Supporting Materials for

Multi-phased ASM evolution and rainfall response during Heinrich Stadial 5

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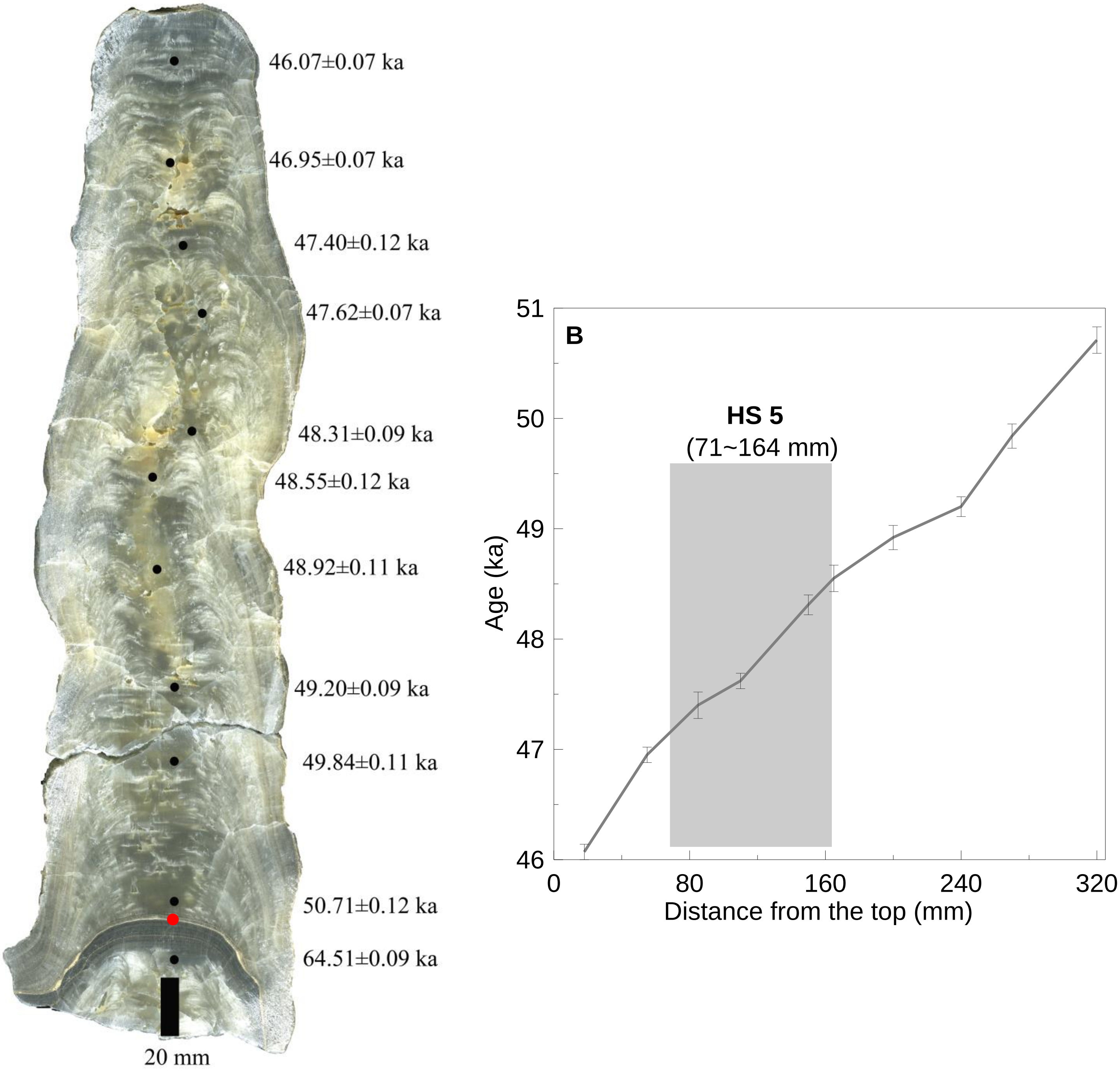

