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Editor of the *Climate of the Past*
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Dear Editor:

Enclosed please find an electronic copy of our revised manuscript "Stalagmite-inferred variability of the Asian summer monsoon during the penultimate glacial/interglacial period" by Li *et al*. (CP-2003-170). We would like to submit it as an article to the special issue entitled "Western Pacific paleoceanography - an ocean history perspective on climate variability at orbital to centennial scales". The material in this submission includes: (1) main text, (2) six figures, and (3) one table. None of the material has been published or is under consideration elsewhere, including the internet.

We are pleased by the very positive and constructive nature of the reviews. We have made attempt to incorporate suggestions and the comments of the Editor, Dr. Mahyar Mohtadi. Please see the details of our implementation of the reviews in the attached file “response_to_review_comments-cp-2003-170.pdf”. We have incorporated reviewers’ suggestions and comments for modifying portions from ABSTRACT to CONCLUSSIONS. The manuscript has, thus, been revised throughout.

If this manuscript can be accepted, please consider arranging a good publication time. It will be much appreciated. Please accept our deep appreciation again for your assistance about this submission. We look forward to hearing from you.

Sincerely,

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Stalagmite-inferred variability of the Asian summer monsoon during the penultimate glacial/interglacial period

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Abstract

The orbital-timescale dynamics of the Quaternary Asian summer monsoons (ASM) are frequently attributed to precession-dominated northern hemisphere summer insolation. However, this long-term continuous ASM variability is inferred primarily from oxygen isotope records of stalagmites, mainly from Sanbao cave in mainland China, and may not provide a comprehensive picture of ASM evolution. A new spliced stalagmite oxygen isotope record from Yangkou cave tracks summer monsoon precipitation variation from 124-206 thousand years ago in Chongqing, southwest China. Our Yangkou record supports that the evolution of ASM was dominated by the North Hemisphere solar insolation (NHSI) on orbital timescales. When superimposed on the Sanbao record, the Yangkou-inferred precipitation time series supports the strong ASM periods at marine isotope stages (MIS) 6.3, 6.5, and 7.1 and weak ASM intervals at MIS 6.2, 6.4, and 7.0. This consistency confirms that ASM events affected most of mainland China. Except for the solar insolation forcing, the large amplitude of minimum $\delta^{18}O$ values in Yangkou record during glacial period, such as MIS 6.5, could presumably related to the enhanced prevailing Pacific trade wind and/or continental shelf exposure in the Indo-Pacific warm pool.

Keywords: Asian summer monsoon, Yangkou cave, stalagmite, glacial/interglacial, Walker Circulation

1 Introduction

Climate in East Asia, the most densely populated region in the world, is profoundly influenced by the Asian monsoon (AM). Asian summer monsoon (ASM) precipitation strongly governs regional vegetation, agriculture, culture, and economies (e.g., Cheng et al., 2012a), and even affected the stability of Chinese dynastic rule (Zhang et al., 2008; Tan et al., 2011). Recent studies have led to significant advances in understanding Quaternary ASM evolution on different time scales (e.g., An, 2000; Wang et al., 2001; 2008; Fleitmann et al., 2003; 2004; Rousseau et al. 2009; Cheng et al., 2009; 2012b; Zhang et al., 2008; Sinha et al., 2011).

Our current understanding of ASM variation over past 500 kyr BP (before AD 1950) has been reconstructed using oxygen isotope records of Chinese stalagmites (Wang et al., 2008; Cheng et al., 2012b) with the advantages of absolute and high-precision chronologies (e.g., Cheng et al., 2000; 2013; Shen et al., 2002; 2012). Stalagmite-inferred orbital-scale ASM intensity closely follows the change in precession-dominated Northern Hemisphere (NH) summer insolation (NHSI) (Wang et al., 2008; Cheng et al., 2012b). However, these 100s-kyr records were mainly from a single cave, namely Sanbao cave, located in Hubei Province, China (Fig. 1; Wang et al., 2008; Cheng et al., 2012b). Utilizing only one site leads to uncertainties in the spatial extent of Quaternary ASM evolution. These uncertainties stem from differences in local or regional climatic and environmental conditions (Lachniet, 2009), hydrological variability of monsoonal sources (e.g., Dayem et al., 2010; Clemens et al., 2010; Pausata et al., 2011), and interactions between climatic subsystems (e.g., Maher and Thompson, 2012; Tan, 2013).

Sanbao records, for example, show distinct ASM events at marine isotope stages (MIS) 6.3 and 6.5 during the penultimate glacial time and a weaker summer monsoon during the penultimate glacial maximum (PGM) at MIS 6.2 (Fig. 1 of Wang et al., 2008). To clarify whether this combination of weak PGM ASM intensities and strong ASM events during the penultimate glacial/interglacial (G/IG) period are local effects, we built an integrated stalagmite oxygen stable isotope record from Yangkou cave, Chongqing, China, covering 124-206 kyr BP (Fig. 1). Comparison with records from other Chinese caves (Cheng et al., 2006; 2009; Wang et al., 2008) confirms the fidelity of Sanbao cave-inferred ASM intensities.

2 Material and methods

2.1 Regional settings and samples

Stalagmites were collected from Yangkou cave (29°02'N, 107°11'E; altitude: 2140 m; length: 2245 m), located at Jinfo Mountain National Park, Chongqing City, southwestern China (Fig. 1) during two field trips in 2010 October and 2011 July. The cave, developed in Permian limestone bedrock, is 400 km southwest of Sanbao cave (31°40'N, 110°26'E) in Hubei Province (Wang et al., 2008). The cave air temperature is 7.5 ^{o}C and the average relative humidity is >80% (2011 October-2013 October). The regional climate is dominated by the AM and annual rainfall is 1400-1500 mm, 83% from April to October (Zhang et al., 1998). Five stalagmites, YK05, YK12, YK23, YK47 and YK61, which formed within a time interval of 124-206 kyr BP were halved and polished for U-Th dating and oxygen stable isotope analysis.

2.2 U-Th dating

Chemistry and instrumental analysis were conducted in the High-Precision Mass Spectrometry and Environment Change Laboratory (HISPEC), Department of Geosciences, National Taiwan University. Fifty three powdered subsamples, 60-80 mg each, were drilled from the polished surface along the deposit lamina of the five stalagmites (Fig. 2, Table 1), on a class-100 bench in a class-10,000 subsampling room. U-Th chemistry (Shen et al., 2003) was performed in a class-10,000 clean room with independent class-100 benches and hoods (Shen et al., 2008). A multi-collector inductively coupled plasma mass spectrometer (MC-ICP-MS), Thermo Fisher Neptune, with secondary electron multiplier protocols, was used for the determination of U-Th isotopic contents and compositions (Shen et al., 2012). The decay constants used are 9.1577×10^{-6} yr^{-1} for ^{230}Th and 2.8263×10^{-6} yr^{-1} for ^{234}U (Cheng et al., 2000), and 1.55125×10^{-10} yr^{-1} for ^{238}U (Jaffey et al., 1971). All errors of U-Th isotopic data and U-Th dates are two standard deviations (2σ) unless otherwise noted. Age (before AD 1950) corrections were made using an $^{230}Th/^{232}Th$ atomic ratio of 4 ± 2 ppm, which are the values for material at secular equilibrium, with the crustal $^{232}Th/^{238}U$ value of 3.8 (Taylor and McLennan, 1995) and an arbitrary uncertainty of 50%

2.3 Stable isotopes

Five-to-seven coeval subsamples, 60-120 μg each, were drilled from one layer per stalagmite to measure the oxygen and carbon isotopic compositions as part of the so-called “Hendy Test” (Hendy, 1971). To obtain oxygen time series, 604 subsamples, 60-120 μg each, were drilled at 0.5-3.0 mm intervals along the maximum growth axis. Measurement of oxygen stable isotopes was performed by two isotope ratio mass spectrometers, including a Finnigan Delta V Plus in the Southwest University, China and a Micromass IsoPrime instrument at the National Taiwan Normal University. Oxygen isotope values were reported as $\delta^{18}O$ (‰) with respect to the Vienna Pee Dee Belemnite standard (V-PDB). An international standard, NBS-19, was used in both laboratories to confirm that the 1-sigma standard deviation of $\delta^{18}O$ was better than ±0.1‰.

3 Results and discussion

3.1 Chronology

U-Th isotopic and concentration data and dates of all stalagmite subsamples are given in Table 1. High uranium levels range from 0.8-13 ppm and relatively low thorium contents from 100s-10,000 ppt. Corrections for initial ^{230}Th are less than 90 yrs, much smaller than dating uncertainties of 400-1,800 yrs that are common for stalagmites with these ^{230}Th ages (Table 1). Determined age intervals are 179.6-189.8, 133.7-181.9, 172.6-206.8, 130.0-132.1, and 97.2-172.5 kyr BP for stalagmites YK05, YK12, YK23, YK47, and YK61, respectively (Fig. 3). One to two hiatuses are observed for stalagmites, YK12, YK23, and YK61 (Figs. 2, 3). The chronology of each stalagmite was developed using linear interpolation between U-Th dates, which are all in stratigraphic order (Fig. 3).

3.2 Yangkou oxygen isotope data

The well-known Hendy Test has been taken as an essential requirement when assessing the ability of stalagmites to serve as paleoclimate archives (Hendy, 1971) (Fig. 4). Despite relative large δ^{13}C variations of 0.2-0.4‰ (1σ) for coeval subsamples on the five selected layers (Fig. 4A), only a small variations in δ^{18}O of ±0.1-0.2‰ (1σ) are observed on individual horizons of coeval subsamples (Fig. 4B). Also, there is no relationship between δ^{18}O and δ^{13}C values, which is an additional part of the Hendy Test (Fig. 4C). The replication of the δ^{18}O records both within Yangkou cave (Fig. 5) and between Chinese caves (Fig. 6), as well as successful Hendy Tests, indicates that the stalagmites formed under an oxygen isotopic equilibrium condition. The Yangkou stalagmite δ^{18}O data therefore represent rainfall oxygen isotopic change, which is a reflection of regional hydrological variability in the AM territory (e.g., Wang et al., 2001, 2008; Cheng et al., 2009; Li et al., 2011).

The oxygen isotope sequences for all of the Yangkou stalagmites are illustrated in Figure 5A. The spliced record covers a time interval from 124-206 kyr BP, with three narrow hiatuses at 132.1-133.5, 190.4-193.2, and 200.3-200.9 kyr BP. This $\delta^{18}O$ record varies from -10‰ to -4‰. The highest $\delta^{18}O$ data of -5‰ ~ -4‰ occurs at 128-136 kyr BP, the PGM.

