



Supplement of

Precipitation extremes in Ukraine from 1979 to 2019: climatology, large-scale flow conditions, and moisture sources

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Supplementary Material: S1 List of events

Table S.1 Extreme precipitation events (≥ 100 mm day⁻¹) recorded by observations of meteorological stations in Ukraine (1979-2019)

	Station	date	lat	long	Precipitation mm day⁻¹
1	Jashkiv	19810916	49.2445003	30.0901794	110.4
2	Krasnograd	19810826	49.3716433	35.4473877	107.3
3	Mogilev-Podilckii	19810701	48.4510656	27.7789307	108.8
4	Belopole(Vin)	19820701	49.8446248	28.8693237	129.1
5	Strelkove	19830727	45.9024330	34.8764420	101.2
6	Loshkarivka	19830705	48.0652321	34.6010971	154.2
7	Mariupol	19830726	47.1299508	37.5292969	102.5
8	Nova Ushica	19830703	48.8294696	27.2598267	126.8
9	Olevsk	19840705	51.2206474	27.6470947	110.8
10	Nijni Serogozi	19850626	46.8423465	34.3721008	114.9
11	Reni	19850803	45.4562776	28.2815552	100.5
12	Doneck	19860905	48.0027873	37.8067017	125.4
13	Klepiline	19890616	45.5941014	34.2169189	114.0
14	Kupyansk	19890804	49.7084965	37.6309204	103.5
15	Lubeshiv	19910703	51.7661401	25.5322266	119.3
16	Volodimir volin	19910617	50.8423702	24.3168640	128.2
17	Novodnistrovsk	19910803	48,5806956	27,4411011	120.5
18	Karadag	19910902	44.9332103	35.2262878	278.0
19	Feodosiya	19910902	45.0279211	35.3814697	132.3
20	Chernovci	19910727	48.32535	28.6883800	111.2
21	Plai	19921029	48.6648907	23.1962585	102.1
22	Ai-Petri	19920218	44.4479970	34.0555573	127.3
23	Rahiv	19931221	48.0468738	24.2028809	101.4
24	Loshkarivka	19950804	48.0652321	34.6010971	107.5
25	Serbka	19960627	47.0095233	30.7610321	148.4
26	Pomoshnaya	19970829	48.2420528	31.4071655	110.2
27	Kolomiya	19970803	48.5238812	25.0309753	124.6
28	Mizhhiria	19981104	48.5275192	23.5079956	103.1
29	Poshtove	19980610	44.8266563	33.9724731	133.0
30	Kherson	19980518	46.6494362	32.6513672	100.5
31	Simferopol	19990801	44.9414734	34.1125488	104.5
32	Ai-Petri	19991227	44.4479970	34.0555573	112.5
33	Ai-Petri	19991228	44.4479970	34.0555573	115.3
34	Sarni	19990727	51.3353308	26.6150665	124.0
35	Yalta	19991228	44.4906277	34.1400146	100.0
36	Opasne	19990729	45.4449577	36.4249992	108.1
37	Opasne	19990826	45.4449577	36.4249992	103.8
38	Opasne	20000802	45.4449577	36.4249992	103.6
39	Kam-Podolsky	20000714	48.6764537	26.5649414	100.0
40	Svitlovodsk	20010726	49.0459698	33.2137299	128.8
41	Feodosiya	20010509	45.0279211	35.3814697	101.4
42	Yaremcha	20010824	48.4419563	24.5379639	106.3

