



Supplement of

Identification of compound drought and heatwave events on a daily scale and across four seasons

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Table S1: The days per year and events number per year compared before after removing and merging

		Without removing and merging			After removing and merging		
Drought	Scales	SPI _T =-0.5	SPI _T =-1	SPI _T =-1.5	SPI _T =-0.5	SPI _T =-1	SPI _T =-1.5
	15	103.6, 11.0	56.8, 7.8	38.4, 5.9	37.8, 1.12	28.3, 1.13	21.2, 1.18
	30	111.6, 7.2	58.8, 5.2	36.9, 3.8	45.7, 0.65	33.6, 0.68	17.9, 0.55
	45	112.4, 6.1	57.8, 4.0	36.4, 2.9	59.8, 0.78	30.8, 0.60	18.7, 0.43
	60	114.7, 5.0	58.4, 3.3	35, 2.4	62.1, 0.58	28.9, 0.43	24.9, 0.39
	90	115.6, 3.8	60.6, 2.9	36.3, 2.1	67.2, 0.43	30.2, 0.25	23.6, 0.28
Heatwave	Scales	SHI _T =-0.5	SHI _T =1	SHI _T =1.5	SHI _T =-0.5	SHI _T =1	SHI _T =1.5
	3	123.1, 21.9	68.8, 16.4	42.9, 12.6	34.9, 1.83	19.2, 1.56	16.4, 1.88
	5	124.9, 16.5	68.3, 12.0	42.8, 9.0	40.6, 1.73	25.5, 1.83	16.4, 1.47
	7	125.1, 13.6	68.3, 9.8	43.4, 7.5	23.5, 0.49	29.9, 1.90	16.5, 1.09
	10	126, 11.1	68.6, 7.8	44.5, 6.1	41.12, 1.23	33.6, 1.76	18.6, 1.08
	15	127.6, 8.5	69.6, 6.2	44.8, 4.6	49.1, 1.03	33.6, 1.30	15.4, 0.58

Table S2: Trend test of annual days for drought, heatwave, and CDHW events based on Mann Kendall statistic test for different cumulation periods and pre-identification thresholds. Values larger than 1.96 mean significant positive trends at 0.05 level while values less than -1.96 means significant negative trends.

Start and end thresholds	Scales of drought	Scales of heatwave	Trend for drought	Trend for heatwave	Union	H D	D H	Intersection
SPI=-1(or SHI=1)	15	3	0.22	3.67	1.47	1.46	1.52	1.53
	30	5	1.33	3.59	1.70	1.67	1.55	1.50
	45	7	0.64	2.54	0.43	0.44	0.30	0.37
	60	10	-0.03	2.57	0.60	0.53	0.64	0.54
	90	15	0.02	2.74	0.33	0.33	0.31	0.28
SPI=-1.3(or SHI=1.3)	15	3	0.42	4.10	1.68	1.70	1.74	1.78
	30	5	0.56	3.88	0.47	0.47	0.44	0.42
	45	7	0.88	2.76	0.51	0.51	0.53	0.49
	60	10	0.30	3.31	0.74	0.76	0.62	0.66
	90	15	0.21	2.30	0.38	0.39	0.40	0.39

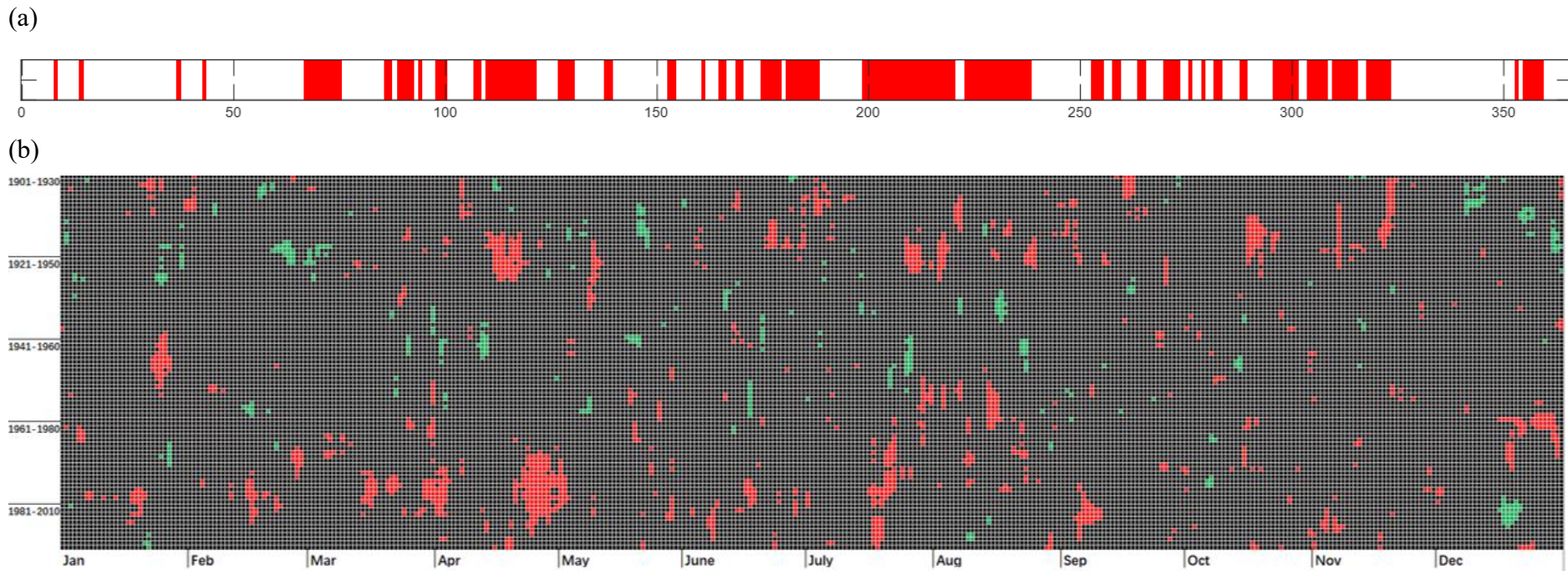


Fig. S1: Mann Kendall statistic test at the 0.05 significant level for daily mean temperature over 1901-1920 (a) and 30-year moving window(b). Red is for significant increasing trends; Green is for significant negative trends; White in (a) and black in (b) mean there is no clear trend. Over the whole time series, test results show 147 days over 365 days have a significant increasing trend and no day has a decreasing trend. For 30-year moving window, on average, only 5.59% periods have a clear trend: 4.38% is increasing and 1.22% is decreasing. Results indicate it is effective to account for climate non-stationarity by using the past 30 years as the historical reference period instead of the whole period.

