Supporting Information for "Coherent streamflow variability in Monsoon Asia over the past eight centuries—links to oceanic drivers"

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Introduction

In this Supporting Information, we provide some information on previous reconstruction works in Monsoon Asia, more details on data: streamflow station metadata, streamflow preprocessing, and MADA's starting year. We also provide a comparison of spatial coherence in the modern period, and a more in-depth analysis of the streamflow–SST teleconnection.

Text S1. Previous streamflow reconstructions in Monsoon Asia

The first streamflow reconstruction in Monsoon Asia was by Davi et al. (2006). Since then, 27 reconstruction studies have appeared, more than half of which were published in the last four years (Figure S1). Each of these works studied a specific river; most of them focused on China (Table S1).

Text S2. Streamflow data preprocessing

We determined the degree of asymmetry of the streamflow data using the Hinkley's D statistic (Hinkley, 1977), formulated according to equation (1)

$$D = \frac{m - \mu}{q} \tag{1}$$

where m is the sample median, μ the sample mean, and q the sample inter-quartile range. If log-transforming reduces the absolute value of D for a station, then we will use the log-transformed flow as reconstruction target; otherwise we use the untransformed flow. We also check the densities of the transformed and untransformed flow visually (Figure S3), and found that the densities are similar for most stations.

Text S3. Spatial coherence in the modern period (1950–2012)

As another reliability test for our reconstructions, we checked the spatial coherence of our reconstructions for the modern period against instrumental streamflow data, using the same standardization as in Figure 5. The results are shown in Figure S5. We observe similar coherence among river basins in the instrumental data as in the reconstruction. The reconstructed streamflow also captures the extreme events very well.

Text S4. Time-varying teleconnection with SST patterns

We split the streamflow–SST correlation analysis into three 50-year periods: 18551904, 19051954, and 19552004. We found that the correlation between SST and streamflow weakened remarkably for the Chao Phraya, Mekong, and Yangtze during 19051954 compared to the other two time windows (Figure S6a, b, and c). The links between Monsoon Asia streamflow and SST patterns varied through time. Figures S6c and d show that our reconstruction captures the teleconnection patterns fairly well for the modern period.

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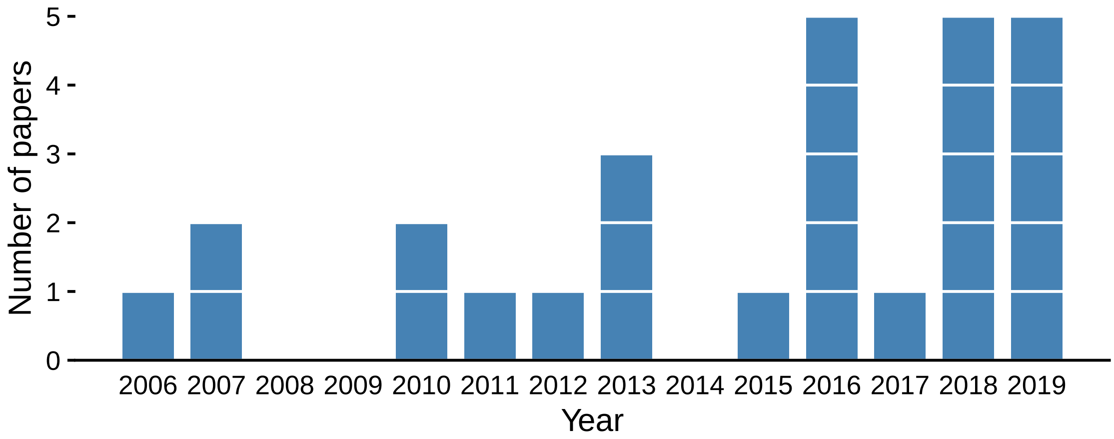

Figure S1. Number of Monsoon Asia streamflow reconstruction papers published each year till September 2019. The publications are listed in Table S1.