46.07±0.07 ka
46.95±0.07 ka
47.40±0.12 ka
47.62±0.07 ka
48.31±0.09 ka
48.55±0.12 ka
48.92±0.11 ka
49.20±0.09 ka
49.84±0.11 ka
50.71±0.12 ka
64.51±0.09 ka
20 mm
B
HS 5
(71~164 mm)
Age (ka)
51
50
49
48
47
46
0
80
160
240
320
Distance from the top (mm)

A

Fig. S1. Image and age model of sample Wu88. In Panel A, black and red dots illustrate positions of U/Th dates and the hiatus, with dating results shown on the right. In Panel B, a linearly-interpolated age model was adopted. The gray bas indicates the depth covering HS 5.

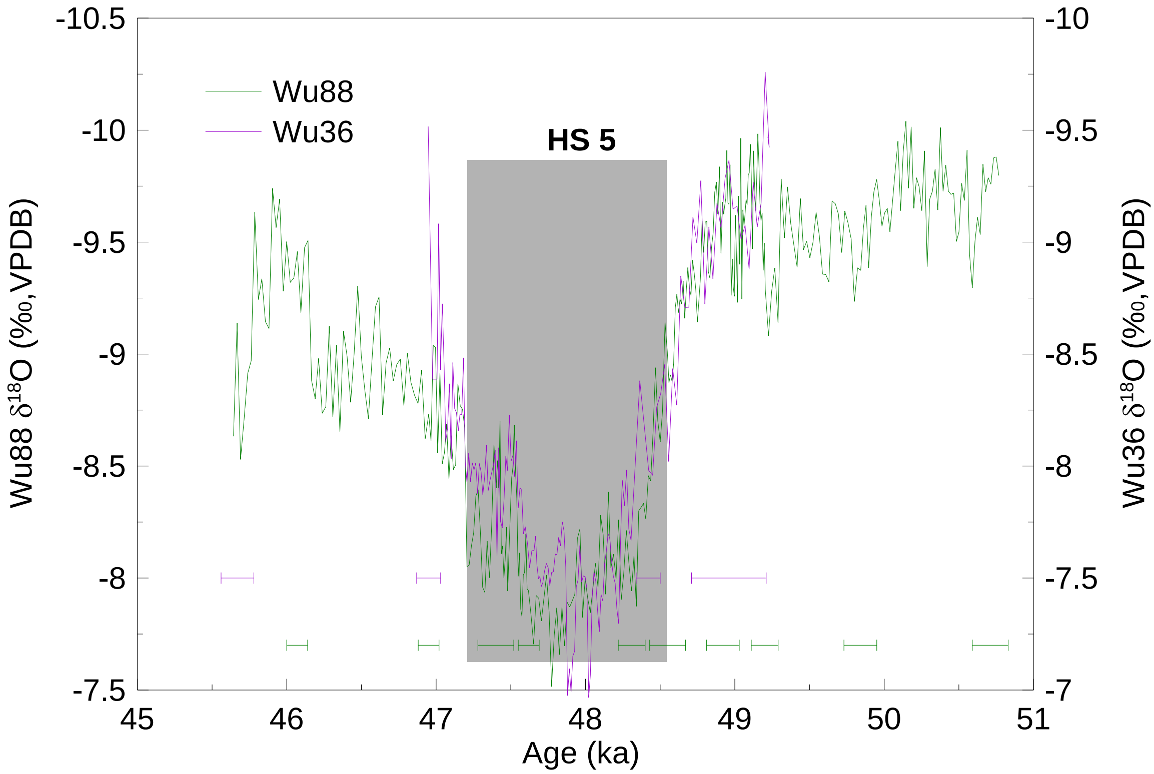


Fig. S2. Replication of Wu88 and Wu36 $\delta^{18}O$ records (Fang et al., 2019) from Wulu Cave, southern China. Dating points and errors were indicated at the bottom. Although Wu36 was of lower resolution, the onset/termination timings of HS 5 in two records were practically identical. Typically, the ^{18}O-depletion event in late HS 5 was similarly expressed in two stalagmites.

