to go beyond simple associations (e.g, moisture source and d-excess) and focus instead on climate drivers so that the reader can understand the mechanisms controlling isotopes in rainfall and speleothem calcite.

Reply: We thank the reviewer for this valuable comment. We agree that our original wording placed too much emphasis on the geographic moisture source and did not sufficiently explain the underlying physical mechanisms controlling d-excess. We have revised the text to clarify that d-excess primarily reflects the climatic conditions during moisture evaporation, particularly relative humidity, while also being influenced by changes in atmospheric circulation, moisture transport pathways, and, to a lesser extent, secondary processes during transport. We further clarify that the observed seasonal cycle in d-excess over the Korean Peninsula arises from seasonal changes in these climatic conditions and associated air masses, rather than the geographic source region alone. The revised text now reads:

"Studies have suggested that variations in $\delta^{18}O_p$ over KP are strongly influenced by seasonal changes in atmospheric circulation and moisture transport, as reflected in the pronounced seasonality of precipitation deuterium excess (d-excess) (Lee et al., 2001; Park et al., 2006). The seasonal cycle in d-excess primarily reflects changes in climatic conditions in the moisture-evaporation region, particularly relative humidity during evaporation. Further, d-excess can also be modified by changes in dominant air masses and moisture transport pathways, as well as secondary processes such as condensation and raindrop evaporation. Consequently, the seasonal contrast in precipitation d-excess, with generally lower values in summer and higher values in winter, has been associated with the distinct climatic conditions accompanying the EASM and East Asian winter monsoon, respectively (Yoshimura and Ichiyanagi, 2009).**"**

L125: the water tagging and modeling experiments are useful, particularly when supporting modern observations. But models are not reality. Are there $\delta^{18}O$ records in precipitation that can reveal these changes?

Reply: We thank the reviewer for this important comment. We agree that model simulations alone cannot demonstrate the underlying mechanisms. Our present-day simulation is supported by modern precipitation isotope observations over East Asia (Figures S10, S11, S12), together with previous observational studies that relate seasonal variations in $\delta^{18}O_p$ to changes in atmospheric circulation, moisture transport, and source-region conditions (Araguás-Araguás et al., 1998; Jung et al., 2022; Kim et al., 2019; Zhu et al., 2023). In this study, the isotope-enabled model simulations and water-tagging experiments provide a physically consistent framework for interpreting these observations and extending the analysis to orbital timescales that cannot be directly observed.

L207: Define "Eastern Asia" as (22-45°N, 100-150°E) in the caption.

Reply: The caption has been revised accordingly.

L239-41: Can you show the antiphase $\delta^{18}O_p$ response in a time series? And the "suppressed" $\delta^{18}O_p$ signal over the KP? Only a snapshot is shown in the geographic plot in Figure 1c. The figures show substantial precessional scale variability, but line 241 states it is absent over the KP. This is going to be a source of confusion for a lot of readers.

Reply: Thank you for pointing out this potential source of confusion. The regional $\delta^{18}O_p$ response/anomaly is determined by the product of the EOF1 spatial loading and the associated PC1 amplitude difference, rather than by the PC1 alone. Although PC1 exhibits pronounced precessional variability, the EOF1 loading over the Korean Peninsula is close to zero, resulting in a strongly suppressed local $\delta^{18}O_p$ response. In contrast, regions with large positive or negative EOF1 loadings (e.g., South China and Japan) exhibit much larger precessional-scale changes.

Specifically, using the maximum peak-to-peak PC1 amplitude (~24‰), the estimated precessional-scale $\delta^{18}O_p$ changes are approximately -2.4‰ over South China (-0.10 × 24‰), +1.4‰ over Japan (0.06 × 24‰), but only +0.36‰ over the Korean Peninsula (0.015 × 24‰). Consequently, in the 130-ka orbitally forced simulation, the KP time series lacks a distinct or persistent precessional cycle, unlike neighboring regions where the precessional signal is readily apparent (Figure S16 in the submitted version).

