Evaporation abrupt changes in the Qinghai-Tibet Plateau during the last half-century

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Supplementary Information Text

Evaluation of E_{pan} simulation

Several evaluation metrics, including the linear regression equation and its determination coefficient (R^2), root mean square error (RMSE) as well as the difference of mean monthly values (MD) between the simulated (E_{pan_simu}) and observed E_{pan} (E_{pan_obs}), were calculated to assess the performance of PenPan model at a monthly time scale (Supplementary Fig. S1 and Table S2). Generally, the agreement between E_{pan_simu} and E_{pan_obs} was satisfactory. As shown in Supplementary Fig. S1, the regression slope between E_{pan_simu} and E_{pan_obs} of all stations was 0.96, and the corresponding R^2, RMSE and MD were 0.96, 16.94 mm and 0.00 mm, respectively. The average value of regression slopes at different stations was 0.92 ± 0.05 (mean ± 1 s.d.), and the corresponding average values of R^2 and RMSE were 0.96 ± 0.03 and (15.92 ± 5.11) mm, respectively (Supplementary Table S2). Additionally, a negligible MD between E_{pan_simu} and E_{pan_obs} presented at 274 stations. These metrics indicated that PenPan model was applicable to estimate monthly E_{pan} in the highlands at both site and regional scales.

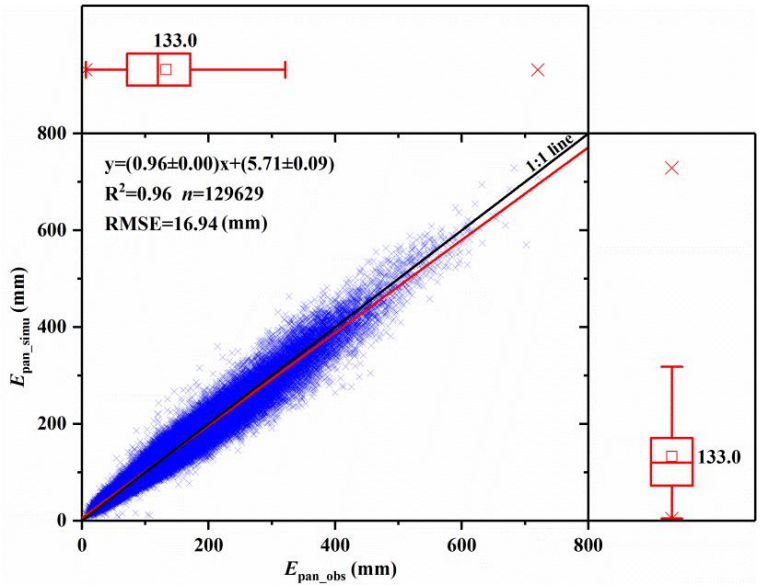

Figure S1. Comparison of simulated and observed monthly $E_{pan.}$ Boxplots showed minima (cross), 25th percentile, median (solid line), average (square), 75th percentile and maxima (cross). The figure was generated by origin 9.0, URL: https://www.originlab.com/.

