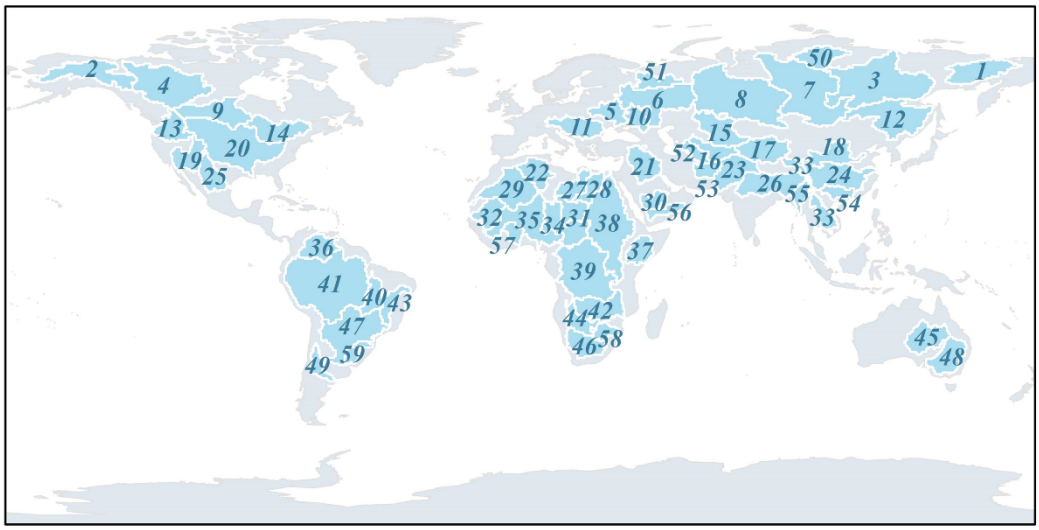
Supporting Information for

Three-Dimensional Assessment of Drought in Global River Basins

Figures



1 Kolyma 2 Yukon 3 Lena 4 Mackenzie 5 Dnieper 6 Volga 7 Yenisey 8 Ob 9 Nelson-Saskatchewan 10 Don 11 Danube 12 Amur
13 Columbia 14 St Lawrence 15 Syr Darya 16 Amu Darya 17 Tarim Interior 18 Yellow River 19 Colorado 20 Mississippi 21 Tigris
22 Chelif River 23 Indus 24 Yangtze 25 Rio Grande-Bravo 26 Ganges 27 Shati 28 North Interior 29 Oued Dra 30 Arabian Peninsula
31 Chari 32 Senegal 33 Mekong 34 Lake Chad 35 Niger 36 Orinoco 37 Shebelli - Juba 38 Nile 39 Congo 40 Tocantins 41 Amazon
42 Zambezi 43 Sao Francisco 44 South Interior 45 Great Artesian Basin 46 Orange 47 La Plata 48 Murray 49 Rio Grande
50 Khataga 51 N.Dvina 52 Ayeyarwady 53 Farah 54 Pearl 55 Irrawaddy 56 Arabian Peninsula 57 Volta 58 Limpopo 59 Rio Ibicui

Fig. S1 The 59 major river basins across the globe used in this study. Each basin has a basin number corresponding to a basin name.

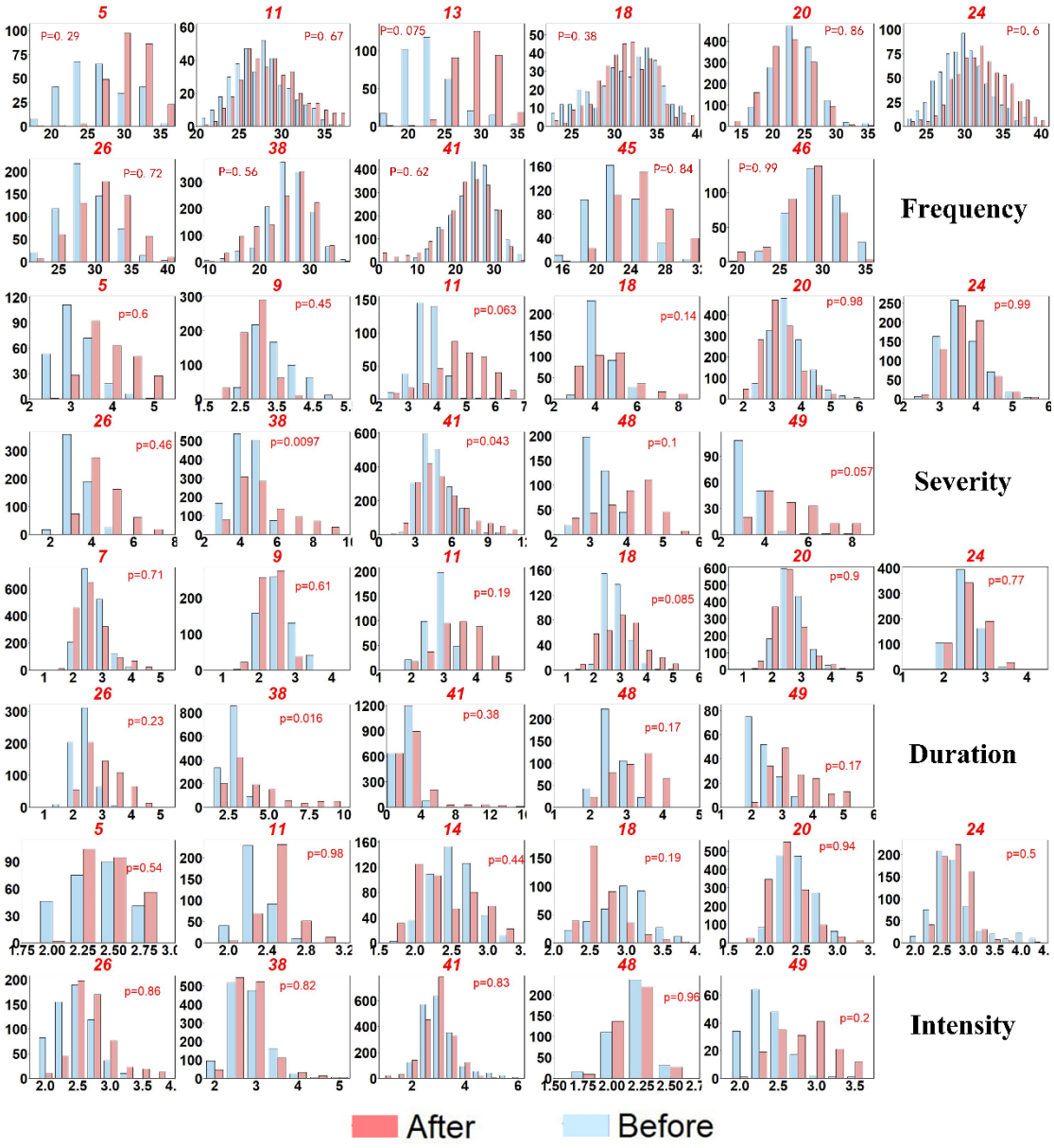


Fig.S2 Changes in histogram distributions of drought frequency, severity, duration, and intensity for 11 typical river basins between two sub periods, 1979-1999 and 2000-2020. The x-axis in each panel represents frequency, severity, duration and intensity of drought, respectively. The y-axis represents number of drought events falling into a specific bin of frequency/ severity/duration/intensity. The number on the top of each panel indicates basin code as shown in Fig. S1.

