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 establishing this model–data correspondence more explicitly 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., which has 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.**

**Please Note:**

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

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 form of the 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 inclusions (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 to help reconcile regional hydroclimatic records from the EASM region 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 reference suggestions. "under equilibrium" corrected to "under near-equilibrium" in the revised 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 standard terminology.**

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 Chinese speleothem $\delta^{18}O_c$ records.**

**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). Its interpretation of 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 summarize the mechanisms identified by Wen et al. (2024). In brief, they emphasize that large-scale circulation adjustments redistribute rainfall, producing an antiphase precipitation pattern between South Asia and Japan. Further, the $\delta^{18}O_p$ dipole is not simply an amount effect but 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/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, which predicts weaker precessional variability over the 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, along with the associated transport pathways and upstream rainout history, all of which influence the isotopic composition of precipitation. We have therefore revised the text for clarification:**

**"**Under present-day conditions, the observed variations in $\delta^{18}O_p$, precipitation isotope compositions over these regions are influenced by seasonal shifts in atmospheric circulation that alter source regions, moisture transport pathways, and the associated upstream rainout history during transport"

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, K.S. et al., 2001; Park, Y. 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, isotopic composition can be modified by shifts in dominant air masses and moisture transport pathways, as well as secondary processes (such as condensation temperature and raindrop evaporation). Consequently, summer precipitation, derived mainly from warm and humid oceanic air masses, is characterized by relatively low d-excess values, whereas winter precipitation exhibits higher d-excess values owing to moisture transported under colder and drier atmospheric conditions associated with the East Asian winter monsoon (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, 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.**

**Text has been revised to:**

**"**To this end, we consider the Korean stalagmites' 550,000-year stable oxygen ($\delta^{18}O_c$) and carbon ($\delta^{13}C_c$) isotope records (discontinuous), which include a new $\delta^{18}O_c$ record from the Eden Cave stalagmite (ED1) and previously published records from ED1 and Gwaneum Cave (GE1) (Jo et al., 2010, 2014). Moreover, to investigate the mechanisms linking large-scale atmospheric circulation, moisture transport, and precipitation isotope variability over the Korean Peninsula on orbital timescales, we conducted a series of transient climate simulations, time-slice experiments, and water-tagging simulations.**"**

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: The regional-wise time series presented in Figure S16 Panel A, provided below, where the Korean Peninsula $\delta^{18}O_p$ record lacks a clear precessional signal compared with neighboring regions.**

**The regional $\delta^{18}O_p$ response/anomaly is determined by the product of the EOF1 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 substantially reduced 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 highest 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‰). While the Korean Peninsula exhibits a small-amplitude $\delta^{18}O_p$ response, the 130-ka orbitally forced simulation does not show a clear or persistent precessional cycle over the Korean Peninsula, in contrast to neighboring regions where the precessional signal is readily apparent (Figure S16).**

**We have now moved Figure S16 (Figure S4 in the revised manuscript) and revised the text to avoid any potential confusion at this stage.**