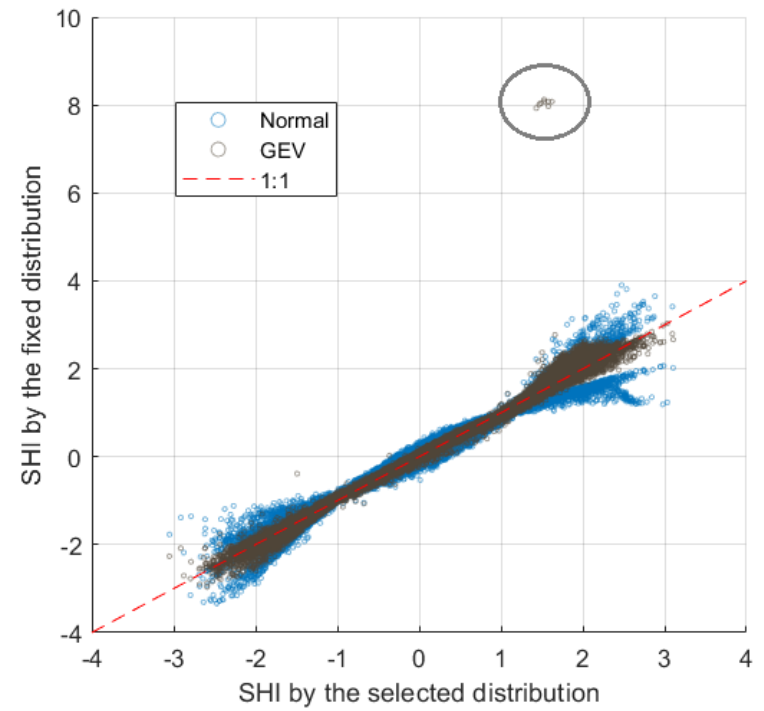
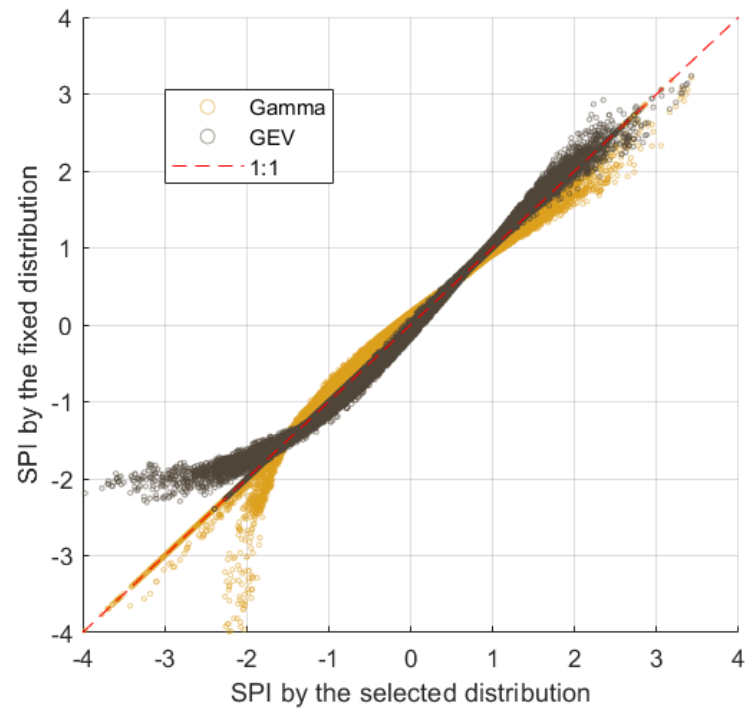
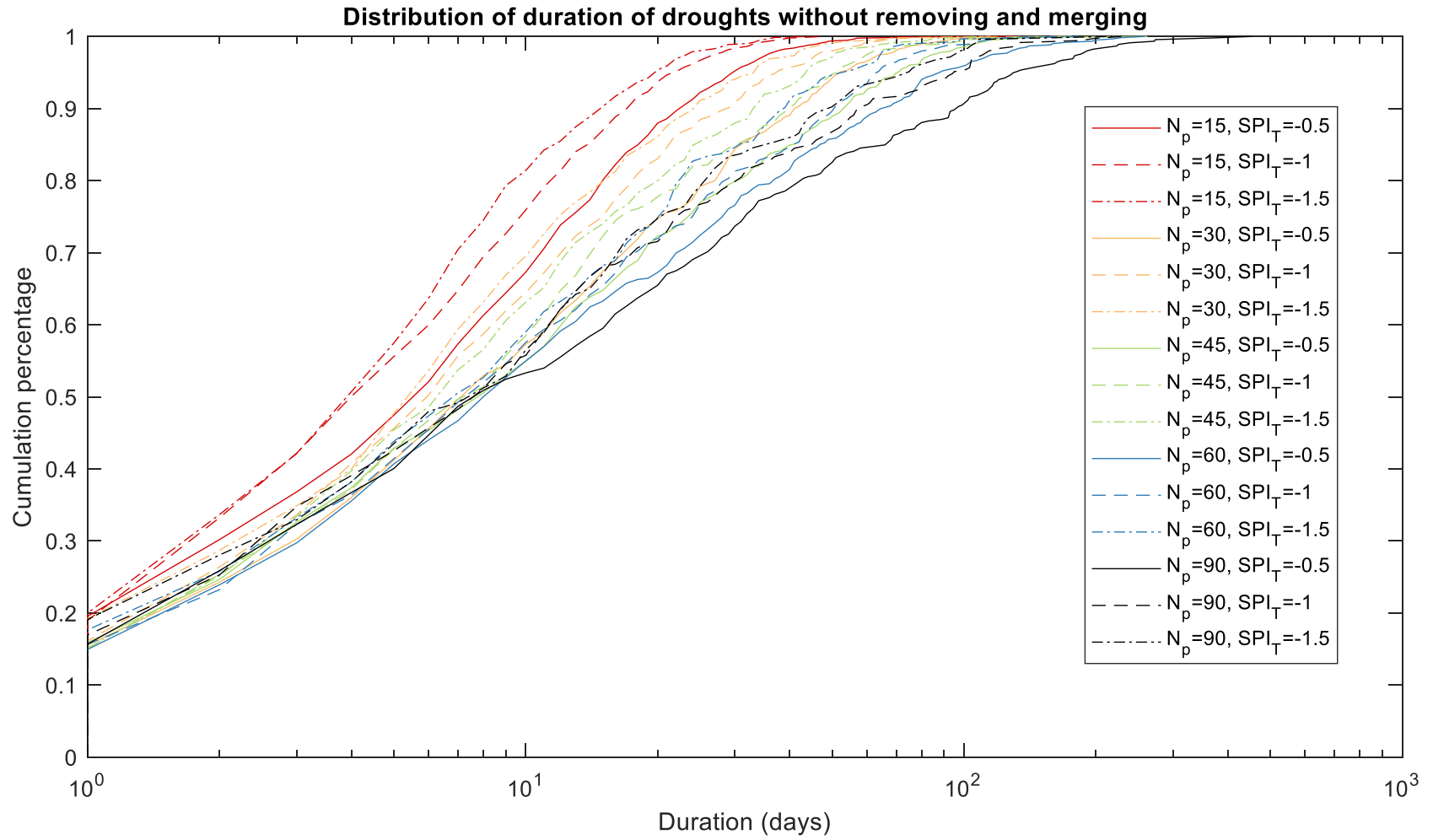


