Supplementary Material

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Position and orientation of the westerly jet determined Holocene rainfall patterns in China
Nature Communications

Supplementary Tables

Supplementary Tab. 1 Summary statistics for canonical correspondence analyses for the whole dataset from China and Mongolia (Cao et al., 2014). P_{ann} – annual precipitation, Mt_{wa} – mean temperature of the warmest month; Mt_{co} – mean temperature of the coldest month; T_{ann} mean annual temperature, P_{amjjas} – precipitation between March and September, P_{amjjas} – precipitation between June and August. Results indicate that P_{ann} explains most variance in the modern pollen dataset. Neither temperature nor seasonal precipitation explains more variance.

Climatic variables	VIF (without T_{ann})	VIF (add T_{ann})	λ_1/λ_2	Climatic variables as sole predictor		Marginal contribution based on climatic variables	
				Explained variance (%)	P-value	Explained variance (%)	P-value
P_{ann}	3.8	3.8	1.58	4.9	0.005	1.50	0.005
Mt_{co}	4.3	221.7	1.36	4.2	0.005	0.67	0.005
Mt_{wa}	1.5	116.6	0.61	2.7	0.005	1.30	0.005
T_{ann}	-	520.4	-	-		-	-
Pamjjas	-	-	1.50	4.9	0.005		
Pjja	-	-	1.30	4.4	0.005		

Cao, X., Herzschuh, U., Telford, R.J., Ni, J. A modern pollen-climate dataset from China and Mongolia: assessing its potential for climate reconstruction. Review of Palaeobotany and Palynology 211, 87-96 (2014).

Supplementary Tab. 2 Summary statistics for canonical correspondence analyses for the southern China dataset <30°N (Cao et al., 2014). P_{ann} – annual precipitation, Mt_{wa} – mean temperature of the warmest month; Mt_{co} – mean temperature of the coldest month; T_{ann} mean annual temperature. Results indicate that P_{ann} explains most variance in the modern pollen dataset. Neither temperature nor seasonal precipitation explains more variance. Results indicate that even in the southern part of China precipitation is the variable that explains most variance in the modern pollen dataset.

Climatic variables	VIF (without T_{ann})	VIF (add T_{ann})	λ_1/λ_2	Climatic variables as sole predictor		Marginal contribution based on climatic variables	
				Explained variance (%)	P-value	Explained variance (%)	P-value
P_{ann}	2.5	2.6	0.89	4.5	0.001	1.82	0.001
Mt_{co}	5.0	400.1	0.83	4.1	0.001	1.45	0.001
Mt_{wa}	4.5	342.5	0.80	4.4	0.001	1.50	0.001
T_{ann}	-	1355.9	-	-		-	-

Supplementary Tab. 3. Supplementary information for each pollen record. We assessed the age-model reliability (age score) and pollen data quality (data score) of each record to be high, intermediate, or low. An age-model was considered highly reliable if it had more than 3 reliable dates within the 10–2 cal ka BP interval, and was considered to be of low reliability if it had only one reliable date, or no dating at all, within that interval. The data quality was considered to be high if it possessed a complete pollen assemblage and original pollen data. The component (Comp) means the selected component of the WA-PLS model; r^2 is the coefficient of determination between observed and predicted environmental values; RMSEP is the root mean square error of prediction; RMSEP percentage means the RMSEP as a percentage of the modern annual precipitation gradient range (P_{ann} gradient); Sig. is the p-value of the statistical significance test of reconstruction (Telford & Birks, 2011).