3.3 Comparison with other Chinese stalagmite records

The new spliced stalagmite $\delta^{18}O$ sequence from Yangkou cave over the time period of 124-206 kyr BP shows four strong ASM intervals at MIS 5.5, 6.3, 6.5, and 7.1 and four weak ASM intervals corresponding to MIS 6.2, MIS 6.4, MIS 7.0, and MIS 7.2 (Fig. 5A). This variation of stalagmite-inferred ASM recorded in Yangkou cave is aligned with previous ASM changes from other Chinese caves, such as Sanbao (Wang et al., 2008; Cheng et al., 2009) and Hulu (32°30'N, 119°10'E) (Cheng et al., 2006), from MIS 5.5-7.2 (Fig. 5).

Onsets of strong ASM intervals at MIS 5.5, 6.5, and 7.1 are at 128.3 ± 0.8, 179.9 ± 0.9, and 201.5 ± 1.1 kyr BP respectively in the Yangkou record and concurrent with their counterparts in Sanbao (Wang et al., 2008; Cheng et al., 2009) and Hulu (Cheng et al., 2006). Transients from strong to weak ASM states occur at 135-136 kyr BP during MIS 6.2-6.3 and 164-165 kyr BP during MIS 6.4-6.5. These also match changes in the Sanbao and Hulu records.

Over the past 200 kyr BP, the weakest ASM interval has been suggested to be at MIS 6.2 in the Sanbao records (Wang et al., 2008). For example, the $\delta^{18}O$ data are 1‰ higher than those at weak ASM intervals of MIS 6.4, 7.0, and 7.2 (Fig. 5). Concurrence between ASM records and ice-rafted debris events in the North Atlantic supports the hypothesis of a forcing on the ASM from NH high latitudes (Cheng et al., 2009). $\delta^{18}O$ values at MIS 6.2 in Yangkou record are 1.5-2‰ higher than those at MIS 6.4, 7.0, and 7.2 (Fig. 5). This large difference suggests that this event in Chongqing may have been relatively intensified through NH forcing as compared with the Hubei regions during the PGM.

The Sanbao record indicates that the strongest ASM condition over the past 500 kyr BP occurs at MIS 6.5 (Cheng et al., 2012b). This ASM event, lasting 13 kyrs, is 3 kyrs longer than a comparable event (in terms of intensity) at interglacial MIS 5.3, and was stronger than at any time during MIS 1, 5.5, 7.3, 9.5, and 11.3, which had higher sea-level and NH insolation (Fig. 1 of Cheng et al., 2012b). The lowest contemporaneous $\delta^{18}O$ data in the Yangkou record (Fig. 5) show a similar ASM intensity at MIS 6.5 in southwest China.

During the MIS 5, the variations of Chinese stalagmite $\delta^{18}O$ records are not consistent among caves (Cheng et al., 2012). In Sanbao record (Wang et al., 2008), a $\delta^{18}O$ minimum at IMS 5.3 is more depleted than one at MIS 5.5. This phenomenon is seemingly illustrated in Yangkou records (Fig. 5A). However, Dongge (Kelly et al. 2006) and Tianmen (Cai et al., 2010a) stalagmite records are characterized by the most depletion in ^{18}O at MIS 5.5 (Fig. 2 of Cai et al., 2010a). This discrepancy may be attributable to different hydrological conditions at MIS 5. Long time series from more Chinese caves are required to derive a clear picture of amplitude changes in relation to orbital forcing at MIS 5.

Overall, consistency of the stalagmite $\delta^{18}O$ sequences between Yangkou and other Chinese caves supports the idea that ASM intensity primarily follows NHSI on orbital timescales and is driven by precessional forcing and is punctuated by NH high-latitude climatic fluctuations (e.g., Wang et al., 2001; 2008; Cheng et al., 2009). Agreement in the amplitude and the transition of $\delta^{18}O$ dynamics during different MIS also confirms that the Sanbao stalagmite-inferred ASM events at MIS 6, including a very weak one at MIS 6.2 and the strongest one at MIS 6.5, are likely predominant over the entire mainland during the past five G/IG cycles (Cheng et al., 2012a) (Fig. 6).

3.4 Forcings for the abnormal strong ASM at MIS 6.5

The extraordinarily strong ASM condition at MIS 6.5 during the penultimate glacial period is one of the most striking features revealed by stalagmite records from three different Chinese caves (Fig. 5). This strong monsoon event is also observed in Chinese Loess plateau record (Rousseau et al., 2009). Modeling experiments suggest this increased monsoon intensity is primarily attributed to high NH insolation (Masson et al., 2000).

Wang et al. (2008) found a correlation between the stalagmite-inferred ASM intensity and the atmospheric $\delta^{18}O$ records from Antarctic Vostok ice core O_2 bubbles (Sowers et al., 1991; Petit et al., 1999), and suggested that the Dole effect (Dole, 1936; Bender et al., 1994) can explain this similarity. A low atmospheric $\delta^{18}O$ ($\delta^{18}O_{atm}$) peak at 170 kyr BP in the Vostok ice core (Petit et al., 1999), for example, matches the strong-ASM period at MIS 6.5.

Vostok ice core-inferred $\delta^{18}O_{atm}$ evolution most likely results from changes of summer insolation and precipitation in NH, where land provides space for the growth of vegetation and intense photosynthesis during glacial periods (Sun et al., 2000). However, the summer insolation at MIS 6.5 is less than the interglacial periods at MIS 5.5 and 7.3 (Fig. 5), suggesting that the minimal stalagmite $\delta^{18}O$ values at MIS 6.5 could also be associated with additional secondary forcing(s).

Climate conditions around Yangkou and Sanbao caves are influenced by the Indian summer monsoon (ISM) and East Asian summer monsoon (EASM) (Fig. 1). The ISM, a typical tropical monsoon system, is driven by a south-north land-sea thermal gradient; instead, the EASM is controlled by both south-north and east-west land-sea gradients (Wang and Lin, 2002). The EASM precipitation is influenced by the Northwestern Pacific Tropical High, developed by the mainland-Pacific thermal gradient (Wang et al., 2003). The Pacific climatic variability can, therefore, affect EASM precipitation (Tan, 2013).

Cai et al. (2010b) and Jiang et al. (2012) argued for a significant impact of the western tropical Pacific sea surface temperature (SST) on the EASM precipitation. They proposed that the evolution and spatial asynchroneity of stalagmite-inferred Holocene precipitation histories at different AM regions could be attributed to SST changes in the western Pacific. Planktonic foraminiferal-inferred SST records of the marine sediment core ODP806B (0°19’N, 159°22’E) in the western Pacific warm pool (WPWP) and TR163-19 (2°16’N, 90°57’W) in the eastern equatorial Pacific (EEP) (Lea et al., 2000) are plotted in Figure 6, along with the LR04 stacked benthic $\delta^{18}O$ sequence (Lisiecki and Raymo, 2005) and Yangkou and Sanbao cave time series. A SST gradient between the WPWP and EEP during the glacial periods of MIS 6 and 8 is 2 ^{o}C, larger than 0.5-1.5 ^{o}C gradient during the warm interglacial windows of MIS 5.5 and 7 (Fig. 6). Combined with salinity gradient data, Lea et al. (2000) suggested that the transport of water vapor to the western Pacific was enhanced during glacial times. This large SST gradient could result in an enhanced Walker circulation in the Pacific, similar to the modern La Niña state, which moves the rainfall zone westward and intensifies EASM precipitation (Clement et al., 1999) (Fig. 1). Under a weak Walker circulation, analogous to present El Niño conditions, the rainfall zone in the Pacific migrated eastward and EASM precipitation was reduced (Clement et al., 1999). We speculate that the extremely strong EASM precipitation at MIS 6.5 was not only governed by high NHSI, but also partially affected by the Pacific SST gradient.

This speculation is supported by modern meteorological observations (e.g, Xue et al., 2007; Tan, 2013) and decadally-resolved marine records (Oppo et al., 2009). La Niña years accompany above-normal precipitation probabilities above normal in mainland China (Tan, 2013 and references therein). Two thousand year-SST and -salinity records from the Makassar Strait (Oppo et al., 2009) also support a strong link between Pacific Ocean climate and the AM. However, comparison of SST histories in the South China Sea and eastern equatorial Pacific SST suggests an El Niño-like condition for the last glacial time (Koutavas et al., 2002), opposite to the findings by Lea et al. (2000). The study by Koutavas et al. (2002) does not support our argument at MIS 6.5.

Sea level change could be one of the secondary factors. Marine proxy records and model simulations show that the exposure of the Sunda shelf at the Last Glacial Maximum (LGM) associated with a low sea-level condition can alters regional hydrologic pattern in Southeast Asia (DiNezio and Tierney, 2013). During the LGM, the strong Pacific equatorial SST gradient could strengthen the Pacific Walker circulation and increase rainfall in the west tropical Pacific. While, as pointed out by DiNezio and Tierney (2013), both of the proxies and model simulations are highly uncertain renditions to climate history, multi-proxy records and high precise models are critical to understand paleoclimate.

3.5 Abrupt ASM changes

One of prominent features ASM dynamics is the occurrence of sudden $\delta^{18}O$ shifts at about the midpoint of NHSI change expressed in all Chinese caves over the study time window (Kelly et al. 2006; Cai et al., 2010a; Wang et al., 2008; Cheng et al., 2012a) (Fig. 5). For example, the jumps from weak to strong ASM states lasted <100 yrs from MIS 6.2-5.5 and 500 yrs from MIS 7.2-7.1 (this study; Wang et al., 2008; Cheng et al., 2009). Climate in Hulu Cave is dominated by EASM; instead, Yangkou and Sanbao caves are located in a region influenced by both EASM and ISM. This agreement of local abrupt $\delta^{18}O$ changes supports the synchroneity of both monsoon sub-system variations on orbital timescale (e.g., Cheng et al., 2012a) and confirms the robustness and regionality of these abrupt transitions in the vast ASM territory. Yangkou records also support the phase lag between ASM and NHSI (Cheng et al., 2009; 2012a). It could be attributed to the influence of millennial-scale abrupt climate change in NH high latitudes (Proter and An, 1995; Sun et al., 2012), which delayed the response of ASM to the rising NHSI (Ziegler et al., 2010; Cheng et al., 2012a).