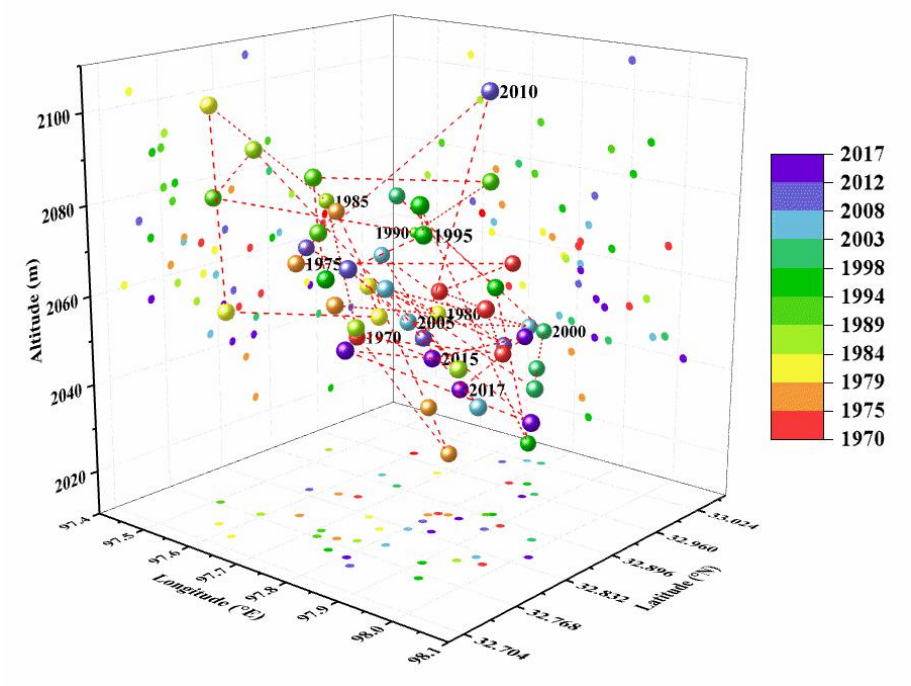

Figure S2. Movement trajectory of regional gravity center of annual E_{pan} during 1970-2017.

The figure was generated by origin 9.0, URL: https://www.originlab.com/.

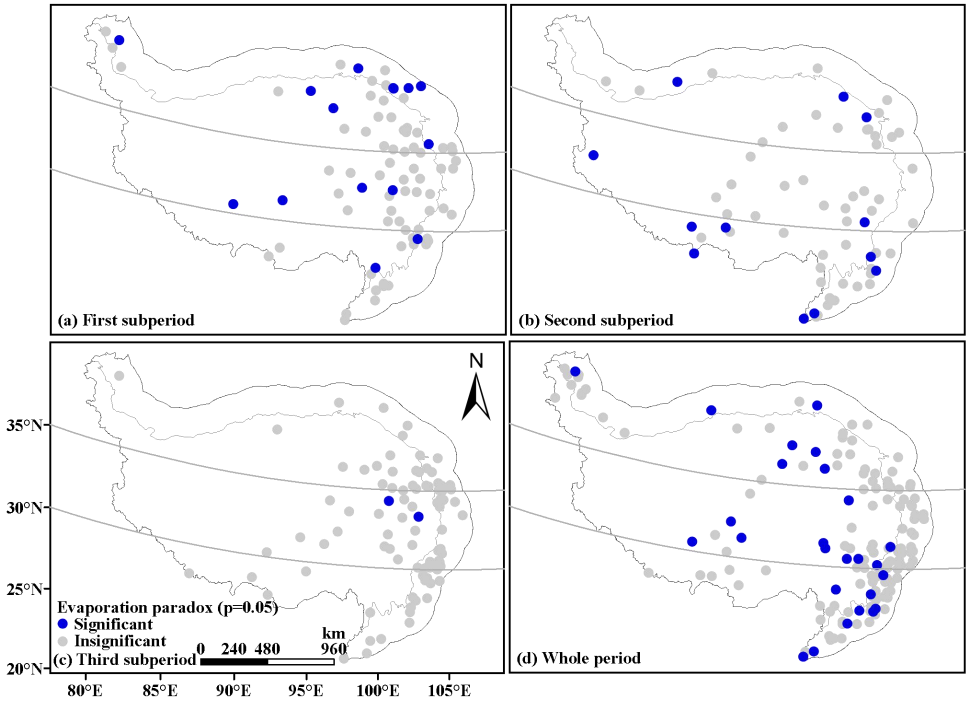

Figure S3. Spatial distributions of pan evaporation paradox in the whole and three-segmented periods. The maps were generated in ArcMap 10.2, URL: http://www.esrichina-bj.cn/softwareproduct/ArcGIS/.

Table S1. Basic information about 274 stations.