Fig. S2: Comparison between SPI and SHI values calculated using fixed distributions and the values using the selected distribution in this study.

(a) Distribution of duration of droughts without removing and merging



(b) Distribution of duration of heatwaves without removing and merging

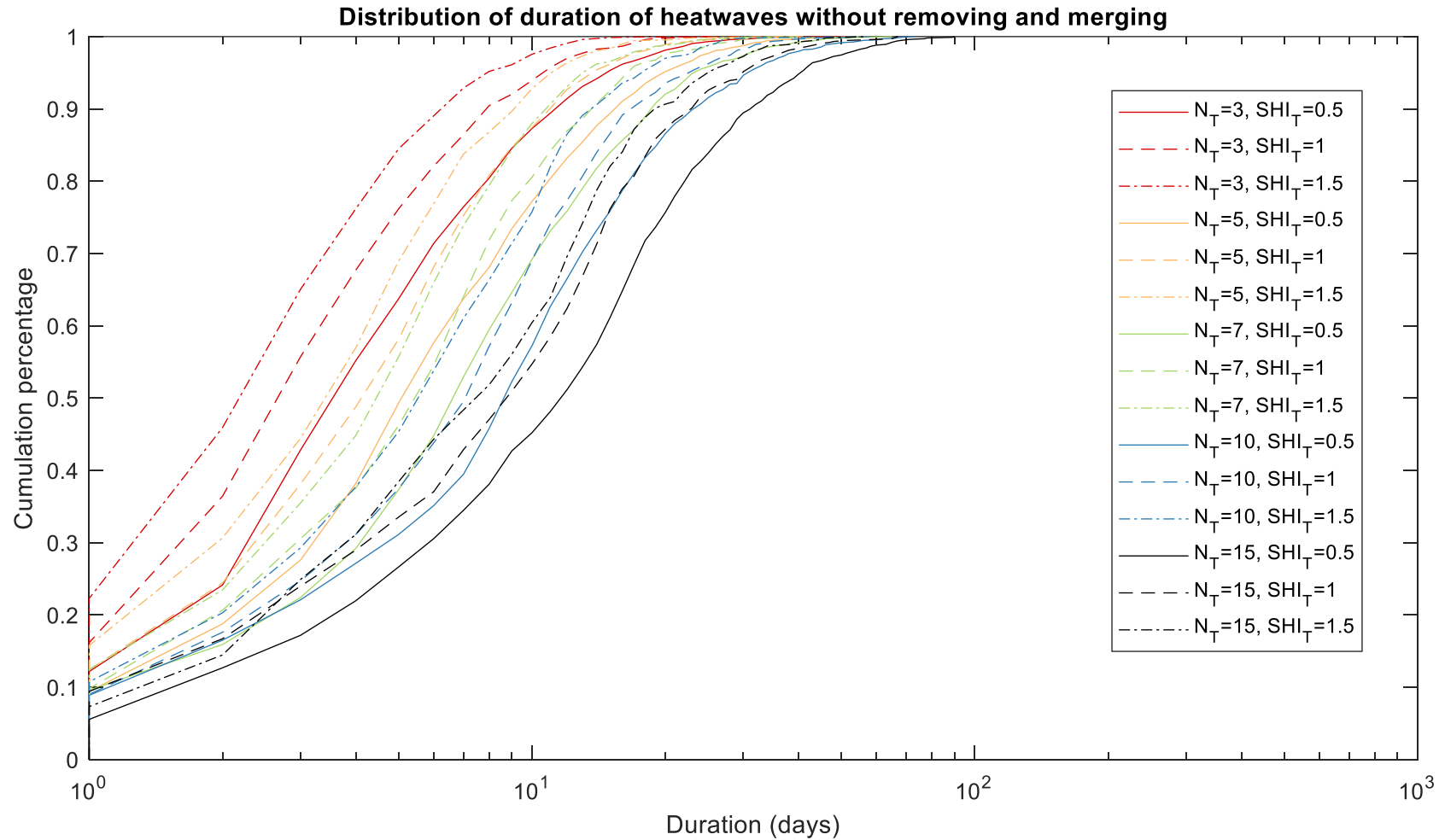
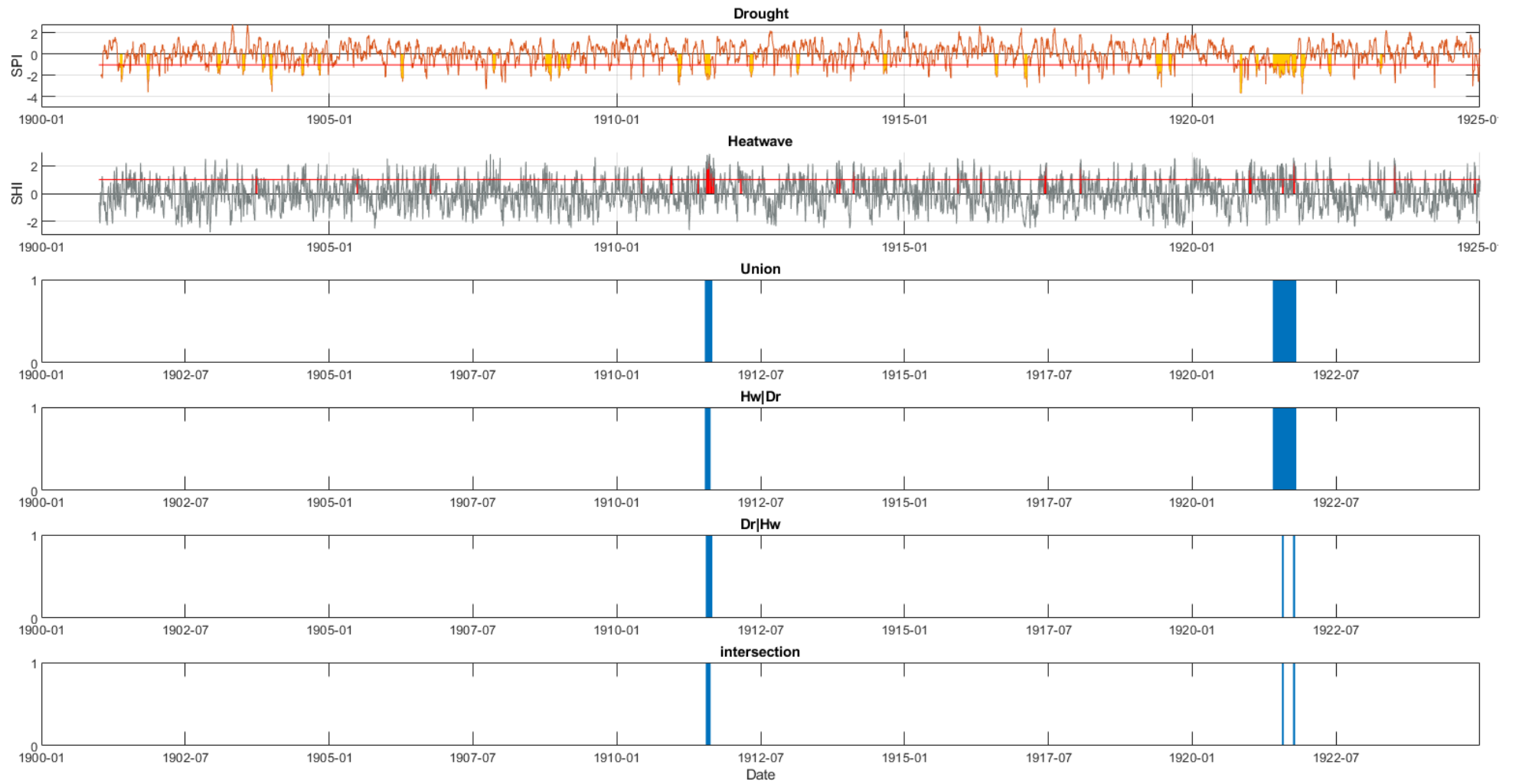
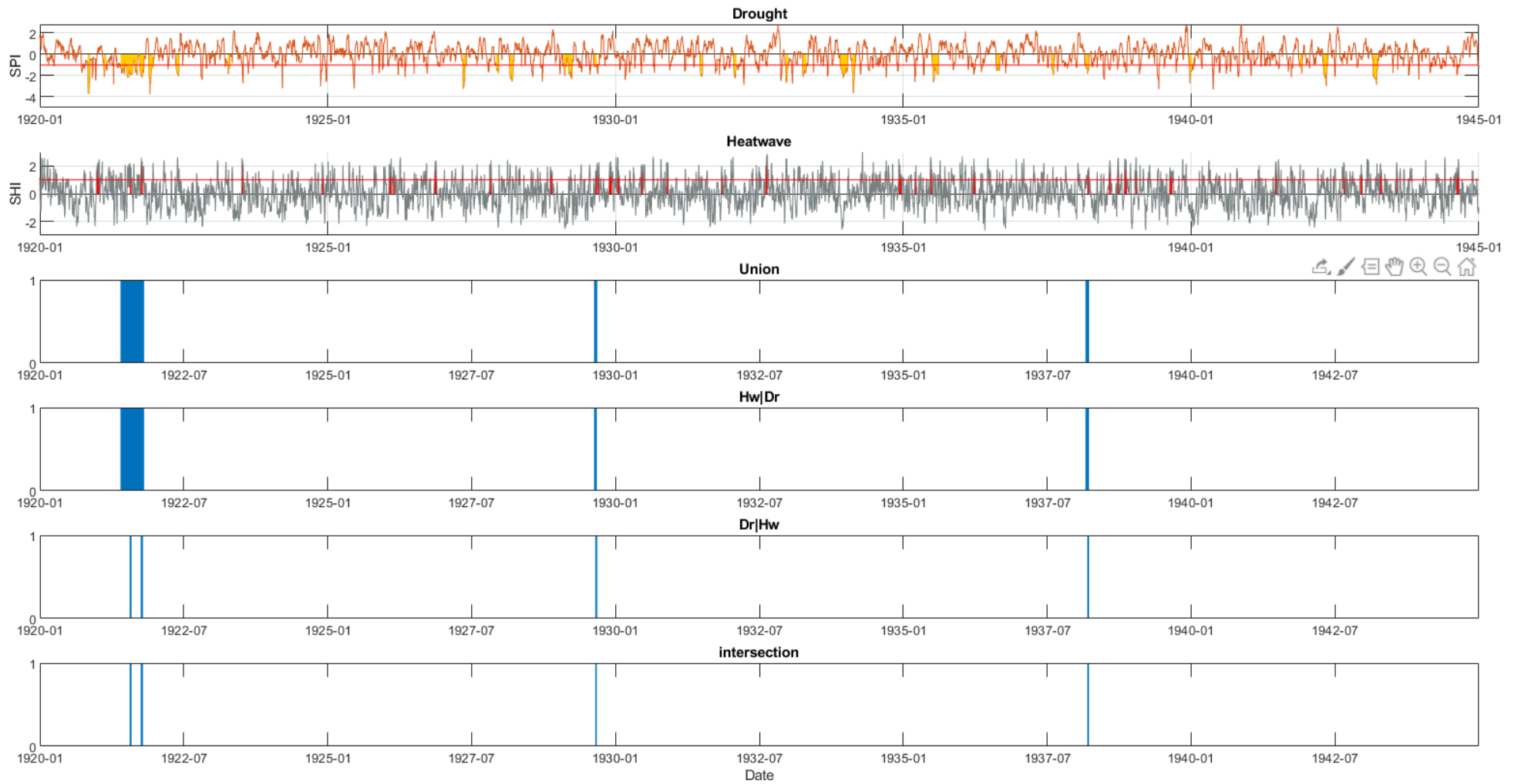