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

A

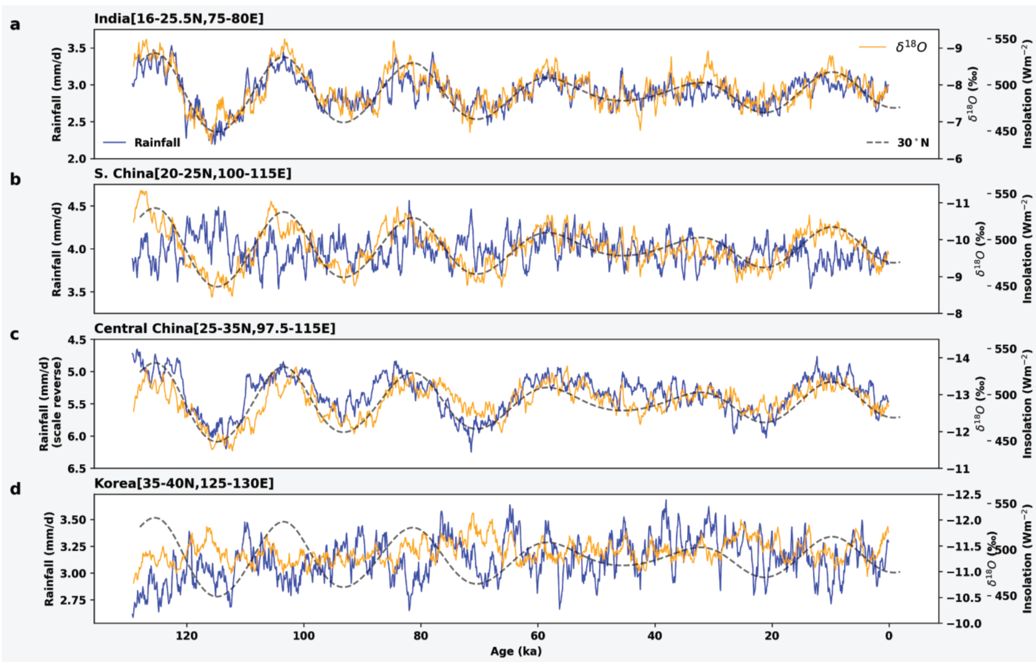



Figure S4: Simulated annual mean variations in precipitation (blue curves) for (a) India, (b) South (S.) China, (c) central China, and (d) Korea in the last 130ka from an orbitally forced transient simulation conducted with iCESM1.2. Orange curves in panel A (B) show precipitation-$\delta^{18}O$ (d-excess).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

**Note: The 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 mean annual value from each annual mean. 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 with respect to VSMOW in ‰. As per the calculation described in the previous response, the MIS5e to 5d $\delta^{18}O_p$ response can be determined by the product of the EOF1 loading over a particular region (Figure 1c) and the PC1 amplitude difference (between 5e and 5d, Figure 1d). The simulated anomalies for MIS5e to 5d over western China would be around -0.015 × -24 ‰ = 3.6 ‰, which is very close to the China composite record anomalies (~4 ‰; Figure 2b).**

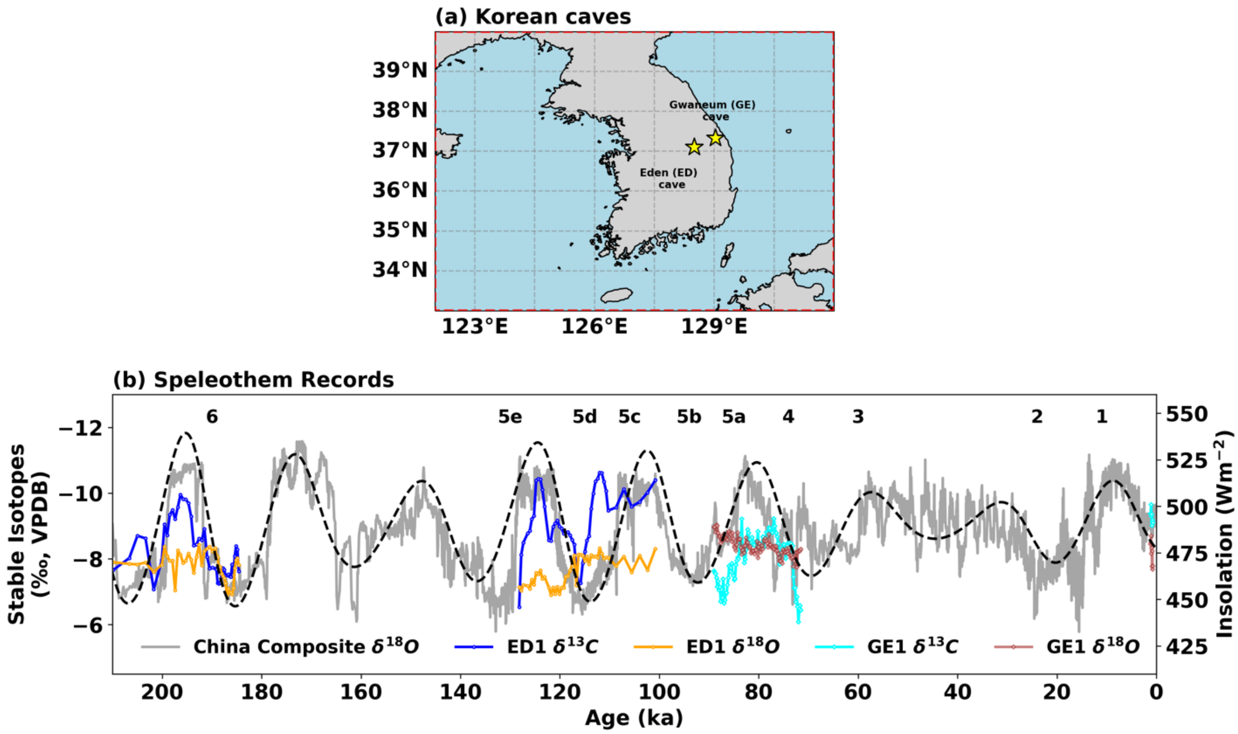
**The text and caption have been revised to:**