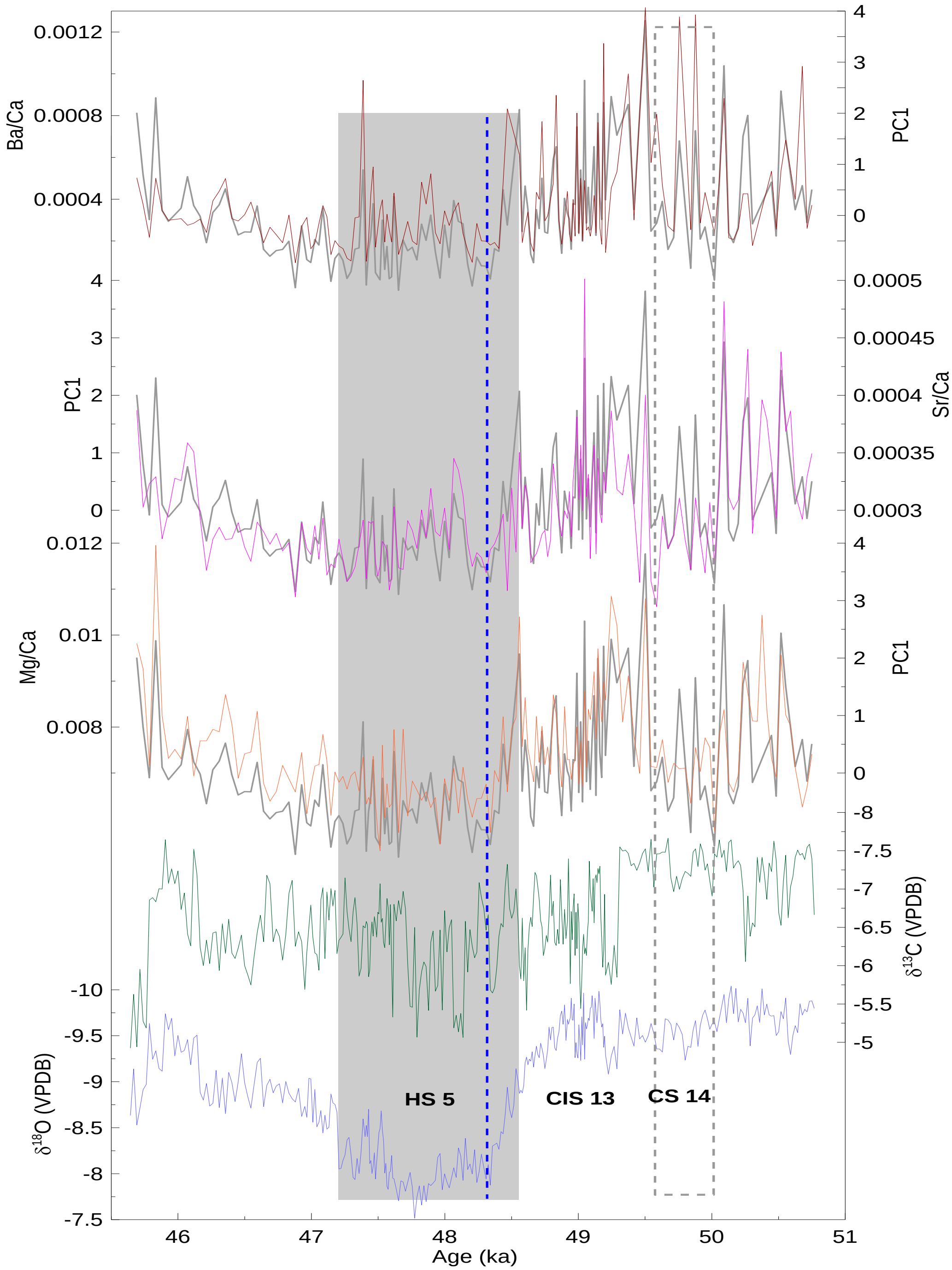


Fig. S3. A detailed comparison of δ^{18}O, δ^{13}C, Mg/Ca, Sr/Ca, Ba/Ca (colorfully coded) and PC1 (gray lines) from sample Wu 88. Gray bar denoted HS 5 and blue dashed line showed the end of first phase of ^{18}O-enrichments in early HS 5, corresponding to a sharp decline in element values. Dotted rectangle indicated CS 14, during which elevated Ba/Ca values can be observed. Heinrich Stadial (HS) 5, Chinese Interstadial (CIS) 13 and Chinese Stadial (CS) 14 were determined by δ^{18}O variability.