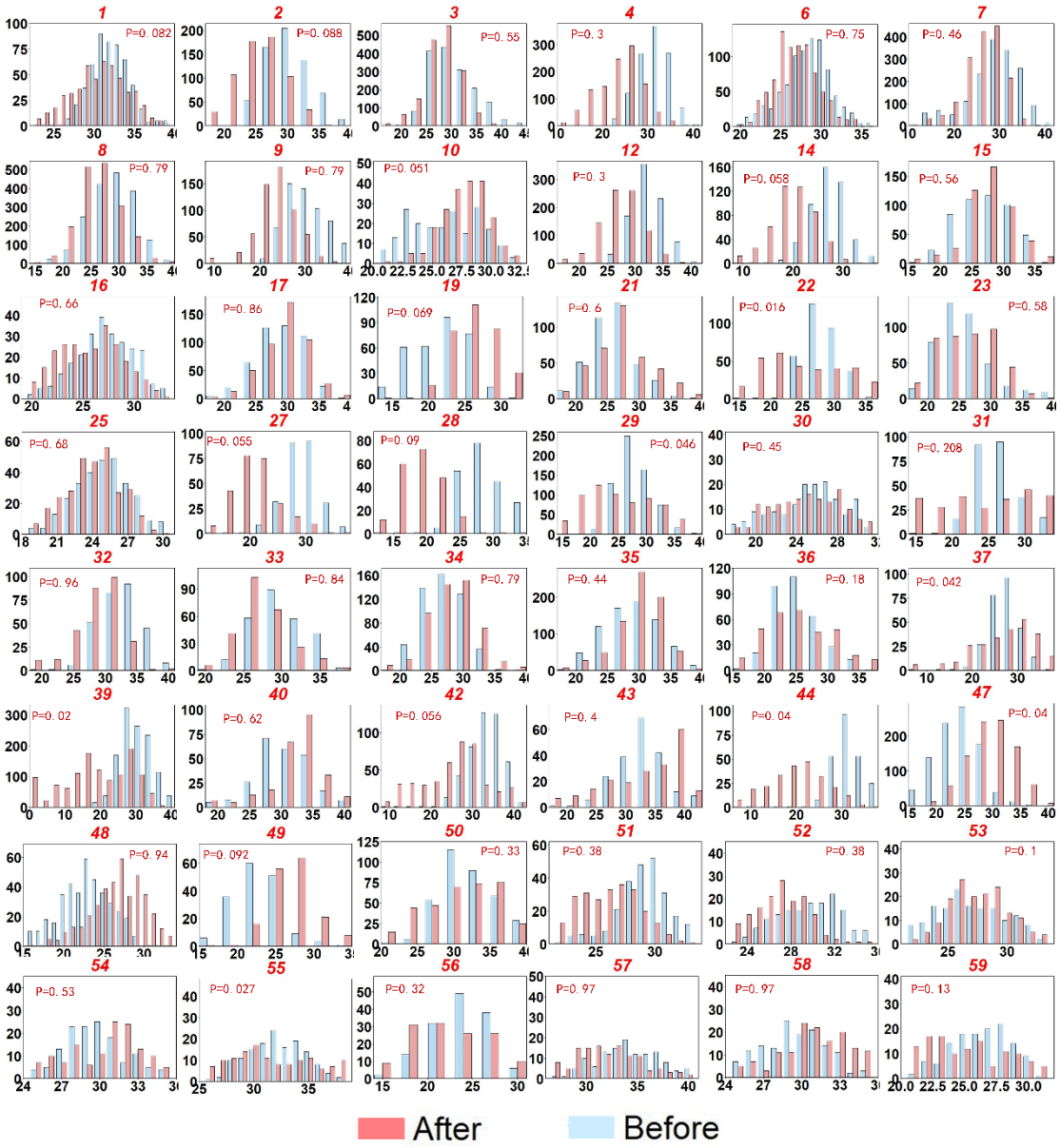


Fig.S3 Changes in distributions of drought frequency for the remaining 48 river basins between two sub periods, 1979-1999 and 2000-2020. The x-axis in each panel represents frequency and the y-axis represents number of drought events falling into a specific bin of frequency. The number on the top of each panel indicates basin code as shown in Fig. S1.

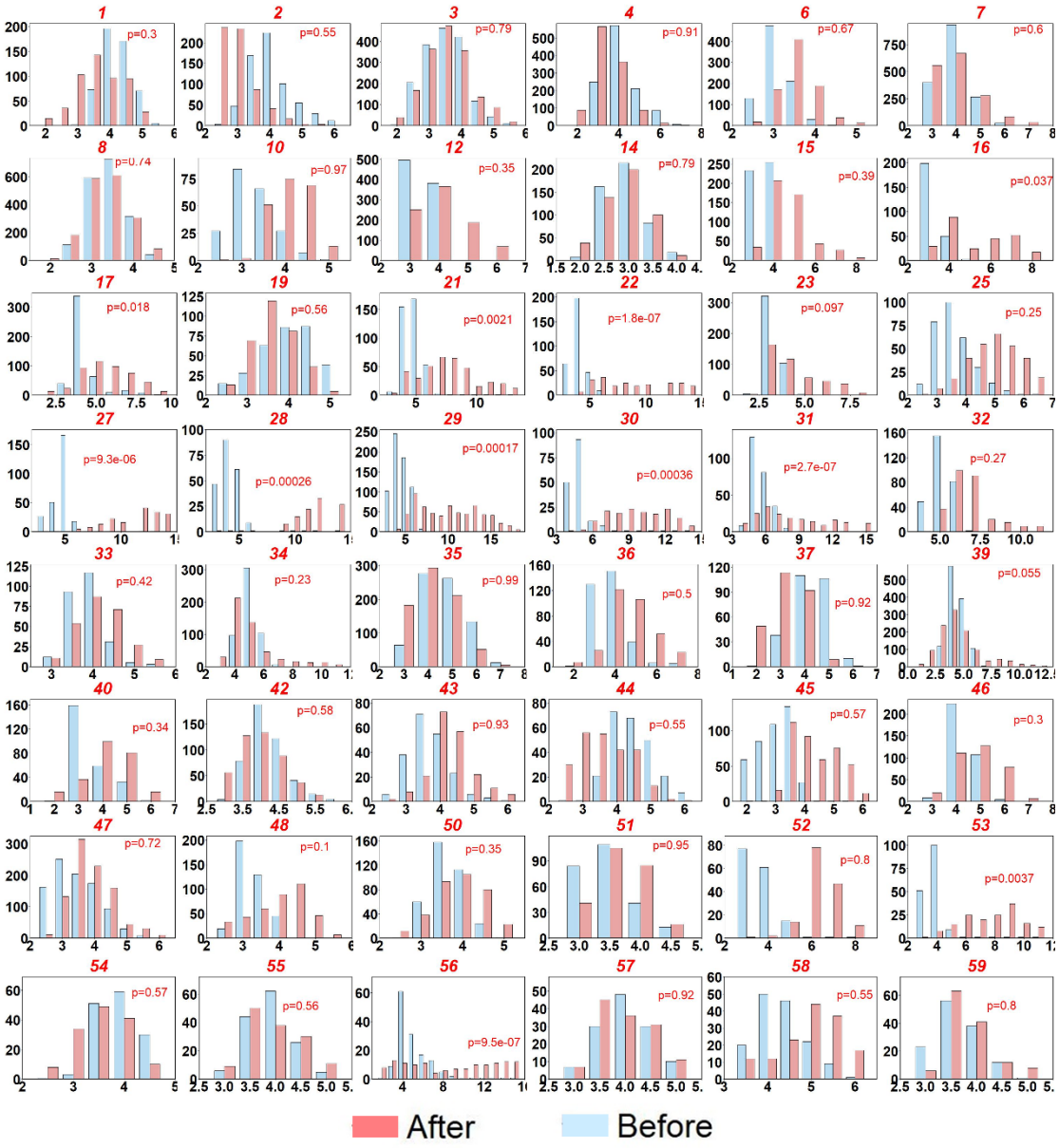


Fig. S4 Changes in distributions of drought severity for the remaining 48 river basins between two sub periods, 1979-1999 and 2000-2020. The x-axis in each panel represents severity and the y-axis represents number of drought events falling into a specific bin of severity. The number on the top of each panel indicates basin code as shown in Fig. S1.

