Spatiotemporal Evolution Characteristics of Summer Dry-Heat Compound Events in Liaoning Province

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Based on the above steps, six Copula functions that are most used in current research were selected, including Clayton Copula (C1), Plackett Copula (C2), Frank Copula (C3), Gumbel Copula (C4), t-Copula (C5) and Joe-Clayton Copula (C6) to construct joint Copula distribution functions for ephemeral and intensity.

(1) Selection of drought duration, intensity fitted marginal distribution function, and Copula function

Table S1. shows the optimal marginal distribution functions for drought duration and intensity and the results of Copula function selection for 25 meteorological stations in Liaoning Province. The results show that the best-fit marginal distribution functions of drought duration for all stations in Liaoning Province are generalised extreme value distributions, and most of the best-fit marginal distribution functions of drought intensity are generalised extreme value distributions. This indicates that the generalised extreme value method is more suitable for establishing the joint distribution among the characteristic variables of this study in the theoretical analysis of drought hazard run in Liaoning Province.

The results of the AIC test are shown in Table S1., and the Copula function screened is optimal if the AIC is minimum among the 25 sites in Liaoning Province, after which the joint probability of drought duration and intensity is calculated based on the optimal Copula function screened. The Copula functions corresponding to the minimum AIC values for the 25 sites summarised in the table are replaced by C1 to C6 (for more information on Copula function names see 3.4).

Table S1. Selection of the best-fit marginal distribution function and optimal Copula function for the duration and intensity of summer drought in Liaoning Province, 1961-2020

Weather station	Marginal distribution function		AIC test for screening optimal Copula functions					
	Duration	Intensity	C1	C2	C3	C4	C5	C6
Anshan	GEV	GEV	-6.85	-17.37	-18.31	-20.6	-15.54	-24.07
Benxi	GEV	GEV	-7.02	-16.38	-16.85	-19.68	-14.84	-22.72
Changtu	GEV	GAM	-2.32	-6.56	-6.5	-4.95	-4.24	-5.07
Chaoyang	GEV	GEV	-5.92	-15.87	-16.49	-19.06	-14.22	-22.21
Dalian	GEV	GEV	-6.43	-11.78	-12.14	-13.56	-11.72	-14.12
Dawa	GEV	RALY	-2.52	-12.71	-14.25	-12.27	-9.64	-14.87
Dandong	GEV	RALY	-1.08	-7.14	-8.28	-5.25	-4.33	-7.08
Fushun	GEV	GEV	-3.12	-7.74	-7.98	-6.7	-5.5	-7.48
Jianchang	GEV	GEV	-10.05	-17.46	-18.97	-6.06	-19.13	-13.74
Jianping	GEV	RALY	-0.57	-6.1	-6.95	-5.93	-5.29	-7.41
Kaiyuan	GEV	GEV	-9.99	-17.33	-18.6	-16.72	-17.38	-16.53
Kuandian	GEV	GEV	-5.09	-15.72	-16.45	-18.67	-12.56	-24.64
Qingyuan	GEV	NORM	-7.77	-22.66	-27.92	-24.88	-20.05	-31.72

Shenyang	GEV	GEV	-6.6	-12.05	-12.2	-8.4	-13.18	-10.78
Suizhong	GEV	GEV	-6.17	-14.01	-14.09	-7.19	-13.72	-10.14
Wafangdian	GEV	GEV	-8.5	-20.46	-21.52	-22.43	-16.65	-27.79
Xinbin	GEV	RALY	-1.62	-9.12	-10	-9.55	-6.96	-11.58
Xinmin	GEV	GEV	-5.25	-9.85	-10.47	-10.9	-10.2	-11.27
Xingcheng	GEV	GEV	-20.51	-23.01	-24.91	3.07	-19.73	-20.83
Xiongyue	GEV	RALY	-1.51	-10	-10.77	-11.34	-7.51	-14.23
Xiuyan	GEV	GEV	-10.46	-14.45	-15.2	-6.99	-15.82	-13.16
Yingkou	GEV	GEV	-7.6	-14.46	-14.91	-11.02	-15.02	-12.41
Zhangwu	GEV	GEV	-5.54	-14.36	-14.24	-14.91	-10.41	-18.15
Changhai	GEV	GEV	-11.45	-21.63	-22.67	-24.55	-19.68	-27.91
Zhuanghe	GEV	RALY	-0.89	-7.31	-8.14	-7.31	-7.16	-8.16