WMO ID	Latitude (°N)	Longitude (°E)	Altitude (m)	WMO ID	Latitude (°N)	Longitude (°E)	Altitude (m)
51804	37.46	75.14	3090.1	52652	39.05	100.17	1461.1
51886	38.15	90.51	2944.8	52661	38.48	101.05	1765.5
52533	39.46	98.29	1477.2	52674	38.13	101.56	2093.9
52602	38.45	93.20	2770.0	52681	38.38	103.05	1367.5
52633	38.49	98.25	3367.0	52797	37.11	104.03	1630.9
52643	38.50	99.37	2311.8	52884	36.21	103.57	1668.5
52645	38.26	99.36	3314.0	52885	36.45	103.15	2118.8
52656	38.28	100.49	2232.0	52889	36.03	103.53	1517.2
52657	38.11	100.15	2787.4	52895	36.34	104.41	1398.2
52679	37.55	102.40	1531.5	52896	36.33	104.09	1736.7
52713	37.51	95.21	3173.2	52980	35.58	103.18	1648.0
52737	37.22	97.23	2981.5	52981	35.41	103.23	2421.0
52745	37.18	99.01	3417.1	52982	35.29	103.33	1953.2
52754	37.20	100.08	3301.5	52983	35.52	104.09	1874.4
52765	37.23	101.37	2850.0	52984	35.35	103.11	1917.2
52784	37.28	102.54	2072.4	52986	35.22	103.52	1893.8
52787	37.12	102.52	3045.1	52993	35.41	105.04	1739.4
52818	36.25	94.55	2807.6	52995	35.35	104.37	1897.2
52825	36.26	96.26	2790.4	52996	35.23	105.01	2450.6
52836	36.18	98.06	3189.0	52998	35.08	104.12	2111.0
52842	36.47	99.05	3087.6	53908	35.13	105.14	1769.8
52855	36.41	101.15	2675.0	55655	28.11	85.58	3810.0
52856	36.16	100.37	2835.0	55690	27.59	91.57	4280.3
52862	36.57	101.41	2450.0	56091	34.51	104.28	1883.3
52863	36.49	101.57	2480.0	56092	35.00	104.39	1728.2
52866	36.44	101.45	2295.2	56093	34.26	104.01	2315.0
52868	36.01	101.22	2273.0	56095	34.02	104.23	1753.2
52869	36.30	101.35	2667.5	56096	33.24	104.55	1079.1
52874	36.29	102.25	2021.0	56181	30.41	103.42	541.7
52876	36.20	102.50	1813.9	56186	31.20	104.12	589.0
52877	36.06	102.15	2834.7	56187	30.45	103.52	547.7
52908	35.13	93.05	4612.2	56188	31.00	103.40	698.5
52943	35.35	99.59	3323.0	56189	30.59	103.56	581.7
52955	35.35	100.44	3120.0	56190	31.33	104.33	519.4
52957	35.15	100.36	3148.2	56192	32.57	104.40	1014.3
52963	35.56	102.01	2085.7	56193	32.25	104.31	893.2
52968	35.02	101.28	3662.8	56195	31.48	104.44	543.1
52972	35.51	102.27	1921.0	56196	31.27	104.44	522.7
52974	35.33	102.02	2475.0	56197	31.09	104.10	535.7
52978	35.11	102.30	2948.3	56198	31.19	104.30	525.7
52985	35.25	103.20	2162.8	56199	31.02	104.41	423.5

52988	35.22	103.43	2015.8	56272	30.49	103.53	558.5
55228	32.30	80.05	4278.6	56273	30.23	102.49	1022.0
55279	31.23	90.01	4700.0	56276	30.27	103.49	467.0
55294	32.21	91.06	4800.0	56278	30.04	102.47	755.8
55299	31.29	92.04	4507.0	56279	30.10	102.57	744.1
55472	30.57	88.38	4672.0	56280	30.05	103.07	691.3
55493	30.29	91.06	4200.0	56281	30.12	103.29	510.8
55578	29.15	88.53	3836.0	56284	30.27	103.26	518.5
55591	29.40	91.08	3648.9	56285	30.34	103.28	544.7
55598	29.16	91.46	3560.0	56287	29.59	103.00	627.6
55680	28.55	89.36	4040.0	56289	30.12	103.52	437.0
55681	28.58	90.24	4431.7	56290	30.47	104.11	514.5
55696	28.25	92.28	3860.0	56291	30.56	104.17	469.0
55773	27.44	89.05	4300.0	56295	30.23	104.33	448.5
56004	34.13	92.26	4533.1	56296	30.49	104.26	493.5
56016	33.51	95.37	4179.1	56297	30.01	104.09	436.5
56018	32.53	95.17	4066.4	56298	30.08	104.36	417.0
56021	34.07	95.48	4175.0	56371	29.53	102.13	1403.2
56029	33.00	96.58	3716.9	56373	29.47	102.51	797.5
56033	34.55	98.13	4272.3	56376	29.20	102.38	1098.0
56034	33.48	97.08	4415.4	56380	29.53	103.21	571.2
56038	32.59	98.06	4200.0	56381	30.04	103.31	630.2
56043	34.29	100.14	3719.0	56382	29.45	103.33	475.0
56046	33.45	99.39	3967.5	56383	29.50	103.52	455.2
56065	34.44	101.36	3500.0	56384	29.36	103.29	446.7
56067	33.26	101.29	3628.5	56385	29.31	103.20	3069.9
56074	34.00	102.05	3471.4	56386	29.34	103.45	424.2
56079	33.35	102.58	3441.4	56387	29.14	103.16	642.2
56080	35.00	102.54	2910.0	56389	29.12	103.57	387.6
56081	34.42	103.21	2810.2	56390	29.40	104.04	404.4
56097	33.16	104.15	1440.5	56394	29.27	104.26	384.1
56106	31.53	93.47	4022.8	56459	27.56	101.16	2426.5
56116	31.25	95.36	3873.1	56473	28.57	102.46	1060.3
56125	32.12	96.28	3643.7	56474	28.33	102.10	1774.0
56137	31.09	97.10	3315.0	56475	28.39	102.31	1659.5
56144	31.48	98.35	3184.0	56478	28.18	102.26	1818.1
56146	31.37	100.00	3393.5	56479	28.00	102.51	2132.4
56147	31.13	98.50	3260.0	56480	28.49	103.32	564.1
56151	32.56	100.45	3530.0	56483	28.35	103.57	496.6
56152	32.17	100.20	3893.9	56485	28.16	103.35	1255.8
56158	31.24	100.40	3250.0	56487	28.20	103.08	1943.9
56164	32.16	100.58	3292.9	56489	28.14	103.37	975.6
56167	30.59	101.07	2957.2	56490	28.57	103.54	424.0
56168	31.29	102.04	2168.9	56533	27.45	98.40	1583.3