Site information						Quality of pollen data			Reliability of reconstruction							
ID	Site	Long.	Lat.	Alt.	Modern Pann	Age score	Data score	Available number	No. of Sample	Pann gradient	Comp.	r^2	RMSEP	RMSEP percentage	Sig.	Reference
1	Achit Nur Lake	90.60	49.50	1435	273	2	2	11	292	60-541	2	0.67	80	16.67	0.01	Gunin et al., 1999
4	Akkol Lake	89.63	50.25	2204	411	3	3	44	283	60-541	2	0.67	81	16.84	0.04	Blyakharchuk et al., 2007
7	Ayongwama Co	98.20	34.83	4220	357	2	1	17	944	35-1069	1	0.79	115	11.14	0.04	Cheng et al., 2004
10	Baikal Lake	105.87	52.08	130	2401	3	3	29	164	93-378	1	0.47	49	17.05	0.01	Demske et al., 2005
16	Barkol Lake	92.80	43.62	1575	163	3	2	85	471	35-541	1	0.63	90	17.84	0.06	Tao et al., 2009
17	Bayanchagan Lake	115.21	41.65	1355	389	3	2	30	584	111-864	1	0.56	115	15.24	0.25	Jiang et al., 2006
22	Bosten Lake	86.55	41.97	1050	74	3	3	18	296	47-541	1	0.68	91	18.48	0.95	Xu, 1998
24	Bunan Lake	90.83	35.95	4876	217	1	2	4	697	40-764	1	0.66	94	12.98	0.16	Shan et al., 1996
28	Chaiwopu Lake	87.78	43.55	1100	223	1	2	6	254	35-541	1	0.70	89	17.64	0.71	Li and Yan, 1990
29	Changjiang River_1997	121.38	31.62	2	1109	3	3	9	249	488-1913	2	0.81	185	12.97	0.53	Yi et al., 2003
30	Changjiang River_1998	120.23	32.25	6	1059	3	3	44	356	476-1913	2	0.81	178	12.42	0.74	Yi et al., 2003
41	Daba Nur Lake	98.79	48.20	2465	365	3	2	12	309	35-541	1	0.67	78	15.39	0.55	Gunin et al., 1999
42	Dabsan Lake	95.50	37.10	2675	58	2	2	4	931	35-1062	1	0.68	115	11.15	0.64	Du and Kong, 1986
45	Dahaizi Lake	102.67	27.83	3660	1069	3	2	17	654	312-1838	1	0.78	180	11.81	0.59	Li and Liu, 1988
46	Dahu Lake	115.03	24.25	250	1780	3	2	15	576	1020-2091	2	0.60	195	18.20	0.37	Zhou et al., 2004
47	Daihai Lake_2004	112.67	40.58	1220	376	3	3	192	643	35-1129	1	0.62	117	10.67	0.05	Xiao et al., 2004
49	Dajiuhu Lake	110.67	31.75	1700	1130	3	2	25	668	144-2011	1	0.81	213	11.39	0.01	Liu H.P. et al., 2001
50	Dalai Nur Lake	116.58	43.28	1200	349	1	2	3	591	111-1006	2	0.66	102	11.43	0.2	Li et al., 1990
52	Daluoba	88.20	47.83	2020	209	1	2	5	252	60-541	2	0.70	81	16.90	0.08	Yan and Xu, 1992
58	Dengjiacun	113.65	34.47	133	661	3	1	9	615	144-1857	2	0.83	159	9.29	0.93	Zhang et al., 2007
61	Dingnan	115.03	24.75	274	1683	3	2	13	579	1020-2091	2	0.61	195	18.17	0.05	Dodson et al., 2006
64	Dongganchi	115.78	39.53	49	509	3	3	42	573	111-1325	1	0.80	115	9.46	0.4	Zhang et al., 1997