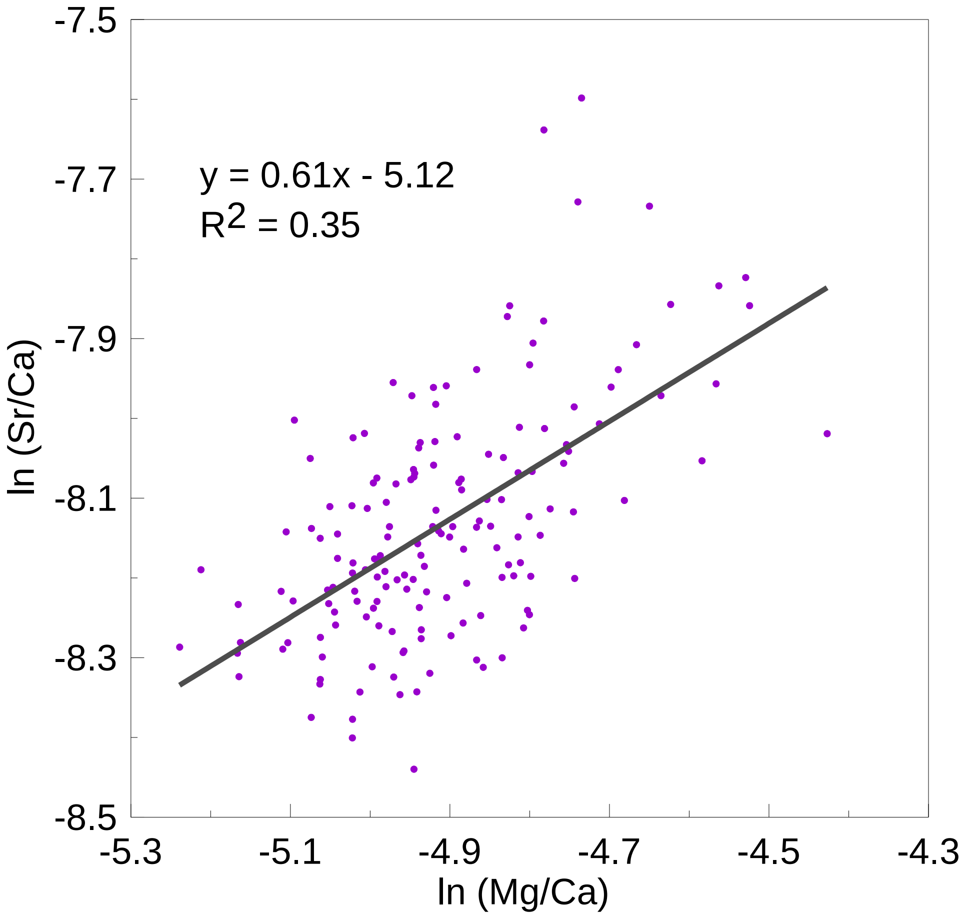