**“**To extract the dominant modes of variability in Eastern Asia, we used precipitation amount and $\delta^{18}O_p$ annual anomalies from the transient iCESM-130ka simulation. 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. We calculated the first Empirical Orthogonal Function (EOF1) and the corresponding principal component (PC1) time series for the selected Eastern Asian region (22-45°N, 100-150°E), including eastern China, the KP, and Japan (Fig. 1).**”**

**“**Figure 1: First empirical orthogonal function (EOF1) and corresponding principal component (PC1) of annual mean precipitation (a, b) and precipitation-$\delta^{18}O$ (c, d) for the selected Eastern Asian region (22-45°N, 100-150°E). Korean caves and cave locations for the China composite record are marked by yellow stars in (a, 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, we have now plotted the actual isotopic compositions on the same scale to better compare the Korean and 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 (δ$^{13}$C and δ$^{18}$O) from Korean caves (Gwaneum (GE1) cave and Eden (ED1) cave) and the Chinese caves composite-δ$^{18}$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 δ$^{18}O_c$ values anywhere near isotopic equilibrium as would be predicted based on drip water δ$^{18}$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 δ$^{18}$O records. The Korean caves and speleothem isotope records mentioned in this study have been previously published, including their chronology, mineralogy, and isotopic data (Jo et al., 2010, 2014). Although previous studies have presented monitoring data from these caves indicating a stable cave environment (Jo et al., 2014; Woo et al., 2006), dripwater data are unavailable.**

**We have revised Section 2.1 (Material and Methods) to address the issues raised above.**

"We present δ$^{18}O_c$ records from two Korean stalagmites obtained from ED1 (Eden Cave (Jo et al., 2014)) and GE1 (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 were previously measured along with $\delta^{13}C_c$ within the scope of Jo et al. (2010, 2014). However, the ED1 $\delta^{18}O_c$ record remained unpublished to date. Further details on the GE1 and ED1 records and the period covered 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 drip-water 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., 2014, 2006). 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, although 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 provide a scatter plot 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 their variations.**

