

INFLUENCE OF A BIG CITY ON PRECIPITATION FIELDS

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Data of observations over precipitation in a big city and in a countryside for a 20-year period are analyzed. Occurrence (the number of cases) and the number of days with precipitation, as well as precipitation amount, intensity, and duration are determined. Influence of a city on the precipitation field is found to be less significant than its influence on the fogs and hazes. The exception is heavy precipitation, occurrence and duration of which in a city are much less than in the countryside. Precipitation characteristics at day- and night-time are close to each other. Dynamic factors, first of all, vertical motions of the synoptic scales, play the decisive role in the formation of precipitation fields. The role of thermal factors (change of the vertical temperature lapse rate under influence of the solar radiation influx) in the formation of precipitation does not exceed 2–5%.

Since, as it follows from Refs. 1 and 2, the temperature and humidity regimes in the air over a big city significantly differ from those in a countryside, it is natural to suppose that the cloud and precipitation fields in a city has certain peculiarities as compared to those in the atmosphere over rural areas.

Table I presents calculated results for a 20-year period (1975–1994) on seasonal occurrence (the

number of cases) and amount of precipitation separately for day-time (08:00 to 20:00 LT in summer and 07:00 to 19:00 LT in winter) and night-time (20:00 to 08:00 LT in summer and 19:00 to 07:00 LT in winter) for observations carried out in St. Petersburg (P) and Belogorka settlement(B).

The frequency of occurrence of precipitation for every season and for year as a whole (averaged over 20 years) is given in Table II.

TABLE I. Occurrence (number of cases) and amount of precipitation (mm) during day-time (d) and night-time (n), number of days and duration (h) of the precipitation of all types and of the heavy types in St. Petersburg (P) and Belogorka (B) during 1975–1994 in winter (W), spring (Sp), summer (Sm), and fall (F).

Season and time		Number of cases		Precipitation amount		Number of days				Duration, h			
						All types		Heavy type		All types		Heavy type	
		P	B	P	B	P	B	P	B	P	B	P	B
1975–1979													
Sp	d	338	276	253	293	237	240	106	153	1158	1056	387	643
	n	329	262	300	340								
Sm	d	197	204	526	537	238	222	236	221	875	844	866	800
	n	187	189	471	481								
F	d	419	341	472	478	309	298	127	177	1787	1586	617	794
	n	422	360	468	427								
W	d	510	499	366	361	430	416	150	340	3420	2795	739	1754
	n	513	492	370	360								
1980–1984													
Sp	d	222	226	253	240	223	244	114	253	1190	1042	433	938
	n	215	223	231	258								
Sm	d	196	196	475	604	244	231	224	226	935	792	759	788
	n	191	224	451	568								
F	d	332	312	645	534	341	332	177	315	2315	1817	855	1694
	n	330	296	524	512								
W	d	383	367	399	391	388	386	108	331	2734	2575	683	1906
	n	362	372	446	331								

Season and time		Number of cases		Precipitation amount		Number of days				Durability, h			
						All types		Heavy type		All types		Heavy type	
		P	B	P	B	P	B	P	B	P	B	P	B
1985–1989													
Sp	d	286	291	233	308	235	236	117	213	1279	1184	385	1090
	n	251	252	224	268								
Sm	d	280	269	741	751	313	319	282	312	1003	846	906	824
	n	269	270	656	643								
F	d	378	402	456	460	326	317	201	293	1911	1813	818	1642
	n	367	365	422	433								
W	d	507	470	287	261	372	352	94	306	3129	2186	538	1694
	n	453	419	299	272								
1990–1994													
Sp	d	292	317	306	333	235	251	129	229	1216	1049	452	875
	n	267	279	290	280								
Sm	d	194	178	595	702	220	234	215	232	648	613	598	593
	n	212	167	519	516								
F	d	362	378	382	489	311	307	162	277	1592	1532	510	1241
	n	326	345	412	549								
W	d	485	461	296	333	361	372	132	305	2401	2420	550	1758
	n	470	451	321	356								
1975–1994													
Sp	d	1138	1110	1045	1467	930	971	466	848	4843	4331	1657	3546
	n	1062	1016	1045	1146								
Sm	d	867	847	2337	2594	1015	1006	957	991	3461	3095	3129	3005
	n	859	850	2097	2208								
F	d	1491	1433	1955	1961	1287	1254	667	1052	7605	6748	2800	5371
	n	1445	1366	1826	1921								
W	d	1885	1797	1348	1346	1551	1526	484	1282	11684	9976	2510	7112
	n	1798	1734	1436	1319								

TABLE II.

