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Reply

Response to Comments by Daniel Gebregiorgis et al. "A Brief Commentary on the Interpretation of Chinese Speleothem $\delta^{18}O$ Records as Summer Monsoon Intensity Tracers". *Quaternary* 2020, 3, 7

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We would like to thank Gebregiorgis et al. for their comments [1].

We contend that Gebregiorgis et al. have misconstrued the significance of the Chinese speleothem $\delta^{18}O$ proxy. On the basis of modern observations, it has long been recognized that variations in the seasonal pattern of rainfall (cave) $\delta^{18}O$, rather than rainfall amount, drive a large spatial coherency across the East Asian summer monsoon (EASM) region that is closely and principally linked to the scale of monsoon circulation (e.g., [2–4]). Correspondingly, it is generally agreed that the "southern flood–northern drought" dipole pattern reflects a weak EASM scenario and vice versa. Both modern observations and paleo-reconstructions indicate that a weak (strong) EASM leads to a longer (shorter) residence of the monsoon rain-belt in South (North) China, which results in the observed dipole pattern of rainfall amount [5,6].

On orbital–millennial timescales, Chinese speleothem $\delta^{18}O$ records also show consistent variations across the EASM domain; however, the associated spatial changes in rainfall amount may have large regional differences, as suggested by both model simulations (e.g., [5,7]) and observations (e.g., [5,6]). Analogous to the seasonal variation, the orbital–millennial variability of Chinese speleothem $\delta^{18}O$ was thus explained as a proxy of broader EASM intensity, rather than local rainfall amount (e.g., [8–11]). This point was emphasized in Section 4.1, entitled "Significance of speleothem $\delta^{18}O$ as a climate proxy in the EASM area", of our article [12] and in a number of recent papers (e.g., [11,13]). Along the lines of this reasoning, evidence of increased rainfall and discharge derived from the Yangtze River Valley into the East China Sea would suggest a weak EASM scenario. Similarly, more rainfall in the Andaman Sea might reflect a weak rather than strong Indian summer monsoon (ISM), as shown by model results (e.g., Figure 1 in [14]). The apparent ~9 kyr lag of the rainfall peak to Northern Hemisphere summer insolation, inferred from the Andaman Sea record at the precessional band [15], is more plausibly consistent with, rather than contradictory to, the Chinese cave records, because it may in fact correspond to a relatively weak ISM state. This interpretation not only reconciles the phase offset between cave and marine proxy records, but it is broadly consistent with monsoon dynamics (e.g., [13]).

The aim of our article (Zhang et al. (2019)) was to review EASM variability and associated mechanisms at key timescales from published Chinese cave records (the caves located in Southwest China are influenced by ISM) as one of the projects of the Speleothem Isotopes Synthesis and Analysis (SISAL) working group [12]. Therefore, a comprehensive review on marine and other terrestrial proxy records is clearly beyond the scope of our paper. Nevertheless, we noted that the interpretation of the Arabian Sea records (i.e., [16,17]) remains inconclusive (i.e., [18–24]). According to model simulations, rainfall amount variations are not very sensitive to the precession change over a large portion of the Chinese Loess Plateau (e.g., [25,26]). Additionally, the recent carbon-isotope record of inorganic carbonate in Chinese loess ($\delta^{13}C_{IC}$, a proxy of monsoon-induced vegetation density) also revealed a persistent precession periodicity which is nearly in-phase with Northern Hemisphere summer insolation [27]. Furthermore, the broad consistency between cave $\delta^{18}O$ records across the vast Asian monsoon domain, including the ISM and EASM regions, precludes the attribution of orbital-scale shifts in cave $\delta^{18}O$ predominantly to changes in moisture sources and pathways. For example, although an alternation in the moisture source between the proximal Pacific Ocean and the remote Indian Ocean can theoretically influence EASM cave records, it could not have simultaneously produced the broadly coherent Holocene pattern observed in cave $\delta^{18}O$ records, including those from regions highly sensitive to the alternation in the moisture source (e.g., [4,13,28]).

In summary, the arguments of Gebregiorgis et al. (2020) [1] regarding the divergence between Chinese cave $\delta^{18}O$ records and marine/loess records stem at least partially from the interpretation of the monsoon intensity as local rainfall amount. Based on the current understanding of monsoon dynamics, such a divergence might be explicable [13].

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