Fig. S3: Distribution of duration of droughts(a) and heatwaves(b) without removing and merging. N_P and N_T are cumulation periods of droughts and heatwaves, respectively. SPI_T and SHI_T are pre-identification thresholds of droughts and heatwaves, respectively. We can find that the too short durations occupy a large percentile without removing and merging, which could disturb the extreme analysis.

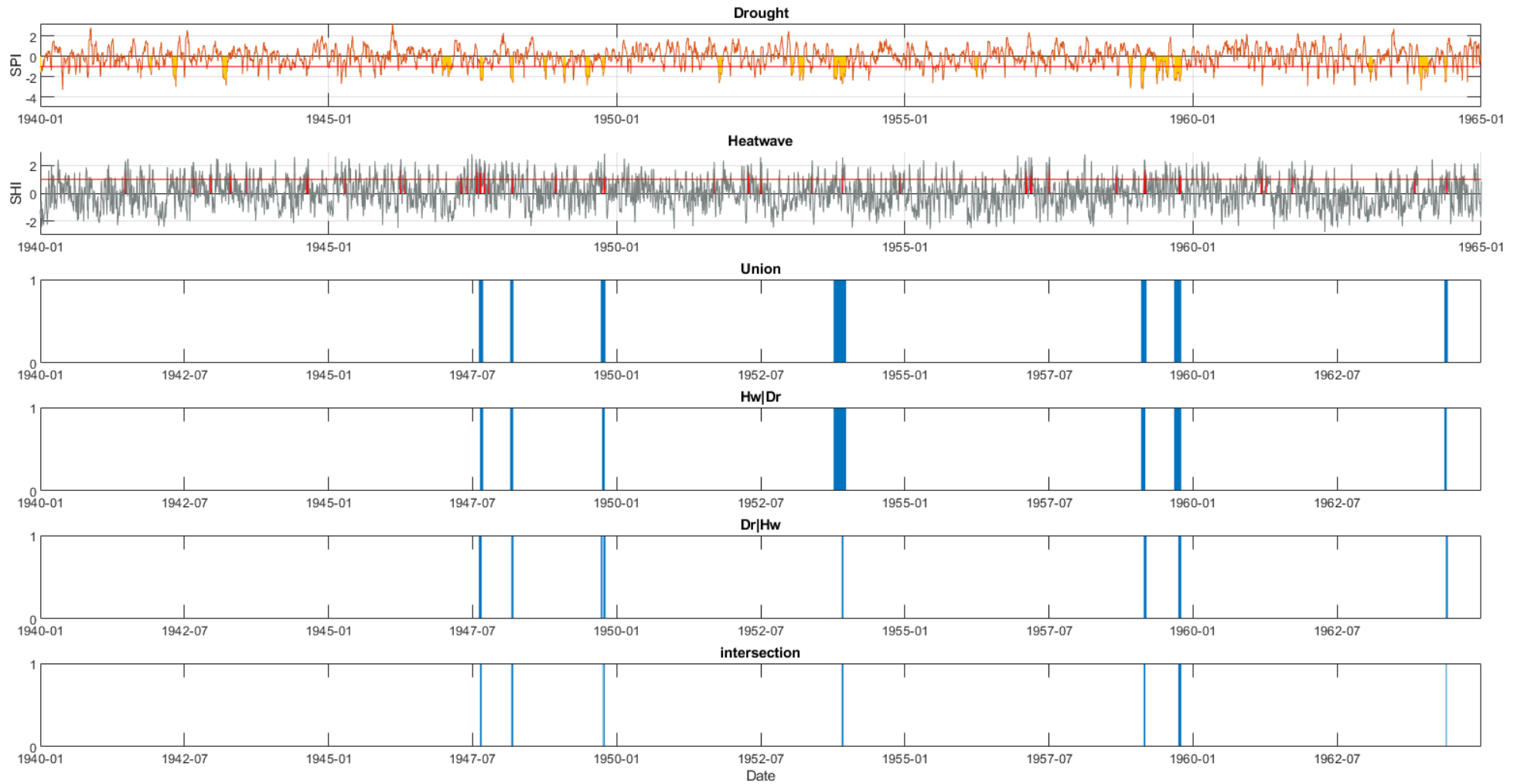
(a) Identification results over the period 1901-1920



