Chapter 2

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Selected Precipitation Characteristics of Seasons in North-Eastern Poland in 1951-2000

Scope and methods of the study

This study presents selected characteristics of precipitation in north-eastern Poland, prepared on the basis of the monthly values of precipitation originating from 18 meteorological stations and posts of the Institute of Meteorology and Water Management. The study covers a fifty-year period (1951-2000). Sums of precipitation are characterized for individual seasons: spring (III-V), summer (VI-VIII), autumn (IX-XI) and winter (XII-II). The research uses a 30-year moving sample, i.e. sequences of variables concerning subsequent 30-year periods are created with application of data from 1951-2000. The first 30-year period covers the years of 1951-80, the second one: 1952-81, and further on, until the last one of 1971-2000. It was assumed that those variables have a gamma distribution of parameters α and β. The parameters of distribution of each of the sequences created were estimated with the application of the maximum likelihood method, using the formula provided by Johnson and Kotz (OTOP, KUCHAR 2004 after JOHNSON and KOTZ 1970). Critical values (X_o) were calculated for each of the obtained distribution of the sums of precipitation, according to the following formula: $P(X>X_o)=p_o$, where X is a seasonal sum for various values of likelihood *(p_o= 0.99, 0.95, 0.90, 0.10, 0.05 and 0.01*).

Additionally, values of precipitation norm were calculated according to MRUGAŁA (1997), determining their upper and lower limits, respectively, as mean values of deviations (positive and negative) from the mean 50-year precipitation total. There were also developed and described, using linear trends, tendencies of sums of precipitation and the probability of the occurrence of precipitation below the lower limit of the norm (negative anomaly) and precipitation exceeding the upper limit of the norm (positive anomaly). For each of the elements, the significance of the regression coefficient for the trend was analysed at a significance level of α = 0.05, 0.01 and 0.001 All calculations were carried out with the statistical

software suite STATISTICA[1] The application used to analyse and graphically present the material was SURFER[2].

Results and discussion

Tendencies of precipitation sums for individual seasons in a 30-year moving sample

The analysis of seasonal values of regression factors for the linear trend (Fig. 1) revealed that increasing tendencies of precipitation sums, most frequently significant ones, occurred in spring in all examined stations (apart from Biskupiec on the Osa and Żuromin), while generally significant decreasing tendencies were observed in summer**.**

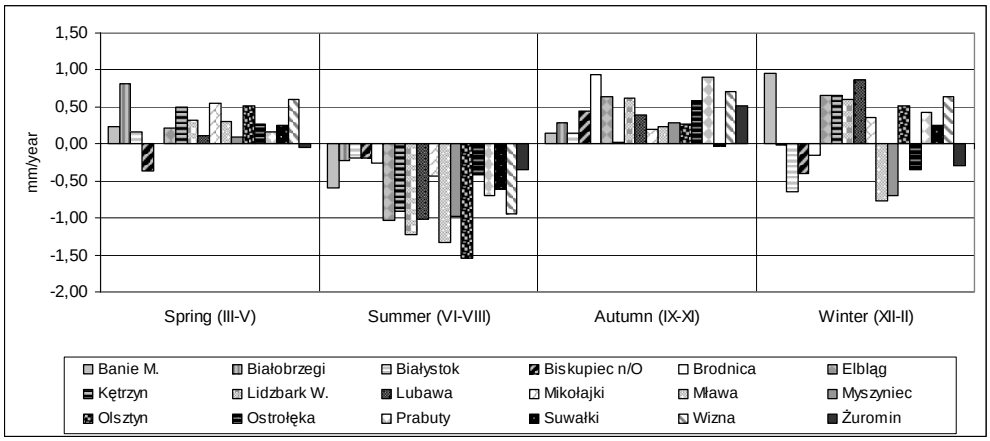

Fig. 1. Tendencies of seasonal precipitation sums in successive 30-year moving sample from 1951-2000 in north-eastern Poland. Coefficients of regression of linear trend (mm/year)

Precipitation demonstrated increasing trends, generally significant, also in autumn in all examined locations except for Suwałki (where an insignificant opposite trend was observed), and in the winter season, generally in the northern part of the region and in Wizna. In winter, predominately significant decreasing tendencies were observed in the southern part of the examined area (Białobrzegi, Białystok, Biskupiec on the Osa, Brodnica, Ostrołęka, Mława, Myszyniec, Żuromin). The trends of precipitation changes in subsequent 30-year periods are similar (in terms of direction) to changes in the sums of precipitation in the Mazurian Lake District in 1951-1995 and 1951-2000 examined by BANASZKIEWICZ *et al.* (2002, 2009ab), and to the average sums of precipitation in Poland from the period of 1951-2000, analysed by ŻMUDZKA (2002, 2004).