66	Dood Nur Lake	99.38	51.33	1538	334	2	2	8	187	37-378	1	0.44	57	16.79	0.01	Gunin et al., 1999
68	Dunde	96.40	38.10	5325	339	3	3	24	944	35-872	1	0.67	111	13.25	0.66	Liu et al., 1998
69	Ebinur Lake	82.45	44.55	212	174	3	2	7	235	53-541	2	0.76	81	16.70	0.01	Wen and Qiao, 1990
71	Erhai Lake	100.20	25.77	1974	785	3	1	40	462	403-1766	1	0.81	152	11.14	0.74	Zhou et al., 2003
72	Erhailongwan Lake	126.37	42.30	724	813	3	2	8	373	220-1006	1	0.60	94	11.94	0.47	Liu et al., 2008
78	Ganhai Lake	112.19	38.89	1854	505	3	3	21	714	40-1348	2	0.81	110	8.44	0.16	Meng et al., 2007
81	Gladkoye Bog	83.33	55.00	80	458	3	3	45	45	96-271	1	0.00	35	19.80	0.68	Firsov et al., 1982
82	Gounong Co	92.15	34.63	4670	274	3	3	31	722	47-872	1	0.66	108	13.15	0.02	Shan et al., 1996
83	Grusha Lake	89.42	50.38	2413	336	3	3	13	270	60-541	2	0.68	82	16.99	0.04	Blyakharchuk et al., 2007
84	Guangfulin	121.19	31.06	4	1179	2	1	35	296	490-1913	2	0.80	177	12.42	0.59	Atahan et al., 2008
87	Gucheng Lake	118.90	31.28	6	1273	2	3	153	371	476-2089	2	0.81	197	12.21	0.87	Yang et al., 1996
88	Gun Nur Lake	106.60	50.25	600	377	3	3	21	252	35-402	1	0.49	57	15.64	0.1	Gunin et al., 1999
91	Halali	99.78	36.72	3220	360	3	2	2	853	35-1062	1	0.74	116	11.30	1	Chen F.H. et al., 1991
95	Haoluku Lake	116.76	42.96	1295	382	2	3	24	595	111-1006	2	0.66	102	11.42	0.87	Wang et al., 2001
99	Hemudu	121.35	29.97	6	1412	3	3	23	244	537-2068	2	0.76	180	11.74	0.36	Li et al., 2009
104	Hongyuanbai River	102.53	32.80	3500	772	3	3	33	935	40-1456	2	0.85	122	8.59	0.06	Wang, 1987
107	Huangjiapu	115.15	40.57	500	376	1	1	16	541	111-1051	1	0.62	117	12.42	0.73	Sun et al., 2001
108	Huangsha	113.23	23.13	40	1822	2	2	16	541	1016-2091	2	0.59	193	17.96	0.83	Li, 1991
111	Huguangyan Maar Lake	110.28	21.15	88	1690	3	3	4	429	892-2091	1	0.50	201	16.76	0.59	Lv et al., 2003
113	Hulun Nur Lake_2006	117.51	49.13	545	284	3	2	103	427	111-710	1	0.49	93	15.49	0.77	Wen et al., 2010
114	Hurleg Lake	96.90	37.28	2817	117	3	3	43	857	35-1062	1	0.71	115	11.16	0.4	Zhao Y. et al., 2007
119	Jiangjunpaozi Lake	117.47	42.37	1490	480	2	1	8	566	111-1006	2	0.66	103	11.56	0.24	Liu H.Y. et al., 2001
124	Jiudaogou	96.65	40.50	2143	59	2	1	24	841	35-806	1	0.59	116	15.06	0.87	Mao et al., 2007
126	Juyan Lake	101.85	41.89	892	40	3	3	59	796	35-850	1	0.64	110	13.46	0.48	Herzschuh et al., 2004
130	Kendegelukol Lake	87.64	50.51	2050	348	3	3	25	247	60-541	2	0.71	81	16.91	0.02	Blyakharchuk et al., 2004
134	Kotokel Lake	108.12	52.78	458	348	3	2	58	210	111-492	1	0.77	46	12.02	0.91	Tarasov et al., 2009
138	Kucha Lake	97.24	34.01	4540	481	3	3	38	929	35-1091	1	0.78	118	11.21	0.1	Herzschuh et al., 2009
139	Kuhai Lake	99.31	35.52	4150	427	3	3	32	941	35-1069	1	0.79	114	11.02	0.51	Wischnewski et al., 2011
144	Liuzhouwan Lake	116.68	42.71	1365	398	2	2	14	594	111-1006	2	0.65	104	11.58	0.21	Wang et al., 2001
146	Longquan Lake	112.24	31.08	80	990	2	2	21	667	179-2091	2	0.86	211	11.03	0.73	Liu, 1991
147	Lop Nur_1983	90.25	40.33	800	17	1	2	7	530	35-541	1	0.63	90	17.83	0.1	Yan et al., 1983
149	Luanhaizi Lake	101.35	37.59	3200	485	3	3	9	763	35-1062	1	0.75	117	11.37	0.38	Herzschuh et al., 2005
151	Luojiang	121.36	29.98	4	1406	2	2	8	241	537-2011	2	0.75	178	12.08	0.1	Atahan et al., 2008
153	Manas Lake	85.92	45.83	251	125	3	3	31	230	47-541	2	0.74	81	16.39	0.31	Sun et al., 1994
159	Mengcun	117.12	38.05	5	552	2	3	19	617	111-1755	2	0.82	140	8.52	0.02	Xu et al., 1993
162	Naleng Co Lake	99.76	31.11	4200	705	3	3	69	922	51-1580	2	0.81	118	7.73	0.15	Kramer et al., 2010
164	Nantun	104.23	26.70	2197	979	3	1	40	564	441-1883	1	0.80	184	12.80	0.64	Chen P.Y. et al., 1991