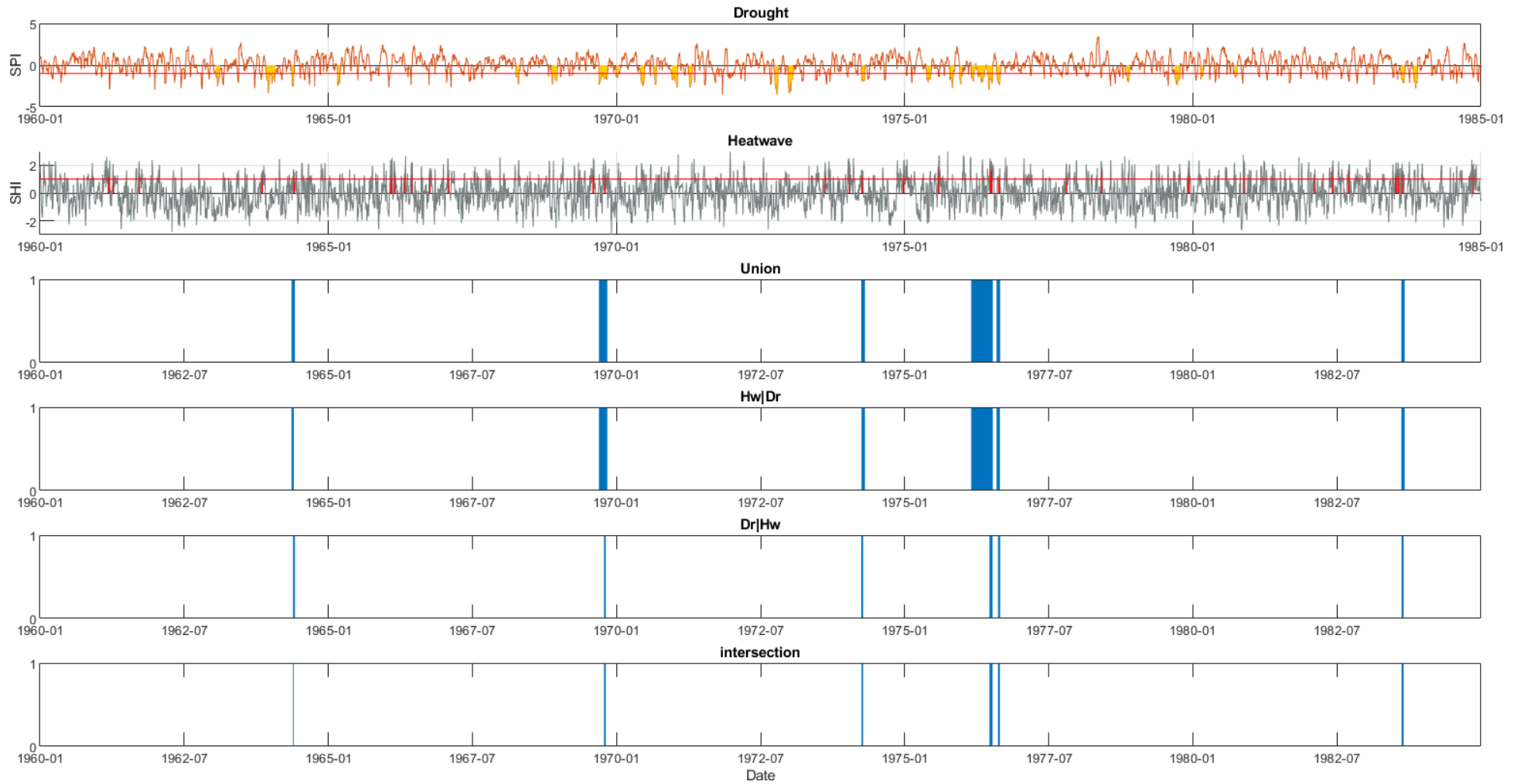
(b) Identification results over the period 1921-1940



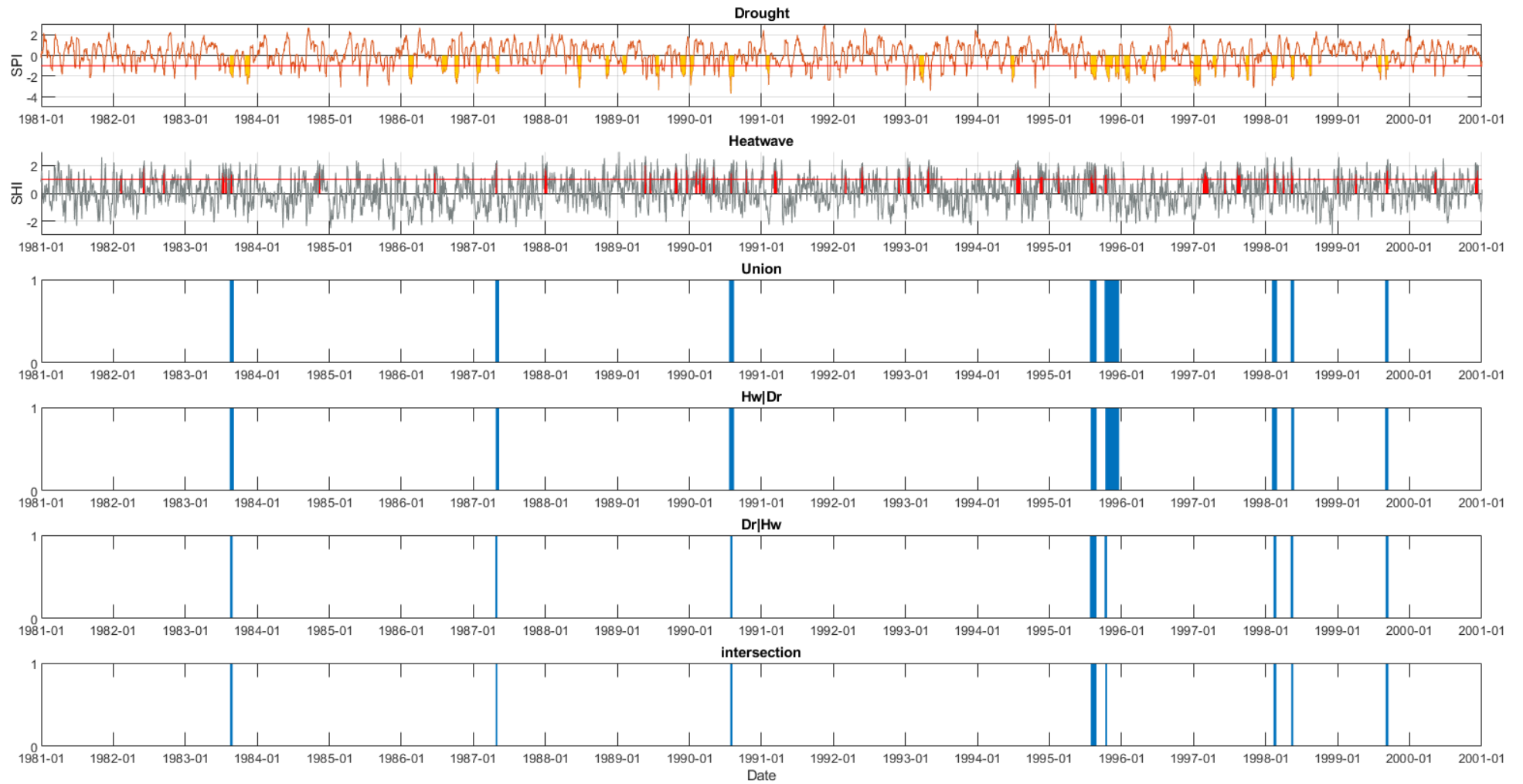
(c) Identification results over the period 1941-1960