Site	Time	Spring	Summer	Fall	Winter	Year
P	d	57	43	75	94	269
	n	53	43	72	90	258
	24 hours	110	86	147	184	527
B	d	55	42	72	90	259
	n	51	42	68	87	248
	24 hours	106	85	140	177	507

Precipitations most frequently occurs in winter while being less frequent in summer. The same annual behavior of precipitation occurrence is observed for every five-year period. The occurrence of precipitation in P and B are close to each other: in P only 20 cases are in excess of those observed in B (with the total number of cases above 500).

Table III presents the number of days with precipitation averaged over the 20-year period for every season and a year as a whole.

The number of days with precipitation of all types at both sites is maximum in winter and minimum in spring (although in summer it approaches minimum). This number is practically the same in P and B.

However, the frequency of occurrence of a heavy precipitation is significantly different at the two sites. In any season, except for summer, the number of days with heavy precipitation (rain and snowfall) in B is 1.5–2.5 times larger than in P. In some cases (winter in the second and third five-year periods) this ratio was above three. In some months (November of the second and third five-year periods; March, April, December, and February of the second five-year period; January and February of the third five-year period), the frequency of occurrence of heavy snowfall in B is 4–5 times higher than that in P.

TABLE III.

Type	Spring		Summer		Fall		Winter		Year	
	P	B	P	B	P	B	P	B	P	B
All types	46	49	51	50	64	63	78	76	239	238
Heavy	23	42	48	49	33	53	24	64	128	209

In B, the number of days with heavy rains, as well as the number of cases and the number of days with precipitation of all types, is maximum in winter and minimum in spring. In P, because of the abrupt

decrease of the number of days with heavy snowfalls in winter, the maximum of the number of days with heavy rains shifts to summer. In winter the number of days with heavy precipitation is as small as in spring.

Presented below is the averaged number of cases of precipitation of all types during a day with precipitation for the 20-year period:

	Spring	Summer	Fall	Winter	Year
P	2.39	1.69	2.30	2.36	2.20
B	2.16	1.70	2.22	2.33	2.13

During a day with a precipitation occurring, on the average, more than twice a day, precipitation of any type may happen.

Averaged (over 20 years) seasonal values of the amount of precipitation (mm) are given in Table IV.

TABLE IV.

Site	Time	Spring	Summer	Fall	Winter	Year
P	d	52	117	98	67	334
	n	52	105	91	72	320
	24 hours	104	222	189	139	654
B	d	73	130	98	67	368
	n	57	110	96	66	329
	24 hours	130	240	194	133	697

The largest amount of precipitation in P and B was recorded in summer then follow the fall and winter seasons. The most dry period of a year (both in the amount of precipitation and in the number of days with precipitation) is spring. The amount of precipitation in P and B is almost the same. Since the number of heavy precipitation in B is significantly larger than in P (2.5 times in winter), and the number of days with precipitation of all types is nearly the same, it follows that heavy precipitation in B are less intense than in P. The amount of precipitation in summer and in spring in B is significantly larger than in P: 7.5 and 20% larger for 24 hours and by 10 and 29% larger for day-time, respectively.

The above data show that the conditions for the precipitation formation in day-time are close to those in night-time. Indeed, the amount of precipitation in fall and winter, during day-time and night-time is practically the same. In summer and spring, the amount of precipitation during day-time is somewhat larger (especially in B) than at night. However, it is just in these seasons that the numbers of cases with precipitation during day- and night-time are most close to each other (in summer those are equal).