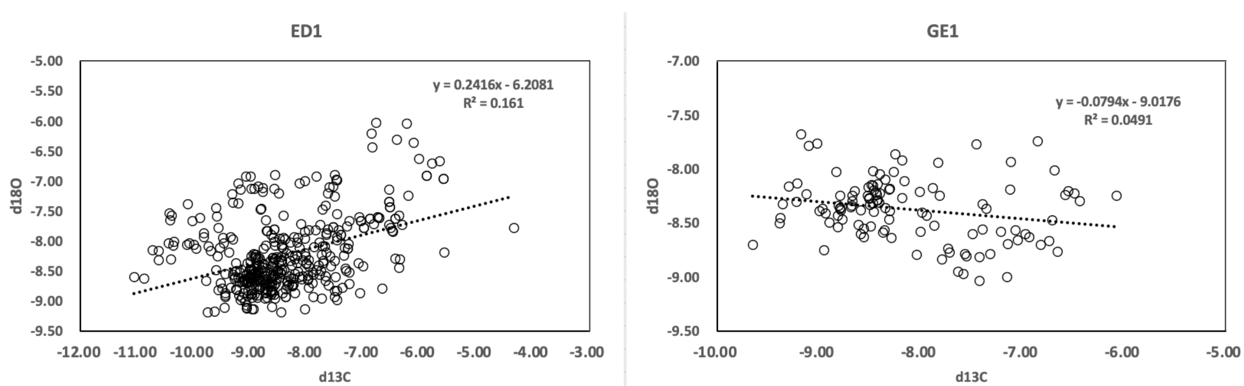



**Figure R1: Scatter diagram between $\delta^{13}C$ and $\delta^{18}O$ of stalagmites from Eden Cave (ED1, left panel) and Gwaneum Cave (GE1, right panel).**

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, strong kinetics would be required to affect speleothem $\delta^{18}O$ enough to mask a 4‰ precession variability. The lack of a 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 (red curves, Fig. 2b). The weak covariation between $\delta^{13}C_c$ and $\delta^{18}O_c$ (ED1, $R^2 = 0.16$, $p < 0.01$; GE1, $R^2 = 0.05$, $p = 0.02$) suggests that kinetic effects are unlikely to be the dominant 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: We revised the text as suggested. We have carefully reviewed the manuscript and revised the terminology (enriched (high) and depleted (low) in $^{18}O$ ($\delta^{18}O$)) throughout to ensure consistency with commonly accepted usage in speleothem and paleoclimate research. These revisions improve the clarity and precision of the manuscript.**

"Using the tagging methods and calculating summer precipitation-weighted $\delta^{18}O_p$ values (Sect. S1 and Table S2) at KP (inset, Figure 5), we find that the moisture transported from the SNP oceanic region to the KP is anomalously enriched in $^{18}O$ (i.e., characterized by higher $\delta^{18}O$ values) during $P_{min}$ relative to $P_{max}$ (+0.22‰), with additional contributions of high $\delta^{18}O$ values also from EAS land moisture ($P_{min} - P_{max}$ = +0.31‰). However, the transport of moisture from the distant Indian Ocean (EQI) and the land (SAS) regions shows a compensating effect (i.e., lower in $\delta^{18}O$ values, EQI + SAS = -0.38‰). Combined the SNP and EAS effects (high $\delta^{18}O$) and the EQI and SAS contributions (low $\delta^{18}O$) result in a small net anomalous enrichment of $^{18}O$ in JJA $\delta^{18}O_p$ (+0.22 ‰) over KP during $P_{min}$. On annual timescales (inset, Fig. S7), the compensation is even more pronounced, leading to a small net low in $\delta^{18}O_p$ (depleted in $^{18}O$) over the KP region by -0.1‰ ($P_{min}$ - $P_{max}$)."

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: Text revised** "Studies have shown that the d-excess in paleowater can, in fact, be recovered from fluid-inclusion data in some speleothems"

**The implication of the 17O excess has been added to the summary of this study, as suggested.**

References

Daëron, M., Drysdale, R. N., Peral, M., Huyghe, D., Blamart, D., Coplen, T. B., Lartaud, F., and Zanchetta, G., 2019, Most Earth-surface calcites precipitate out of isotopic equilibrium: Nature Communications, v. 10, no. 1, p. 429.

Mickler, P. J., Banner, J. L., Stern, L., Asmerom, Y., Edwards, R. L., and Ito, E., 2004, Stable isotope variations in modern tropical speleothems: Evaluating equilibrium vs. kinetic isotope effects: Geochimica et Cosmochimica Acta, v. 68, no. 21, p. 4381.

**References**

Araguás-Araguás, L., Froehlich, K., and Rozanski, K.: Stable isotope composition of precipitation over southeast Asia, J. Geophys. Res., 103, 28721–28742, https://doi.org/10.1029/98JD02582, 1998.

Beck, J. W., Zhou, W., Li, C., Wu, Z., White, L., Xian, F., Kong, X., and An, Z.: A 550,000-year record of East Asian monsoon rainfall from $^{10}$Be in loess, Science, 360, 877–881, https://doi.org/10.1126/science.aam5825, 2018.