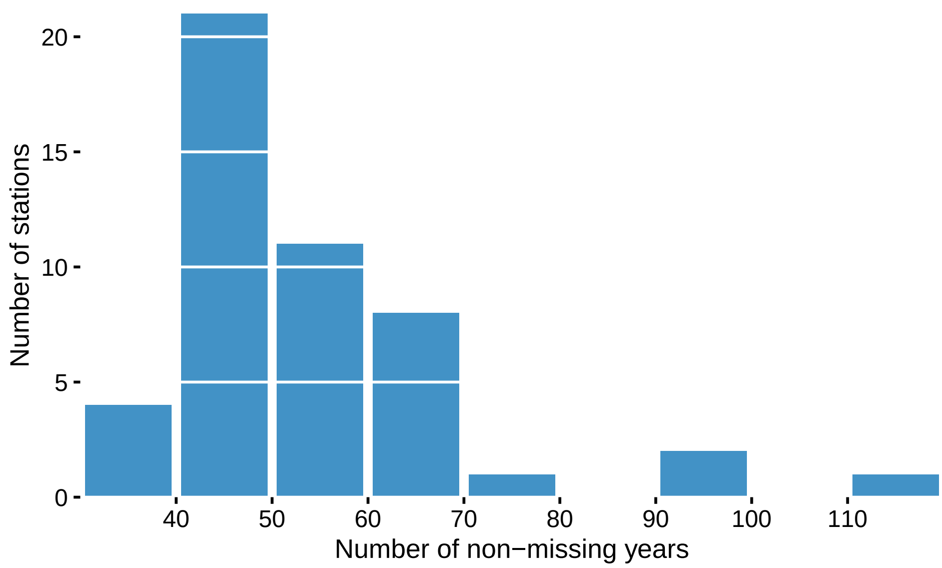

Figure S2. Distribution of the number of non-missing years of the streamflow data set.