4 Conclusions

In this study, our new spliced $\delta^{18}O$ record of five stalagmites from Yangkou cave, Chongqing, exhibits ASM variability over the time period during 124-206 kyr BP. The prominent consistency between the Yangkou and previous Chinese cave $\delta^{18}O$ sequences confirms the duration and intensity of the encompassed ASM events in the entire mainland. Our data supports the hypothesis that the ASM change primarily follows NHSI on a precessional orbital timescale. The weakest ASM condition during low-insolation MIS 6.2 was influenced by meridional forcing originating from the North Atlantic. The strongest ASM intensity at MIS 6.5 over the past 500 kyr BP (Cheng et al., 2012b) was presumably partially related to zonal forcing and/or sea level change associated with G/IG dynamics of Walker circulation in the Pacific. More robust geological archives and model simulations are needed to decipher detailed mechanism and forcings for G/IG ASM evolution.

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Figure captions

Fig. 1. (A) Map of precipitation anomaly (mm/day) in June, July, and August (JJA) of AD 1998-2000 during a La Niña event from July 1998 to 2001 April (http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml) comparing with averaged state of JJA from 1980-2010. Triangle symbols denote cave sites of Yangkou (this study), Sanbao (Wang et al., 2008), and Hulu (Clemens 2006). Solid circles indicate marine sediment cores of ODP806B and TR163-19 (Lea et al., 2000). Arrows depict present ground wind directions of the ISM and EASM and also trade wind in the equatorial Pacific. Summer precipitation intensity in eastern and southern China was enhanced during the La Niña event. **(B)** An enlarged map of precipitation anomaly with cave sites of Yangkou, Sanbao, and Hulu.

Fig. 2. Photographs of the five stalagmites collected from Yangkou cave. Brown dashed curves show hiatuses. Straight lines represent subsampling routes for oxygen isotope measurement. Yellow curves denote drilled subsamples for U-Th dating. White dots are the subsamples collected for Hendy Test (Hendy, 1971).

Fig. 3. Age models of Yangkou stalagmites, established with U-Th dates with precisions of ±0.3-1.0% (horizontal error bars).

Fig. 4. Hendy Test on the arbitrarily selected laminae of five stalagmites with coeval data of **(A)** $\delta^{13}C$ and **(B)** $\delta^{18}O$. **(C)** An absence of relationship between $\delta^{18}O$ and $\delta^{13}C$ indicates insignificant kinetic fractionation.

Fig. 5. Cave stalagmite oxygen isotope records of **(A)** Yangkou (this study), **(B)** Sanbao (Wang et al., 2008; Cheng et al., 2009), and **(C)** Hulu (Cheng et al., 2006). U-Th ages and 2-sigma errors were color-coded by stalagmite. Numbers of MIS 5.5-7.3 are given by Sanbao record. Gray line is NHSI on 21 July at 30^{o}N.

Fig. 6. Comparison of Chinese cave $\delta^{18}O$ records of **(A)** Yangkou and **(B)** Sanbao (Wang et al., 2008; Cheng et al., 2009) with **(C)** reconstructed SST records in the WPWP (core ODP806B) and EEP (core TR163-19) (Lea et al., 2000) and **(D)** a global stack benthic foraminifer $\delta^{18}O$ sequence LR04 (Lisiecki and Raymo, 2005). Numbers of MIS 5.5-8 are given by LR04 record. Gray line is NHSI on 21 July at 30^{o}N. Vertical bars denote high insolation intervals.

Table 1. U-Th isotopic compositions and ^{230}Th ages for subsamples of five Yangkou stalagmites on MC-ICP-MS at the HISPEC, NTU

Subsample ID	Depth (mm)	^{238}U (ppb)	^{232}Th (ppt)	δ^{234}U measured[a]	[^{230}Th/^{238}U] activity[c]	[^{230}Th/^{232}Th] (ppm)[d]	Age (kyr) uncorrected	Age (kyr, BP) corrected[c, e]	δ^{234}U$_{initial}$ corrected[b]
Stalagmite: YK5									
YK5-01	3.0	8730 ±13	553.0 ±7.1	215.8 ±2.1	1.0192 ±0.0024	265626 ±3445	179,706 ±1325	179,643 ±1325	358.5 ±3.7
YK5-02	24.0	7335 ±14	263.1 ±7.1	218.4 ±2.7	1.0235 ±0.0027	471128 ±12563	180,437 ±1600	180,375 ±1600	363.6 ±4.8
YK5-03	57.0	4322.4 ±7.6	5997 ±17	192.9 ±2.3	1.0002 ±0.0024	11903 ±39	181,192 ±1438	181,102 ±1438	321.9 ±4.1
YK5-04	79.0	5041 ±10	500.2 ±5.7	187.7 ±2.9	0.9997 ±0.0026	166348 ±1928	183,234 ±1713	183,171 ±1713	315.1 ±5.0
YK5-05	88.0	5729.6 ±9.4	356.1 ±5.1	184.6 ±2.4	0.9986 ±0.0027	265267 ±3814	184,166 ±1611	184,103 ±1611	310.6 ±4.2
YK5-06	103.0	5375.3 ±9.9	593.2 ±5.0	202.1 ±2.6	1.0161 ±0.0022	152028 ±1290	184,207 ±1499	184,143 ±1499	340.1 ±4.7
YK5-07	128.0	4986.2 ±8.8	137.6 ±5.8	201.6 ±2.3	1.0175 ±0.0023	608876 ±25827	185,061 ±1436	184,999 ±1436	340.0 ±4.1
YK5-08	149.0	6076 ±14	269.0 ±5.2	205.0 ±3.0	1.0259 ±0.0028	382639 ±7471	187,222 ±1841	187,159 ±1841	348.1 ±5.3
YK5-09	177.0	8808 ±11	1103.7 ±7.2	215.0 ±1.9	1.0374 ±0.0016	136699 ±889	187,890 ±1128	187,826 ±1128	365.7 ±3.5
YK5-10	188.0	12100 ±19	168.3 ±6.1	210.0 ±2.5	1.0368 ±0.0027	1230671 ±44610	189,876 ±1694	189,815 ±1694	359.2 ±4.7
Stalagmite: YK12									
YK12-01	3.6	6262.6 ±4.1	3895 ±24	309.6 ±1.2	0.9620 ±0.0015	25540 ±164	133,762 ±462	133,690 ±462	451.8 ±1.9
YK12-02	10.5	5016.7 ±2.5	12393 ±25	296.1 ±1.2	0.9590 ±0.0017	6410 ±17	135,884 ±510	135,777 ±511	434.7 ±1.8
YK12-03	21.5	6384.1 ±3.6	1050 ±21	296.2 ±1.1	0.9796 ±0.0014	98334 ±1947	141,426 ±463	141,362 ±463	441.8 ±1.7
YK12-04	40.0	5675.3 ±5.8	9675 ±32	273.0 ±1.6	0.9792 ±0.0017	9483 ±34	147,071 ±670	146,978 ±670	413.7 ±2.6
YK12-05	57.5	13314 ±13	1488 ±21	259.4 ±1.5	0.9840 ±0.0015	145382 ±2094	152,201 ±622	152,138 ±622	398.9 ±2.4
YK12-06	78.0	11746.6 ±5.5	1425 ±24	253.54 ±0.90	0.9852 ±0.0013	134061 ±2272	154,298 ±485	154,235 ±485	392.1 ±1.5
YK12-07	80.0	8830.3 ±5.3	38573 ±98	212.8 ±1.2	0.9796 ±0.0027	3702 ±14	165,267 ±1071	165,120 ±1071	339.4 ±2.2
YK12-08	92.0	7106.6 ±3.6	7546 ±25	199.70 ±0.89	0.9823 ±0.0014	15274 ±55	171,076 ±643	170,993 ±643	323.9 ±1.5
YK12-09	101.0	9513.1 ±6.5	4483 ±23	203.4 ±1.1	0.9976 ±0.0013	34954 ±182	175,795 ±717	175,725 ±717	334.3 ±2.0
YK12-10	105.0	5118.6 ±6.7	2378 ±21	185.4 ±1.9	0.9924 ±0.0018	35265 ±317	181,021 ±1132	180,949 ±1132	309.3 ±3.3
YK12-11	109.5	6109.1 ±3.8	572 ±18	178.4 ±1.2	0.9875 ±0.0013	174125 ±5633	181,929 ±770	181,866 ±770	298.4 ±2.1
Stalagmite: YK23									
YK23-01	2.4	2893.2 ±2.3	13899 ±26	102.8 ±1.5	0.8935 ±0.0018	3070.9 ±8.0	172,790 ±1035	172,620 ±1035	167.6 ±2.4
YK23-02	9.6	2608.9 ±1.7	13210 ±23	99.6 ±1.1	0.9008 ±0.0016	2937.3 ±7.1	177,700 ±946	177,525 ±947	164.5 ±1.9
	Hiatus								
YK23-03	11.2	2705.2 ±1.3	1370 ±17	59.55 ±0.91	0.8799 ±0.0016	28683 ±355	187,327 ±1030	187,254 ±1030	101.1 ±1.6
YK23-04	14.8	2541.1 ±1.2	10313 ±20	60.06 ±0.89	0.8830 ±0.0015	3592.3 ±8.9	188,729 ±982	188,571 ±982	102.4 ±1.5
	Hiatus								
YK23-05	16.8	3255.5 ±2.0	1365 ±14	32.5 ±1.1	0.8632 ±0.0012	33986 ±363	193,472 ±994	193,401 ±994	56.1 ±1.8
YK23-06	27.6	3084.7 ±1.5	2354 ±14	32.53 ±0.92	0.8671 ±0.0012	18764 ±112	195,871 ±932	195,791 ±932	56.6 ±1.6
YK23-07	35.6	2208.7 ±1.3	2343 ±15	47.1 ±1.0	0.8848 ±0.0014	13768 ±89	197,538 ±1069	197,451 ±1069	82.2 ±1.8
YK23-08	42.4	1917.04 ±0.90	4503 ±17	39.3 ±1.1	0.8795 ±0.0013	6182 ±25	199,294 ±1103	199,175 ±1103	68.9 ±1.9
	Hiatus								
YK23-09	43.0	2720.4 ±1.5	1128 ±14	21.23 ±0.90	0.8633 ±0.0013	34369 ±430	200,953 ±1095	200,882 ±1095	37.5 ±1.7
YK23-10	62.4	3355.3 ±2.2	698 ±23	16.2 ±1.0	0.8657 ±0.0014	68753 ±2263	206,207 ±1217	206,141 ±1217	29.0 ±1.8
YK23-11	77.2	2262.6 ±1.5	899 ±19	15.0 ±1.1	0.8655 ±0.0015	35976 ±777	206,922 ±1340	206,839 ±1340	26.9 ±2.1
Stalagmite: YK47									
YK47-01	118.8	812.37 ±0.81	6437 ±11	395.2 ±1.8	1.0173 ±0.0022	2120.0 ±6.0	130,186 ±610	129,991 ±612	570.7 ±2.8
YK47-02	137.5	765.96 ±0.70	2997.5 ±7.6	398.9 ±1.8	1.0295 ±0.0019	4343 ±13	132,271 ±565	132,144 ±566	579.7 ±2.8
Stalagmite: YK61									
YK61-01	13.6	3427.4 ±2.1	13736 ±25	295.8 ±1.2	0.9172 ±0.0019	3779 ±10	125,391 ±512	125,255 ±513	421.5 ±1.8
YK61-02	15.5	3636.8 ±1.9	4502 ±12	275.4 ±1.2	0.9027 ±0.0013	12039 ±37	125,800 ±410	125,715 ±411	393.0 ±1.8
YK61-03	17.0	3974.8 ±2.4	4663 ±10	261.5 ±1.2	0.8936 ±0.0013	12577 ±32	126,291 ±408	126,207 ±408	373.6 ±1.8
YK61-04	20.0	3418.6 ±3.7	1271.0 ±8.9	302.6 ±1.8	0.9278 ±0.0013	41205 ±291	126,643 ±476	126,575 ±476	432.9 ±2.6
YK61-05	22.4	1520.4 ±2.4	3627 ±33	340.2 ±2.4	0.9619 ±0.0024	6658 ±63	127,602 ±716	127,496 ±716	487.8 ±3.5
YK61-06	26.0	2414.5 ±4.3	2217 ±29	315.2 ±2.4	0.9448 ±0.0027	16993 ±229	128,330 ±800	128,250 ±800	453.0 ±3.6
YK61-07	28.3	4454.4 ±4.8	801.0 ±8.8	313.7 ±1.7	0.9452 ±0.0013	86784 ±959	128,698 ±470	128,633 ±470	451.4 ±2.5
YK61-08	30.1	2434.4 ±2.3	657.4 ±8.6	314.5 ±1.6	0.9479 ±0.0012	57958 ±756	129,213 ±431	129,146 ±431	453.1 ±2.3
YK61-09	40.8	3633.5 ±4.6	207 ± 25	302.5 ±2.1	0.9389 ±0.0019	271567 ±32442	129,373 ±635	129,309 ±635	436.1 ±3.2
YK61-10	47.8	3140.5 ±3.0	132.3 ±7.0	305.6 ±1.6	0.9459 ±0.0013	370865 ±19563	130,518 ±452	130,455 ±452	441.9 ±2.3
YK61-11	61.3	5420.5 ±6.6	3648 ±10	306.2 ±1.8	0.9502 ±0.0016	23311 ±67	131,466 ±546	131,393 ±546	443.9 ±2.7
	Hiatus								
YK61-12	63.1	2307.3 ±1.8	1947.5 ±8.3	303.9 ±1.3	0.9801 ±0.0012	19171 ±84	139,776 ±445	139,699 ±445	451.0 ±2.0
YK61-13	74.0	5853.2 ±7.4	3435 ±11	287.2 ±1.7	0.9743 ±0.0017	27409 ±90	142,087 ±626	142,014 ±626	429.2 ±2.7
YK61-14	88.0	3614.8 ±7.1	352 ±20	321.2 ±2.9	1.0365 ±0.0027	175586 ±9727	151,405 ±1087	151,340 ±1087	492.7 ±4.7
YK61-15	110.0	4705.3 ±8.5	672 ±16	320.3 ±2.6	1.0476 ±0.0026	121199 ±2976	154,945 ±1061	154,880 ±1061	496.2 ±4.4
YK61-16	130.0	5173.2 ±8.0	646 ±18	303.7 ±2.3	1.0495 ±0.0022	138661 ±3763	160,250 ±982	160,184 ±982	477.6 ±3.8
YK61-17	137.8	6174.8 ±8.5	405.3 ±7.9	299.4 ±2.0	1.0514 ±0.0019	264459 ±5140	162,165 ±869	162,102 ±869	473.5 ±3.4
YK61-18	167.8	4766.3 ±5.3	347.8 ±7.3	274.1 ±1.7	1.0478 ±0.0014	237115 ±4998	169,056 ±774	168,993 ±774	441.9 ±3.0
YK61-19	185.8	2984.1 ±2.9	1897.4 ±9.4	239.0 ±1.7	1.0238 ±0.0015	26585 ±135	172,561 ±837	172,487 ±837	389.2 ±2.9