167	Niangziguan	113.88	37.95	500	519	1	2	5	638	104-1755	2	0.81	145	8.79	0.35	Yang et al., 1999
179	Qidong	121.70	31.90	10	1089	3	3	16	249	488-1880	2	0.82	182	13.06	0.23	Liu et al., 1992
181	Qinghai Lake	100.52	36.67	3200	421	3	3	114	816	35-1062	1	0.75	117	11.41	0.01	Liu et al., 2002
183	Qiumu	99.87	26.53	2200	916	1	3	10	568	338-1766	2	0.81	136	9.49	0.8	Kong et al., 1986
184	Qongjiamong Co	92.37	29.81	4980	556	3	3	35	577	51-1091	1	0.75	113	10.85	0.38	Shen, 2003
185	Ren Co	96.68	30.73	4450	653	3	2	21	844	51-1192	2	0.79	113	9.93	0.38	Tang et al., 1999
189	Sanyixiang	117.38	43.62	1541	417	2	1	6	582	111-1006	2	0.66	102	11.43	0.46	Wang et al., 2005
190	Selin Co	88.52	31.57	4530	299	3	3	30	364	51-743	1	0.75	84	12.18	0.11	Sun et al., 1993
194	Shayema Lake	102.22	28.58	2400	1034	3	3	53	730	150-1838	1	0.80	174	10.34	0.01	Tang and Shen., 1996
195	Shidicun	117.52	43.25	1077	390	2	2	4	580	111-1006	2	0.66	102	11.43	0.23	Liu, 2002
206	Sujiawan	104.52	35.54	1950	426	3	3	32	861	35-1348	2	0.86	109	8.28	0.01	Feng et al., 2006
219	Tolmachevsko	84.00	55.00	110	715	3	3	18	49	89-271	1	0.04	41	22.67	0.75	Volkov and Arkhipov, 1978
225	Ulan Ul Lake	90.50	34.87	4854	249	1	2	8	604	47-764	1	0.67	93	12.94	0.23	Shan et al., 1996
227	Uzunkol Lake	87.11	50.48	1985	168	3	2	47	242	60-541	2	0.71	82	16.99	0.54	Blyakharchuk et al., 2004
231	Wangjiadian	114.67	36.16	67	532	3	3	54	622	137-1857	2	0.81	157	9.11	0.05	Cao et al., 2010
237	Wuqia Bridge	83.50	43.20	1320	410	1	2	4	250	53-541	2	0.75	82	16.76	0.66	Lin, 1994
238	Wuying River	105.82	35.76	1400	435	3	3	32	892	35-1348	2	0.86	108	8.23	0.49	Xia et al., 1998
244	Xiehu Lake	121.00	37.38	0	711	2	2	22	415	208-1755	1	0.77	140	9.04	0.27	Zhou et al., 2008
245	Ximen Co Lake	101.47	33.38	4020	720	3	3	34	1003	35-1348	2	0.85	118	8.96	0.14	Herzschuh et al., 2014
246	Xinghua	119.88	32.71	2	1031	2	2	12	385	376-1869	2	0.83	173	11.61	0.06	Shu et al., 2008
249	Yamant Nur Lake	102.60	49.90	1000	179	1	2	23	212	35-378	2	0.70	49	14.40	0.01	Gunin et al., 1999
250	Yangerzhuang	117.35	38.35	5	562	2	3	21	583	111-1755	2	0.83	133	8.12	0.01	Xu et al., 1993
251	Yanghu Lake	84.65	35.43	4778	189	2	2	10	386	51-680	1	0.67	88	14.05	0.14	Zhao Z.M. et al., 2007
255	Yangyuan_Xipu	114.22	40.12	912	389	2	1	2	549	53-1129	1	0.65	118	10.93	0.13	Wang et al., 2003
258	Yidun Lake	99.55	30.30	4470	726	2	2	15	902	51-1597	2	0.83	118	7.63	0.6	Shen et al., 2006
268	Zigetang Lake	90.90	32.00	4560	384	3	3	46	519	51-832	1	0.74	89	11.42	0.21	Herzschuh et al., 2006
270	Zoige_RH	103.35	33.95	3400	655	2	2	15	914	35-1348	2	0.86	119	9.04	0.47	Tang and Shen, 1996
271	Zoige_RM	102.35	33.95	3401	669	3	3	35	949	35-1348	2	0.85	118	9.01	0.26	Shen et al., 1996
272	Dongi Cona Lake	98.50	35.50	4090	311	3	3	33	936	35-1069	1	0.79	114	11.00	0.48	Wang et al., 2014
273	Sumxi Lake	80.24	34.61	5059	68	3	3	70	92	53-433	1	0.75	57	14.89	0.23	Campo and Gasse, 1993
274	Bayan Nuur Lake	93.00	50.00	932	172	3	3	40	311	37-541	2	0.66	80	15.86	0.11	Krengel, 2000
278	Sayram Lake	81.09	44.34	2125	254	3	3	96	224	53-541	2	0.76	81	16.50	0.68	Jiang et al., 2013
279	Qigai Nuur Lake	109.50	39.50	1408	393	3	3	98	882	35-1348	2	0.80	112	8.52	0.01	Sun and Feng, 2013
280	Tiancai Lake	99.72	26.63	3898	970	3	3	154	569	338-1766	2	0.81	131	9.20	0.49	Xiao et al., 2014
281	Shaamar	105.20	50.20	650	291	3	3	16	225	35-378	2	0.56	53	15.52	0.18	Ma et al., 2013
282	Toushe_2013	120.88	23.82	1014	1424	3	3	72	341	1046-2091	2	0.70	159	15.24	0.51	Li H.C. et al., 2013
284	Gantang	119.03	26.77	1007	1900	3	3	85	464	691-2091	2	0.68	198	14.12	0.01	Yue et al., 2012
285	Dajiuhu_2013	110.00	31.49	1751	1130	3	3	27	737	138-2091	1	0.82	211	10.80	0.71	Li J. et al., 2013