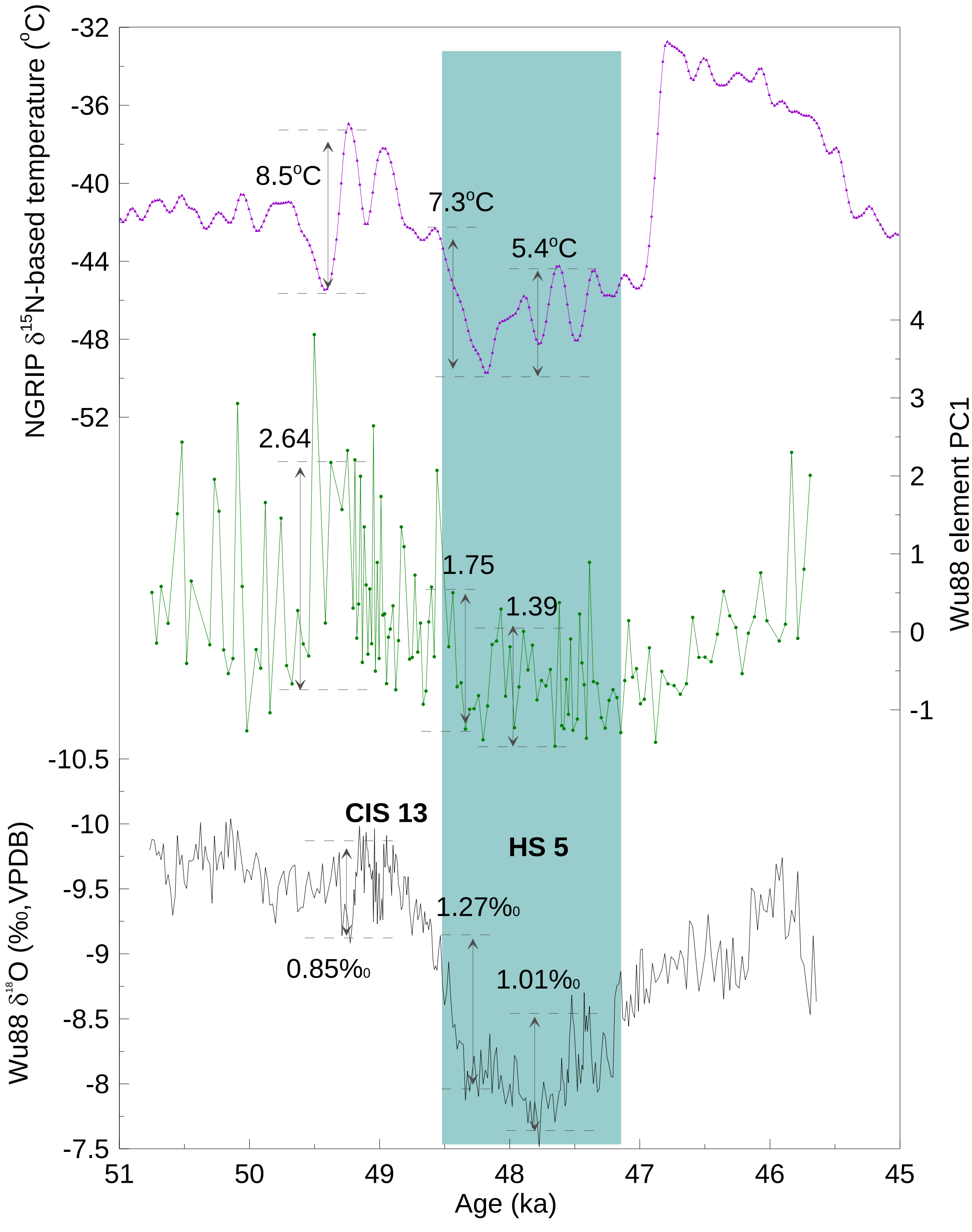