To clarify this point for readers, we have now moved the region-wise time series figure to Figure S4 in the revised manuscript and revised the text accordingly.

"For the KP region, the simulated precessional signal in $\delta^{18}O_p$ is strongly suppressed (similar to the rainfall pattern), and no distinct precession cyclicity is evident in the simulated time series (Fig. S4).**"**

A

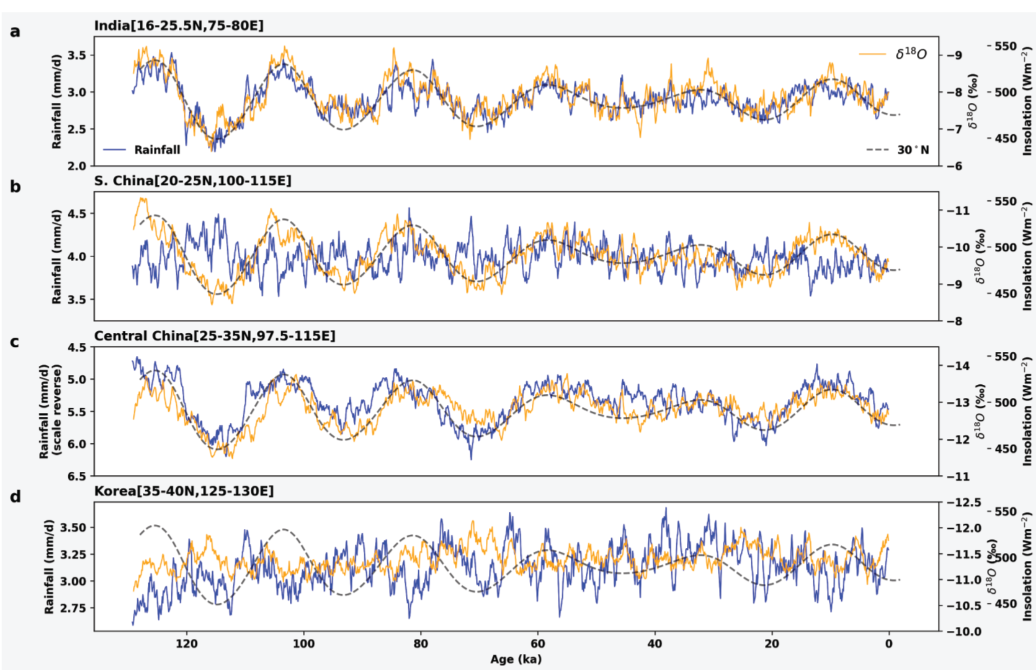


Figure S4: Simulated annual mean variations in precipitation (blue curves) for (a) India, (b) South (S.) China, (c) central China, and (d) Korea in the last 130ka from an orbitally forced transient simulation conducted with iCESM1.2. Orange curves in panel A (B) show precipitation-$\delta^{18}O$ (d-excess). Dashed black curves represent insolation (30 °N) insolation changes.

Note: Panel B is not shown here; please refer to the supplementary material.

In Figure 1d, it is stated that $\delta^{18}O_p$ are anomalies. With respect to what? A zero mean? Detrended? Or are they $\delta^{18}O$ ‰ VSMOW values? Aslo, are we really to believe that $\delta^{18}O_p$ varies by up to 24‰ VSMOW over a precessional cycle, as is seemingly the case for MIS5e to 5d? How realistic are these anomalies?

Reply: The $\delta^{18}O_p$ anomalies are zero-mean anomalies, calculated by subtracting the long-term annual mean from each individual annual mean value. Specifically, annual means were first computed from the monthly simulated $\delta^{18}O_p$ values, and the long-term mean of these annual means was then subtracted from each annual mean. No detrending was applied. We have clarified this in the revised manuscript.