One important conclusion follows from the data on the amount and the number of cases with precipitation. It is the dynamic, rather than thermal factors, that play the decisive role in the formation of precipitation fields. Indeed, at night, precipitation, including heavy

precipitation, can be formed only under the effect of dynamic factors, most important among which, according to Refs. 3 and 4, are the vertical motions of a synoptic scale.

Since the probability of forming precipitation on site or because of a cyclone arrival, with which the formation (under the influence of dynamic factors) of continuous and heavy precipitation is only related, during day-time is the same as at night-time, we can conclude that in summer the amount of precipitation formed under the effect of thermal factor (change of the temperature lapse rate in day-time because of solar irradiation) is no more than 5% in P and 8% in B, 2% in P and 6% in B on average for a year, as well as 12% in B in spring.

The duration of precipitation during a season and a year, averaged over 20 years (in hours), for the precipitation of all types (ATP) and heavy precipitation (HP) is given in Table V.

TABLE V.

Site	Spring		Summer		Fall		Winter		Year	
	ATP	HP	ATP	HP	ATP	HP	ATP	HP	ATP	HP
P	242	83	173	156	380	140	584	126	1379	505
B	216	177	155	150	327	268	499	356	1197	952

According to the number of cases and days with precipitation given in Table III, the duration of precipitation of all types is maximum in winter, medium in fall and spring, while being minimum in summer. In a countryside (B), the annual behavior of precipitation duration remains the same for heavy precipitation as well. In the city (P), the maximum duration (as well as the number of days) of heavy precipitation is observed in summer, next are the fall, winter, and spring seasons.

The duration of precipitation of all types in P is a bit longer than in B (182 hours longer on the average for a year). However, both the number of days and the duration of precipitation in all seasons, except for summer, in B is 1.5–2.5 times larger than in P.

The values of the ratio between the number of days and the duration of heavy precipitation in B and the same characteristics in P are presented below.

Relation (B/P)	Spring	Summer	Fall	Winter	Year
Number of days	1.83	1.02	1.61	2.67	1.63
Duration	2.13	0.96	1.91	2.83	1.89

According to these data, not only the number of heavy precipitation in B is significantly larger than in P in all seasons (except for summer) and during a year as a whole, but each heavy rain or snowfall in B is longer (on the average) than in P.

The number of days with precipitation and especially the number of cases both in P and B (as well as in the north-east Europe as a whole) is rather significant. It is every other day in spring and in

summer, two of three days in fall, and three of four days in winter.

The probability (%) of precipitation of all types (ATP) and heavy precipitation (HP), equal to the ratio of their duration to the total period of observations, is given in Table VI.

TABLE VI.

Site	Spring		Summer		Fall		Winter		Year	
	ATP	HP	ATP	HP	ATP	HP	ATP	HP	ATP	HP
P	11.0	3.8	7.8	7.1	17.4	6.4	27.0	5.8	15.7	5.8
B	9.8	8.0	7.0	6.8	15.0	12.3	23.0	16.4	13.7	10.9

The probability of precipitation of all types varies between 8% (summer) and 27% (winter) in P and between 7% (summer) and 23% (winter) in B.

Season average values of the intensity of precipitation of all types (mm/h) that are the ratios between the amount of precipitation and their duration are given below:

	Spring	Summer	Fall	Winter	Year
P	0.43	1.28	0.50	0.24	0.47
B	0.60	1.55	0.59	0.27	0.58

The intensity of precipitation is maximum in summer (when the precipitation is most of a heavy type) and minimum in winter.

The following conclusions come from the above-said:

a) the influence of the anthropogenic factors on the occurrence, amount, intensity, and duration of precipitation is less significant than on fogs and hazes, temperature and humidity fields;

b) the exception is heavy precipitation, the occurrence and duration of which in a big city is significantly smaller than in a countryside;

c) there is no any significant difference between the characteristics of day-time and night-time precipitation;

d) the dynamic factors, first of all, the vertical motions of the synoptic factor, play the decisive role in the formation of precipitation fields (including heavy precipitation), while the part of thermal factor in the formation of precipitation does not exceed 2–5%.

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