Chemistry was performed during 2011-2012 (Shen et al., 2003) and instrumental analyses on MC-ICP-MS (Shen et al., 2012).

Analytical errors are 2σ of the mean.

[a] $\delta^{234}U = ([^{234}U/^{238}U]_{activity} - 1) \times 1000$.

[b] $\delta^{234}U_{initial}$ corrected was calculated based on ^{230}Th age (T), i.e., $\delta^{234}U_{initial} = \delta^{234}U \times e^{\lambda_{234} * T}$, and T is corrected age.

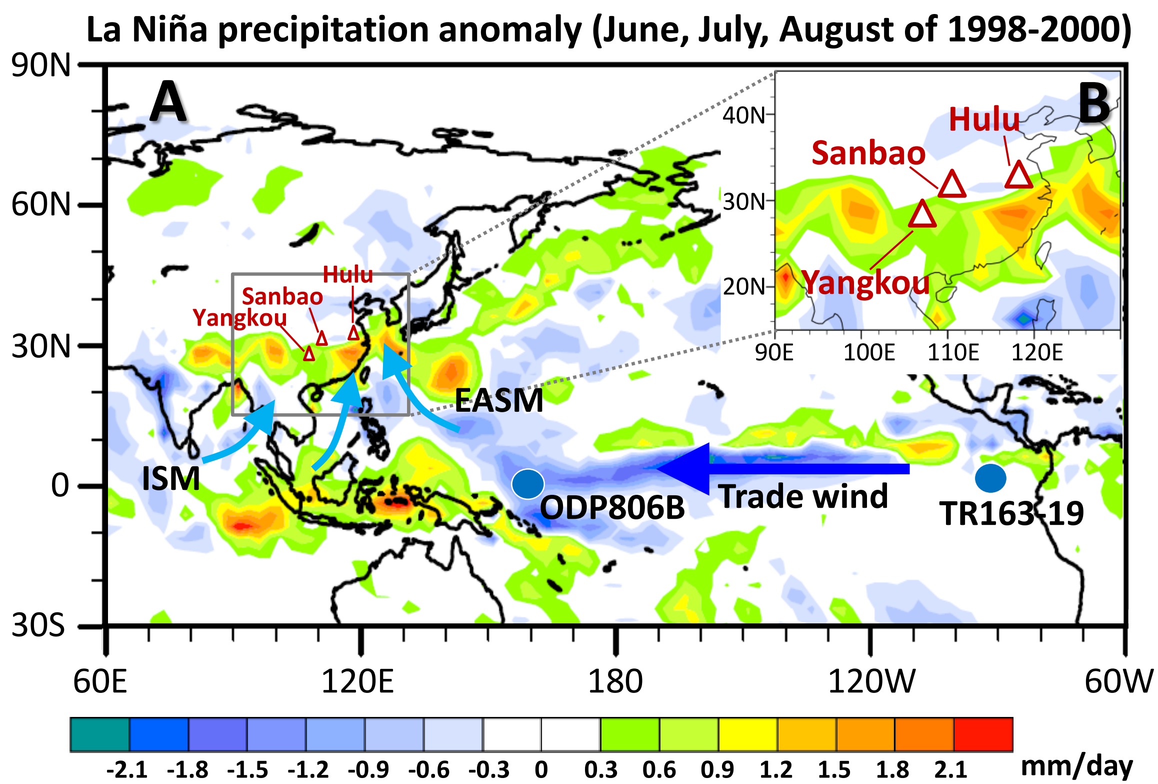
[c] $[^{230}Th/^{238}U]_{activity} = 1 - e^{-\lambda_{230} T} + (\delta^{234}U/1000)[\lambda_{230}/(\lambda_{230} - \lambda_{234})](1 - e^{-(\lambda_{230} - \lambda_{234}) T})$, where T is the age.

Decay constants used are available in Cheng et al. (2000).