Cai, Y., Fung, I. Y., Edwards, R. L., An, Z., Cheng, H., Lee, J.-E., Tan, L., Shen, C.-C., Wang, X., Day, J. A., Zhou, W., Kelly, M. J., and Chiang, J. C. H.: Variability of stalagmite-inferred

Indian monsoon precipitation over the past 252,000 y, Proc. Natl. Acad. Sci. U.S.A., 112, 2954–2959, https://doi.org/10.1073/pnas.1424035112, 2015.

Cheng, H., Edwards, R. L., Sinha, A., Spötl, C., Yi, L., Chen, S., Kelly, M., Kathayat, G., Wang, X., Li, X., Kong, X., Wang, Y., Ning, Y., and Zhang, H.: The Asian monsoon over the past 640,000 years and ice age terminations, Nature, 534, 640–646, https://doi.org/10.1038/nature18591, 2016.

Clemens, S. C., Holbourn, A., Kubota, Y., Lee, K. E., Liu, Z., Chen, G., Nelson, A., and Fox-Kemper, B.: Precession-band variance missing from East Asian monsoon runoff, Nat Commun, 9, 3364, https://doi.org/10.1038/s41467-018-05814-0, 2018.

Hendy, C. H.: The isotopic geochemistry of speleothems—I. The calculation of the effects of different modes of formation on the isotopic composition of speleothems and their applicability as palaeoclimatic indicators, Geochimica et Cosmochimica Acta, 35, 801–824, https://doi.org/10.1016/0016-7037(71)90127-X, 1971.

Jo, K., Woo, K. S., Cheng, H., Edwards, L. R., Wang, Y., Kim, R., and Jiang, X.: Textural and carbon isotopic evidence of monsoonal changes recorded in a composite-type speleothem from Korea since MIS 5a, Quat. res., 74, 100–112, https://doi.org/10.1016/j.yqres.2010.04.005, 2010.

Jo, K., Woo, K. S., Yi, S., Yang, D. Y., Lim, H. S., Wang, Y., Cheng, H., and Edwards, R. L.: Mid-latitude interhemispheric hydrologic seesaw over the past 550,000 years, Nature, 508, 378–382, https://doi.org/10.1038/nature13076, 2014.

Jo, K., Yi, S., Lee, J.-Y., Woo, K. S., Cheng, H., Edwards, L. R., and Kim, S.-T.: 1000-Year Quasi-Periodicity of Weak Monsoon Events in Temperate Northeast Asia since the Mid-Holocene, Scientific Reports, 7, 15196, https://doi.org/10.1038/s41598-017-15566-4, 2017.

Jo, K. N., Woo, K. S., Kim, J. C., Yang, D. Y., Lawrence, E. R., Cheng, H., and Wang, Y.: Paleoclimatic implications recorded in the late Pleistocene stalagmite, Eden Cave, Danyang, Korea, jgsk, 42, 127–142, https://doi.org/10.14770/jgsk.2006.42.1.127, 2006.

Jung, Y.-Y., Shin, W.-J., Seo, K.-H., Koh, D.-C., Ko, K.-S., and Lee, K.-S.: Spatial distributions of oxygen and hydrogen isotopes in multi-level groundwater across South Korea: A case study of mountainous regions, Science of The Total Environment, 812, 151428, https://doi.org/10.1016/j.scitotenv.2021.151428, 2022.

Kathayat, G., Cheng, H., Sinha, A., Spötl, C., Edwards, R. L., Zhang, H., Li, X., Yi, L., Ning, Y., Cai, Y., Lui, W. L., and Breitenbach, S. F. M.: Indian monsoon variability on millennial-orbital timescales, Sci Rep, 6, 24374, https://doi.org/10.1038/srep24374, 2016.

Kim, S., Han, Y., Hur, S. D., Yoshimura, K., and Lee, J.: Relating Moisture Transport to Stable Water Vapor Isotopic Variations of Ambient Wintertime along the Western Coast of Korea, Atmosphere, 10, 806, https://doi.org/10.3390/atmos10120806, 2019.