56171	32.54	101.42	3275.1	56543	27.51	99.45	3341.5
56172	31.54	102.14	2664.4	56548	27.10	99.17	2326.1
56173	32.48	102.33	3491.6	56565	27.26	101.29	2516.8
56178	31.00	102.21	2438.0	56569	27.25	102.11	1380.0
56180	31.41	103.51	1590.1	56571	27.54	102.16	1590.9
56182	32.40	103.36	2881.3	56575	27.22	102.33	1530.7
56183	31.30	103.37	1370.1	56578	27.04	102.45	993.6
56185	32.05	102.59	2400.1	56580	27.43	102.48	2460.0
56202	30.40	93.17	4488.8	56584	27.42	103.15	1093.0
56227	29.52	95.46	2736.0	56641	26.54	98.52	1189.7
56247	30.00	99.06	2589.2	56645	26.25	99.25	2344.9
56251	30.56	100.19	3000.0	56649	26.06	99.58	2059.9
56263	30.53	101.53	1949.7	56651	26.51	100.13	2380.9
56267	30.02	101.01	2600.9	56652	26.41	100.45	2130.5
56312	29.40	94.20	2991.8	56654	26.35	100.11	2195.4
56357	29.03	100.18	3727.7	56664	26.38	101.16	1230.8
56374	30.03	101.58	2615.7	56665	26.41	101.51	1140.3
56378	29.14	102.21	890.7	56670	26.55	102.07	1136.9
56434	28.39	97.28	2327.6	56671	26.39	102.15	1787.3
56443	28.56	99.48	2842.0	56739	24.59	98.30	1695.9
56444	28.29	98.54	3319.0	56742	25.53	99.22	1723.9
56462	29.00	101.30	2925.0	56745	25.41	99.57	1626.1
56567	27.15	100.51	2367.2	56746	25.28	99.31	1616.7
51704	39.43	76.10	1298.7	56748	25.07	99.11	1652.2
51705	39.43	75.15	2175.7	56751	25.42	100.11	1977.7
51707	39.30	76.47	1204.7	56752	25.50	100.34	1438.7
51708	39.09	75.57	1325.1	56835	24.10	97.47	959.1
51709	39.29	75.45	1385.6	56836	24.42	97.57	826.7
51717	39.15	76.47	1206.3	56838	24.00	97.51	762.9
51777	39.02	88.10	887.7	56840	24.49	98.18	1012.9
51802	38.56	76.10	1297.5	56841	24.36	98.41	1528.0
51810	38.55	77.38	1178.2	56842	24.44	99.11	1471.2
51811	38.26	77.16	1231.2	56844	24.26	98.35	913.8
51814	37.55	77.24	1360.4	57001	34.45	105.2	1271.9
51815	38.12	77.16	1274.7	57002	34.51	105.39	1216.1
51818	37.37	78.17	1375.4	57004	34.44	104.53	1495.4
51826	37.01	80.48	1336.5	57006	34.34	105.45	1149.8
51827	37.10	79.38	1348.9	57007	34.11	105.11	1404.6
51828	37.08	79.56	1375.0	57008	34.02	105.18	1579.0
51829	37.03	80.14	1295.6	57014	34.34	105.52	1085.2
51839	37.04	82.43	1409.5	57102	33.45	105.43	970.0
51855	38.09	85.33	1247.2	57105	33.20	105.36	1221.2
51931	36.51	81.39	1422.0	57106	33.19	106.09	794.2
52418	40.09	94.41	1139.0	57110	33.47	106.05	930.8