(2) Selection of high temperature duration, intensity fitted marginal distribution function, and Copula function

TableS2. shows the optimal marginal distribution functions for the duration and intensity of high temperatures at 25 meteorological stations in Liaoning Province and the results of Copula function selection. The results show that the best-fit marginal distribution functions for the duration and intensity of high temperatures at most stations in Liaoning Province are generalised extreme value distributions. In the theoretical analysis of high temperature disaster run in Liaoning Province, the generalised extreme value method is more suitable for establishing the joint distribution among the characteristic variables of this study.

The results of the AIC test are shown in Table S2., and the Copula function screened is optimal if the AIC is minimum among the 25 stations in Liaoning Province, after which the joint probability of high temperature duration and intensity is calculated based on the screened optimal Copula function. The Copula functions corresponding to the minimum AIC values for the 25 sites summarised in the table are replaced by C1 to C6 (for more information on Copula function names see 3.4).

Table S2. Selection of the best-fit marginal distribution function and optimal Copula function for the duration and intensity of summer high temperature in Liaoning Province, 1961-2020

Weather station	Marginal distribution function		AIC test for screening optimal Copula functions					
	Duration	Intensity	C1	C2	C3	C4	C5	C6
Anshan	GEV	GAM	-8.76	-18.04	-22.48	-13.98	-15.32	-11.51
Benxi	GEV	GEV	-10.24	-20.64	-22.81	-18.75	-15.99	-19.69
Changtu	GEV	GEV	-6.95	-14.91	-15.87	-16.76	-12.86	-20.5

Chaoyang	GEV	GEV	-8.78	-17.08	-18.14	-17.63	-14.01	-21.45
Dalian	EXP	GEV	-6.56	-21.75	-22.23	-27.95	-19.52	-35.7
Dawa	EV	GEV	-27.55	-34.01	-35.86	-37.69	-38.3	-37.08
Dandong	GEV	GEV	-9.55	-25.83	-28.47	-27.49	-18.55	-45.47
Fushun	GEV	GEV	-8.93	-18.9	-20.02	-18.74	-15.14	-22.09
Jianchang	GEV	GEV	-10.54	-21.22	-24.14	-19.23	-16.73	-20.83
Jianping	GEV	GEV	-6.5	-14.88	-17.08	-13.91	-11.85	-17.19
Kaiyuan	GEV	GEV	-5.84	-10.05	-11.16	-8.2	-8.75	-7.54
Kuandian	GEV	GEV	-9.75	-20.51	-21.45	-20.76	-16.15	-25.06
Qingyuan	GEV	GEV	-8.28	-17.39	-19.55	-19.38	-17.71	-20.1
Shenyang	GEV	GEV	-7.81	-17.21	-18.7	-20.44	-15.59	-25.4
Suizhong	GEV	GEV	-10.75	-24.36	-26.95	-23.7	-18.43	-30.2
Wafangdian	GEV	GEV	-6.34	-11.81	-13.38	-9.97	-10.01	-9.69
Xinbin	GEV	GEV	-7.93	-17.83	-19.36	-20.35	-15.64	-24.44
Xinmin	GEV	GEV	-7.87	-16.11	-16.84	-18.19	-15.4	-19.41
Xingcheng	GEV	GEV	-9.24	-23.07	-25.59	-21.84	-16.49	-29.94
Xiongyue	GEV	GAM	-7.86	-18.67	-23.88	-13.55	-15.27	-11.68
Xiuyan	GEV	GEV	-12.83	-27.13	-30.16	-31.16	-24.48	-37.04
Yingkou	GEV	GEV	-7.24	-15.26	-17.51	-13.87	-12.55	-15.95
Zhangwu	GEV	GEV	-7.47	-14.28	-15.05	-13.04	-11.24	-14.3
Changhai	GEV	GEV	-8.57	-18.06	-20.03	-18.37	-14.51	-23.37
Zhuanghe	GEV	GEV	-18.68	-19.18	-23.23	62.38	-0.04	-14.15

