# Reply to Weiss:

# Tree-ring stable oxygen isotopes suggest an increase in Asian monsoon rainfall at 4.2 ka BP

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Weiss (1) raises interesting points on our article (2). He observes that the Delingha tree-ring $\delta^{18}O$ record matches KM-A speleothem $\delta^{18}O$ record from the Mawmluh Cave in India, that defines the 4.2 ka (thousand years before 1950 CE) event's global type stratum (3). This event is also manifested as a multi-centennial drought in the Iranian Gol-E-Zard speleothem record (4). Weiss further argues that the Delingha record is also consistent with the 4.2 ka anomaly recorded in low-resolution proxy records from northern China despite inherent limitations of these proxies.

Our Delingha $\delta^{18}O$ record shows a persistent transition following gradual drying that instead occurred during 4–3.5 ka. This is associated with generally wet conditions ca. 4.5–4.0 ka (Fig. 1), in contrast with the KM-A $\delta^{18}O$ record. We thus do not observe such a close correspondence between the two records in Weiss's Fig. 1A and want to exercise caution in drawing conclusions based on a limited number of proxy records with considerable age uncertainties.

To complement the four speleothem $\delta^{18}O$ records presented by Weiss, we assembled a total of 24 additional records from eastern Asia and India covering Holocene hydroclimate dynamics. In western China, only one out of three speleothem records from Kesang cave, KS06-A-H (5), has a good dating accuracy to resolve centennial drought anomalies and shows dry climate conditions at 4.2 ka (see ref. 6). In northern China, all records except Dongshiya and Zhenzhu indicate an anomalously wet interval around 4.2 ka (see ref. 6). Both exceptions are characterized by few and uncertain dating points and a coarse sampling resolution (see ref. 6). In southern China, investigating the full set of records yields no clear picture (see ref. 6). However, a composite based on six high-precision (Fig. 1) records shows generally wet conditions at 4.2 ka.

In India, two more recent replicated speleothem $\delta^{18}O$ records from Mawmluh Cave with exceptional chronologic constraints and high sampling resolution have

challenged the interpretation of KM-A (see ref. 6). One of these records, ML.1, shows wet conditions at 4.1–4.0 ka (7)，and the subsequent long-term multi-centennial drying is consistent with our Delingha $\delta^{18}O$ record and with a long-term drying trend in a recent high-resolution speleothem $\delta^{18}O$ record from Sahiya Cave in northern India (8).

In conclusion, our well-replicated Delingha $\delta^{18}O$ record does *not* support a significant hydroclimate transition in our study region around 4.2 ka, nor the notion that this rapid climate deterioration should be regarded as generalized climatic transition from the mid to late Holocene. There is the need for further development of accurate, replicated, and high-resolution proxy data, based on dense sampling, a mechanistic understanding of climatic controls, and representative chronological control points to elucidate the spatial-temporal dynamics of Holocene climate and cultural responses. Our Delingha $\delta^{18}O$ record makes considerable progress towards those aims.


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## CONFLICT OF INTEREST

The authors declare no competing financial interests.

## AUTHOR CONTRIBUTIONS

B.Y. designed the study. N.C.S., C.Q., A.B., T.J.O., V.T., F.C.J., J.E., L.S., J.G., U.B., S.R., G.D., B.X., M.Y., L.N., J.W., X.W., S.W., B.F., J.L., and E.R.C. performed research, and B.Y. wrote the paper in close interactions with all authors.