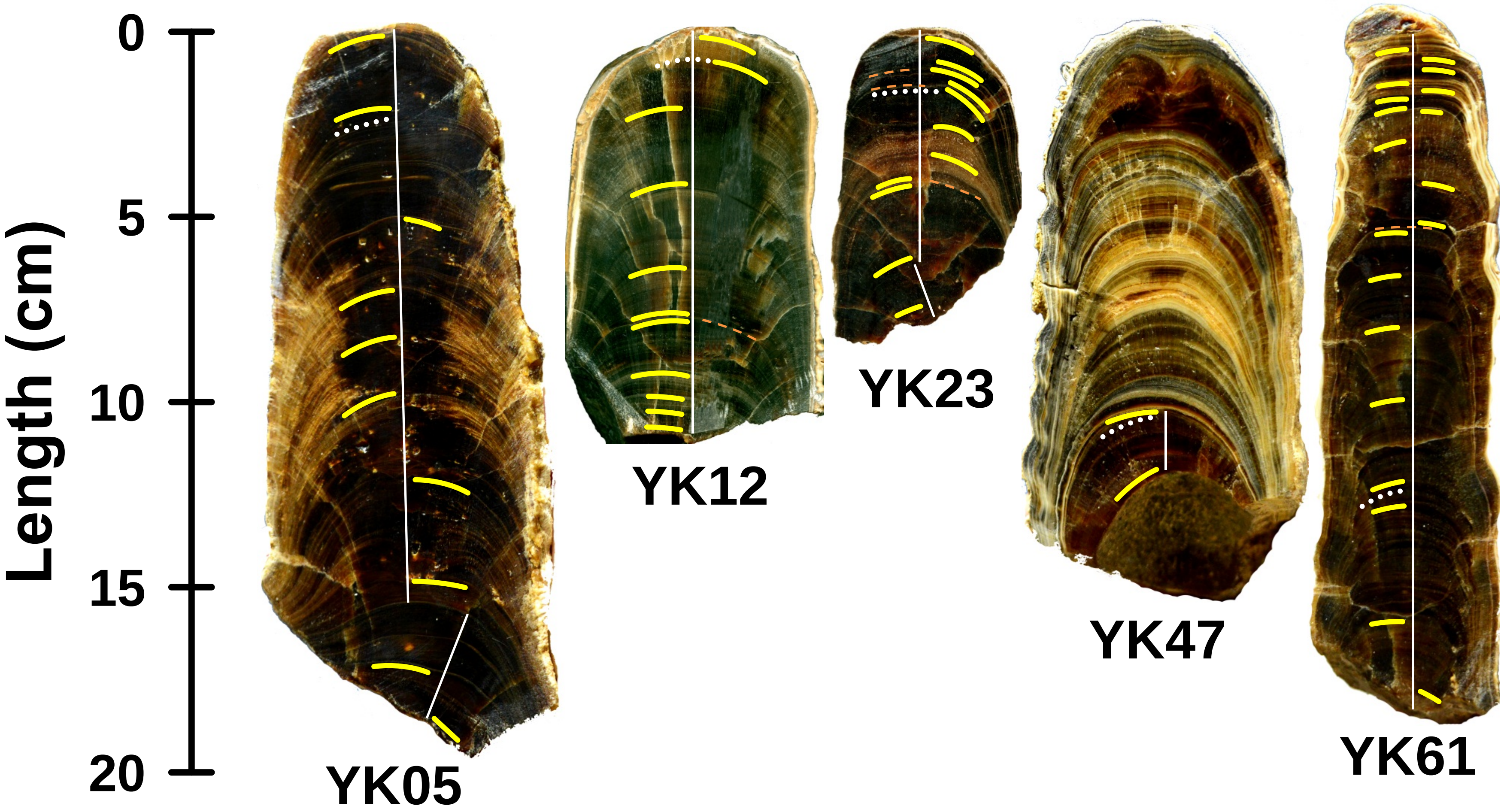
[d] The degree of detrital ^{230}Th contamination is indicated by the [^{230}Th/^{232}Th] atomic ratio instead of the activity ratio.

[e] Age [yr BP (before AD 1950)] corrections were made using an ^{230}Th/^{232}Th atomic ratio of 4 ± 2 ppm.

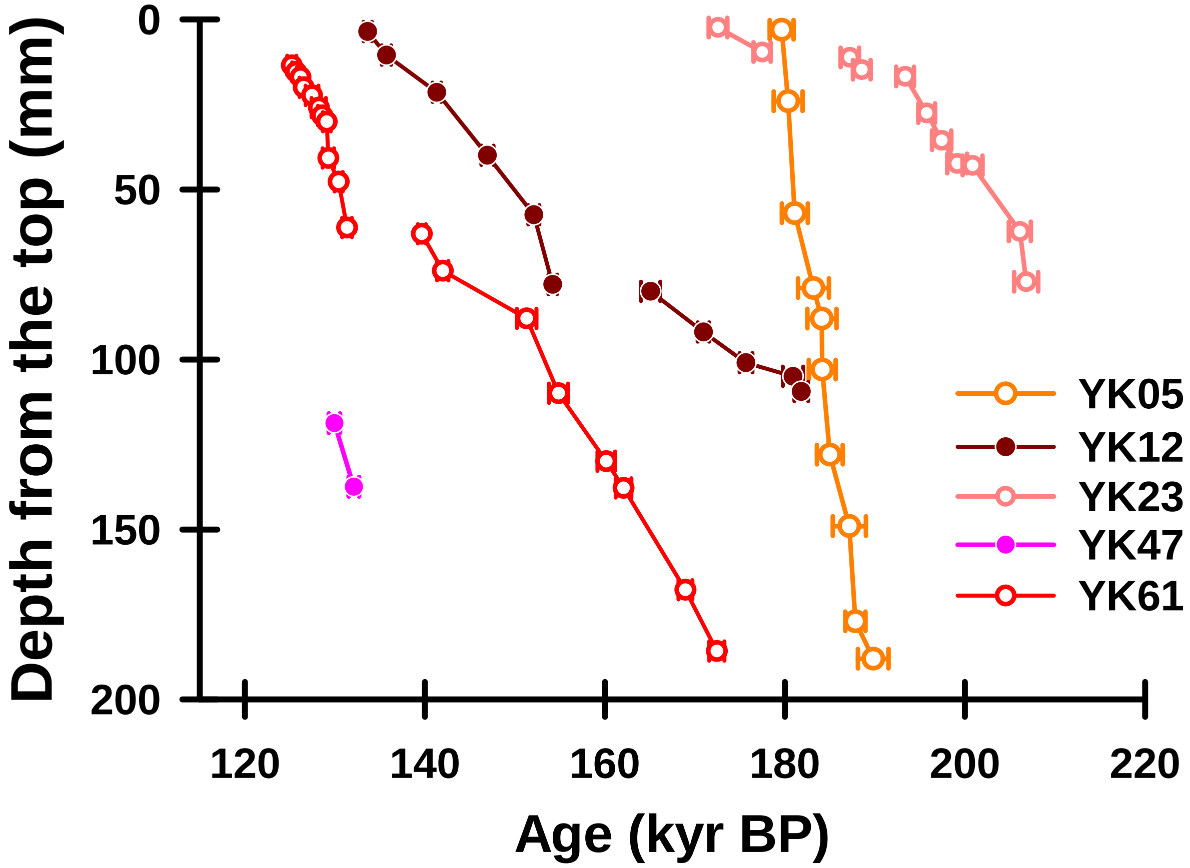
Those are the values for material at secular equilibrium, with the crustal ^{232}Th/^{238}U value of 3.8. The errors are arbitrarily assumed to be 50%.



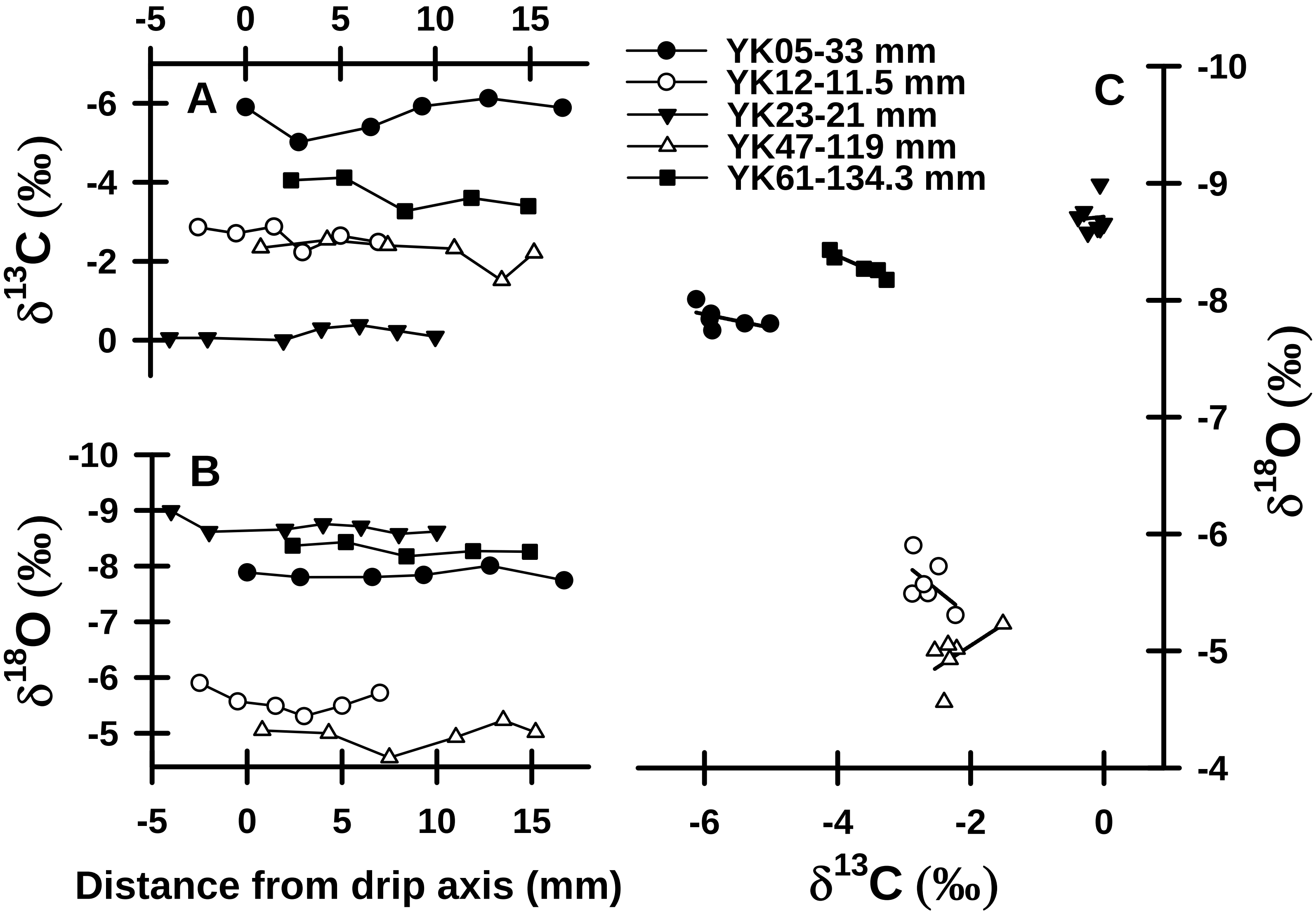
La Niña precipitation anomaly (June, July, August of 1998-2000)
A
B
90N
60N
30N
0
30S
60E
120E
180
120W
60W
Hulu
Sanbao
Yangkou
EASM
ISM
ODP806B
Trade wind
TR163-19
40N
30N
20N
90E
100E
110E
120E
-2.1
-1.8
-1.5
-1.2
-0.9
-0.6
-0.3
0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
mm/day