[1] [1]StatSoft, Inc. (2007). STATISTICA (data analysis software system), version 8.0. www.statsoft.com.
[2] [2]*Surfer Version 8.05 – May 11 200. Surface Mapping System 1993-2004 Golden Software, Inc. Serial Number WS –075888-1983*

On the other hand, comparative studies of precipitation in individual seasons of the years carried out for decades of 1959-1968 and 1989-1998 showed that Suwałki had decreasing tendencies in summer and increasing tendencies in winter, spring, and also autumn (KOŻUCHOWSKI 2000).

The values of lower and upper precipitation norm

Mean 50-year sums of precipitation in spring in the examined locations ranged from 112 to 134 mm (Table 1). The lower limit of the precipitation norm was 81-104 mm, the upper: 146-187 mm. Multi-year sums of precipitation in summer ranged from 200 to 250 mm, with the highest values of their lower and upper limit of precipitation norm observed in the north and the west of the region, and lower values recorded for locations situated in the its southern and south-eastern part.

Table 1

Average sums of precipitation and lower and upper limits of precipitation norm (mm) of seasons in north-eastern Poland (1951-2000)

Stations	Average				Lower limit of norm				Upper limit of norm			
	III-V	VI-VIII	IX-XI	XII-II	III-V	VI-VIII	IX-XI	XII-II	III-V	VI-VIII	IX-XI	XII-II
Banie Maz	129	250	177	126	102	190	133	95	156	333	251	149
Białobrzegi	125	211	148	117	98	157	114	93	159	266	194	139
Białystok	126	213	142	102	100	167	111	80	169	279	183	129
Biskupiec n/O	119	215	145	119	93	159	113	87	165	296	187	152
Brodnica	118	219	142	111	92	164	104	82	163	295	189	138
Elbląg	118	238	185	117	87	172	141	89	149	315	237	145
Kętrzyn	117	220	147	87	93	170	118	66	151	284	196	104
Lidzbark W.	121	224	167	112	92	165	128	79	164	284	214	132
Lubawa	134	234	161	128	104	155	131	98	187	302	214	156
Mikołajki	123	231	146	90	103	167	112	65	158	293	205	108
Mława	112	212	133	100	82	153	97	73	148	267	171	134
Myszyniec	124	223	138	101	95	159	105	76	176	286	185	128
Olsztyn	126	228	159	111	95	172	129	87	172	297	210	139
Ostrołęka	122	208	137	100	100	161	102	77	155	262	189	123
Prabuty	121	237	152	108	93	180	117	81	167	316	197	132
Suwałki	121	217	150	99	94	164	108	77	159	277	202	117
Wizna	115	200	133	91	90	154	104	70	146	267	184	113
Żuromin	115	218	135	107	81	165	85	81	164	289	171	143
Max	134	250	185	128	104	190	141	98	187	333	251	156
Min	112	200	133	87	81	153	85	65	146	262	171	104
SD	5.4	12.3	14.8	11.7	6.5	9.3	14.3	9.4	10.5	19.1	20.9	14.8

In autumn, the mean sums of precipitation varied from 133 (Wizna) to 185 mm (Elbląg), while precipitation norms ranged between 133-251 mm in Elbląg and Banie Mazurskie to 85-171 mm in Mława and Żuromin. The mean 50-year sums of precipitation in winter (87-127 mm) and values of both norms were the lowest

among the examined seasons, amounting to 65-98 mm for the lower limit, and 104-156 mm for the upper one.

The limits of precipitation norms expressed as the percentage of the mean 50-year sum of precipitation were generally lower by 16-37% (Table 2) in the case of the lower limit of the norm, and higher than it by 18-43% in the case of the upper limit. Standard deviations of multi-year means and of both limits of norms were the lowest in spring and the highest in autumn and summer in the case of the upper limit of the norm. The presented seasonal precipitation norms are similar to the norms for north-eastern Poland from the period of 1951-1990 reported by MRUGAŁA (2001).

Table 2

Lower and upper limits of precipitation norm of seasons as a percentage frequency of average of north-eastern Poland (1951-2000)

Stations	Lower limit of norm (%)				Upper limit of norm (%)			
	III-V	VI-VIII	IX-XI	XII-II	III-V	VI-VIII	IX-XI	XII-II
Banie Maz	79.0	76.0	75.2	75.6	120.6	133.4	142.2	118.5
Białobrzegi	78.4	74.4	77.3	79.0	127.3	126.3	131.5	118.7
Białystok	79.6	78.7	78.1	79.0	134.5	131.3	129.0	126.8
Biskupiec n/O	78.4	74.1	77.7	73.6	138.3	137.8	129.0	128.0
Brodnica	78.1	74.9	73.2	73.7	138.6	134.8	133.0	124.4
Elbląg	73.9	72.6	76.4	76.2	126.5	132.5	128.2	124.0
Kętrzyn	79.3	77.0	80.2	75.2	129.8	128.7	133.7	119.0
Lidzbark W.	75.7	73.7	76.9	70.8	135.4	126.9	128.4	117.7
Lubawa	78.2	66.2	81.7	76.5	140.4	129.0	133.1	122.1
Mikołajki	83.6	72.2	76.4	71.5	129.0	127.0	140.3	119.5
Mława	73.8	72.1	72.7	73.1	132.5	125.9	128.4	134.1
Myszyniec	76.4	71.3	76.2	75.6	142.0	128.6	134.0	127.6
Olsztyn	75.4	75.5	81.1	78.2	137.2	130.6	132.1	125.0
Ostrołęka	81.4	77.7	74.7	76.8	126.9	126.1	138.1	123.9
Prabuty	76.5	75.9	77.4	74.5	137.7	133.6	129.6	121.6
Suwałki	77.9	75.5	71.7	77.9	131.5	127.5	134.4	118.5
Wizna	78.5	76.8	77.7	76.3	127.3	133.1	138.1	124.2
Żuromin	70.3	75.4	62.9	75.3	142.6	132.4	126.3	132.8