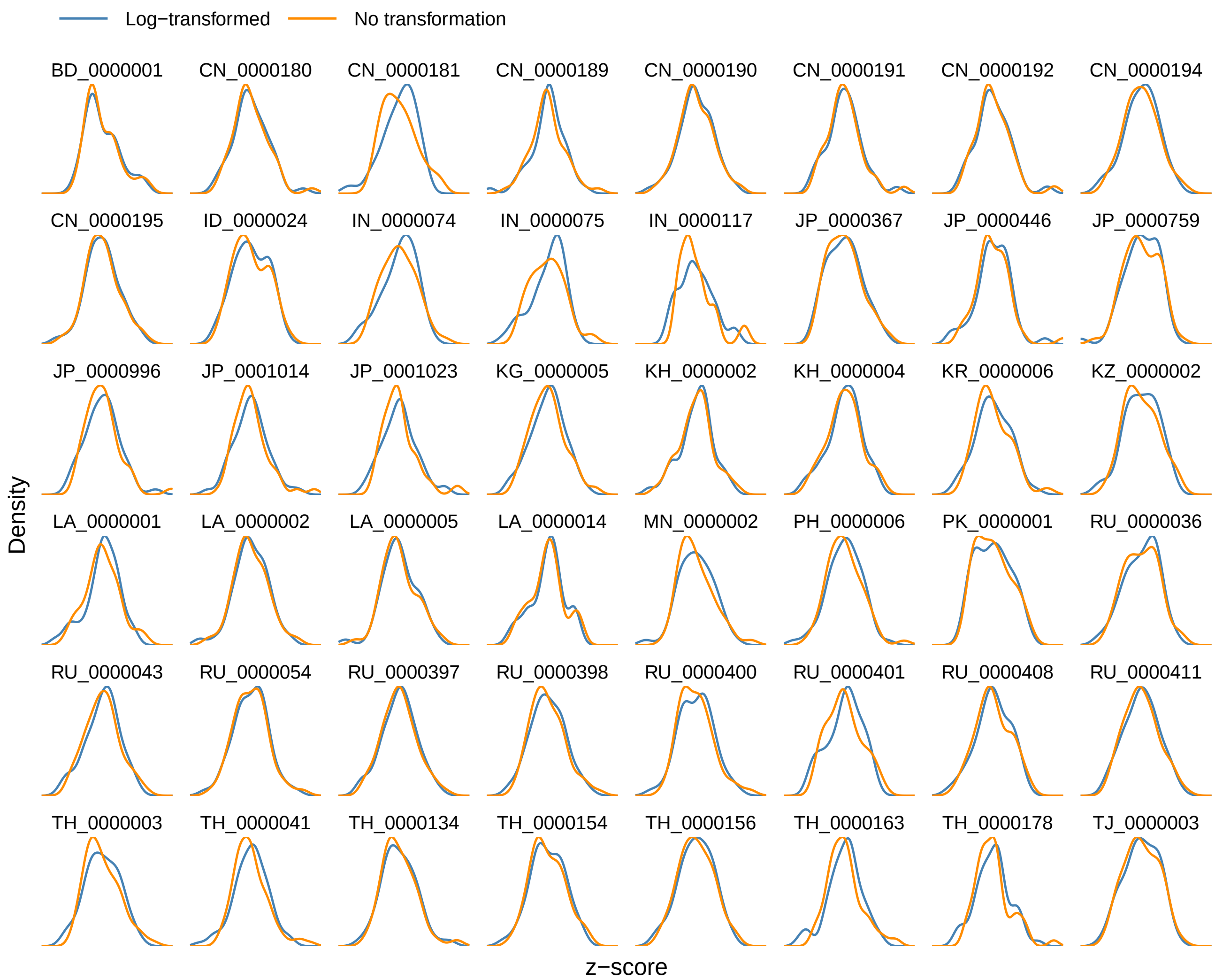

Figure S3. Densities of the transformed and untransformed flow at each station. The densities are centralized and rescaled for comparison.

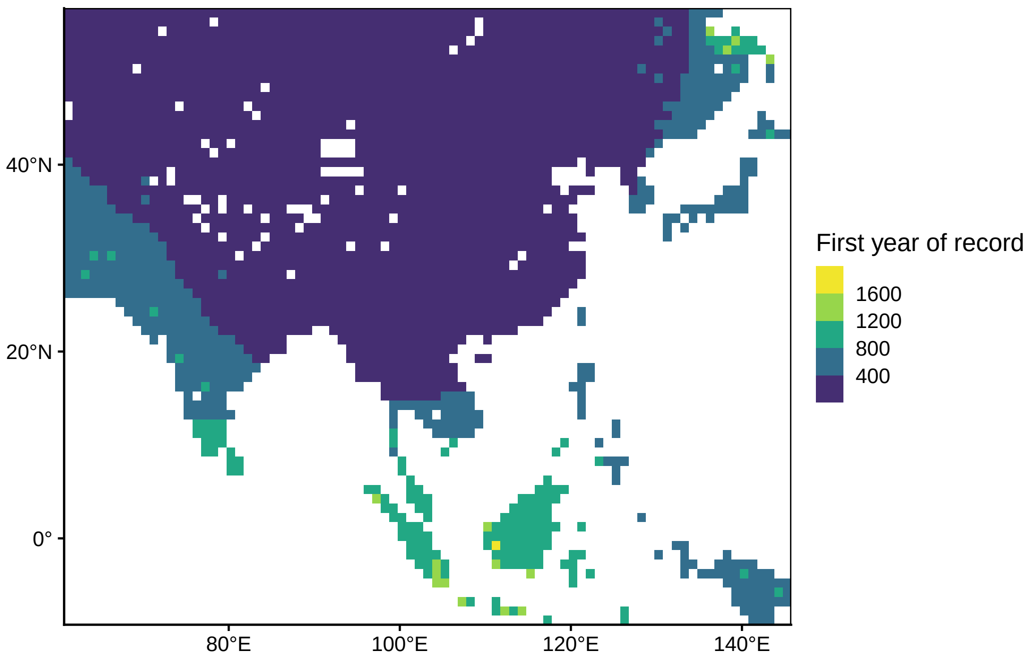

Figure S4. First year of record for each MADA grid point. 2716/2732 grid points start at or before 1200. The remaining grid points are not used.