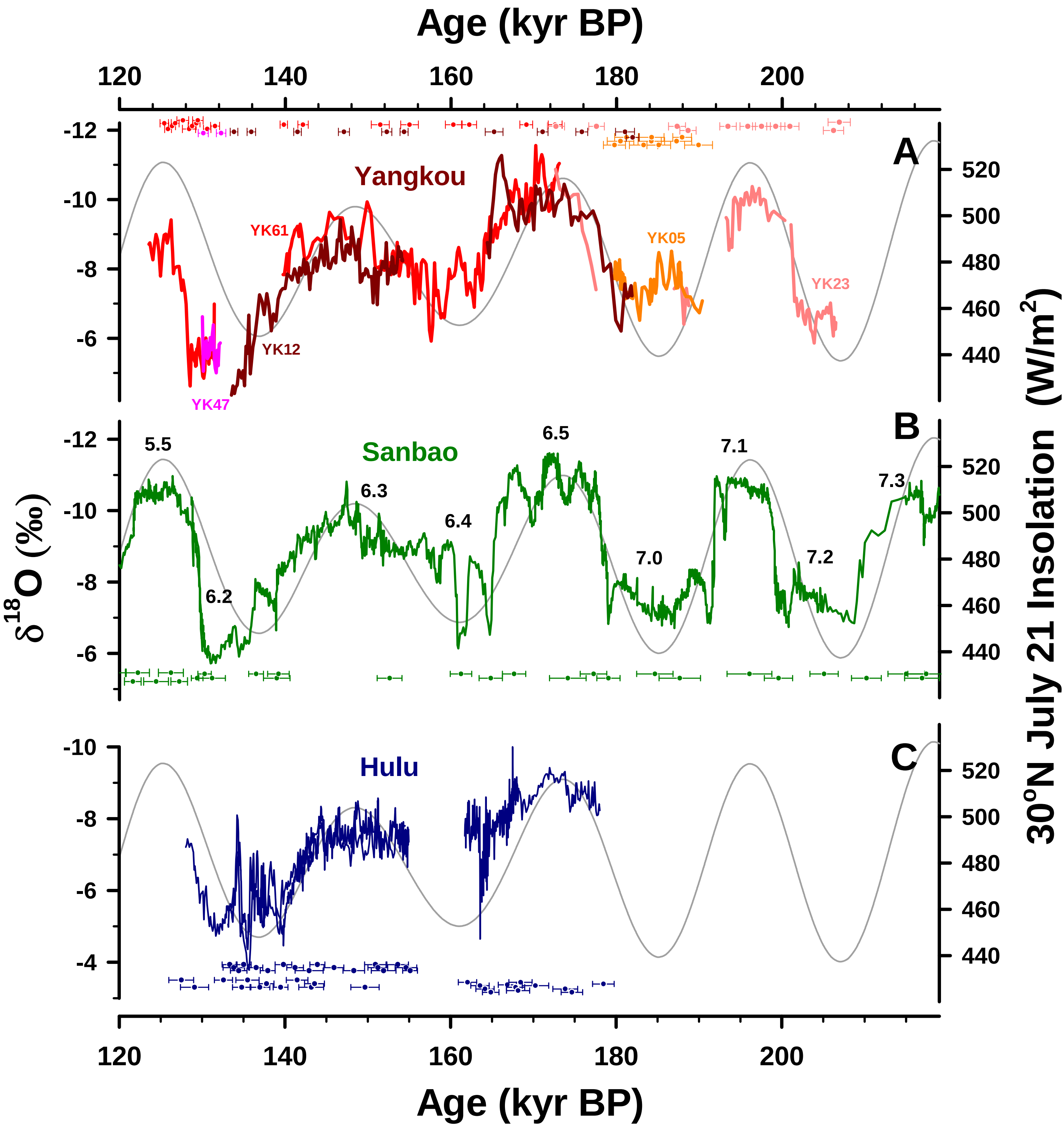
Length (cm)
0
5
10
15
20
YK05
YK12
YK23
YK47
YK61



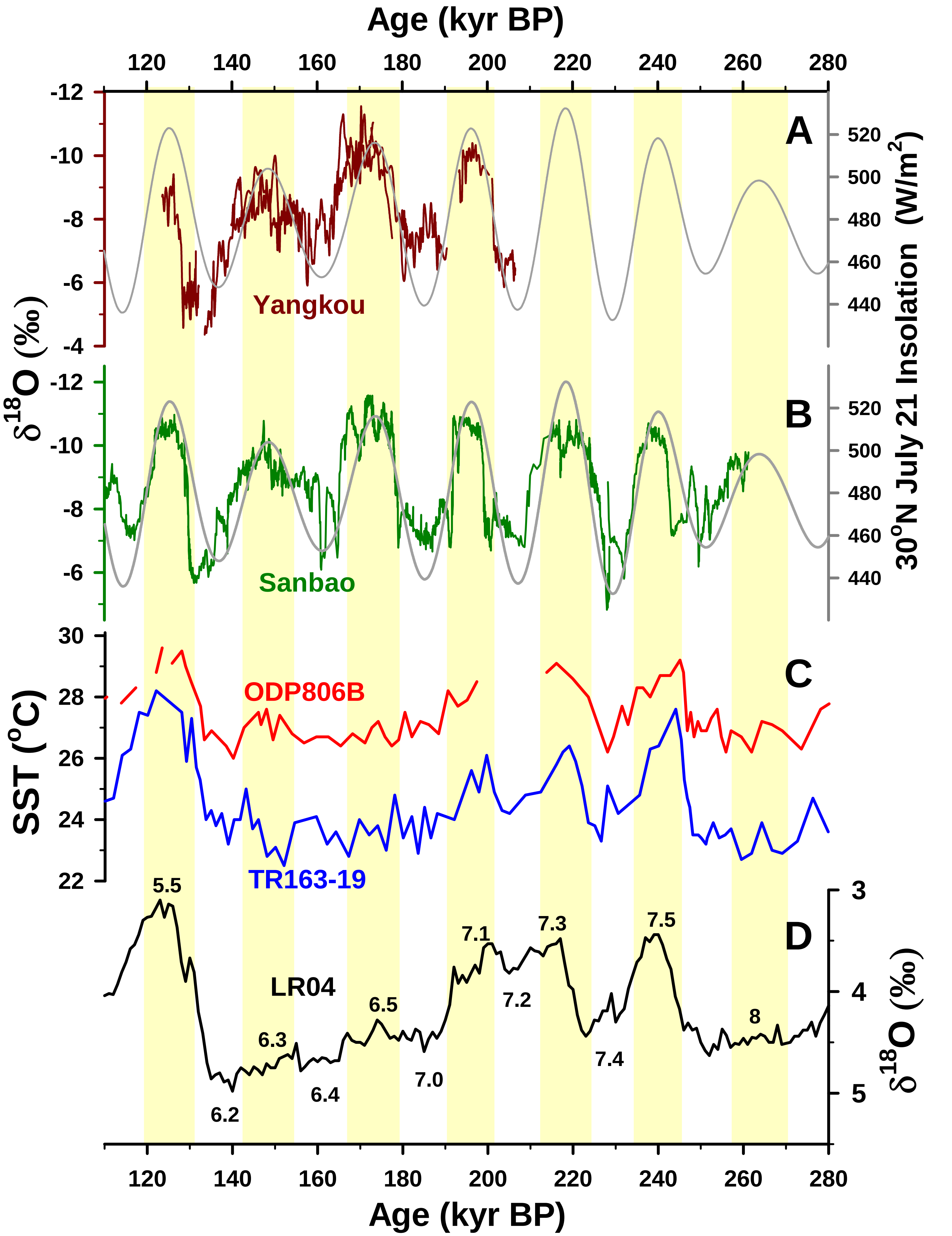
Depth from the top (mm)
0
50
100
150
200
120
140
160
180
200
220
Age (kyr BP)
YK05
YK12
YK23
YK47
YK61



A
B
C
YK05-33 mm
YK12-11.5 mm
YK23-21 mm
YK47-119 mm
YK61-134.3 mm
δ13C (‰)
δ18O (‰)
Distance from drip axis (mm)
-5
0
5
10
15
-6
-4
-2
0
-10
-9
-8
-7
-6
-5
-4



Age (kyr BP)
120
140
160
180
200
A
Yangkou
YK61
YK12
YK47
YK05
YK23
B
Sanbao
5.5
6.2
6.3
6.4
6.5
7.0
7.1
7.2
7.3
C
Hulu
δ18O (‰)
30°N July 21 Insolation (W/m2)
-12
-10
-8
-6
-4
440
460
480
500
520
Age (kyr BP)


Age (kyr BP)
120
140
160
180
200
220
240
260
280
A
B
C
D
Yangkou
Sanbao
ODP806B
TR163-19
LR04
δ18O (‰)
30°N July 21 Insolation (W/m2)
SST (°C)
5.5
6.2
6.3
6.4
6.5
7.0
7.1
7.2
7.3
7.4
7.5
8

We are pleased by the very positive and constructive reviews. We have made every attempt to incorporate the comments/arguments. We believe that we have addressed all reviewers' comments. Please see the details of our implementation of the reviews below.

Points raised by reviewers and editor are shown in blue, Arial type, while our responses are shown in black, Times New Roman type.

Editor: Dr. Mahyar Mohtadi

E1 "First and foremost my apologies regarding the long delay of the review process. We had a large (double-digit) number of declined review invitations, possibly because of the timing of your submission right before the Christmas. When revising your manuscript, please address all the referees' comments in full and send a point-by-point response to their comments. I agree with both referees suggesting to remove the rather speculative discussion of the stalagmite $\delta^{18}O$ forcing by tropical Pacific SST gradient, unless you find more convincing evidence for this hypothesis. Please also consider that your revised manuscript could be sent to the same referees for further advice, particularly in light of the referee #2 suggestions of expanding certain parts of the discussion on the expense of the others. Hope you find these comments helpful."

Thank Dr. Mohtadi for handing with our case and summarizing issues raised by the reviewers. We have addressed all points, including comments, questions, and suggestions given by reviewers. Please consider our revised manuscript if this version can be accepted by your journal.

Reviewer #1: anonymous

We would like to thank this reviewer for reviewing our manuscript, giving us very valuable suggestions and comments. He said "**General comments:** The manuscript by Li et al. presents a stalagmite oxygen isotope ($\delta^{18}O$) record from Yangkou Cave, Chongqing, Southwestern China, to infer Asian summer monsoon (ASM) variability during the penultimate glacial/interglacial period. With high-precision ^{230}Th dating, the authors have found that the Asian summer monsoon variability was dominated by strong precessional cycles, consistent with previous stalagmite results from Sanbao and thus suggesting that the stalagmite records indicate a large-scale phenomenon. The authors further suggest that the ASM intensity was strongest at MIS 6.5 during the penultimate glacial period. The authors then compared their records with marine SST and salinity records from the tropical Pacific and suggest that larger zonal SST gradient, and thus intensified Walker Circulation (a La Nina-like state), would have contributed to the stronger ASM intensity at MIS 6.5. I believe that it is an excellent contribution to CPD and recommend its publication."