Yes, simulated $\delta^{18}O$ values are reported with respect to VSMOW in ‰. As per the calculation described in the previous response, the MIS5e to 5d $\delta^{18}O_p$ response is determined by the product of the EOF1 loading over a particular region (Figure 1c) and the PC1 amplitude difference (between 5e and 5d, Fig. 1d). The simulated anomalies for MIS5e to 5d over western China would be around -0.15 × -24 ‰ = 3.6 ‰, which is very close to the China composite record anomalies (~4 ‰; Fig. 2b).

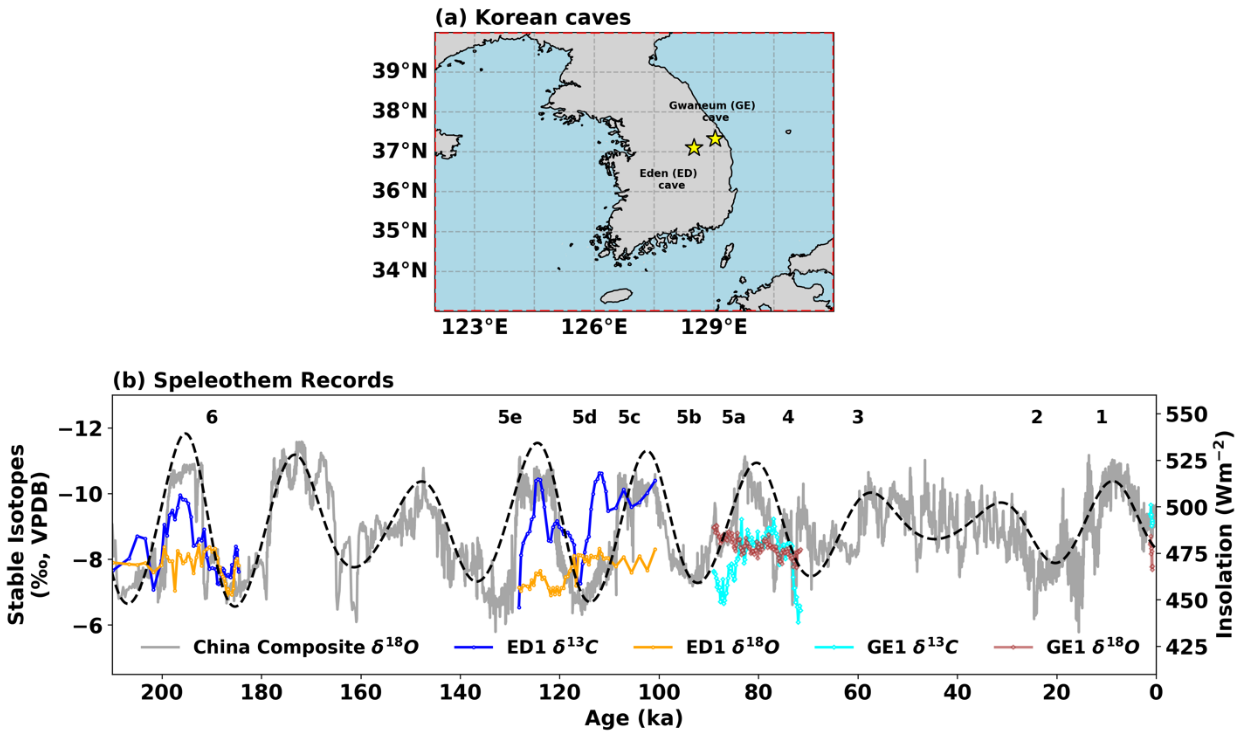
The caption has been revised to:

"Figure 1: First empirical orthogonal function (EOF1) and corresponding principal component (PC1) of precipitation (a, b) and precipitation-$\delta^{18}O$ (c, d) annual anomalies for the selected Eastern Asian region (22-45°N, 100-150°E). Annual anomalies were calculated by subtracting the long-term annual mean value (i.e., the climatological annual mean) from each annual mean. Annual means were obtained by averaging the monthly simulated values. Korean caves and cave locations for the China composite record are marked with yellow stars in (a) and (c). A red dashed box marks the Korean Peninsula (KP) region. The black dashed curve in (b, d) represents summer insolation at 30°N.**"**

L255 caption for Figure 2. Describe how the isotopes were normalized. It is hard to read the data with the large symbols on the Korean data. A solid line or smaller symbols would be easier.

