Table S1. Statistical characteristics of tree ring $\delta^{18}O$ time series.

Statistical parameters	07A	31B	30A	19A	22A	05B
Time period	1784–2013	1814–2013	1784–2013	1764–2013	1920–2013	1950–2013
$\delta^{18}O_{tree}$ Range (‰)	24.41–35.01	25.45–33.60	25.03–34.32	25.66–36.01	27.16–32.87	27.06–32.09
Mean value (‰)	29.89	30.08	30.47	30.14	29.79	29.67
Standard deviation(‰)	1.80	1.46	1.57	1.91	1.41	1.28
Skewness	–0.32	–0.31	–0.39	0.14	0.08	–0.21
Kurtosis	0.01	0.03	0.34	0.16	–0.70	–0.87
Autocorrelation	0.47	0.29	0.37	0.40	0.24	0.07

Table S2. Correlation coefficients among individual tree ring $\delta^{18}O$ series.

	07A	31B	30A	19A	22A	05B
07A	1					
31B	0.67/171	1				
30A	0.55/194	0.70/164	1			
19A	0.68/192	0.66/163	0.68/187	1		
22A	0.63/84	0.78/83	0.72/80	0.58/80	1	
05B	0.55/50	0.73/55	0.65/58	0.63/54	0.63/63	1

Table S3. Statistical characteristics of composite $\delta^{18}O$ chronology.

Statistical term	Sequence length	Start and end year	Skewness	Kurtosis	Mean correlation within series
Statistic	230	1784–2013 AD	–0.19	–0.34	0.66

Table S4. Calibration and verification statistics for the $P_{J\text{-}J}$ reconstruction in Heng Mountain.

Calibration Period	r	ST	t	Verification Period	r	RE	CE	ST	t
1957–1985	–0.73**	26+/3–**	4.48**	1986–2013	–0.62**	0.36	0.34	21+/7–**	5.21**
1985–2013	–0.63**	23+/6–**	5.13**	1957–1984	–0.72**	0.49	0.48	24+/4–**	4.20**
1957–2013	–0.67**	47+/10–**	6.59**						

Note: ** represents the significance is at the 99.9% confidence level.

Table S5. Comparisons between the reconstructed precipitation and historical records.

Dry year	Precipitation (mm)	Historical records	Wet year	Precipitation (mm)	Historical records
1792	33.52	The great drought and famine led to grain prices soaring, and people had to sell children to live.	1822	231.83	After the flood, plague ensued, and countless houses collapsed.
1832	97.78	Huge swarms of locusts had destroyed crops and people suffer hunger.	1912	275.78	The Yellow River flood caused some villages submerged.
1836	94.04	Locust plague resulted in poor harvests, and people were homeless and dead.	1939	258.12	Flood hit 38 counties in Shanxi Province, and the north was worst.

1877	116.35	Widespread and prolonged drought make people eat weeds and bark to stay alive, and some starved to death.	1950	279.86	Flash floods and hail occurred simultaneously, people suffering great losses.
1928	112.97	Great drought covered over whole province, causing enormous casualties and property losses.	1954	291.23	Serious floods greatly decreased food production, hitting 1273 villages.
1972	89.91	The drought had left 1.87 million of people and 31 thousand head of livestock in Shanxi short of water.	1996	257.61	Rainstorm resulted in destruction of many croplands and houses.

Table S6. Correlation between several Asian summer monsoon indices and the reconstructed precipitation.

Monsoon indices	Reference	Defining variable(s), level (hPa), and regions	Reanalysis data	Correlation coefficient
I_{ZTC}	Zhang et al., 2003	vorticity, 850, (10°–35°N, 100°–150°E)	20CR (1851–2013)	r=0.23, n=163, p < 0.005 (June)
I_{WY} (SAMI)	Webster and Yang, 1992	u, 200–850, (0°–20°N, 40°–110°E)	NCEP/NCAR (1948–2013)	r=0.44, n=66, p < 0.001 (May)

I_{ZHW}	Zhu et al., 2000	u, 850–200 (0°–10°N, 100°–130°E)	NCEP/NCAR (1948–2013)	r=0.45, n=66, p < 0.001 (May)
I_{LKY} (SAMI)	Lau and Yang, 2000	v,850–300, (10°–30°N, 70°–110°E)	JRA–55 (1958–2013)	r=0.37, n=56, p < 0.005 (June–July)
I_{LKY} (EAMI)		u,200, (20°–50°N, 100°–150°E)	20CR (1851–2013)	r=0.20, n=163, p < 0.01 (July)
AIRI	Indian Institute of Tropical Meteorology	monthly All-India Rainfall precipitation	(1871–2013)	r=0.24, n=142, p < 0.005 (May–July)

Note: here, u=zonal winds, v=meridional winds.

Table S7. Cross-dating results of tree-ring samples in Heng Mountain.