Thank this reviewer for recommending publishing. We believed that we have addressed all points raised. Our response is shown in the following section of **R1.1 specific comments**.

R1.1: Specific comments:

The authors specifically picked MIS 6.5 as an example to illustrate the role of tropical Pacific thermal state in affecting the ASM intensity. However, it appears to me that the ASM intensity at MIS 6.5 is largely comparable to other periods such as MIS 6.3, 5.5, and 7.1 (MIS 7.3 and 7.5 as well as inferred from the Sanbao record). If the tropical Pacific thermal state (zonal SST gradient) were so important at orbital timescales, based on the authors' reasoning, much weaker ASM intensity would have occurred at MIS 5.5, 7.1 and 7.3. However, the stalagmite records do not support this argument. Thus, in my opinion, the ASM variability at orbital timescales, as inferred from stalagmite records, is largely independent of the thermal state of tropical Pacific. Why this is the case is still a mystery to most of us. However, the stalagmite records suggest that the $\delta^{18}O$ signal is dominantly controlled by the northern hemisphere summer insolation. The thermal state of tropical Pacific, if there is any role at orbital timescales, would be at most secondary.

We thank this reviewer for giving the comments. We agree with the reviewer's comments. The NH summer insolation dominantly controlled the evolution of ASM at orbital timescales all through the late Quaternary epoch. The tropical Pacific thermal state (zonal SST gradient) could be one of possible secondary factors. Reviewer #2 also pointed out this issue more detailed about possible monsoonal forcings at MIS 6.5. We accepted the suggestions of both reviewers and revised all related sections from ABSTRACT to CONCLUSIONS. Please refer to the sections of **R2.2-R2.5** in the reply for reviewer #2 shown below.

Reviewer #2: anonymous

We would like to thank this reviewer for reviewing our manuscript, giving us very constructive suggestions and comments. He said "The authors present a new stalagmite $\delta^{18}O$ record from a cave in Southwest China, which covers one glacial-interglacial cycle from 206 ka to 124 ka. This record is a valuable addition to the growing number of long speleothem records from China. The important contribution of this new record is that it reproduces interesting features of the Sanbao record, like the large amplitude of the precession-related $\delta^{18}O$ minimum during glacial stage 6.5. In light of recent debates of the origin of the $\delta^{18}O$ signal in Chinese caves, the reproducibility of the signal over large areas is an important aspect. In my opintion this is therefore a valuable contribution and should be published in Climate of the Past. The authors nicely lay out the basis of their study (Hendy test results, age models) and provide clear and informative figures. However, I have some concerns about the discussion and interpretation of the record. In my view the explanation of the strong MIS 6.5 signal is overly confident (see below) and should be tuned down to a possibility."

Thank this reviewer for recommending publishing. We agree with the suggestion about the possible forcings at MIS 6.5, which was also questioned by reviewer #1. We have tuned down the zonal forcing as one of possibilities. Please refer to the following sections. We believed that we have addressed all points raised. Our responses have been shown as sections of particular concerns (**R2.1-R2.5**) and additional specific notes (**R2.6-R2.7**).

R2.1: On the other hand, an important contribution of this record is only mentioned but not discussed further, namely the fact that the timing of the sudden jumps in δ ^{18}O match between the different records, confirming their robustness and regionality. The sudden δ ^{18}O decreases (increases) consistently occur about halfway during NH summer insolation increases (decreases). I suggest adding a discussion about this robust observation.

Thank this reviewer for giving this valuable suggestion. We accepted the suggestion and add a more section of "**3.5 Abrupt ASM changes**".

We wrote "***3.5 Abrupt ASM changes:*** *One of prominent features ASM dynamics is the occurrence of sudden $\delta^{18}O$ shifts at about the midpoint of NHSI change expressed in all Chinese caves over the study time window (Kelly et al. 2006; Cai et al., 2010a; Wang et al., 2008; Cheng et al., 2012a) (Fig. 5). For example, the jumps from weak to strong ASM states lasted <100 yrs from MIS 6.2-5.5 and 500 yrs from MIS 7.2-7.1 (this study; Wang et al., 2008; Cheng et al., 2009). Climate in Hulu Cave is dominated by EASM; instead, Yangkou and Sanbao caves are located in a region influenced by both EASM and ISM. This agreement of local abrupt $\delta^{18}O$ changes supports the synchroneity of both monsoon sub-system variations on orbital timescale (e.g., Cheng et al., 2012a) and confirms the robustness and regionality of these abrupt transitions in the vast ASM territory. Yangkou records also support the phase lag between ASM and NHSI (Cheng et al., 2009; 2012a). It could be attributed to the influence of millennial-scale abrupt climate change in NH high latitudes (Proter and An, 1995; Sun et al., 2012), which delayed the response of ASM to the rising NHSI (Ziegler et al., 2010; Cheng et al., 2012a).*" (**Lines 269-284**)

R 2.2: The suggested explanation for the large amplitude of the MIS 6.5 δ ^{18}O minimum (i.e., association with stronger tropical Pacific SST gradients and Walker circulation) is highly speculative and should be stated much more carefully (in the abstract, L. 21-23 on Page 6290, and L. 23-25 on page 6296).

Reviewer #1 questioned the same issue. We thank both reviewers for giving the comments. We have much carefully interpreted the large amplitude of the MIS 6.5 δ^{18}O minimum.

In ABSTRACT, we revised as "*Except for the solar insolation forcing, the large amplitude of minimum $\delta^{18}O$ values in Yangkou record during glacial period, such as MIS 6.5, could presumably related to the enhanced prevailing Pacific trade wind and/or continental shelf exposure in the Indo-Pacific warm pool.*" (**Lines 41-44**).

In INTRODUCTION, we revised a sentence of "Comparison with records from other Chinese caves would confirm the fidelity of Sanbao cave-inferred ASM intensities. Our results also demonstrate that a strong Walker circulation in the Pacific could enhance glacial ASM precipitation." to "*Comparison with records from other Chinese caves (Cheng et al., 2006; 2009; Wang et al., 2008) confirms the fidelity of Sanbao cave-inferred ASM intensities*." (**Lines 79-81**).

In the section **3.4 Forcings for the abnormal strong ASM at MIS 6.5**, we revised a sentence of "The extremely strong EASM precipitation at MIS 6.5 was not only governed by high NHSI, but also enhanced by the Pacific SST gradient." to "*We speculate that the extremely strong EASM precipitation at MIS 6.5 was not only governed by high NHSI, but also partially affected by the Pacific SST gradient.*". (**Lines 247-249**)

We revised the last paragraph of Section 3.4 of the original manuscript to "*This speculation is supported by modern meteorological observations (e.g, Xue et al., 2007; Tan, 2013) and decadally-resolved marine records (Oppo et al., 2009). La Niña years accompany above-normal precipitation probabilities above normal in mainland China (Tan, 2013 and references therein). Two thousand year-SST and -salinity records from the Makassar Strait (Oppo et al., 2009) also support a strong link between Pacific Ocean climate and the AM. However, comparison of SST histories in the South China Sea and eastern equatorial Pacific SST suggests an El Niño-like condition for the last glacial time (Koutavas et al., 2002), opposite to the findings by Lea et al. (2000). The study by Koutavas et al. (2002) does not support our argument*.". (**Lines 250-259**)

R2.3: Firstly, from the Chinese stalagmite records it is not at all clear that amplitudes of precession-related $\delta^{18}O$ minima are larger during glacial times than during interglacials. In the Sanbao record, the amplitude of MIS 6.5 is similar to or slightly smaller than that of MIS 5.3 (an interglacial period). Furthermore, the amplitudes of the $\delta^{18}O$ minima seem to not always be consistent among different sites in China. The subdued signal for MIS 5.5 in comparison to MIS 5.3 in Sanbao is not observed in Dongge cave (see Fig 5 in Cheng et al 2012). In my opinion, the large amplitude of the MIS 6.5 minimum in the presented record is indeed a very interesting feature, and it is important that it is replicated in 2 caves 400 km apart. The authors could also mention the correspondence to the Loess plateau record of Rousseau et al. (2009) (as highlighted by Cheng et al. 2012). But given the ambiguities outlined above the interpretation should be done much more carefully. It probably needs long time series from multiple Chinese caves to derive a clear picture of amplitude changes in relation to orbital forcing.

Thank this reviewer for giving the valuable suggestions. In the new version, we discussed the inconsistent change of stalagmite records among Chinese cave as: "*During* *the MIS 5, the variations of Chinese stalagmite $\delta^{18}O$ records are not consistent among caves (Cheng et al., 2012). In Sanbao record (Wang et al., 2008), a $\delta^{18}O$ minimum at IMS 5.3 is more depleted than one at MIS 5.5. This phenomenon is seemingly illustrated in Yangkou records (Fig. 5A). However, Dongge (Kelly et al. 2006) and Tianmen (Cai et al., 2010a) stalagmite records are characterized by the most depletion in ^{18}O at MIS 5.5 (Fig. 2 of Cai et al., 2010a). This discrepancy may be attributable to different hydrological conditions at MIS 5. Long time series from more Chinese caves are required to derive a clear picture of amplitude changes in relation to orbital forcing at MIS 5.".* (**Lines 184-192**)

The Loess plateau record was cited as "*This strong monsoon event is also observed in Chinese Loess plateau record (Rousseau et al., 2009). Modeling experiments suggest this increased monsoon intensity is primarily attributed to high NH insolation (Masson et al., 2000).*". (**Lines 205-208**)

R2.4: Secondly, the hypothesis that glacial times were associated with more La Niña-like conditions in the tropical Pacific is also highly uncertain. While the SST differences observed by Lea et al. (2000), which the authors refer to, suggest enhanced zonal temperature gradients during glacial times, other studies have inferred the opposite, more El Niño-like conditions, for glacial times (Koutavas et al 2002). Furthermore, the exposure of the Sunda Shelf during glacial times likely had a strong influence on regional circulation patterns (e.g., DiNezio 2009), which is at present largely unconstrained.