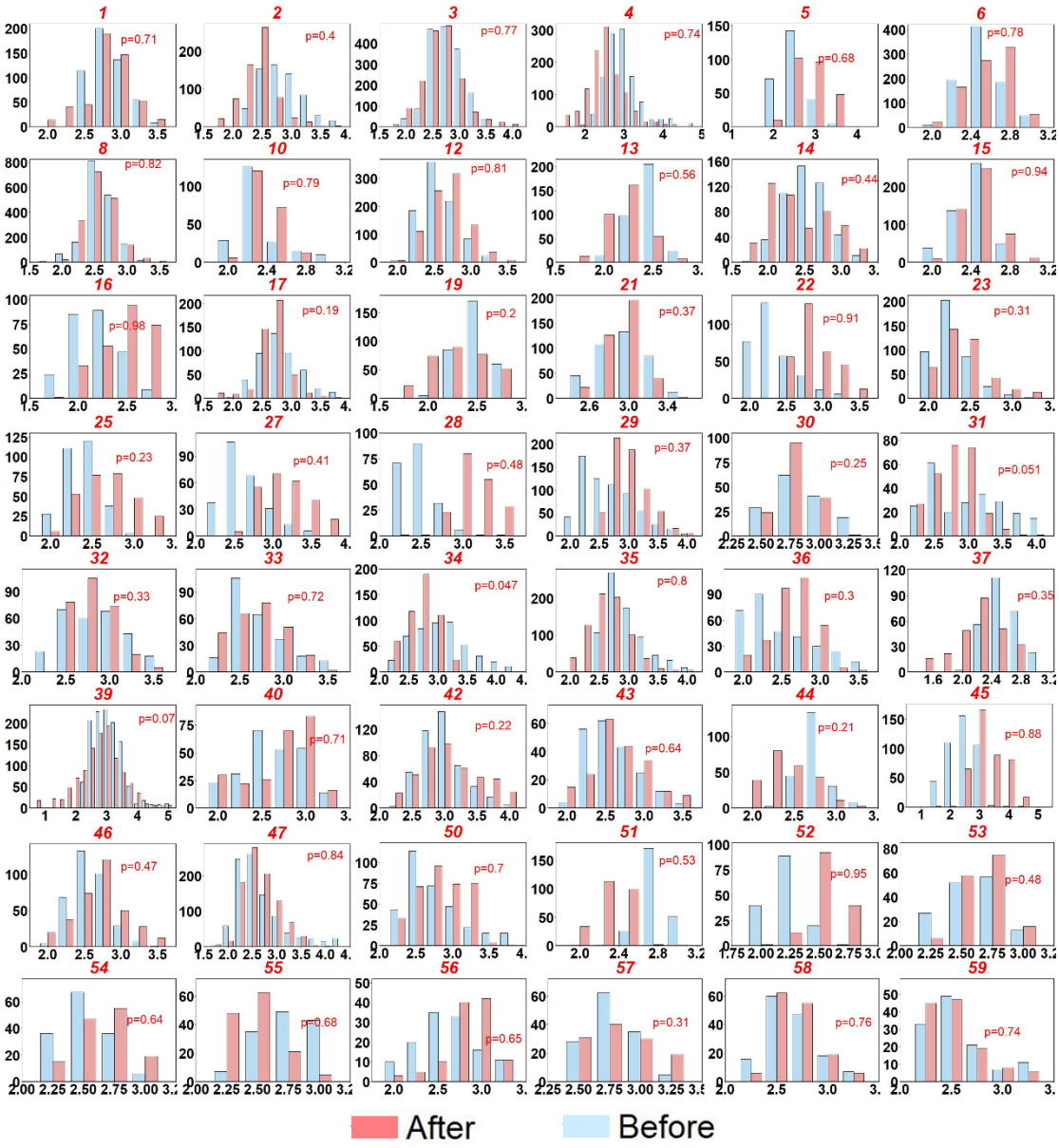


Fig. S5 Changes in distributions of drought duration for the remaining 48 river basins between two sub periods, 1979-1999 and 2000-2020. The x-axis in each panel represents duration and the y-axis represents number of drought events falling into a specific bin of duration. The number on the top of each panel indicates basin code as shown in Fig. S1.

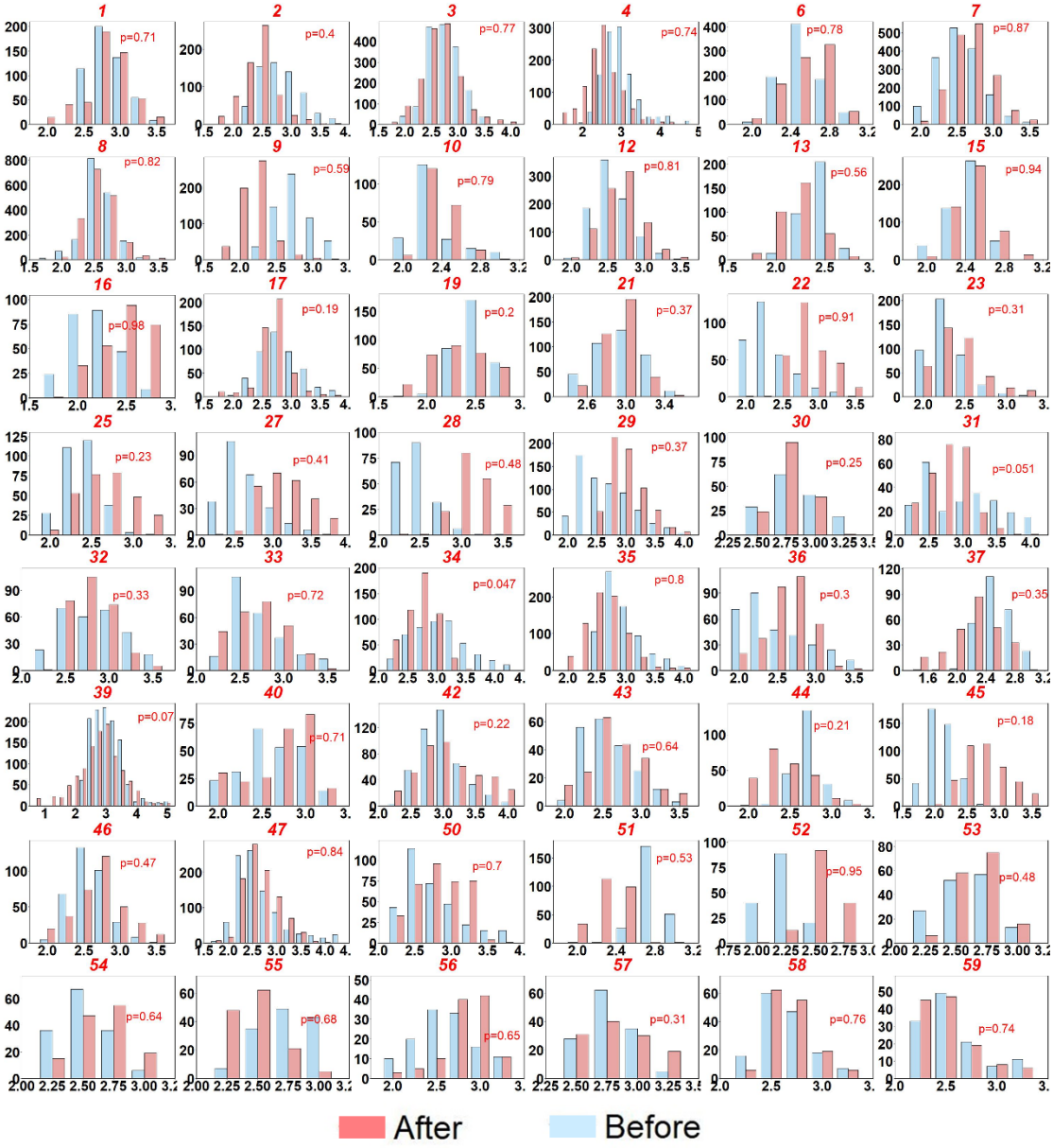


Fig.S6 Changes in distributions of drought intensity for the remaining 48 river basins between two sub periods, 1979-1999 and 2000-2020. The x-axis in each panel represents intensity and the y-axis represents number of drought events falling into a specific bin of intensity. The number on the top of each panel indicates basin code as shown in Fig. S1.