(d) Identification results over the period 1961-1980



(e) Identification results over the period 1981-2000



(f) Identification results over the period 2001-2020

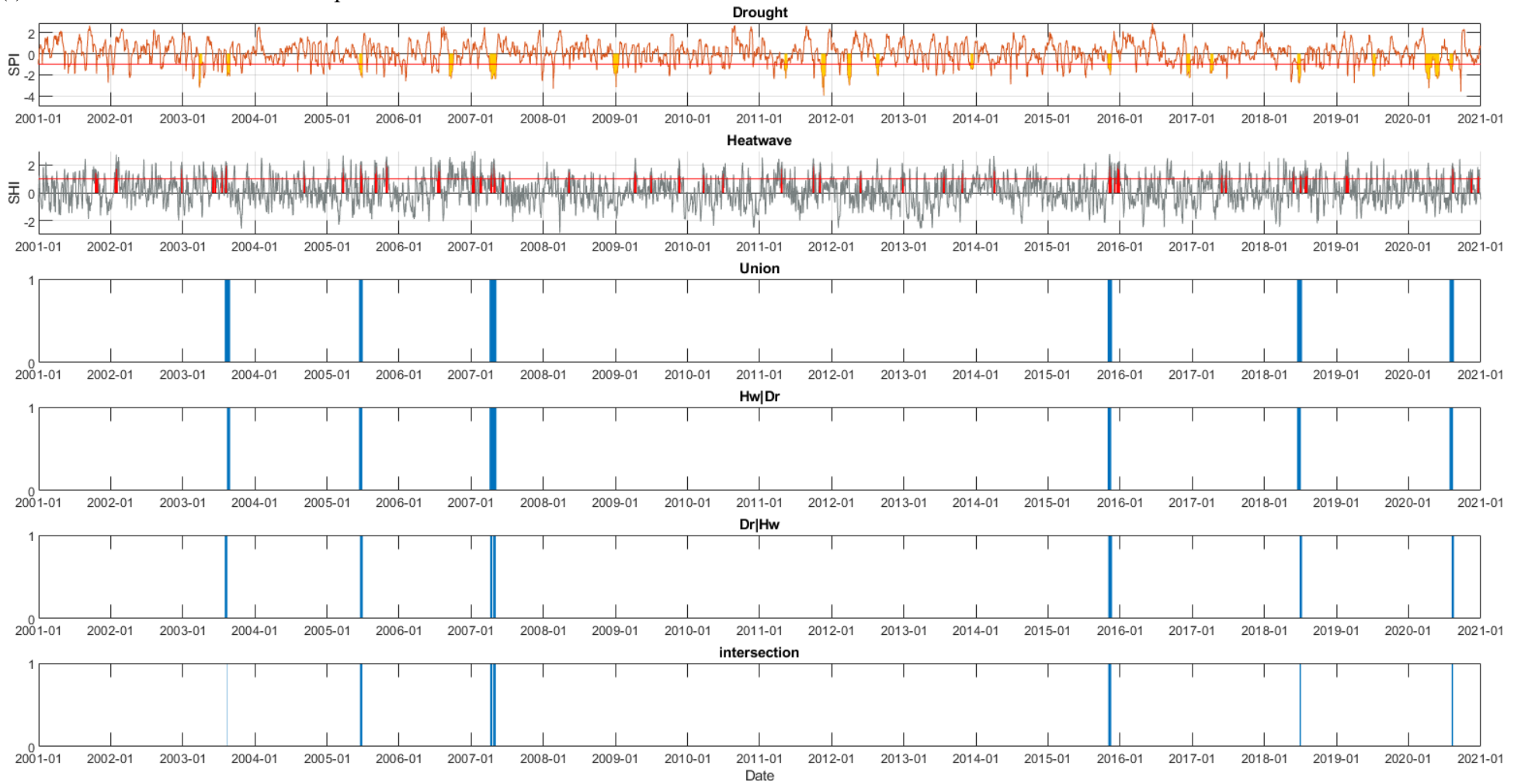


Fig. S4: Identification of drought, heatwave, and CDHW events (union, conditioned on drought, conditioned on heatwave, and intersection). SPI is with 15-days scale and pre identification threshold equals -1; SHI is with 3-days scale and pre identification threshold equals 1.