52424	40.32	95.47	1170.9	57204	32.34	105.13	782.0
52436	40.16	97.02	1526.0	57206	32.25	105.54	545.4
52446	40.18	99.31	1177.4	57208	32.17	105.31	544.5
52447	40.00	98.53	1270.5	57304	31.40	105.10	516.5
52546	39.22	99.50	1332.2	57307	31.06	105.05	459.9
52557	39.09	100.10	1453.7	57308	31.13	105.23	421.3
52575	39.25	102.47	1239.5	57401	30.52	105.22	383.3
52576	39.13	101.41	1510.1	57407	30.17	105.02	462.6

Table S2. The performance of PenPan model for monthly E_{pan} at 274 stations in the QTP.

Metrics	Minima	Maxima	Mean ± 1s.d.	Station proportion
Slope	0.72	0.99	0.92 ± 0.05	
R^2	0.85	0.99	0.96 ± 0.03	100%
MD (mm)	-0.40	0.00	0.00 ± 0.03	0
RMSE (mm)	6.68	41.48	15.92 ± 5.11	

Table S3. Climate zones of China.

No	Major Climate Zone	Minor Climate Zone Code	Name
1	I North Temperate Zone	IA1	Genhe Zone
2	II Mid-temperate Zone	**IIC5**	**Yining Zone**
		IIC3	Fuyun Zone
		IIC4	Tacheng Zone
		IIC1	Mengdong Zone
		IIC2	**Mengzhong Zone**
		IIA1	Xiaoxinganling Zone
		IIB1	Daxinganling Zone
		IID1	**Menggan Zone**
		IID2	Beijiang Zone
		IIA2	Sanjiang-Changbai Zone
		IIB2	Songliao Zone
3	III South Temperate Zone	**IIID1**	**Nanjiang Zone**
		IIIC1	Jinshangan Zone
		IIIB1	Hebei Zone
		IIIB3	**Weihe Zone**
		IIIA1	Liaodong-Jiaodongbandao Zone
		IIIB2	Lvhuai Zone
4	IV North Subtropical Zone	**IVA2**	**Qinba Zone**
		IVA1	Jiangbei Zone
5	V Mid-subtropical Zone	VA2	Oujiang, Minjiang, Nanling Zone
		VA1	**Jiangnan Zone**
		VA3	**Sichuan Zone**
		VA4	Guizhou zone
		VB1	**Jinshajiang-Chuxiong-Yuxi Zone**
		VA5	**Dianbei Zone**
6	VI South Subtropical Zone	VIA1	Taibei Zone
		VIA2	Minnan-Zhujiang Zone
		VIA3	**Diannan Zone**
7	VII North Subtropical Zone	VIIA2	Leiqiong Zone
		VIIA1	Tainan Zone
		VIIB1	Qiongxi Zone
		VIIA3	Diannanhegu Zone
		VIIC1	Yuanjiang Zone
		VIIA1	Tainan Zone
8	VIII Mid-tropical Zone	VIIIA1	Qiongnan-Xisha Zone
9	IX South Tropical Zone	IXA1	Nansha Zone
10	H Highland Climate	**HD2**	**Zangbei Zone**

	Zone	**HC3**	**Zangnan Zone**
		HC2	**Zangzhong Zone**
		HB2	**Changdu Zone**
		HA1	Bomi-Chuanxi Zone
		HVVIVIIA1	**Dawang-Chayu Zone**
		HC1	**Qilian-Qinghaihu Zone**
		HB1	Qingnan Zone
		HD1	**Chaidamu zone**

Note: Climate zones used in this study were in bold.