Thank this reviewer for the in-depth comments. We wrote "*This speculation is supported by modern meteorological observations (e.g, Xue et al., 2007; Tan, 2013) and decadally-resolved marine records (Oppo et al., 2009). La Niña years accompany above-normal precipitation probabilities above normal in mainland China (Tan, 2013 and references therein). Two thousand year-SST and -salinity records from the Makassar Strait (Oppo et al., 2009) also support a strong link between Pacific Ocean climate and the AM. However, comparison of SST histories in the South China Sea and eastern equatorial Pacific SST suggests an El Niño-like condition for the last glacial time (Koutavas et al., 2002), opposite to the findings by Lea et al. (2000). The study by Koutavas et al. (2002) does not support our argument at MIS 6.5.*

Sea level change could be one of the secondary factors. Marine proxy records and model simulations show that the exposure of the Sunda shelf at the Last Glacial Maximum (LGM) associated with a low sea-level condition can alters regional hydrologic pattern in Southeast Asia (DiNezio and Tierney, 2013). During the LGM, the strong Pacific equatorial SST gradient could strengthen the Pacific Walker circulation and increase rainfall in the west tropical Pacific. While, as pointed out by DiNezio and Tierney (2013), both of the proxies and model simulations are highly uncertain renditions to climate history, multi-proxy records and high precise models are critical to understand paleoclimate.". (**Lines 250-268**)

R2.5: The discussion of the Dole effect could be shortened - it would be sufficient to state that the δ ^{18}Oatm record from ice cores shows a strong peak at MIS 6.5 as well, and that the inferred enhanced biosphere activity fits well to enhanced precipitation in the low latitudes.

We shortened the description of Dole effect and **deleted** the following sentences: *"*The Dole effect was first described by Dole in 1936. This effect is an inequality of δ^{18}O values between the atmosphere and seawater. Modern δ^{18}O of atmospheric O_2 ($\delta^{18}O_{atm}$) is ~23.5‰ heavier than the seawater value (Kroopnick and Craig, 1972). This inequality is caused by respiration, which prefers depleted $^{16}O_2$ rather than $^{18}O_2$, and is balanced by photosynthesis, which emits oxygen with the δ^{18}O value equal to the water used in the reaction (Guy et al., 1989), resulting in a net decrease of the $\delta^{18}O_{atm}$ value. Accordingly, the $\delta^{18}O_{atm}$ variation can depend on the activity of photosynthesis.*"*.

R2.6: Detailed comments:

R2.6.1: The authors should consider shortening the title.

We shortened the title from "Variability of the Asian summer monsoon during the penultimate glacial/interglacial period inferred from stalagmite oxygen isotope records from Yangkou cave, Chongqing, southwestern China" to "*Stalagmite-inferred variability of the Asian summer monsoon during the penultimate glacial/interglacial period*".

R2.6.2: Abstract:

L. 5 "mainly from Sanbao": What about the Hulu and Dongge records (which are further apart from Sanbao than the record presented here)? I assume the authors mean that only Sanbao provides a continuous, long record, but the current statement neglects the other available records.

Thank this reviewer for giving this comment. We revised the sentence to "*However, this long-term continuous ASM variability is inferred primarily from oxygen isotope records of stalagmites, mainly from Sanbao cave in mainland China, and may not provide a comprehensive picture of ASM evolution*." (**Lines 31-33**)

R2.6.3: Introduction:

Page 6289

L. 22-25: Records from other archives besides speleothems should be mentioned here, like the Loess sequences or lake records.

We accepted the suggestion given by this reviewer and added Loess records in the reference. We wrote "Recent studies have led to significant advances in understanding Quaternary ASM evolution on different time scales (e.g., An, 2000; Wang et al., 2001; 2008; Fleitmann et al., 2003; 2004; ***Rousseau et al. 2009***; Cheng et al., 2009; 2012b; Zhang et al., 2008; Sinha et al., 2011).". (**Lines 55-58**)

R2.6.4: Page 6290

L. 20-23: This sentence again disregards the replication already achieved by other speleothem records (such as that from Hulu cave shown in Figure 5).

Thank this reviewer for pointing out this point. We revised the sentence to "*Comparison with records from other Chinese caves (Cheng et al., 2006; 2009; Wang et al., 2008) confirms the fidelity of Sanbao cave-inferred ASM intensities*.". (**Lines 79-81**) Hulu and Sanbao records were studied in the cited references.

R2.6.5: Material and Methods:

Dating: Since the dating uses three different isotopes of U and Th, the authors should either say "^{238}U-^{234}U-^{230}Th dating" or simply U-Th dating. The authors should mention here details currently only given in the footnotes to Table 1, namely, which half-lives were used and the assumed detrital Th isotope ratio. It is furthermore not clear what is included in the errors. E.g., is the uncertainty of the detrital Th ratio included?

We replaced all "^{230}Th dating" by "U-Th dating" throughout the manuscript. The details about the decay constants, assumed detrital Th isotope ratio and error calculation were added.

We wrote "*The decay constants used are 9.1577 × 10^{-6} yr^{-1} for ^{230}Th and 2.8263 × 10^{-6} yr^{-1} for ^{234}U (Cheng et al., 2000), and 1.55125 × 10^{-10} yr^{-1} for ^{238}U (Jaffey et al., 1971). All errors of U-Th isotopic data and U-Th dates are two standard deviations (2σ) unless otherwise noted. Age (before AD 1950) corrections were made using an ^{230}Th/^{232}Th atomic ratio of 4 ± 2 ppm, which are the values for material at secular equilibrium, with the crustal ^{232}Th/^{238}U value of 3.8 (Taylor and McLennan, 1995) and an arbitrary uncertainty of 50%.*" (**Lines 104-111**)

R2.7: Minor comments

R2.7.1:

Page 6289

L. 2-4: give references

Thank this reviewer for giving this suggestion of listing references in ABSTRACT. However, for this journal, references should not be cited. One of online guidelines is "Reference citations should not be included in this section,…". So, we cannot give references here. Besides, listing the related references is not urgently required here.

R2.7.2:

L. 9: time series supports the strong

Corrected.

R2.7.3:

L. 15: past five G/IG cycles

Corrected. It was a typo. We corrected "fiver" to "five".

R2.7.4: Page 6291

L. 11: Use the same ages for start and end of the record as in the rest of the manuscript.

Corrected. We corrected the ages for start and end of our record, such as 124-206 kyr BP, throughout the manuscript.

R2.7.5: L. 16: 53 instead of fifty-three

Arabic numerals cannot be the 1st word in a sentence. We still wrote "***Fifty three*** *powdered subsamples, 60-80 mg each, were drilled from the polished surface along the deposit lamina of the five stalagmites (Fig. 2, Table 1), on a class-100 bench in a class-10,000 subsampling room*.". (**Lines 97-100**)

R2.7.6: Page 6292

L. 17: 100s - 10000 ppt

Corrected.

R2.7.7: L. 21: One to two

Corrected.

R2.7.8: Page 6293

L. 17-19: leave out the exact time intervals for _18O maxima and minima; these can be seen in the Figure. Replace " _" by " to"

Corrected. We deleted the time intervals. We changed this sentence from "This $\delta^{18}O$ record varies from -10‰ ~ -9‰ at 124-127, 141-155, 165-177, and 193-201 kyr BP, to -7‰ ~ -6‰ at 128-136, 155-165, 177-190, and 201-206 kry BP." to "*This $\delta^{18}O$ record varies from -10‰ to -4‰*.". (**Lines 151-152**)

R2.7.9: Page 6294

L. 20: " thermal conditions" is a vague expression

Corrected. We revised it to "…NH insolation…" (**Line 181**)

R2.7.10: Page 6297

L. 7: encompassed instead of enclosed

Corrected.

R2.7.11: Table 1: Ages are in kyr (not yr). Also, the Th isotope ratio for date YK5-08 contains too many digits.

Corrected. Thank this reviewer for this comment. We corrected the "yr" to "kyr" and shortened the digits of the isotope ratio for date YK5-08. Please refer to the revised Table 1 for details.

R2.7.12: Figure 1: The colored arrow for the trade winds is confusing.

In order to avoid the confusion, we changed the color of the arrow for the trade winds to only blue color shown below.

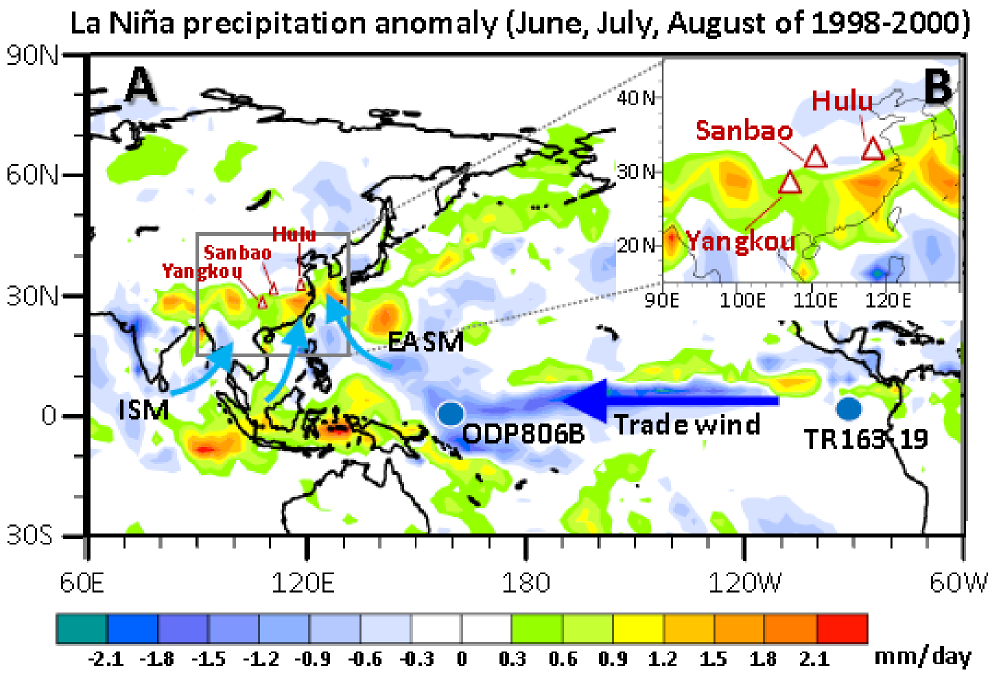


Figure R1. Revised figure 1.

References:

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