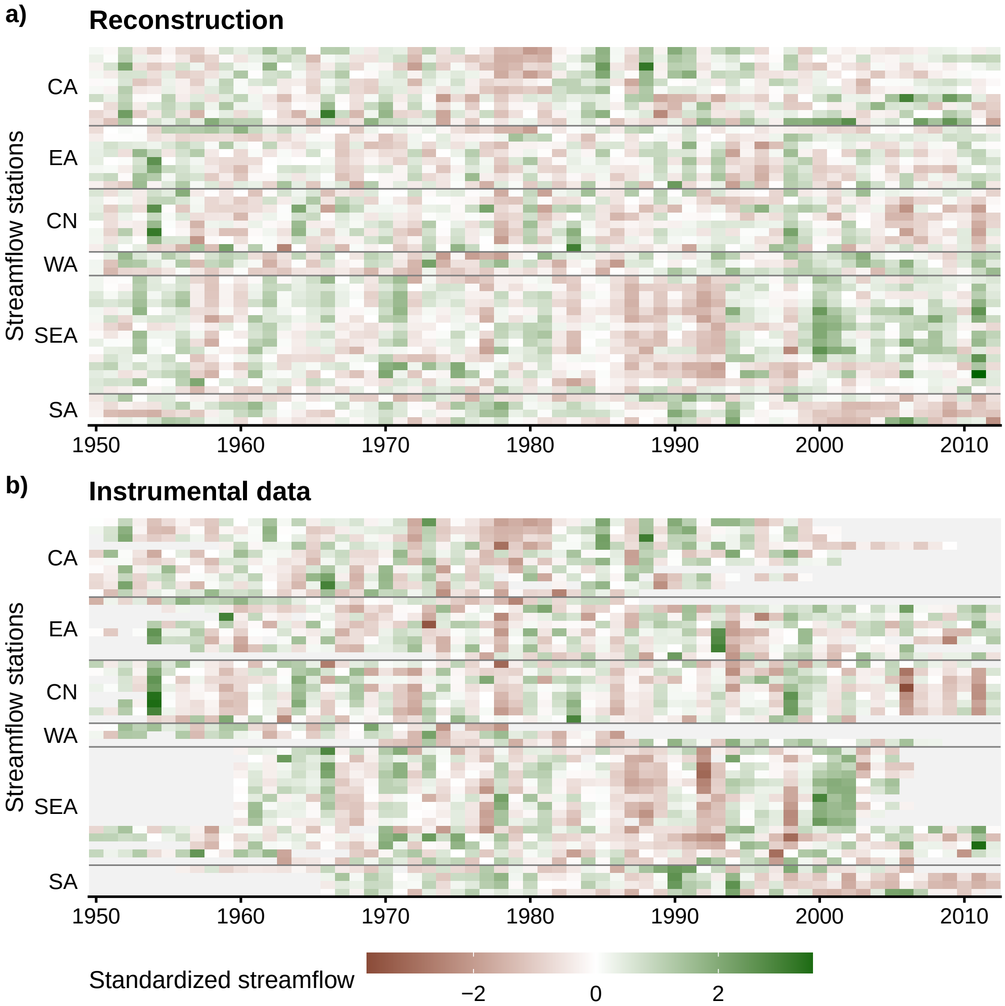

Figure S5. Comparing the reconstructed spatiotemporal variability of streamflow in the period 1950–2012 with instrumental streamflow data. Gray areas denote no data; color scale and annotations are the same as Figure 5 in the main text. The reconstruction captures well the spatial coherence and the extreme events in this period.