Reply: Each individual isotope record was normalized using z-score standardization. The time mean was subtracted from each value, and the result was divided by the corresponding standard deviation. In the revised figure (Fig. 2), we have now plotted the actual isotopic compositions on the same scale to facilitate a direct comparison between the Korean $\delta^{18}O$ record and the Chinese composite $\delta^{18}O$ records. It clearly shows damped

signals in the Korean speleothem $\delta^{18}O_c$ record on precessional timescales. Further, the line color and thickness are revised as per the suggestion for better visibility (provided below).



"Figure 2: Korean Peninsula (red box, Figure 1) with Korean cave locations (a). Speleothem records ($\delta^{13}C$ and $\delta^{18}O$) from Korean caves (Gwaneum (GE) cave and Eden (ED) cave) and the Chinese caves composite-$\delta^{18}O$ record comparison (b). The marine isotope stage (MIS) is indicated above the curves in (b). The black dashed curve in (b) represents summer insolation at 30°N."

Regarding the KP speleothem isotope records (L513 and elsewhere): Are the modern measured $\delta^{18}O_c$ values anywhere near isotopic equilibrium as would be predicted based on drip water $\delta^{18}O$ and measured cave temperature? Do any of the samples replicate the isotope signal over coeval periods? Are the samples well-dated in terms of precision? Do the caves have stable cave-climates? Are any samples recrystallized or suffer from poor dating? These are all lines of evidence that can establish whether the material is robust as a paleoclimate proxy or close to isotopic equilibrium.

Reply: We agree that evaluating proxy fidelity, including isotopic equilibrium, replication, chronology, cave monitoring, and potential recrystallization/diagenesis, is essential when interpreting speleothem $\delta^{18}O$ records. The Korean caves and speleothem isotope records presented in this study have been previously published, including their chronology, mineralogy, and isotopic data (Jo et al., 2010, 2014). Although previous studies reported a stable cave environment based on monitoring data (Jo et al., 2014; Woo et al., 2006), dripwater data are currently unavailable.

We have revised Section 2.1 (Material and Methods) to address these points.

“We present $\delta^{18}O_c$ records from two Korean stalagmites obtained from ED (Eden Cave (Jo et al., 2014)) and GE (Gwaneum Cave (Jo et al., 2010)) (see locations in Fig. 1 and Fig. 2a), which grew intermittently. The $\delta^{18}O_c$ records for ED1 and GE1 stalagmites were previously measured along with stable carbon isotope ($\delta^{13}C_c$) within the scope of Jo et al. (2010, 2014). However, the ED1 $\delta^{18}O_c$ record remained unpublished to date. Further details regarding the GE1 and ED1 records and their covered time spans are provided in Supplementary Table S1.

Previous studies of the ED1 and GE1 stalagmites documented their growth fabrics, depositional histories, stable cave environment, and stable-isotope characteristics, thereby constraining the conditions under which their isotopic signals were preserved. The principal growth phase of GE1 was interpreted to have formed under conditions approaching isotopic equilibrium, based on its calcite textures and stable-isotope characteristics, whereas intervals associated with coralloid growth and limited dripwater supply were identified as distinct depositional phases (Jo et al., 2010). ED1, similarly, contains well-characterized growth intervals separated by hiatuses and changes in depositional fabric, supported by an extensive U-series chronology (Jo et al., 2006, 2014). Although certain intervals exhibit high $\delta^{18}O_c$ variability, partially due to the low resolution of the records, the absence of a pronounced precessional cycle is notably observed in the $\delta^{18}O_c$ profiles (Fig. S1). From another Korean cave, Jo et al. (2017) identified clear millennial-scale resemblances among late Holocene $\delta^{18}O_c$ records from both Korean and Chinese stalagmites, providing an in-depth discussion on the issue in question. These observations suggest that, despite potential site-specific modifications of the calcite isotopic signal, the well-characterized portions of these records can provide observational constraints for evaluating the modeled $\delta^{18}O_p$ response over the KP.