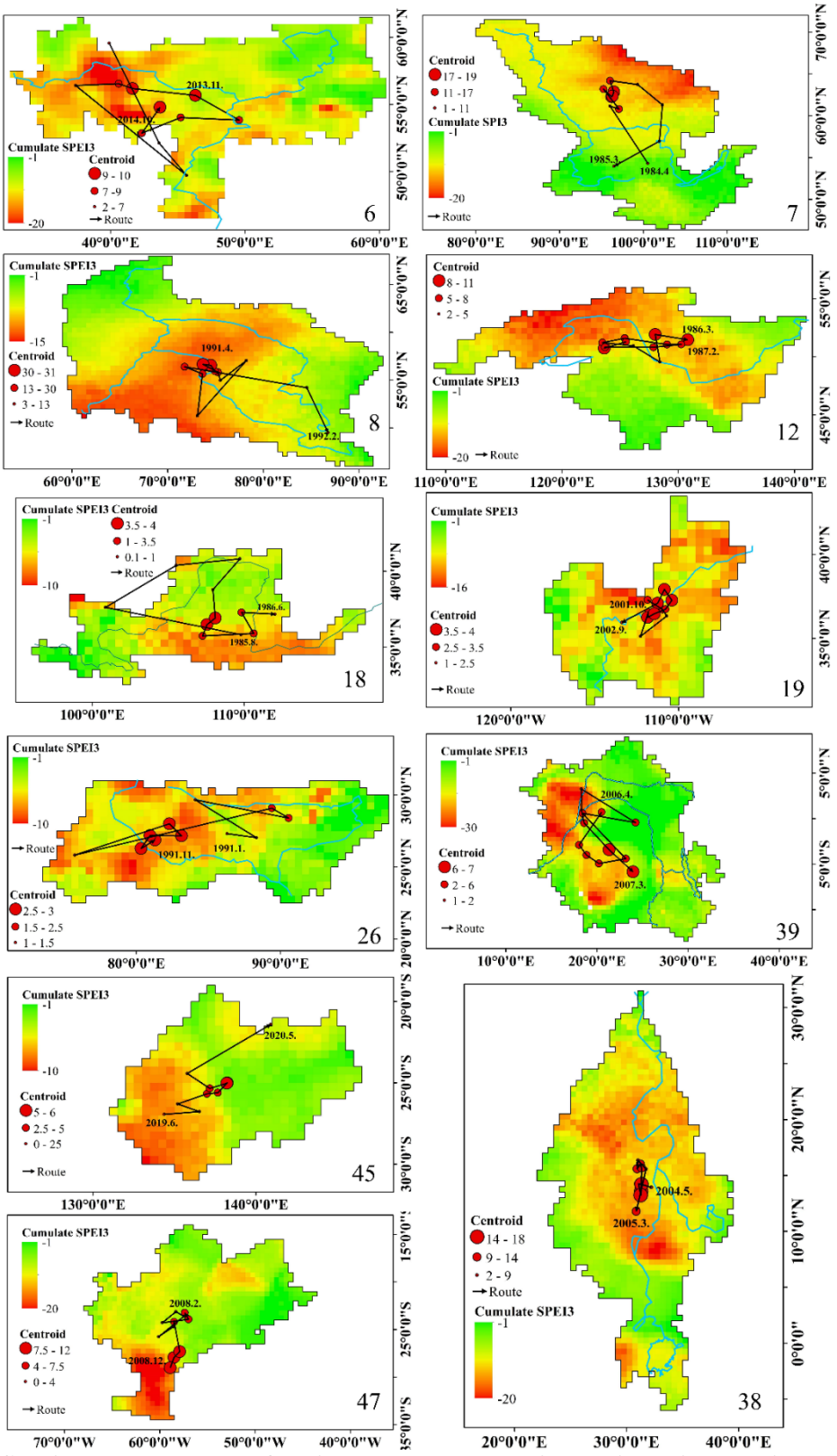
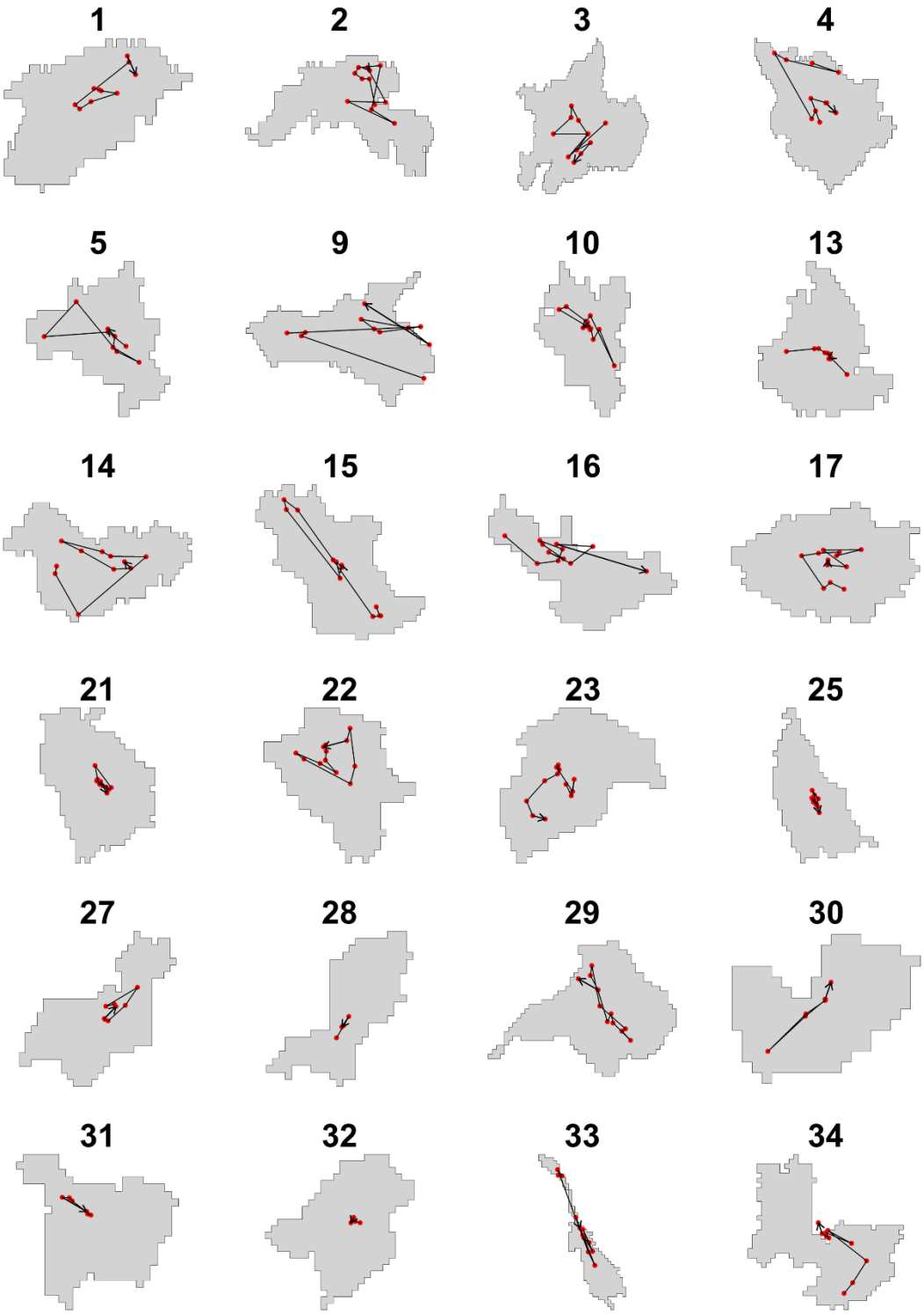