(3) Selection of dry heat duration, intensity fitted marginal distribution function, and Copula function

Table S3. shows the optimal marginal distribution functions for dry heat calendar time and intensity and the results of Copula function selection for 25 meteorological stations in Liaoning Province. The results show that the best-fit marginal distribution function for the dry heat calendar time and intensity at most stations in Liaoning Province is a generalised extreme value distribution. In the theoretical analysis of the dry heat disaster run in Liaoning Province, the generalised extreme value method is more suitable for establishing the joint distribution among the characteristic variables of this study.

The results of the AIC test are shown in Table S3., and the Copula function screened is optimal if the AIC is minimum among the 25 stations in Liaoning Province, after which the joint probability of dry heat duration and intensity is calculated based on the screened optimal Copula function. The Copula functions corresponding to the minimum AIC values for the 25

sites summarised in the table are replaced by C1 to C6 (for more information on Copula function names see 3.4).

Table S3. Selection of the best-fit marginal distribution function and optimal Copula function for the duration and intensity of summer high temperature in Liaoning Province, 1961-2020

Weather station	Marginal distribution function		AIC test for screening optimal Copula functions					
	Duration	Intensity	C1	C2	C3	C4	C5	C6
Anshan	GEV	GEV	-9.08	-22.74	-24.69	-21.99	-21.07	-22.94
Benxi	GEV	RALY	-4.32	-12.75	-14.23	-9.88	-8.88	-10.95
Changtu	GEV	RALY	-3.57	-9.77	-10.66	-9.73	-10.09	-9.91
Chaoyang	GEV	GEV	-10.91	-22.97	-23.45	-23.74	-18.05	-27.23
Dalian	GEV	GEV	-7.9	-16.69	-17.97	-15.61	-13.25	-18.17
Dawa	GEV	GEV	-6.79	-12.04	-12.09	-0.42	-12.45	-9.29
Dandong	GEV	GEV	-7.77	-15.84	-16.65	-17.71	-14.91	-18.58
Fushun	GEV	GEV	-7.24	-10.5	-11.36	-11.01	-11.95	-11.25
Jianchang	GEV	RALY	-2.68	-11.92	-14.25	-11.33	-9.05	-15.28
Jianping	GEV	GEV	-11.39	-22.38	-24.45	-16.7	-21.2	-16.57
Kaiyuan	GEV	RALY	-6.34	-15.11	-17.25	-13.16	-14.51	-12.88
Kuandian	GEV	GEV	-7.72	-18.47	-19.32	-18.76	-14.29	-23.82
Qingyuan	GEV	GEV	-10	-20.49	-21.46	-22	-18.39	-22.95
Shenyang	GEV	GEV	-3.43	-8.34	-8.69	-11.52	-8.47	-12.9
Suizhong	GEV	GAM	-6.47	-14.14	-15.06	-16.82	-14.94	-16.72
Wafangdian	EV	GEV	-27.49	-28.17	-29.63	-25.62	-29.03	-28.72
Xinbin	GEV	RALY	-5.39	-17.13	-19.07	-16.97	-15.66	-17.29
Xinmin	GEV	GEV	-7.67	-15.15	-15.77	-16.32	-14.49	-16.67
Xingcheng	GEV	GEV	-4.52	-9.72	-10.39	-7.95	-7.56	-8.16
Xiongyue	GEV	GEV	-5.66	-8.75	-9.09	-10.51	-10.07	-10.53
Xiuyan	GEV	RALY	-5.89	-18.76	-22.35	-14.23	-13.23	-15.77
Yingkou	GEV	GEV	-6.14	-13.61	-13.79	-14.1	-12.12	-14.58
Zhangwu	GEV	RALY	-3.61	-12.57	-14.67	-12.45	-10.24	-15.23

Changhai	GEV	GEV	-6.89	-10.99	-12.31	-8.74	-9.94	-7.43
Zhuanghe	GEV	GEV	-5.59	-12.47	-12.86	-11.42	-9.29	-13.56