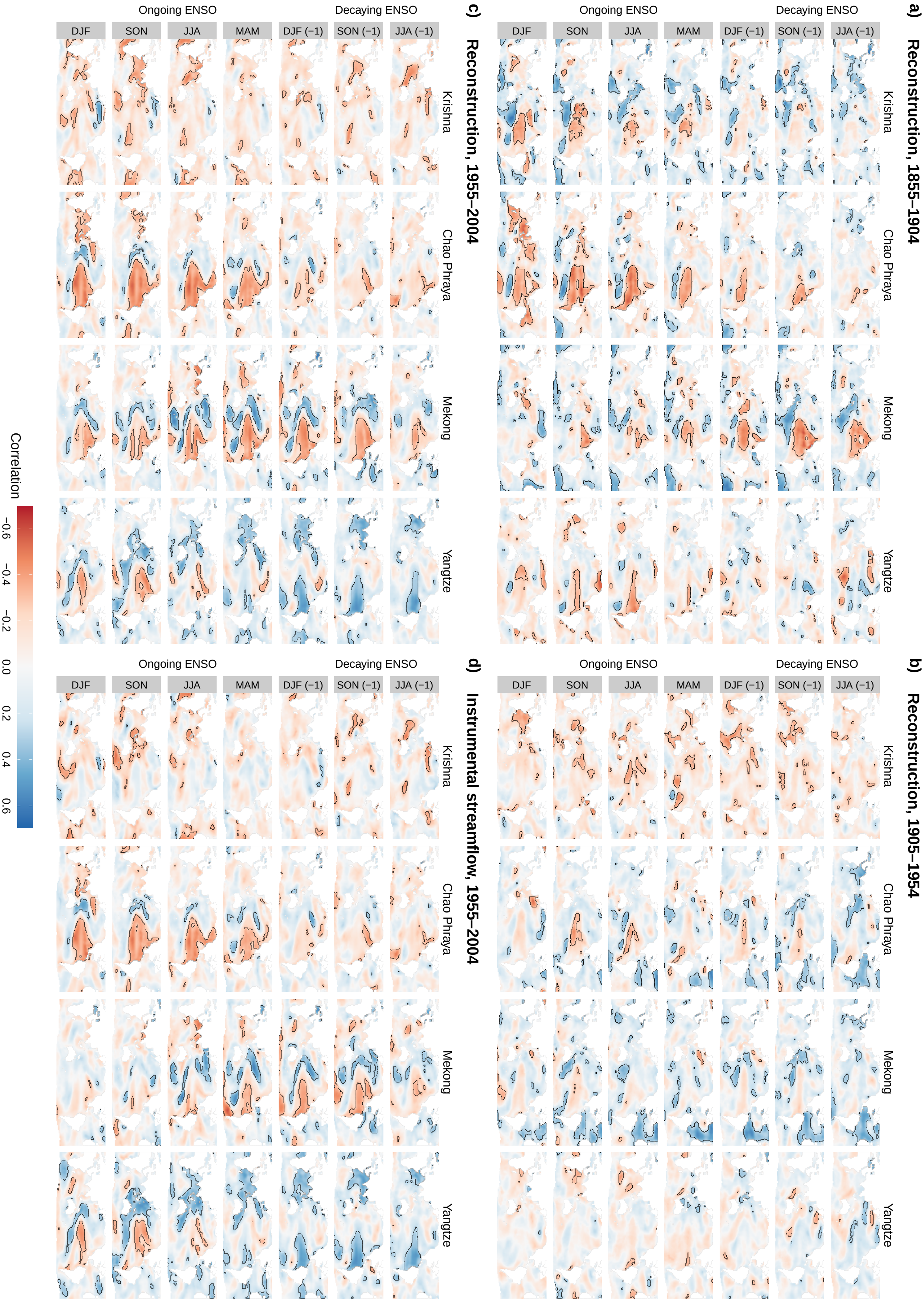

Figure S6. Temporal variability of the streamflow–sea surface temperature correlations.

Table S1. List of Monsoon Asia streamflow reconstruction papers

Reference	Proxy	River	Country
Davi et al. (2006)	Tree ring	Selenge	Mongolia
Yuan et al. (2007)	Tree ring	Manasi	China
X. Gou et al. (2007)	Tree ring	Yellow	China
Liu et al. (2010)	Tree ring	Heihe	China
X. H. Gou et al. (2010)	Tree ring	Yellow	China
D'Arrigo et al. (2011)	Tree ring	Citarum	Indonesia
Yang et al. (2012)	Tree ring	Heihe	China
Cook et al. (2013)	Tree ring	Indus	Pakistan
Davi et al. (2013)	Tree ring	Kherlen	Mongolia
Pederson et al. (2013)	Tree ring	Yeruu	Mongolia
J. Xu (2015)	Stalagmite δ^{18}O	Jialingjiang	China
Chen, Yuan, Davi, and Zhang (2016)	Tree ring	Irtysh	China
Chen and Yuan (2016)	Tree ring	Guxiang	China
Chen, Yuan, Zhang, et al. (2016)	Tree ring	Shiyang	China
D. Zhang et al. (2016)	Tree ring	Aksu	China
R. Zhang et al. (2016)	Tree ring	Tuoshigan	China
Chen et al. (2017)	Tree ring	Kurshab	Kyrgyzstan
Panyushkina et al. (2018)	Tree ring	Ili	Kazakhstan
T. Zhang et al. (2018)	Tree ring	Haba	China
Rao et al. (2018)	Tree ring	Indus	Pakistan
Nguyen and Galelli (2018)	MADA[a]	Ping	Thailand
Li et al. (2018)	Tree ring	Yangtze	China
Chen, Shang, Panyushkina, Meko, Yu, et al. (2019)	Tree ring	Lhasa	China
Chen, Shang, Panyushkina, Meko, Li, et al. (2019)	Tree ring	Salween	China
Yang et al. (2019)	Tree ring	Lancang	China
Li et al. (2019)	Tree ring	Yellow	China
C. Xu et al. (2019)	Tree ring δ^{18}O	Chao Phraya	Thailand

[a] Monsoon Asia Drought Atlas (Cook et al., 2010)

Table S2. Metadata of the streamflow stations used.