Fig. S7 Spatiotemporal track of typical drought events in medium-sized basins. Red dots represent the center points of drought, with the sizes of the circles indicating drought severity. The black arrows represent the movement path. The starting and ending months of the droughts are marked on each panel. The color bar shows the cumulate SPEI-3 over the entire duration of the drought event. The number at the right lower of each panel is the basin code.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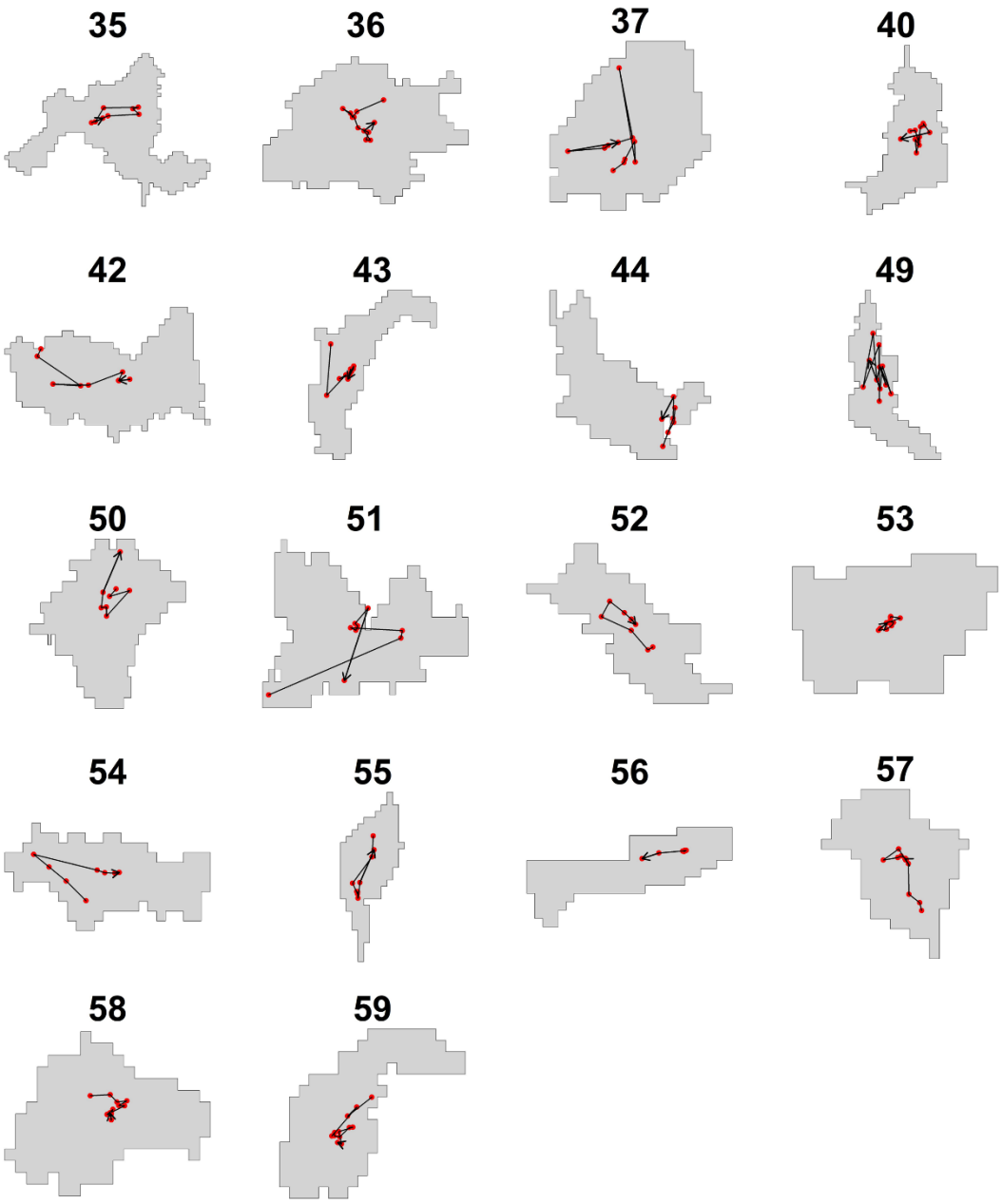

Fig. S8 Spatiotemporal track of typical drought events in small-sized basins. Red dots represent the center points of drought, with the sizes of the circles indicating drought severity. The black arrows represent the movement path. The numbers at the top of each panel are basin codes.

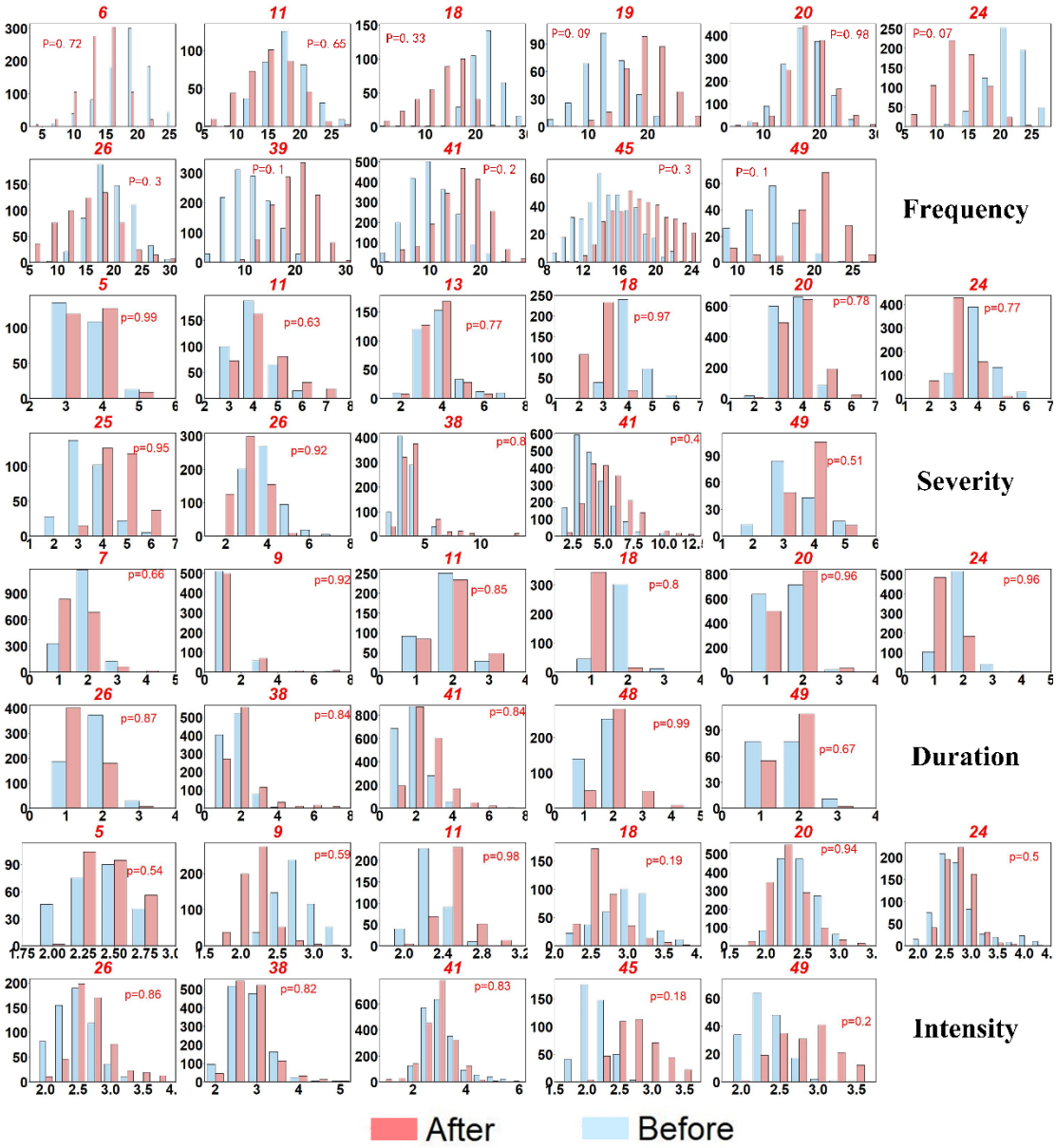

Fig.S9 Changes in distributions of drought frequency, severity, duration, and intensity identified by SPI for 11 typical river basins between two sub periods, 1979-1999 and 2000-2020. The x-axis in each panel represents frequency, severity, duration and intensity of drought, respectively. The y-axis represents number of drought events falling into a specific bin of frequency/ severity/duration/intensity. The number on the top of each panel indicates basin code as shown in Fig. S1.