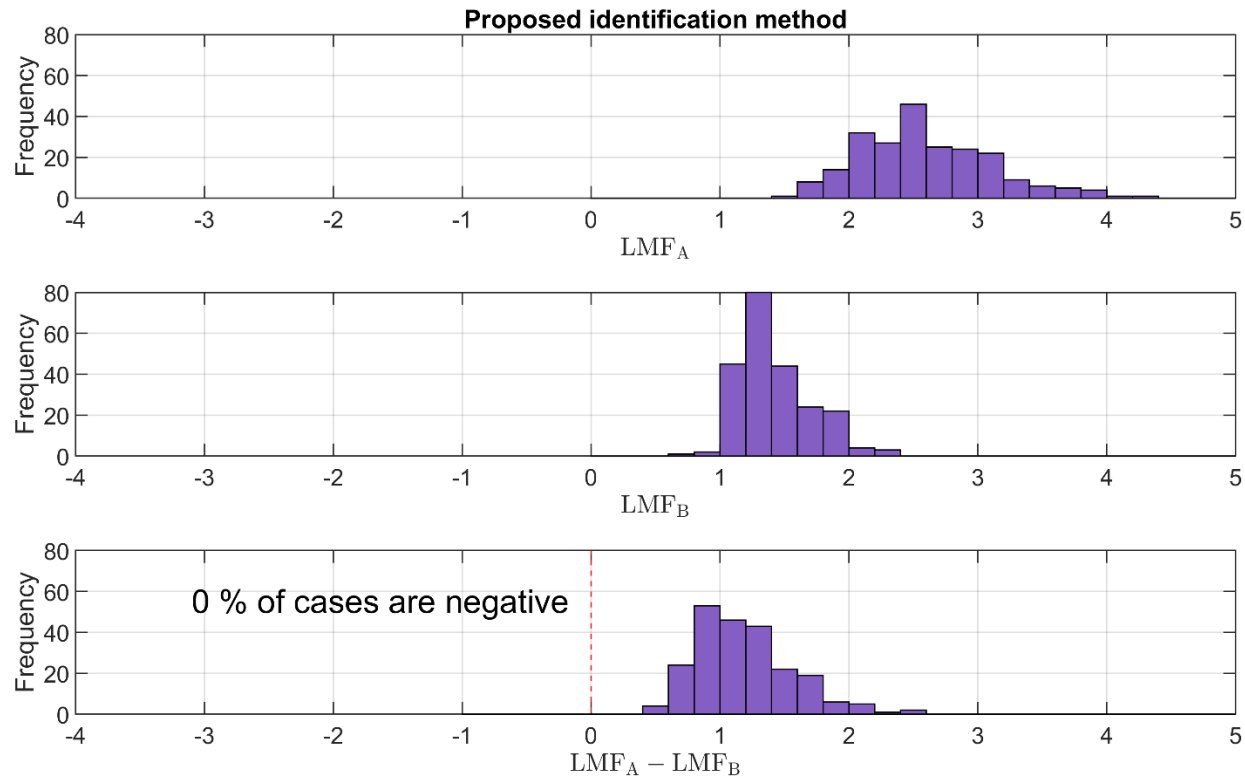


Fig. S5: Validation results when using the proposed removal and merging method. LMF is used to quantify the dependence strength. If the identification method works well, we expect $LMF_A > 1$ and $LMF_A - LMF_B > 0$. A: Drought and heatwave events using the proposed identification method; B: Short dry and heatwave spells that are removed in the removal step but still fall below (or above) the pre-identification threshold.

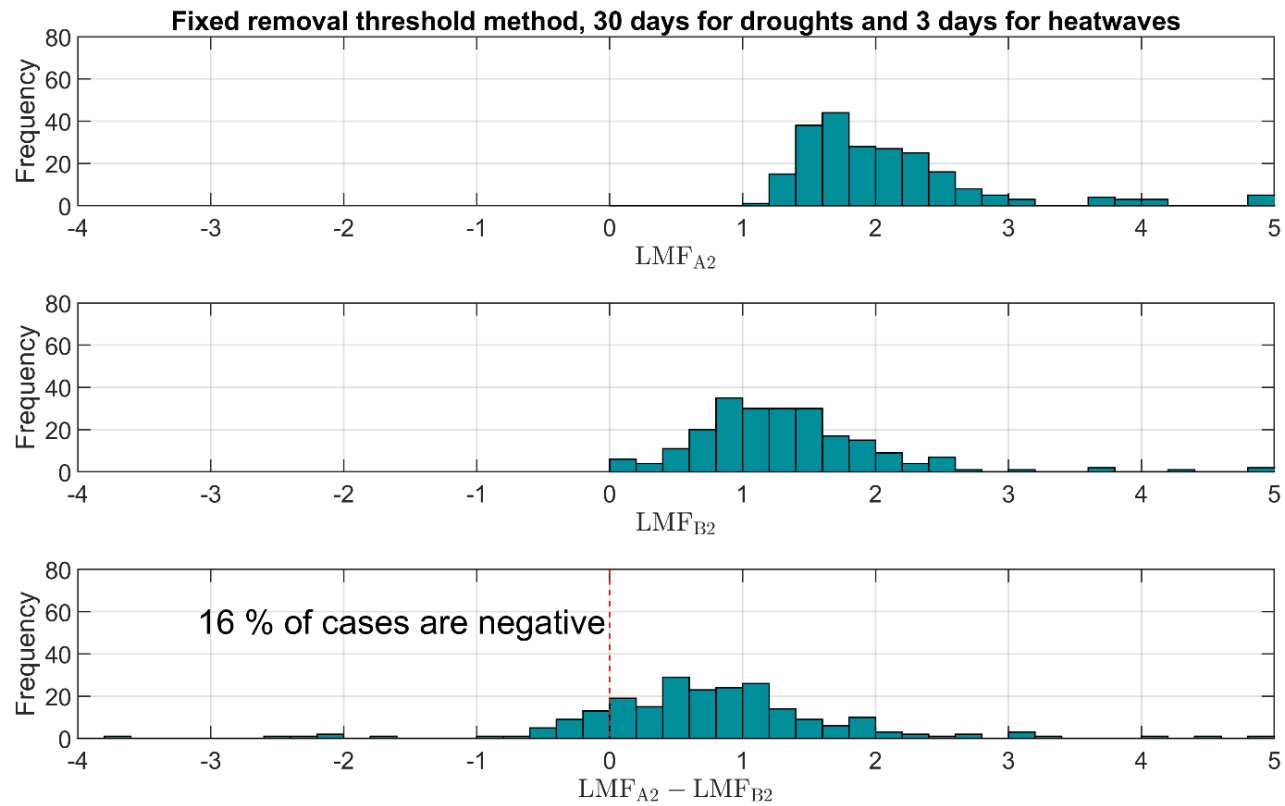


Fig. S6: Validation results when using the fixed removal threshold method. LMF is used to quantify the dependence strength. If the identification method works well, we expect $LMF_{A2} > 1$ and $LMF_{A2} - LMF_{B2} > 0$. A2: drought and heatwave events identified using the fixed removal threshold method; B2: dry and heatwave spells with a duration shorter than the fixed removal thresholds.