ID[a]	Region	Basin	River	Name	Longitude	Latitude
RU_0043	CA	Selenga	Selenga	Mostovoy	107.496	52.021
RU_0401	CA	Selenga	Khilok	Khailastuy	106.987	51.204
RU_0400	CA	Selenga	Chikoy	Gremyachka	108.612	50.313
RU_0397	CA	Upper Angara	Verkhnyaya Angara	Verkhnyaya Zaimka	110.154	55.846
RU_0398	CA	Upper Angara	Barguzin	Barguzin	109.596	53.596
RU_0408	CA	Yenisei	Biryusa	Biryusinsk	97.779	55.963
RU_0411	CA	Yenisei	Tuba	Bugurtak	92.871	53.796
RU_0054	CA	Yenisei	Yenisei	Kyzyl	94.404	51.721
MN_0002	CA	Selenga	Yeruu	Yeruu	106.653	49.738
KZ_0002	CA	Irtysh	Irtysh	Buran	85.221	48.004
RU_0036	EA	Amur	Amur	Khabarovsk	135.046	48.446
JP_0367	EA	Mogami	Mogami	Inakudashi	140.346	38.481
JP_0446	EA	Edogawa	Edogawa	Noda	139.893	35.987
JP_0759	EA	Yuragawa	Yuragawa	Fukuchiyama	135.128	35.305
JP_1023	EA	Ono	Ono	Shirataki Bridge	131.647	33.164
JP_1014	EA	Oyodo	Oyodo	Takaoka	131.301	31.955
JP_0996	EA	Sendaigawa	Sendaigawa	Onofuchi	130.336	31.863
KR_0006	EA	Han	Soyang	Soyanggang	127.816	37.946
CN_0181	CN	Yangtze	Huai He	Bengbu	117.362	32.954
CN_0190	CN	Yangtze	Yangtze	Cuntan	106.596	29.613
CN_0194	CN	Yangtze	Yangtze	Wulong	107.762	29.321
CN_0195	CN	Yangtze	Yangtze	Yichang	111.279	30.696
CN_0192	CN	Yangtze	Yangtze	Luoshan	113.346	29.688
CN_0191	CN	Yangtze	Yangtze	Hankou	114.296	30.579
CN_0180	CN	Yangtze	Yangtze	Datong	117.621	30.771
CN_0189	CN	Pearl	Dong Jiang	Boluo	114.304	23.163
KG_0005	WA	Syr Darya	Naryn	Uch-Kurgan	72.112	41.154
TJ_0003	WA	Amu Darya	Vakhsh	Garm	70.329	39.004
PK_0001	WA	Indus	Indus	Kachora	75.437	35.462
TH_0134	SEA	Mekong	Mekong	Chiang Saen	100.096	20.271
LA_0001	SEA	Mekong	Nam Khan	Ban Mixay	102.179	19.779
LA_0002	SEA	Mekong	Mekong	Luang Prabang	102.137	19.896
LA_0005	SEA	Mekong	Mekong	Vientiane	102.612	17.929
TH_0154	SEA	Mekong	Mekong	Nakhon Phanom	104.795	17.397
TH_0156	SEA	Mekong	Mekong	Mukdahan	104.746	16.538
TH_0163	SEA	Mekong	Nam Mun	Ubon	104.862	15.221
LA_0014	SEA	Mekong	Mekong	Pakse	105.804	15.113
KH_0004	SEA	Mekong	Mekong	Stung Treng	105.946	13.529
KH_0002	SEA	Mekong	Mekong	Kompong Cham	105.471	11.996
TH_0003	SEA	Chao Phraya	Nan	N.1	100.779	18.771
TH_0041	SEA	Chao Phraya	Ping	P.1	99.004	18.788
TH_0178	SEA	Chao Phraya	Chao Phraya	C.2	100.112	15.671
PH_0006	SEA	Angat	Angat	Angat	121.199	14.999
ID_0024	SEA	Citarum	Citarum	Citarum	107.294	-6.731
BD_0001	SA	Brahmaputra	Brahmaputra	Bahadurabad	89.696	25.179
IN_0074	SA	Godavari	Godavari	Jagdalpur	82.021	19.113
IN_0075	SA	Godavari	Godavari	Nowrangpur	82.512	19.196
IN_0117	SA	Krishna	Karad	Karad	74.187	17.296

[a] The first two letters denotes country code.