43	Pozhezhevsca	20010305	48.1436398	24.5232010	116.9
44	Sarata	20010906	46.0179461	29.6740723	118.8
45	Odesa	20020815	46.4775908	30.6985474	106.3
46	Pochtove	20020723	44.8266563	33.9724731	137.8
47	Nejin	20020530	51.0301674	31.8754578	103.2
48	Mironovka	20030804	48.4610840	38.2557678	105.6
49	Alushta	20040714	44.6745126	34.4146729	107.4
50	Nijni Serogoz	20040807	46.847043	34.3789673	106.7
51	Simferopol	20040811	44.9453614	34.0960693	119.2
52	Volodimir volin	20070602	50.8423702	24.3168640	110.9
53	Bilgor Dnestr	20080921	46.1798304	30.3497314	100.2
54	Yaremcha	20080625	48.4419563	24.5379639	111.4
55	Mariupol	20080727	47.1299508	37.5292969	111.0
56	Luibashivka	20080723	47.8279082	30.2618408	131.4
57	Rakhiv	20080301	48.0468738	24.2028809	100.4
58	Slabojanske	20100921	49.5929095	36.5185547	117.5
59	Strelkove	20100709	45.9024330	34.8764420	100.7
60	Yaremcha	20100708	48.4419563	24.5379639	103.2
61	Dolincka	20100711	48.1055972	32.7749634	121.9
62	Izum	20100711	49.1888842	37.2656250	128.2
63	Baryshivka	20110701	50.3656128	31.3069153	130.5
64	Novomirgorod	20110627	48.7960089	31.6625977	100.0
65	Yagotin	20110701	50.2761763	31.7642212	101.7
66	Luck	20130730	50.7503593	25.3125000	122.0
67	Ai-Petri	20140924	44.4479970	34.0555573	107.8
68	Klepinine	20140603	45.5941014	34.2169189	102.8
69	Lozova	20140531	48.8936154	36.2796021	104.4
70	Pryshyb	20140924	47.2764041	35.3320100	114.7
71	Synelnykove	20140924	48.3270391	35.5215454	100.1
72	Yaremcha	20140515	48.4419563	24.5379639	104.7
73	Gaivoron	20150709	48.3325173	29.8196411	108.2
74	Bilhorod Dnistrovskiy	20160920	46.1798304	30.3497314	135.2
75	Bolhrad	20161012	45.6946698	28.6029053	102.9
76	Odessa	20160920	46.4775908	30.6985474	112.9
77	Feodosiya	20180906	45.0279211	35.3814697	107.0
78	Berdyansk	20180916	46.7455071	36.8151855	111.9
79	Drogobich	20190813	49.3483882	23.5368347	108.0
80	Khorly	20190804	46.0793038	33.2966423	106.4
81	Bilhorod Dnistrovskiy	20190804	46.1798304	30.3497314	125.2
82	Gaivoron	20190605	48.3452973	29.8223877	104.0

Supplementary Material: S2 Moisture sources regions

Table S.2 Moisture sources regions and relative contribution of terrestrial and oceanic sources (%) for individual EPEs in Ukraine

Moisture uptake regions																	
Station	Date	Ukraine	Italy	the Balkans	Asia	Africa	the East European Plane	Western Europe	Eastern Europe	the Azov Sea	Arctic	North Atlantic midlatitude	North Atlantic (sub)tropical	Western Med.	Eastern Med.	the Caspian Sea	the Black Sea
Ai-Petri	19991227	0.8	4.9	8.4	5.0	1.8	0.1	7.9	3.7	0.1	0.2	15.6	0.3	23.5	10.9	0.0	13.5
Ai-Petri	19991228	0.2	5.5	6.5	6.6	1.8	0.02	7.9	0.2	0.0	0.0	28.0	0.7	18.6	14.2	0.0	6.5
Yalta	19991228	0.2	5.5	6.5	6.6	1.8	0.02	7.9	0.2	0.0	0.0	28.0	0.7	18.6	14.2	0.0	6.5
Rakhiv	19931221	2.1	4.4	2.6	0.0	0.0	0.0	9.4	13.1	0.0	0.1	39.2	18.1	9.3	0.0	0.0	0.0
Yaremcha	20140515	19.1	4.0	7.6	0.4	0.6	0.41	8.2	36.6	0.0	0.1	11.1	0.5	6.3	0.9	0.0	2.8
Lozova	20140531	15.0	0.1	1.5	27.1	0.2	0.91	0.2	18.4	5.5	0.7	0.7	0.0	0.4	1.1	14.7	13.1
Barishivka	20110701	18.5	0	0.4	32.4	0.0	29.3	0.4	9.07	0.3	1.0	1.7	0.0	0.0	0.3	2.3	4.12
Khorly	20190804	9.6	2.4	9.4	0.0	4.2	0.0	9.8	47.9	0.0	0.1	9.0	0.3	5.8	0.0	0.0	1.1
Ai-Petri	20140924	16.0	0.3	0.7	1.1	0.1	22.07	3.4	9.1	0.1	8.4	15.5	0.0	0.5	0.1	0.2	21.1
Pryshyb	20140924	15.0	0.1	1.5	27.1	0.2	18.41	0.2	0.9	5.5	0.7	0.7	0.0	0.4	1.1	14.7	13.0
Synelnykove	20140924	15.0	0.1	1.5	27.1	0.2	18.41	0.2	0.9	5.5	0.7	0.7	0.0	0.4	1.1	14.7	13.0
Bolhrad	20161012	7.4	3.5	12.4	5.0	1.2	2.3	4.1	10.8	2.6	0.3	2.5	0.0	16.2	8.5	0.1	21.5