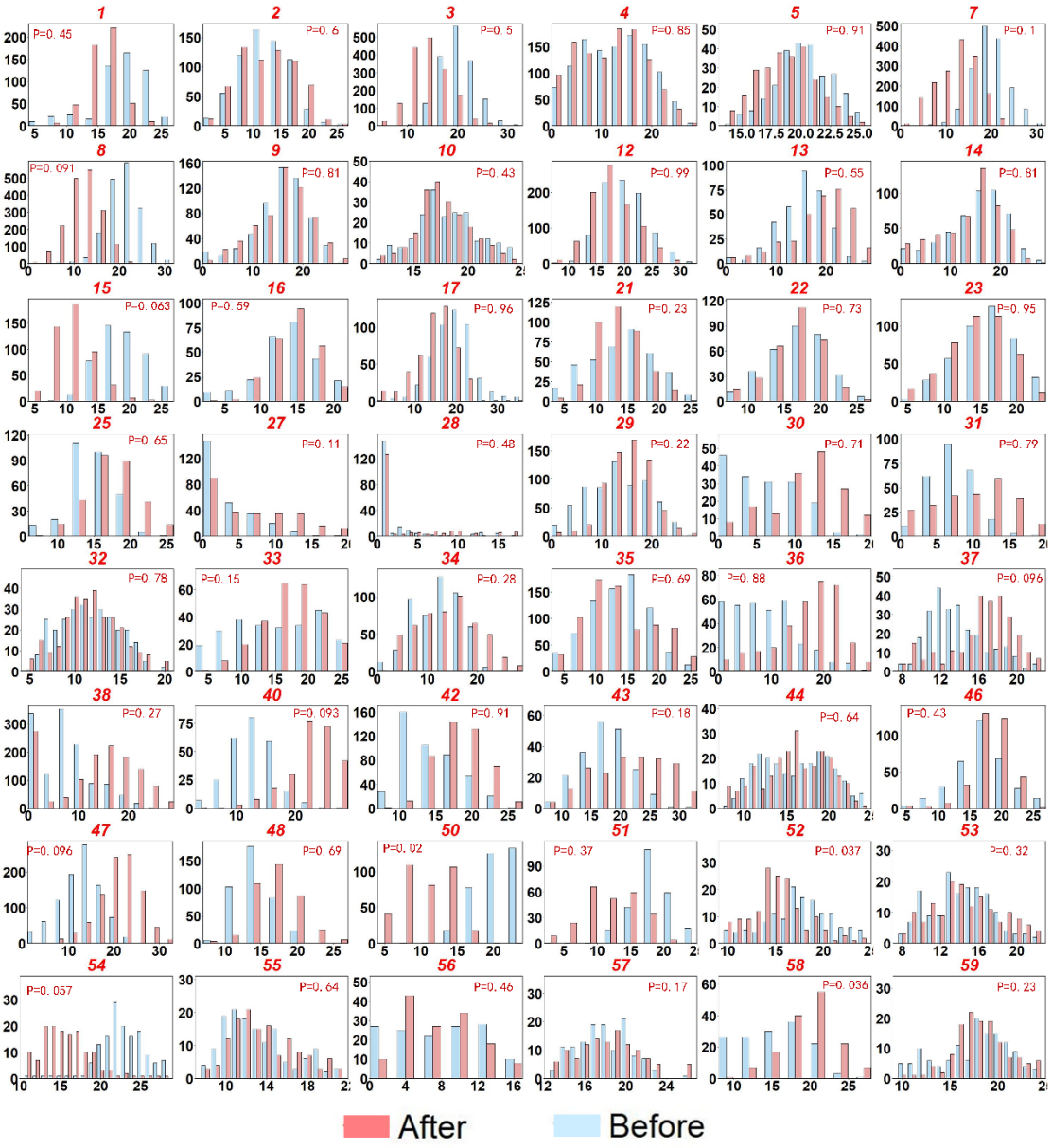

Fig.S10 Changes in distributions of drought frequency identified by SPI for the remaining 48 river basins between two sub periods, 1979-1999 and 2000-2020. The x-axis in each panel represents frequency and the y-axis represents number of drought events falling into a specific bin of frequency. The number on the top of each panel indicates basin code as shown in Fig. S1.

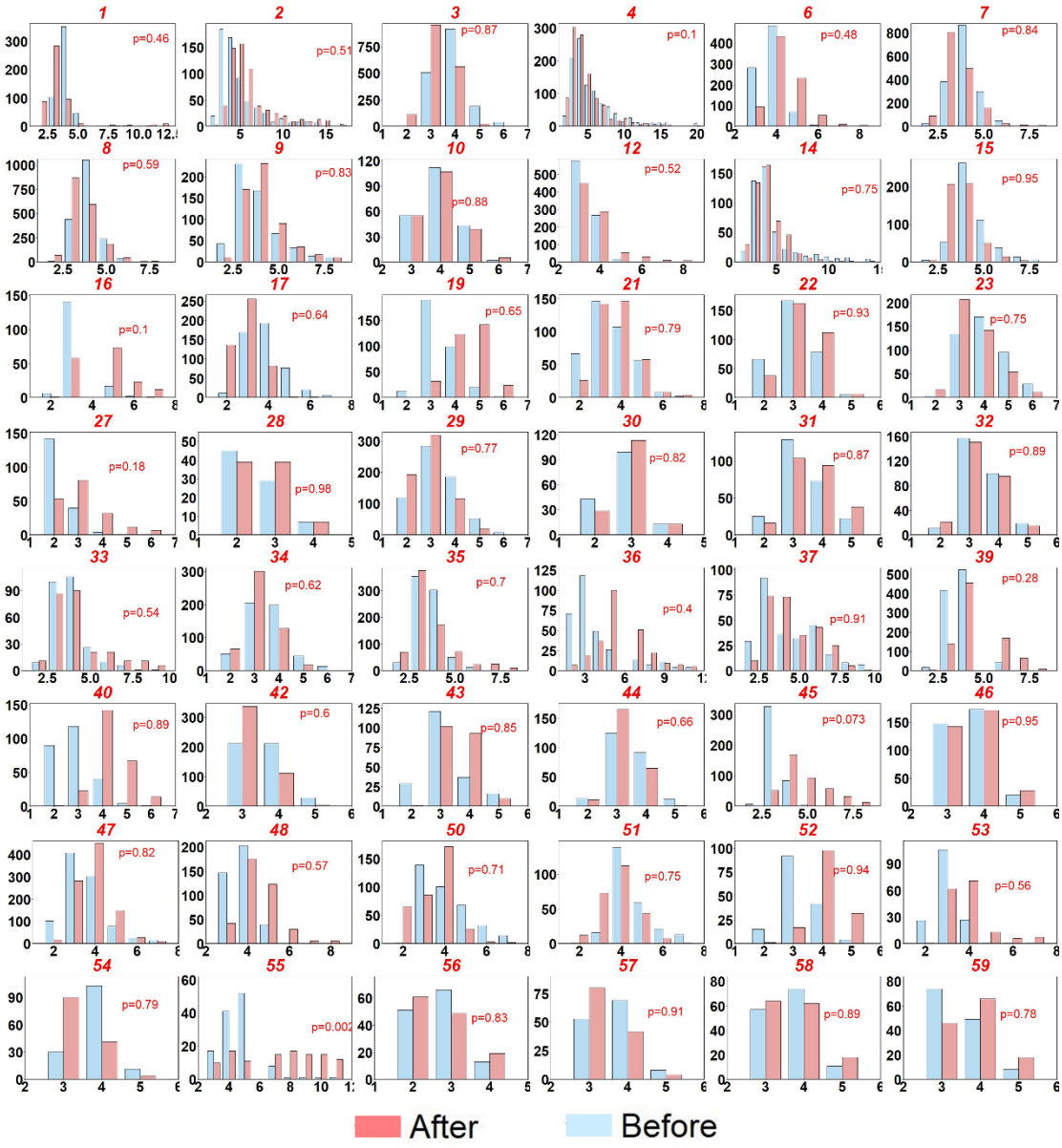

Fig.S11 Changes in distributions of drought severity identified by SPI for the remaining 48 river basins between two sub periods, 1979-1999 and 2000-2020. The x-axis in each panel represents severity and the y-axis represents number of drought events falling into a specific bin of severity. The number on the top of each panel indicates basin code as shown in Fig. S1.