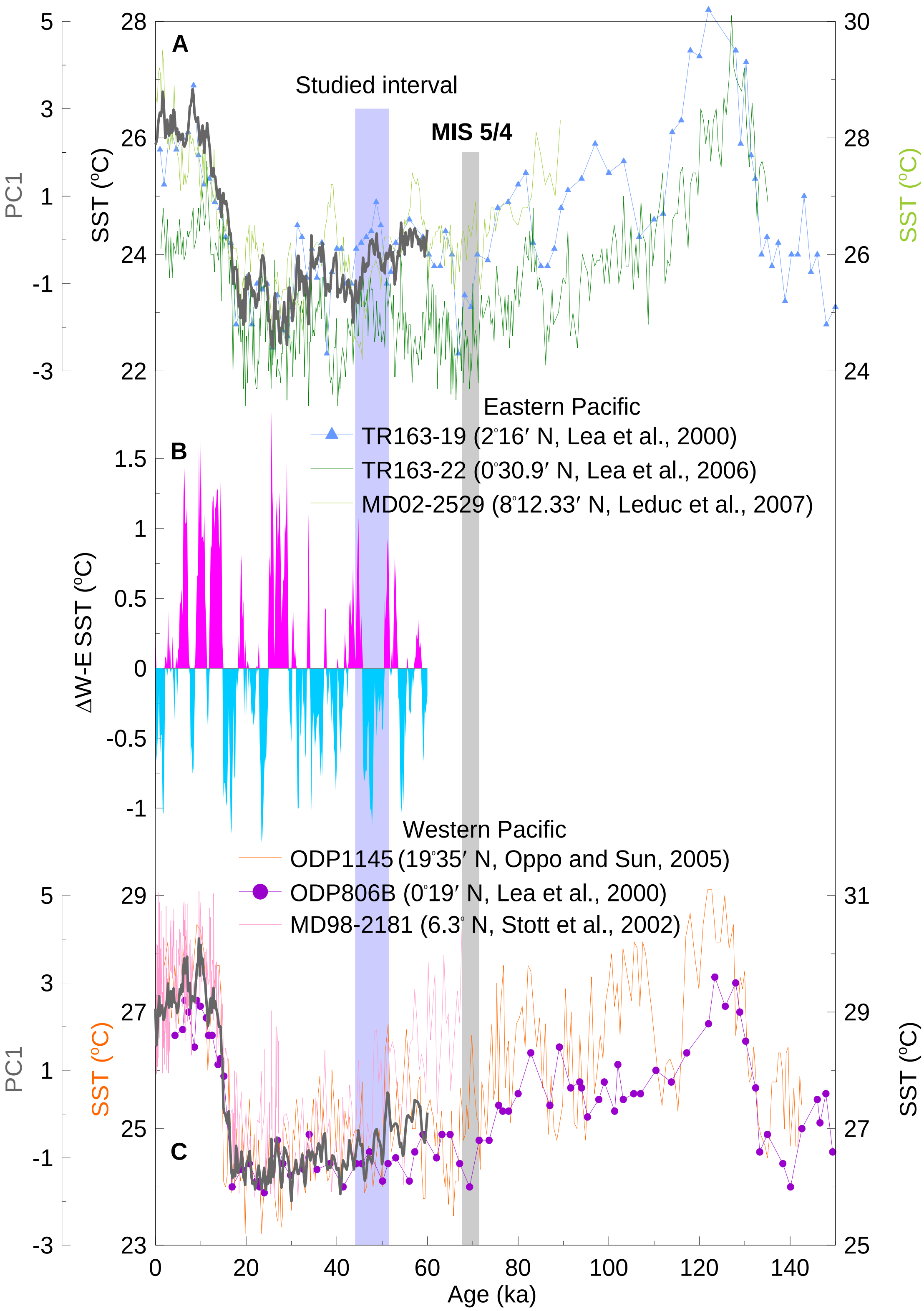