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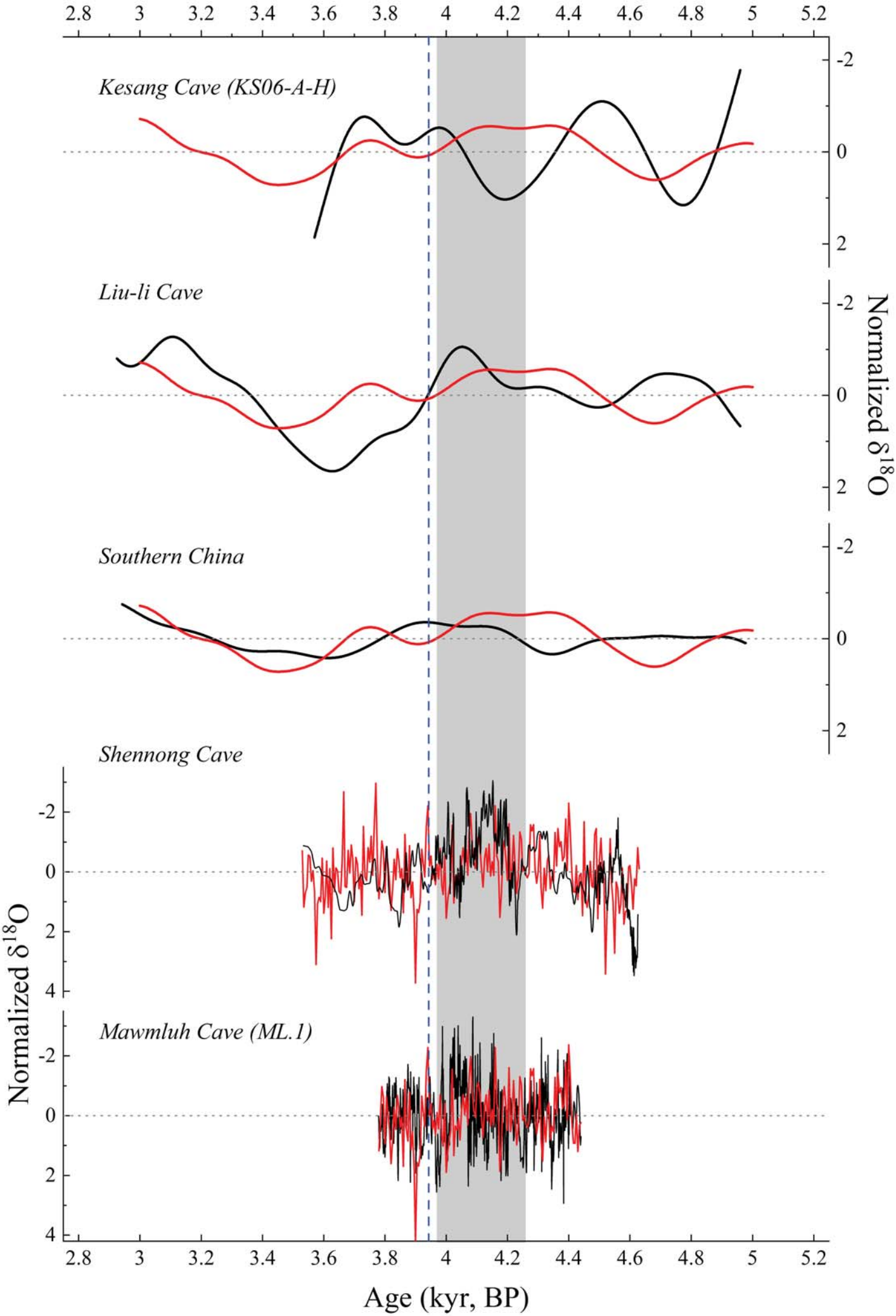
## *Figure captions*

**Fig. 1 The Delingha tree-ring $\delta^{18}O$ record (red line) and normalized speleothem $\delta^{18}O$ records collected from different parts of continental Asia spanning 5–3 ka.** To place the 4.2 ka event in high-resolution and high-precision context, we constrained our analyses to speleothem records with coverage of 5–3 ka. A regional composite for southern China is shown, which is derived by averaging the six speleothem $\delta^{18}O$ series from Dongge Cave, Xianglong Cave, Wuya Cave, Sanbao Cave 43, Heshang Cave and Shennong Cave using Z-score method. Each of the six speleothem records has a temporal resolution better than 20 years, at least 5 U-Th ages and dating precision higher than 60-yr average age error ($2\sigma$) in the 5–3 ka interval. Prior to averaging, each of the six records is first linearly interpolated annually, and then their long-term linear trends in the common period 5–3 ka are removed to highlight climate fluctuations on multidecadal to centennial timescales before normalization. See ref. 6 for details about each stalagmite record employed in the calculation. The Liu-li cave in northern China and Kesang cave (KS06-A-H) in western China speleothem $\delta^{18}O$ records are intentionally included for comparison in that both records have a dating point around 4.2 ka (see ref. 6). The 100-point low-pass filters are shown for Kesang cave (KS06-A-H), Liu-li Cave and southern China records. The Shennong Cave and Mawmluh Cave (ML.1) speleothem $\delta^{18}O$ records have bi-annual and sub-annual resolution and therefore we plot their unsmoothed series for comparison. All horizontal lines represent the long-term average calculated over the common period 5–3 ka. The vertical dashed blue line

indicates the mid-to late Holocene transition as defined by the Delingha $\delta^{18}O$ record via trend-point analysis (2). The grey bar covers the period 3.97–4.26 ka that is demonstrated as the 4.2 ka event in the mid-latitudes of the Northern Hemisphere by the Iranian Gol-E-Zard speleothem record (4). The y-axis of the composite $\delta^{18}O$ record was reversed for easier inspection.


Kesang Cave (KS06-A-H)
Liu-li Cave
Southern China
Shennong Cave
Mawmluh Cave (ML.1)
Normalized δ18O
Normalized δ18O
Age (kyr, BP)
2.8
3
3.2
3.4
3.6
3.8
4
4.2
4.4
4.6
4.8
5
5.2
-2
0
2
4