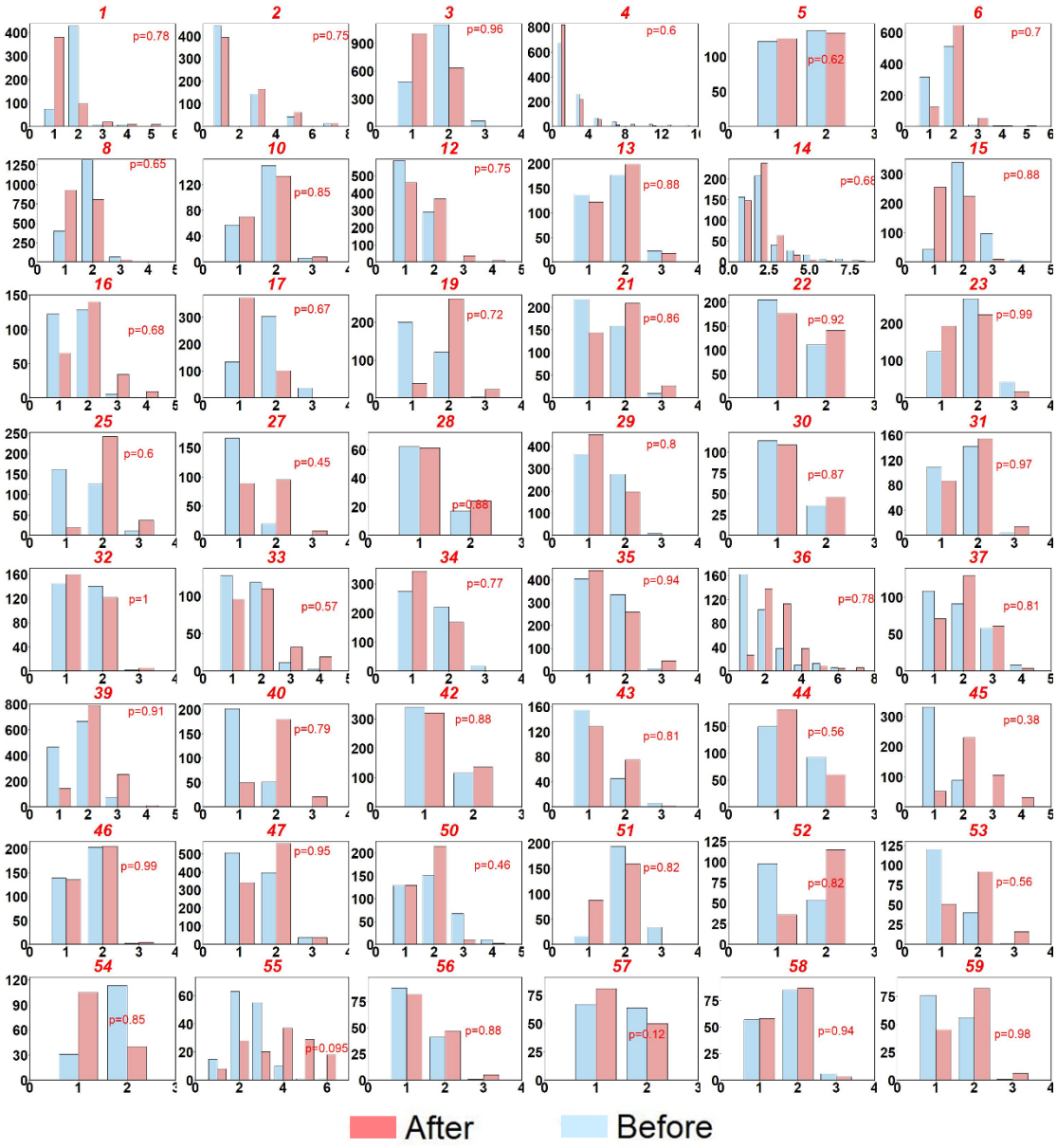

Fig.S12 Changes in distributions of drought duration identified by SPI for the remaining 48 river basins between two sub periods, 1979-1999 and 2000-2020. The x-axis in each panel represents duration and the y-axis represents number of drought events falling into a specific bin of duration. The number on the top of each panel indicates basin code as shown in Fig. S1.

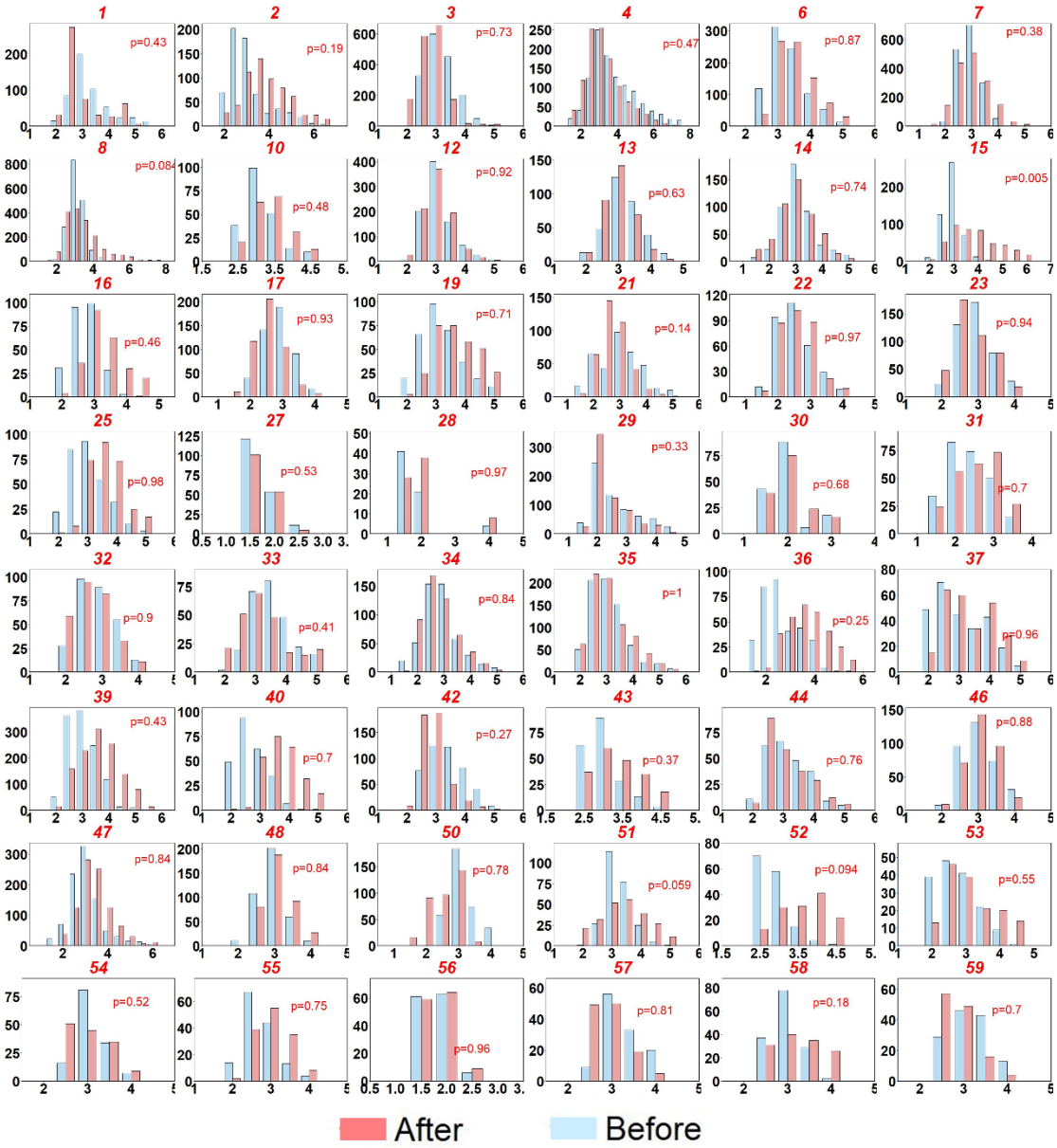

Fig.S13 Changes in distributions of drought intensity identified by SPI for the remaining 48 river basins between two sub periods, 1979-1999 and 2000-2020. The x-axis in each panel represents intensity and the y-axis represents number of drought events falling into a specific bin of intensity. The number on the top of each panel indicates basin code as shown in Fig. S1

Tables

Table S1. The drought classification criteria.