Fig. S4. Evaluation of the correlation between ln(Mg/Ca) and ln(Sr/Ca), the slope of which was used to judge the PCP effect when reached about 0.71 to 1.45 (Sinclair et al., 2012; Wassenburg et al., 2020). In this study, a slope of 0.61 was estimated, slightly smaller than the above values.



NGRIP δ15N-based temperature (oC)
-32
-36
-40
-44
-48
-52
8.5oC
7.3oC
5.4oC
2.64
1.75
1.39
Wu88 element PC1
4
3
2
1
0
-1
-10.5
-10
-9.5
-9
-8.5
-8
-7.5
Wu88 δ18O (‰,VPDB)
CIS 13
HS 5
1.27‰
0.85‰
1.01‰
51
50
49
48
47
46
45
Age (ka)

Fig. S5. Sensitivity tests of ASM and monsoonal rainfall to temperature changes. Blue bar denoted HS 5. During CIS 13, early and late HS 5, the amplitudes of Wu88 $\delta^{18}O$, PC1 and Greenland temperature variations (Kindler et al., 2014) were calculated respectively (arrowed and dotted lines), with estimations shown on each figure. Sensitivity estimations were listed in Table S2.



A
B
C
Studied interval
MIS 5/4
Eastern Pacific
TR163-19 (2°16′ N, Lea et al., 2000)
TR163-22 (0°30.9′ N, Lea et al., 2006)
MD02-2529 (8°12.33′ N, Leduc et al., 2007)
Western Pacific
ODP1145 (19°35′ N, Oppo and Sun, 2005)
ODP806B (0°19′ N, Lea et al., 2000)
MD98-2181 (6.3° N, Stott et al., 2002)
PC1
SST (°C)
ΔW-E SST (°C)
Age (ka)

Fig. S6. Investigating sea surface temperature (SST) changes in the eastern (A) and western (C) tropical Pacific Ocean. SST records in Figure A were from sites TR163-19 (blue, Mg/Ca-derived, Lea et al., 2000), TR163-22 (dark green, Mg/Ca-derived, Lea et al., 2006) and MD02-2529 (light green, alkenone-based, Leduc et al., 2007). In Figure C, SST records were from sites ODP1145 (orange, Mg/Ca-derived, OPP and Sun, 2005), ODP806B (purple, Mg/Ca-derived, Lea et al., 2000) and MD98-2181 (light pink, Mg/Ca-derived, Stott et al., 2002). Gray and blue bars illustrated the MIS 5/4 transition and our studied interval, respectively. Gray lines in Figures A and C represented PC1 for each group of SST records, in which the primary component analysis was performed on the data since 60 ka to reconcile with MD98-2181 record. In the last 140 kyr, the interglacial/glacial cycle is clear in these SST records, with a concurrence of MIS 5/4 transition. During the studied interval (about between 51 and 44 ka), SST in the western tropical Pacific remained at a stable level, while a pronounced rise was observed in the eastern. Western to eastern SST contrast (ΔW-E SST) was calculated with SST PC1 records (B). Apparently, a significantly negative ΔSST anomaly surrounding HS 5 suggests that the western Pacific was over 0.8℃ cooler than the eastern.

Table S1. Correlation analysis of isotopic and trace elemental records.

	$\delta^{18}O$	$\delta^{13}C$	Mg/Ca	Sr/Ca	Ba/Ca	PC1
$\delta^{18}O$	/	0.56	-0.42	-0.39	-0.27	-0.44
$\delta^{13}C$		/	-0.04	-0.02	-0.24	-0.09
Mg/Ca			/	0.59	0.42	0.84
Sr/Ca				/	0.40	0.83
Ba/Ca					/	0.74
PC1						/

Table S2. Sensitivity of ASM and rainfall to temperature changes [a].

Time interval	Amplitude of temperature changes (℃)	Amplitude of stalagmite $\delta^{18}O$ changes (‰)	Amplitude of PC1	Ratio of $\delta^{18}O$ to temperature	Ratio of PC1 to temperature
CIS 13	8.5	0.85	2.64	0.10	**0.31**
Early HS 5	7.3	1.27	1.75	0.17	0.24
Late HS 5	5.4	1.01	1.39	**0.19**	0.26

[a]Sensitivity values were estimated by ratios of stalagmite $\delta^{18}O$/PC1 and temperature as shown in Figure 5, and indicated in bold. These values could be regarded as minimum estimation, because SST and continental temperature changes were significantly smaller than Greenland ice-core records surrounding HS 5.

Supplementary References

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