”

A positive correlation between $\delta^{13}C_c$ and $\delta^{18}O_c$ has traditionally been interpreted as evidence of kinetic isotope fractionation associated with CO_2 degassing resulting from calcite precipitation (Hendy, 1971; Mickler et al., 2004). Here, we present scatter plots of speleothem $\delta^{13}C_c$ versus $\delta^{18}O_c$ for ED1 and GE1 (Figure R1). In our records, the weak correlation, explaining <16% of the variance, suggests that kinetic effects are not the dominant driver of isotopic variations.

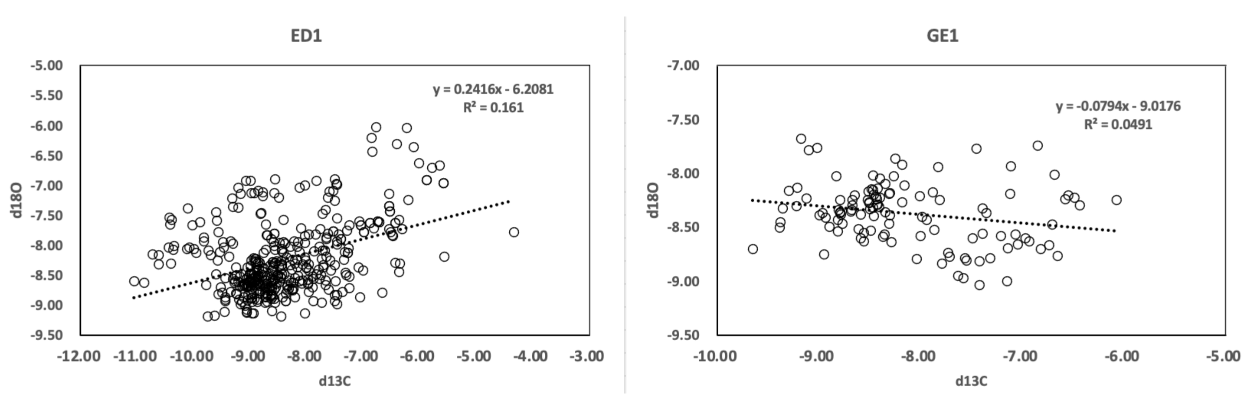


Figure R1: Scatter diagram between $\delta^{13}C$ and $\delta^{18}O$ of stalagmites from Eden Cave (ED1, left panel) and Gwaneum Cave (GE1, right panel).

I recognize that some of these data have already been published, but the authors haven't demonstrated that the speleothems are trustworthy proxies of drip water $\delta^{18}O$, hence the interpretation of dampened orbital signals is not convincing yet, but it could be made so with this information. An alternative hypothesis is that the KP $\delta^{18}O_c$ records reflect isotopic disequilibrium between drip waters and calcite, and therefore do not reflect climate changes.

Reply: We thank the reviewer for raising this point. We agree that the extent to which speleothem $\delta^{18}O_c$ faithfully records drip-water $\delta^{18}O$ is a key consideration when interpreting speleothem isotope records. The possibility that isotopic disequilibrium or other cave-specific processes may modify the speleothem signal represents an important alternative hypothesis.

However, our principal finding is that the modeled precipitation $\delta^{18}O_p$ exhibits a strongly suppressed orbital-scale response over the Korean Peninsula relative to neighboring regions. When we compare the Chinese composite $\delta^{18}O$ record to the Korean $\delta^{18}O$ speleothem proxy data (Figure 2b, also provided above), it is immediately clear that relative changes in Korean $\delta^{18}O$ are small. In addition, a strong kinetic effect would be required to suppress speleothem $\delta^{18}O$ enough to mask a 4‰ precession variability. The lack of a strong positive correlation between $\delta^{18}O$ and $\delta^{13}C$ (Figure R1) supports our interpretation that the dampened $\delta^{18}O$ in Korean speleothems is not attributable to kinetic isotope effects.