SPEI values	Drought category
>2	Extremely wet
1.5–1.99	Very wet
1–1.49	Moderately wet
−0.99–0.99	Near normal
−1 to − 1.49	Moderately dry
−1.5 to − 1.99	Severely dry
< − 2	Extremely dry

Table S2. Drought events with the greatest severity in each basin.

Basin	Persistent Period (yyyy.mm)	Duration (month)	Centroid (lon, lat, t) (E, N, yyyy.mm)	Affected area (10^6km^2)	Severity (10^6km^{2}month)	Intensity
1	2001.8-2002.7	10	157.47,66.13,2002.2	0.93	1.21	-1.10
2	2007.6-2008.5	12	-141.14,65.78,2007.11	0.29	0.28	-0.91
3	1992.5-1993.4	12	121.26,60.47,1992.10	2.22	2.67	-1.15
4	1997.8-1998.6	11	-119.66,61.68,1998.1	1.65	2.43	-1.20
5	2013.7-2014.4	9	32.08,51.23,2013.12	0.48	0.54	-1.01
6	2013.11-2014.10	11	44.13, 54.93, 2014.5	1.15	1.38	-1.09
7	1984.4-1985.3	12	96.79, 62.09, 1984.9	2.23	3.03	-1.23
8	1991.4-1992.2	11	74.25, 56.08, 1991.9	2.71	3.92	-1.17
9	1994.12-1995.11	11	-103.42, 52.64, 1995.5	0.43	0.43	-0.84
10	2014.2-2015.1	12	40.89,50.33,2014.7	0.50	0.61	-1.12
11	1989.10-1990.8	11	20.87, 46.62, 1990.3	0.81	1.02	-1.19
12	1986.3-1987.2	12	126.74, 50.91, 1986.8	1.85	2.38	-1.25
13	1993.10-1994.8	11	-117.06,45.91,1994.3	0.80	0.95	-1.15
14	1994.6-1995.5	11	-81.25,45.99,1994.12	0.63	0.67	-1.00
15	1983.11-1984.10	12	68.83,45.33,1984.4	0.66	0.89	-1.12
16	2013.1-2013.12	12	64.46,39.87,2013.6	0.29	0.28	-0.84
17	1985.3-1986.2	12	83.6,38.84,1985.8	0.92	1.11	-1.16
18	1985.8-1986.6	11	108.25, 36.78, 1986.1	0.38	0.41	-0.97
19	2001.10-2002.9	12	-111.3, 36.82, 2002.3	0.78	0.83	-1.03
20	1980.6-1981.5	12	-96.8, 40.67, 1980.11	2.84	3.92	-1.34
21	1998.10-1999.8	11	43.13,33.66,1999.3	1.02	1.70	-1.59
22	1983.11-1984.10	12	5,32.28,1984.4	0.41	0.46	-0.97
23	1999.11-2000.10	12	71.98,31.19,2000.4	0.74	0.95	-1.20
24	1997.2-1998.4	12	107.88, 31.43, 1997.7	0.74	0.91	-1.14
25	2010.12-2011.11	12	-103.88,29.78,2011.5	0.89	1.50	-1.69
26	1991.1-1991.11	11	83.06, 27.41, 1991.6	0.54	0.55	-0.95
27	2017.11-2018.6	8	19.59,26.44,2018.2	0.55	0.75	-1.23
28	1999.2-1999.5	4	24.09,24.38,1999.3	0.44	0.44	-0.99
29	1984.1-1984.12	12	-2.07,25.45,1984.6	0.88	1.05	-1.05
30	2007.12-2008.6	7	46.06,21.9,2008.3	0.36	0.48	-1.19
31	2013.6-2013.11	6	17.19,19.29,2013.8	0.49	0.61	-1.24
32	1983.7-1983.12	6	-9.34,17.43,1983.9	0.86	1.84	-2.12
33	2009.4-2010.3	12	101.39,21.96,2009.9	0.36	0.43	-1.16
34	1990.3-1990.12	10	16.32,13.26,1990.7	1.02	1.48	-1.34
35	2001.5-2001.12	8	2.25,16.06,2001.8	1.34	1.72	-1.26
36	2015.5-2016.4	12	-67.77,5.84,2015.10	0.74	1.02	-1.33
37	2010.11-2011.9	11	40.66,3.28,2011.4	0.23	0.20	-0.86
38	2004.5-2005.3	11	31.25, 14.27, 2004.10	2.80	3.51	-1.20
39	2006.4-2007.3	12	20.91, -2.78, 2006.9	0.90	1.05	-1.12
40	2017.4-2018.3	12	-48.67,-10.79,2017.9	0.45	0.61	-1.25
41	2005.1-2005.12	12	-65.33, -7.45, 2005.6	2.66	3.34	-1.23
42	1997.10-1998.6	9	27.7,-15.18,1998.2	0.72	0.91	-1.13
43	2007.3-2008.1	11	-43.65,-14.04,2007.8	0.49	0.69	-1.30
44	2018.10-2019.6	7	25.07,-21.64,2019.1	0.10	0.09	-0.84
45	2019.6-2020.4	10	137.43, -25.36, 2019.10	0.73	0.74	-0.90
46	1994.4-1995.3	12	23.42, -26.9, 1994.9	0.74	0.92	-1.17

47	2008.2-2008.12	11	-58.4, -24.3, 2008.7	1.25	1.62	-1.20
48	2019.3-2020.2	12	145.98, -32.05, 2019.8	0.76	0.85	-1.03
49	1995.1-1995.12	12	-67.56,-33.55,1995.6	0.25	0.26	-0.96
50	2000.9-2001.4	8	102.43,71.13,2000.12	0.76	1.13	-1.35
51	1995.9-1996.8	10	46.98,62.11,1996.2	0.43	0.70	-1.20
52	2014.1-2014.8	8	60.11,38.01,2014.4	0.35	0.46	-1.21
53	2017.7-2018.6	12	63.99,31.81,2017.12	0.47	0.76	-1.58
54	1992.5-1992.12	8	108,24.49,1992.8	0.26	0.41	-1.34
55	2001.3-2002.2	9	95.8,23.21,2001.7	0.19	0.21	-1.05
56	2015.4-2015.10	7	52.66,18.95,2015.7	0.26	0.37	-1.40
57	1983.2-1984.1	12	-1.28,10.31,1983.7	0.31	0.52	-1.56
58	1991.8-1992.7	12	30,-22.83,1992.1	0.41	0.65	-1.53
59	1988.11-1989.10	12	-55.72,-30.86,1989.4	0.28	0.37	-1.33

Table S3. Summary of major drought event characteristics at different basin scales

	Large basin (>3 million km^2)	Medium basin (>1 million km^2)	Small basin
Average Severity($10^6 km^2 month$)	13.87	4.66	2.37
Average number of drought events with severity > 12× $10^6 km^2 month$	25	17.47	7.24
Average Duration (month)	6.86	4.85	4.81
Average number of drought events with duration > 8 months	10.63	10.24	8.71

Table S4 Summary of major drought event characteristics at different basin scales identified by SPI

	Large basin (>3 million km^2)	Medium basin (>1 million km^2)	Small basin
Average Severity($10^6 km^2 month$)	4.166	1.88	0.84
Average number of drought events with severity > 12× $10^6 km^2 month$	18.125	7.29	1.38
Average Duration (month)	6.25	4	2.21
Average number of drought events with duration > 8 months	3.062	2.97	2.72