Seq	Series	Time_span	1725 1774	1750 1799	1775 1824	1800 1849	1825 1874	1850 1899	1875 1924	1900 1949	1925 1974	1950 1999	1975 2024
1	hs02a	1772 2014		.70	.71	.76	.67	.66	.64	.57	.56	.70	.77
2	hs02b	1767 2014		.83	.73	.62	.74	.72	.59	.50	.50	.63	.68
3	hs03a	1763 2014		.65	.72	.71	.86	.74	.75	.84	.75	.74	.73
4	hs03b	1789 2014			.44	.56	.89	.80	.76	.85	.81	.84	.89
5	hs04a	1787 2014			.64	.68	.88	.88	.82	.82	.81	.84	.85
6	hs04b	1787 2014			.70	.77	.92	.84	.82	.79	.70	.81	.85
7	hs05a	1767 2014		.86	.85	.85	.88	.90	.92	.91	.87	.86	.85
8	hs05b	1767 2014		.87	.87	.83	.89	.91	.89	.84	.68	.77	.80
9	hs06a	1830 2014					.87	.84	.83	.91	.84	.78	.82
10	hs06b	1769 2014		.86	.85	.83	.92	.88	.88	.94	.84	.66	.73
11	hs07a	1786 2014			.78	.69	.80	.80	.78	.62	.31A	.45	.57
12	hs07b	1786 2014			.63	.52	.62	.62	.75	.77	.66	.71	.80
13	hs08a	1769 2014		.73	.72	.66	.89	.85	.91	.93	.88	.80	.81
14	hs08b	1822 2013				.85	.85	.79	.65	.86	.86	.81	.81
15	hs08c	1745 1875	.56	.56	.58	.41	.86	.86					
16	hs09a	1772 2014		.84	.84	.82	.90	.87	.85	.90	.84	.79	.86
17	hs09b	1772 2014		.81	.81	.70	.72	.71	.74	.74	.66	.67	.77
18	hs10a	1765 1948		.84	.79	.75	.67	.70	.83	.83			
19	hs10b	1765 2014		.84	.70	.61	.75	.86	.86	.87	.75	.70	.78
20	hs11a	1757 2013		.76	.79	.73	.87	.93	.88	.83	.82	.87	.87
21	hs11b	1757 2013		.81	.86	.88	.84	.82	.90	.84	.81	.82	.81
22	hs12a	1782 1949			.70	.56	.62	.66	.85	.87			
23	hs12b	1782 2003			.80	.77	.88	.87	.89	.89	.75	.48	.41
24	hs13a	1776 2014			.87	.80	.84	.88	.86	.77	.65	.71	.73
25	hs13b	1776 2014			.78	.79	.92	.87	.88	.91	.86	.77	.76
26	hs14a	1753 2014		.42	.52	.74	.88	.80	.78	.85	.85	.70	.72
27	hs14b	1753 2014		.38	.46	.71	.86	.82	.86	.92	.88	.84	.85
28	hs15a	1798 2014			.73	.72	.79	.78	.74	.80	.82	.81	.81
29	hs15b	1805 2014				.67	.77	.73	.74	.87	.83	.79	.86
30	hs16a	1810 2014				.85	.90	.87	.89	.91	.80	.77	.83
31	hs16b	1810 2013				.79	.88	.91	.82	.85	.84	.81	.87
32	hs17a	1790 2013			.75	.78	.87	.87	.81	.86	.83	.78	.84
33	hs17b	1790 2011			.65	.70	.83	.91	.92	.93	.92	.88	.76
34	hs18a	1842 2013					.93	.93	.86	.88	.85	.73	.77
35	hs18b	1794 2014			.58	.64	.89	.91	.90	.90	.84	.78	.81
36	hs19a	1765 2014		.88	.89	.87	.92	.90	.93	.90	.86	.89	.87
37	hs19b	1759 2014		.80	.92	.86	.87	.88	.94	.94	.84	.84	.86
38	hs20a	1795 2014			.81	.80	.86	.81	.80	.81	.65	.45	.59
39	hs20b	1795 2014			.86	.87	.89	.81	.84	.90	.87	.80	.79
40	hs21a	1778 2014			.86	.86	.92	.85	.78	.83	.83	.83	.80
41	hs21b	1830 2014					.89	.88	.80	.80	.83	.75	.73
42	hs22a	1773 2014		.85	.85	.73	.72	.76	.89	.93	.87	.86	.86
43	hs22b	1768 2014		.91	.90	.84	.90	.90	.85	.88	.83	.79	.84
44	hs23a	1778 2014			.90	.88	.92	.92	.88	.90	.92	.83	.85
45	hs23b	1774 2014		.86	.87	.79	.82	.75	.77	.82	.75	.74	.81
46	hs24a	1783 2014			.67	.72	.76	.68	.66	.75	.62	.61	.74
47	hs24b	1763 2014		.77	.78	.80	.80	.67	.71	.74	.64	.68	.76
48	hs25a	1803 2014				.42	.80	.68	.59	.78	.70	.69	.79
49	hs25b	1787 2014			.72	.65	.78	.74	.67	.75	.79	.72	.79
50	hs26a	1771 2014		.73	.71	.72	.91	.90	.88	.92	.88	.86	.90
51	hs26b	1760 2014		.83	.82	.74	.91	.92	.89	.90	.87	.84	.84
52	hs27a	1759 2014		.64	.70	.70	.86	.88	.90	.92	.86	.80	.86
53	hs27b	1742 2014	.48	.48	.82	.70	.80	.83	.82	.84	.78	.81	.83
54	hs28a	1782 2014			.74	.67	.78	.78	.70	.80	.76	.73	.81
55	hs28b	1790 2014			.68	.79	.91	.77	.77	.88	.86	.82	.79
56	hs29a	1801 2014				.57	.82	.82	.87	.94	.80	.77	.85
57	hs29b	1801 2013				.62	.81	.84	.90	.88	.79	.73	.77
58	hs30a	1785 2014			.79	.62	.83	.94	.84	.83	.89	.83	.79
59	hs30b	1772 2014		.82	.81	.65	.80	.88	.89	.93	.89	.82	.80
60	hs31a	1781 2014			.38	.33A	.44	.39	.74	.83	.74	.75	.84
61	hs31b	1805 2014				.20B	.43	.31A	.37	.70	.79	.68	.68
Av segment correlation			.52	.75	.75	.71	.82	.81	.81	.84	.79	.76	.79