287	Gonghai Lake	112.23	38.90	1860	505	3	3	288	704	51-1348	2	0.81	111	8.56	0.44	Chen et al., 2015
288	Sihailongwan Lake	126.60	42.28	797	775	3	3	118	366	226-1006	1	0.60	94	12.02	0.32	Stebich et al., 2015
290	Aibi Lake	82.83	45.02	200	95	3	2	51	216	53-541	2	0.76	82	16.74	0.6	Wang et al., 2013
297	Zoige_2011	102.63	33.45	3467	648	3	3	104	943	35-1348	2	0.85	119	9.08	0.25	Zhao et al., 2011

References Supplementary Tab. 1

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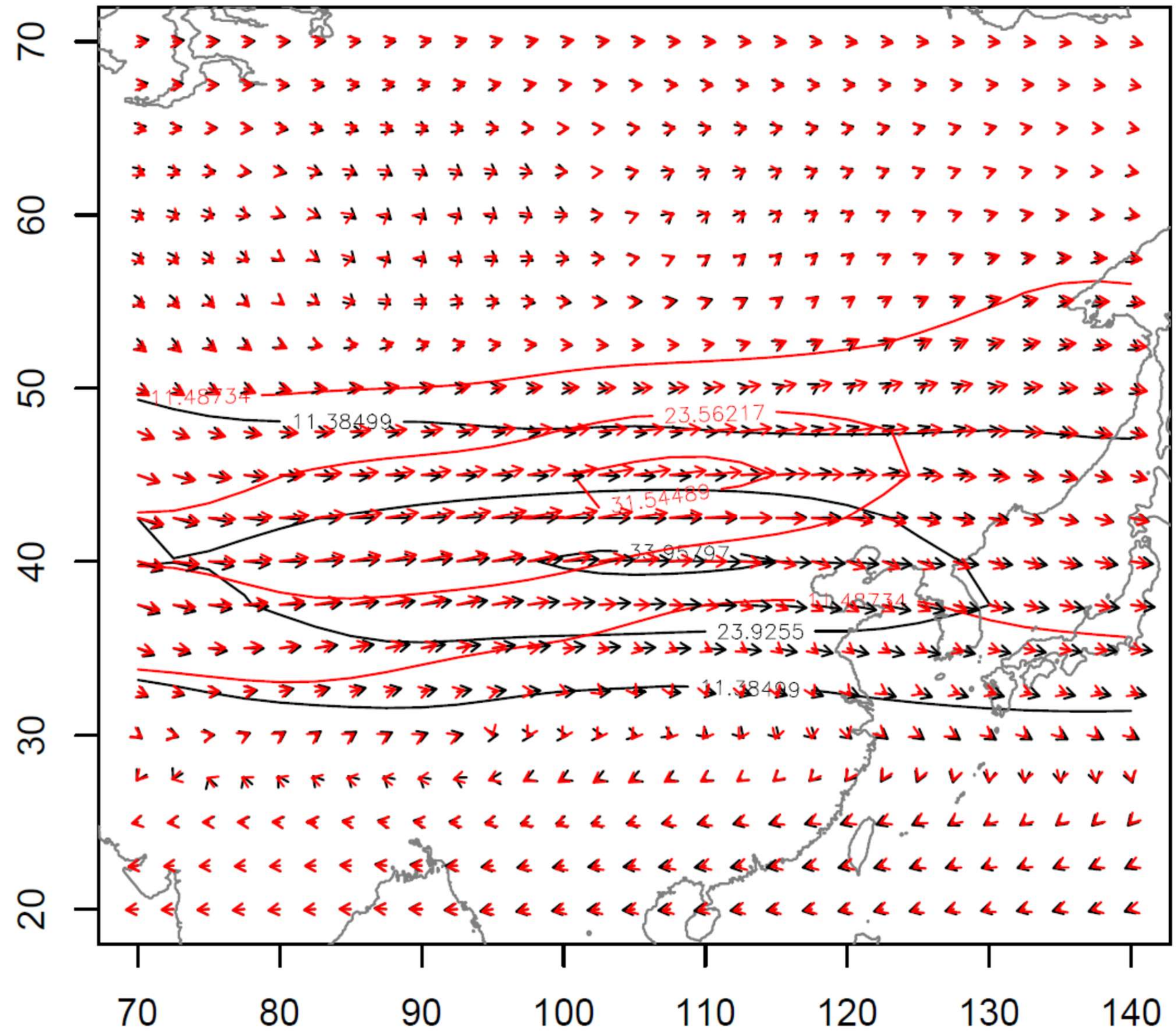
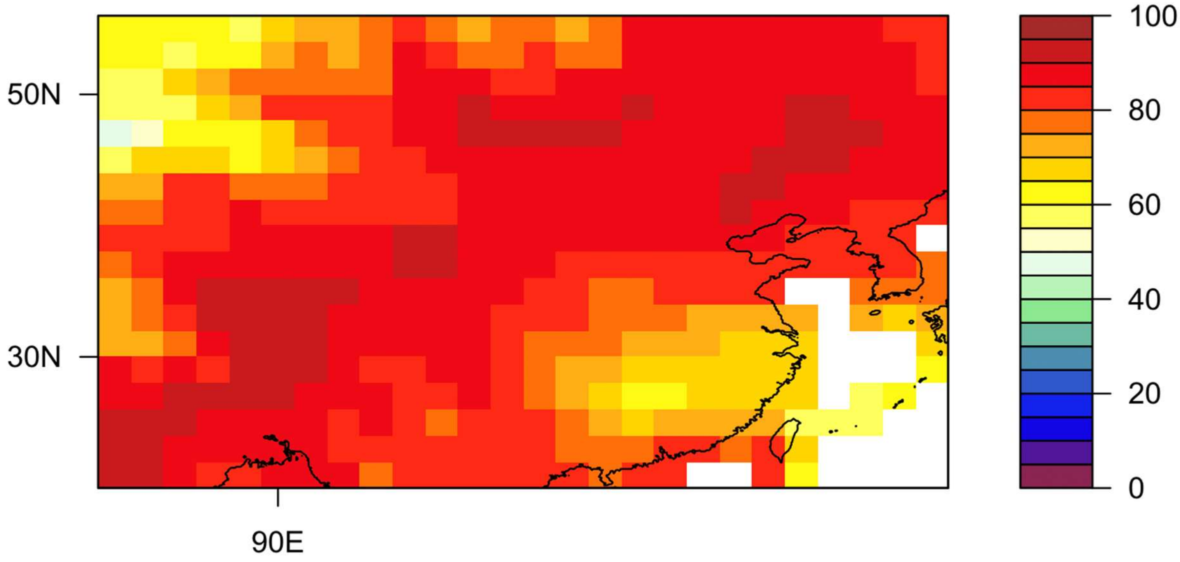
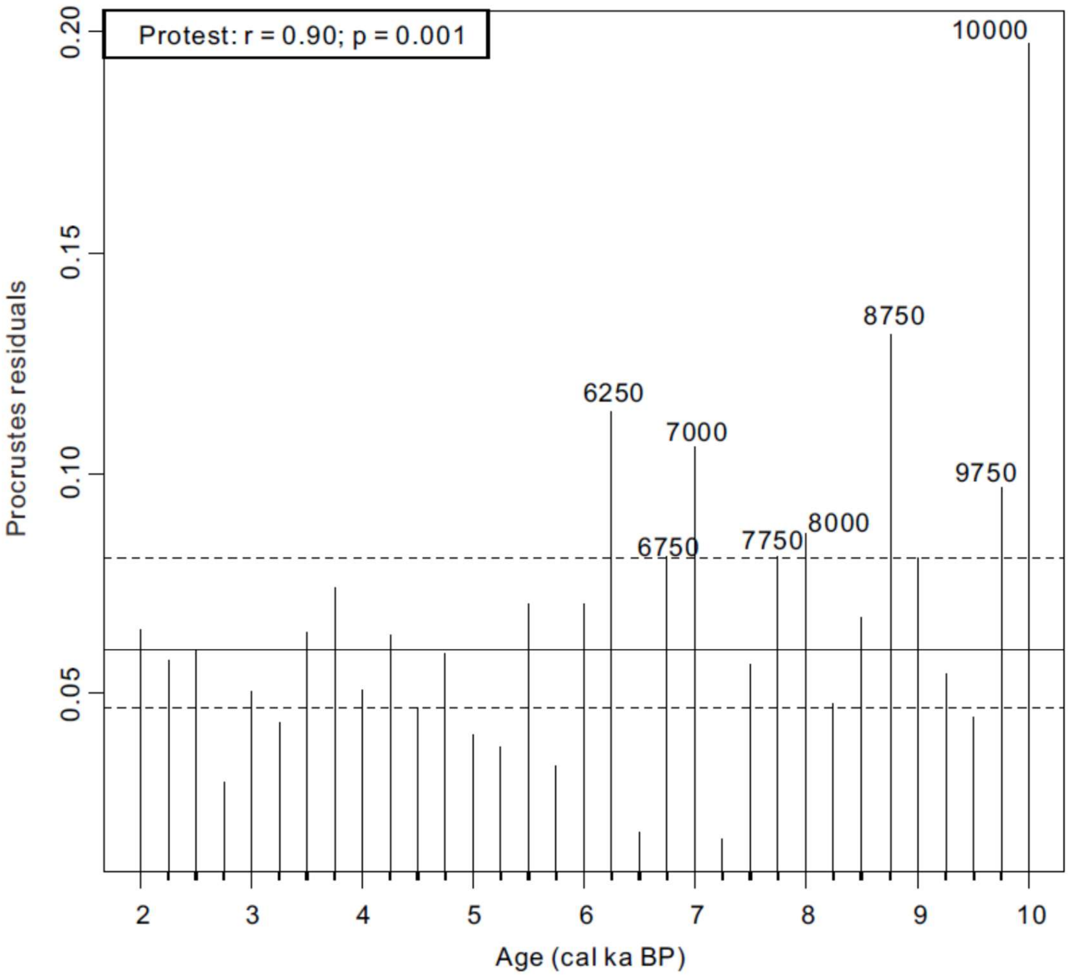