Supplementary Material: S3 Seasonal average anomalies

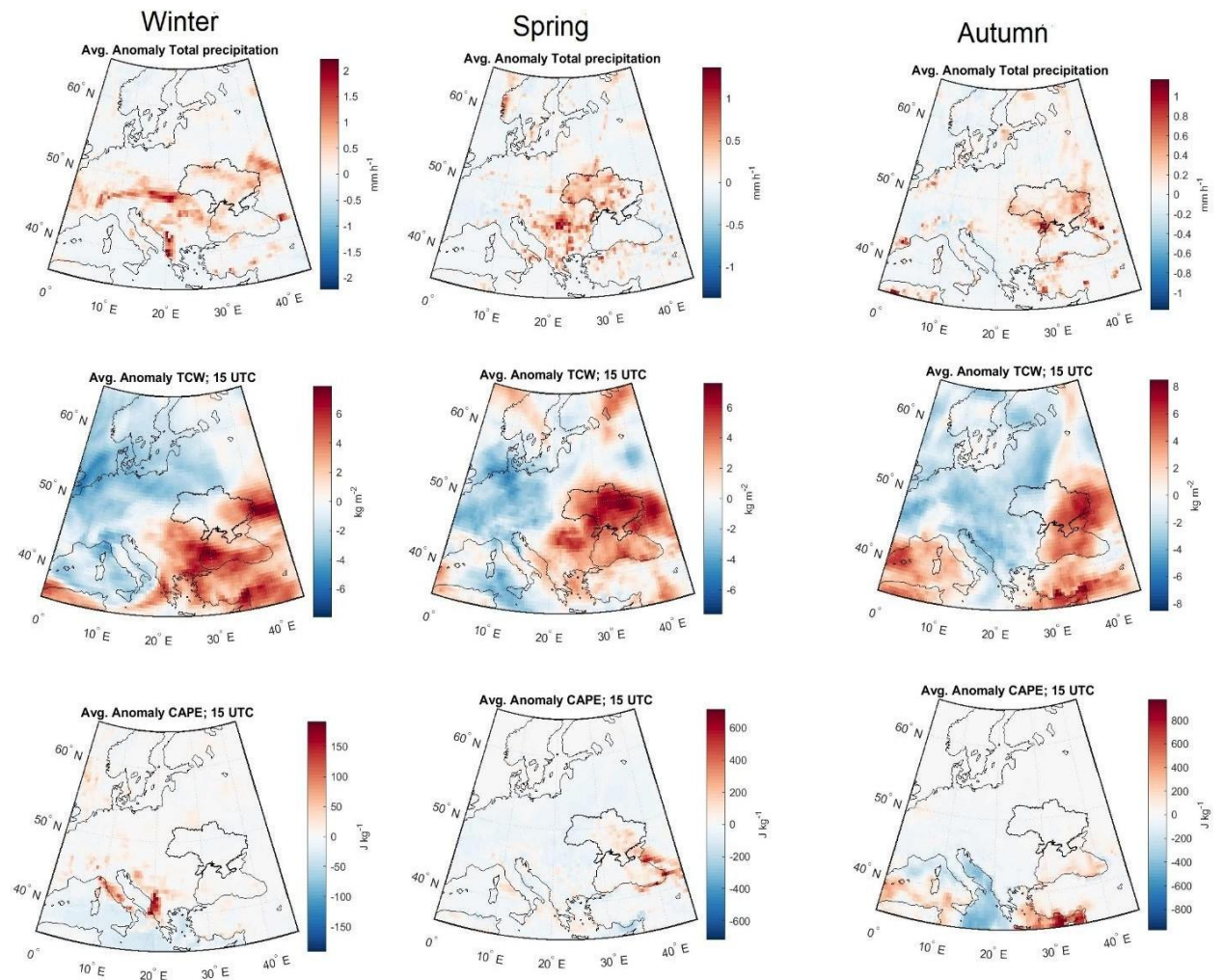


Fig. S1 Seasonal anomalies of total precipitation, TCW and CAPE on EPE days

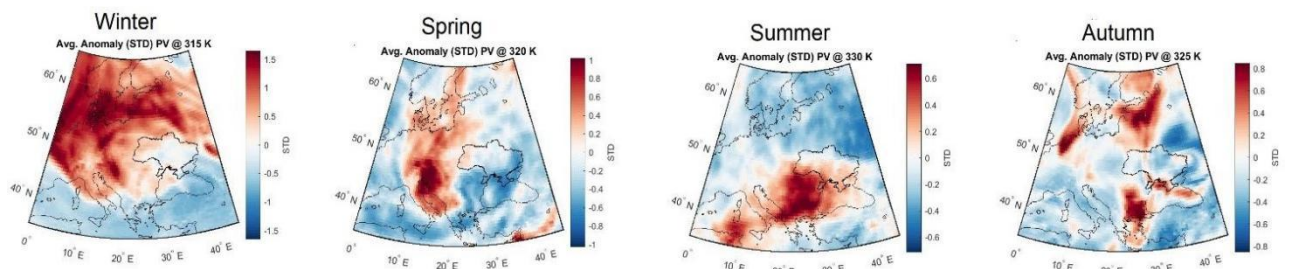


Fig. S2 Variability of PV anomalies during EPEs for the different seasons (in standard deviation units).

Supplementary Material: S4 Mean seasonal characteristics of EPEs in Ukraine

Table S3 Mean seasonal characteristics of EPEs in Ukraine: Anomalies (units), moisture sources (MS, %) and affected regions. Table abbreviations: W-west, E-east, S-south, N-north.

	Winter	Spring	Summer	Autumn
Z ₅₀₀	Upper-level trough over E Europe & Ukraine: -241 m	Upper-level low over E & S Europe, Ukraine: -48 m	Upper-level low over the Balkans, the Black Sea & Ukraine: -43 m	Upper-level low over the Black Sea & Ukraine: -79 m
MSLP	Low over the Balkans: -24 hPa SE Ukraine: -20 hPa	Low over W & SW Ukraine: -6 hPa	Low over Ukraine: -4 hPa	Low over the Black Sea & E Ukraine: -12 hPa
PV (+)	Isentropic levels			
	315 K	325 K	335 K	330 K