Discussion is revised to:

"The near absence of precessional variability in hydroclimate predicted by the models can now be tested using our speleothem isotope data from the KP (Fig. 2a). The Korean speleothem stable carbon isotope ($\delta^{13}C_c$) records aligns well with Chinese $\delta^{18}O_c$ during overlapping periods (Fig. 2b), and the growth frequency of Korean speleothems exhibits clear signals that correspond to orbital-timescale hydrologic changes (Jo et al., 2014). However, Korean stalagmites records show no apparent precessional signal (Fig. 2b). The weak covariation between $\delta^{13}C_c$ and $\delta^{18}O_c$ (ED1, $R^2 = 0.16$, $p < 0.01$; GE1, $R^2 = 0.04$, $p = 0.02$) suggests that kinetic effects are unlikely to be the primary control on their variability. Moreover, the precessional-scale variability in the Korean $\delta^{18}O_c$ records is strongly suppressed relative to the relatively pronounced (~4‰) variability observed in the Chinese composite $\delta^{18}O_c$ record (Fig. 2b). This observational evidence is consistent with the muted response of $\delta^{18}O_p$ over the KP to precessional forcing in the simulations (Fig. 1c).**"**

L344: Should read "… enriched in heavy isotopes during Pmin", as it is not possible to enrich Pmin. It is accurate to state that (paraphrasing) "$\delta^{18}O$ values are 0.22‰ higher during Pmin", but it is not correct that $\delta^{18}O$ (which contains both 18O and 16O in its definition) can be "enriched" or "depleted" unless you are referring to the isotope of interest (e.g., enriched in 18O, enriched in 16O). See Zach Sharp's free online textbook for recommendations on correct stable isotopic terminology.

Reply: Thank you for this important clarification regarding stable isotopic terminology. We have carefully reviewed the entire manuscript and revised the relevant phrasing to

ensure consistency with commonly accepted usage in speleothem and paleoclimate research. These revisions improve the clarity and physical precision of our manuscript.

“Using the isotope tagging method, we calculated summer precipitation-weighted $\delta^{18}O_p$ values (Sect. S1 and Table S2) at the KP (inset, Fig. 5). We find that the moisture transported from the SNP oceanic region to the KP is characterized by anomalously high $\delta^{18}O$ values (i.e., enriched in ^{18}O) during P_{min} relative to P_{max} by +0.22‰, with EAS land moisture also contributing higher $\delta^{18}O$ values ($P_{min} – P_{max}$ = +0.31‰). However, the moisture transported from the distant Indian Ocean (EQI) and the land (SAS) regions shows a compensating effect, with lower $\delta^{18}O$ values (EQI + SAS = -0.38‰). Combining the positive $\delta^{18}O$ contributions from the SNP and EAS regions with the negative contributions from the EQI and SAS regions results in a small net increase in $\delta^{18}O$, corresponding to higher JJA $\delta^{18}O_p$ values (+0.22 ‰) over the KP during P_{min}. On annual timescales (inset, Fig. S7), this compensation is even more pronounced, leading to a slight net depletion in ^{18}O (lower in $\delta^{18}O_p$ values) over the KP by -0.10‰ (P_{min} - P_{max}). Furthermore, the tagging experiment reveals that, for annual means, the Indian region plays a negligible role in precessional-scale changes in precipitation and $\delta^{18}O_p$ over the KP (Fig. S7, Table S2).**”**

L406: Important distinction: in *some* speleothems, not all. This is important because the paper has implications for future work to test their model-based results. I would broaden the discussion here, and later, to include Δ17O, which co-varies with d-excess in precipitation but is not sensitive to temperature variations, and could, in principle, be measured in speleothem carbonate.

Reply: We thank the reviewer for this valuable suggestion. We have revised the text to clarify this distinction.

The text has been revised to:

“Studies have shown that the d-excess in paleowater can, in fact, be recovered from fluid-inclusion data in certain speleothems**”**

References

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