Supplementary Fig. 1: Modeled 250 hPa wind (and wind vectors) for 2 ka (black) and 9 ka (red) on the day of the year when the westerly wind stream reached its most northerly position, indicating the position and orientation of the westerly jet stream during the early Holocene compared with the late Holocene.



Supplementary Fig. 2: Percentage of precipitation during summer months (March to September) as calculated using the APHRODITE dataset (Yatagai et al., 2012). Results indicate that over the whole domain, 80% falls in the summer half year and that the summer contribution at all proxy sites (even in the northwest of the study area) is larger than 60%. (Even with respect to our modeling domain there is only one grid-cell in the northwestern-most part where winter precipitation dominates slightly. Southeastern China has a high share of autumn precipitation originating from to the southward transition of the westerly jet after summer.) Accordingly, we focus our argumentation on circulation mechanisms and related precipitation patterns during the summer (MAMJJAS).

Yatagai, A., Kamiguchi, K., Arakawa, O., Hamada, A., Yasutomi, N., Kitoh, A., 2012. APHRODITE: Constructing a Long-Term Daily Gridded Precipitation Dataset for Asia Based on a Dense Network of Rain Gauges. Bulletin of the American Meteorological Society 93, 1401-1415.



Supplementary Fig. 3: Comparison of pollen-based and non-pollen-based reconstructions. Non-pollen-based climate reconstructions were also available for 82 of the sites in the fossil pollen dataset. We extracted semi-quantitative moisture signals according to Herzschuh (2006) and Wang et al. (2010) from non-pollen proxies, including biological data (e.g. diatoms, ostracods, chironomidae), geochemical data (e.g. organic and inorganic carbon content, stable carbon and oxygen isotope ratios, elemental compositions), and geophysical data (e.g. grain size, magnetic susceptibility; Table 1). We translated the moisture signals at 500-year time intervals for 10–2 ka from these non-pollen studies into moisture signals on a five-part scale (−2, −1, 0, +1, +2), with the lowest value (−2) indicating the driest period for each site and the highest value (+2) indicating the wettest interval; the intermediate value (0) indicated moisture conditions similar to today. The moisture information is therefore on a relative scale and only tracks the changes at each individual site.

Multivariate datasets can be compared using Procrustes rotation, which assesses the overall degree of correlation between two or more ordination results and finds an optimal superimposition that maximizes their fit (Peres-Neto & Jackson, 2001). PROTEST performs a random permutation test and assesses the degree of concordance between two matrices, presenting the significance of the

Procrustes fit as an r-value with an associated p-value to indicate the likelihood of the relationship occurring by chance (Jackson, 1995). In our study we evaluated the similarity/dissimilarity between pollen-based and non-pollen-based inferences of moisture levels, using Procrustes rotation, and then tested the significance of any of the relationships detected using the associated PROTEST permutation test (Peres-Neto & Jackson, 2001) for non-metric multidimensional scaling (NMDS) results, covering the period from 10 to 2 cal. ka BP. The results are shown as residuals, with low residual values indicating a good agreement between datasets and high values indicating a weak agreement. The NMDS, Procrustes, and PROTEST (Peres-Neto & Jackson, 2001) analyses were carried out using the vegan package (Oksanen et al., 2012) in R 3.0.2 software (R Core Team, 2016).

References Supplementary Fig. 3

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Supplementary Fig. 4 Correlation of the predicted and observed local climatological daily precipitation. Hashed areas are statistically significant (p=0.01)."