	PV(+) north of 40°N: 0.1-2.5 PVU Cutoff over NE Black Sea region: 0.2-0.5 PVU	PV(+) over E Europe & W Ukraine: 1-2 PVU	Cutoff over the Balkans, Black Sea & SW Ukraine: 0.2-1 PVU	PV(+) over the Baltic region, N, Central & SW of Ukraine: 0.2-1 PVU; Cutoff over E Ukraine: 0.2-1 PVU
U ₃₀₀	SW jet stream over Mediterranean: +35 m·s ⁻¹ , the Balkans: +30 m·s ⁻¹ Ukraine, the Black & Azov Seas: +15-25 m·s ⁻¹	N jet stream over E Europe, the Balkans & W Ukraine: +10 m·s ⁻¹	Negative anomaly over W Ukraine: -10 m·s ⁻¹ Positive anomaly over the Balkans & the Black Sea: +5 m·s ⁻¹	SW jet stream over the Black Sea & E Ukraine: +10 m·s ⁻¹
MS	1. North Atlantic (24 %), 2. Western Med (18 %) 3. Eastern Med (12 %) 4. Black Sea (7 %)	1. Eastern Europe (22 %) 2. North Atlantic (14 %) 3. Ukraine (14 %) 4. East European Plain & Asia (17 %) 5. Caspian Sea (3%)	1. Eastern Europe (25 %) 2. Ukraine (19 %) 3. East European Plain (11 %) 4. Black Sea (8 %) 5. North Atlantic (7 %) 6. Caspian Sea (2 %)	1. Eastern Europe (18 %) 2. Ukraine (13 %) 3. Asia (12 %) 4. N Atlantic & W Med (14 %) 5. Black Sea (14 %) 6. Azov Sea (3 %) 7. Caspian Sea (4 %)
EPE regions	W Ukraine, Crimea	W Ukraine, Crimea	Entire territory of Ukraine	W, SW & SE Ukraine, Crimea