Lee, K.S., Woo, N.C., and Kim, K.: Factors controlling stable isotope composition of precipitation in Northeast Asia, JGSK, 37, 183–192, 2001.

Mickler, P. J., Banner, J. L., Stern, L., Asmerom, Y., Edwards, R. L., and Ito, E.: Stable isotope variations in modern tropical speleothems: Evaluating equilibrium vs. kinetic isotope effects, Geochimica et Cosmochimica Acta, 68, 4381–4393, https://doi.org/10.1016/j.gca.2004.02.012, 2004.

Park, Y., Lee, K.S., and Yu, J.Y.: Seasonal variations of dissolved ions and oxygen and hydrogen isotopic compositions of precipitation in Chuncheon, Korea, JGSK, 42, 283–292, 2006.

Sha, L., Mahata, S., Duan, P., Luz, B., Zhang, P., Baker, J., Zong, B., Ning, Y., Brahim, Y. A., Zhang, H., Edwards, R. L., and Cheng, H.: A novel application of triple oxygen isotope ratios of speleothems, Geochimica et Cosmochimica Acta, 270, 360–378, https://doi.org/10.1016/j.gca.2019.12.003, 2020.

Sha, L., Wassenburg, J. A., Sha, L., Li, Y., Zhou, S., Liang, Q., Zhao, J., Ruan, J., Li, H., Zhao, X., Duan, P., Wang, J., Lu, J., Zhang, H., Kathayat, G., Mahata, S., Ban, F., Li, T.-Y., and Cheng, H.: Variations in triple oxygen isotope of speleothems from the Asian monsoon region reveal moisture sources over the past 300 years, Commun Earth Environ, 4, 384, https://doi.org/10.1038/s43247-023-01043-6, 2023.

Sun, Y., Clemens, S. C., An, Z., and Yu, Z.: Astronomical timescale and palaeoclimatic implication of stacked 3.6-Myr monsoon records from the Chinese Loess Plateau, Quaternary Science Reviews, 25, 33–48, https://doi.org/10.1016/j.quascirev.2005.07.005, 2006.

Wang, Y. J., Cheng, H., Edwards, R. L., An, Z. S., Wu, J. Y., Shen, C.-C., and Dorale, J. A.: A High-Resolution Absolute-Dated Late Pleistocene Monsoon Record from Hulu Cave, China, Science, 294, 2345–2348, https://doi.org/10.1126/science.1064618, 2001.

Wen, Q., Liu, Z., Jing, Z., Clemens, S. C., Wang, Y., Yan, M., Ning, L., and Liu, J.: Grand dipole response of Asian summer monsoon to orbital forcing, npj Clim Atmos Sci, 7, 202, https://doi.org/10.1038/s41612-024-00749-4, 2024.

Woo, K. S., Jo, K., Edwards, L. R., Cheng, H., Wang, Y., and Yoon, H.: Kinetic fractionation processes recorded in the stalagmites of some limestone caves in Korea, AGU Fall Meeting Abstracts, ADS Bibcode: 2006AGUFMPP51D1160W, PP51D-1160, 2006.

Yoshimura, K. and Ichiyanagi, K.: A reconsideration of Seasonal Variation in Precipitation Deuterium Excess Over East Asia, J. Japan Soc. Hydrol. and Water Resour., 22, 262–276, https://doi.org/10.3178/jjshwr.22.262, 2009.

Zheng, Y., Liu, H., Yang, H., Wang, H., Zhao, W., Zhang, Z., Huang, M., and Liu, W.: Decoupled Asian monsoon intensity and precipitation during glacial-interglacial transitions on the Chinese Loess Plateau, Nat Commun, 13, 5397, https://doi.org/10.1038/s41467-022-33105-2, 2022.

Zhu, H., Zhu, L., Luo, L., and Li, J.: Seasonal Variations of Modern Precipitation Stable Isotopes over the North Tibetan Plateau and Their Influencing Factors, Water, 16, 150, https://doi.org/10.3390/w16010150, 2023.