Probability of negative and positive precipitation anomaly

After determining critical values from the gamma distribution for various values of probability and their trends for norms in individual seasons of the year, the probability of the occurrence of negative and positive anomaly was calculated, presenting their spatial variety in Figures 2abcd and 3abcd.

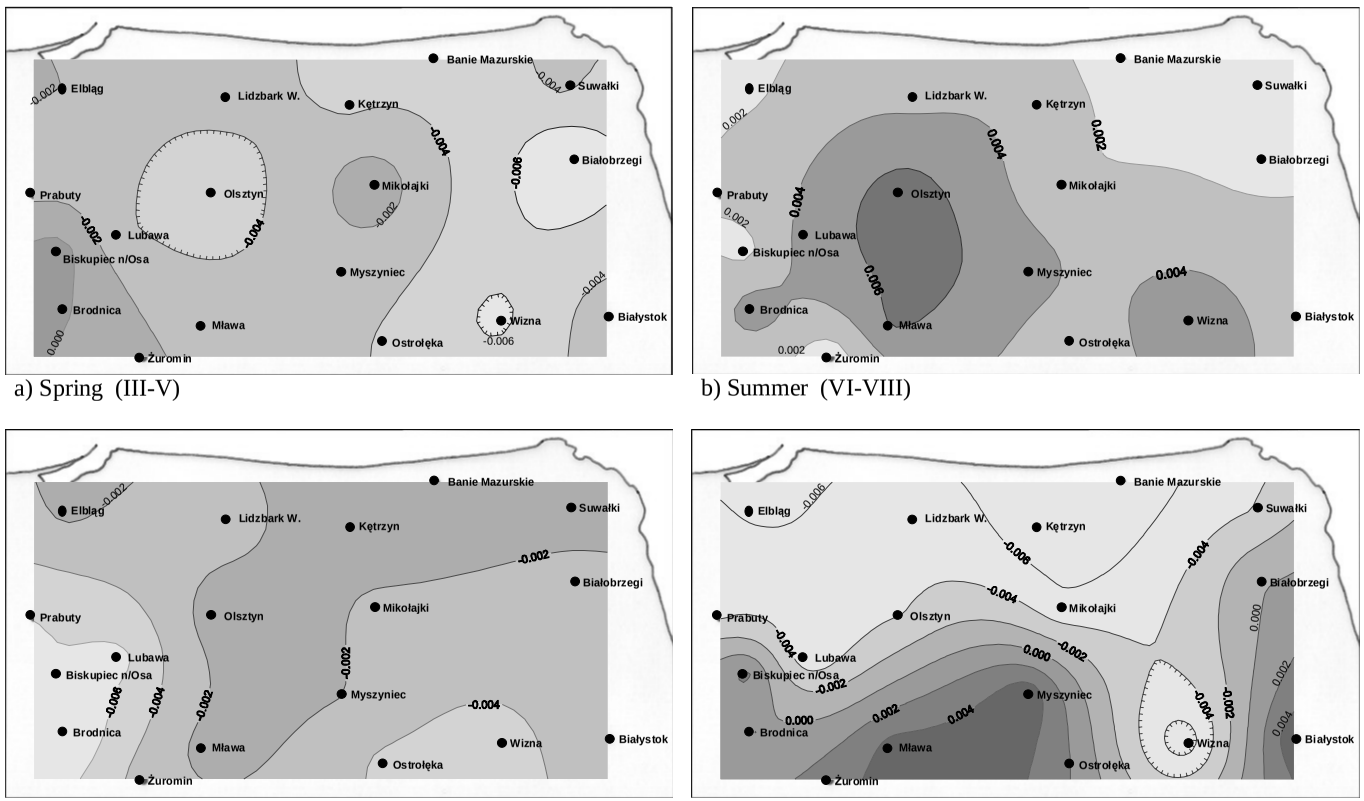

Fig. 2 abcd. Spatial distribution of slope coefficients in linear trend (mm/year) for probability of seasonal precipitation below lower limit of norm in the north-eastern Poland (1951-2000)

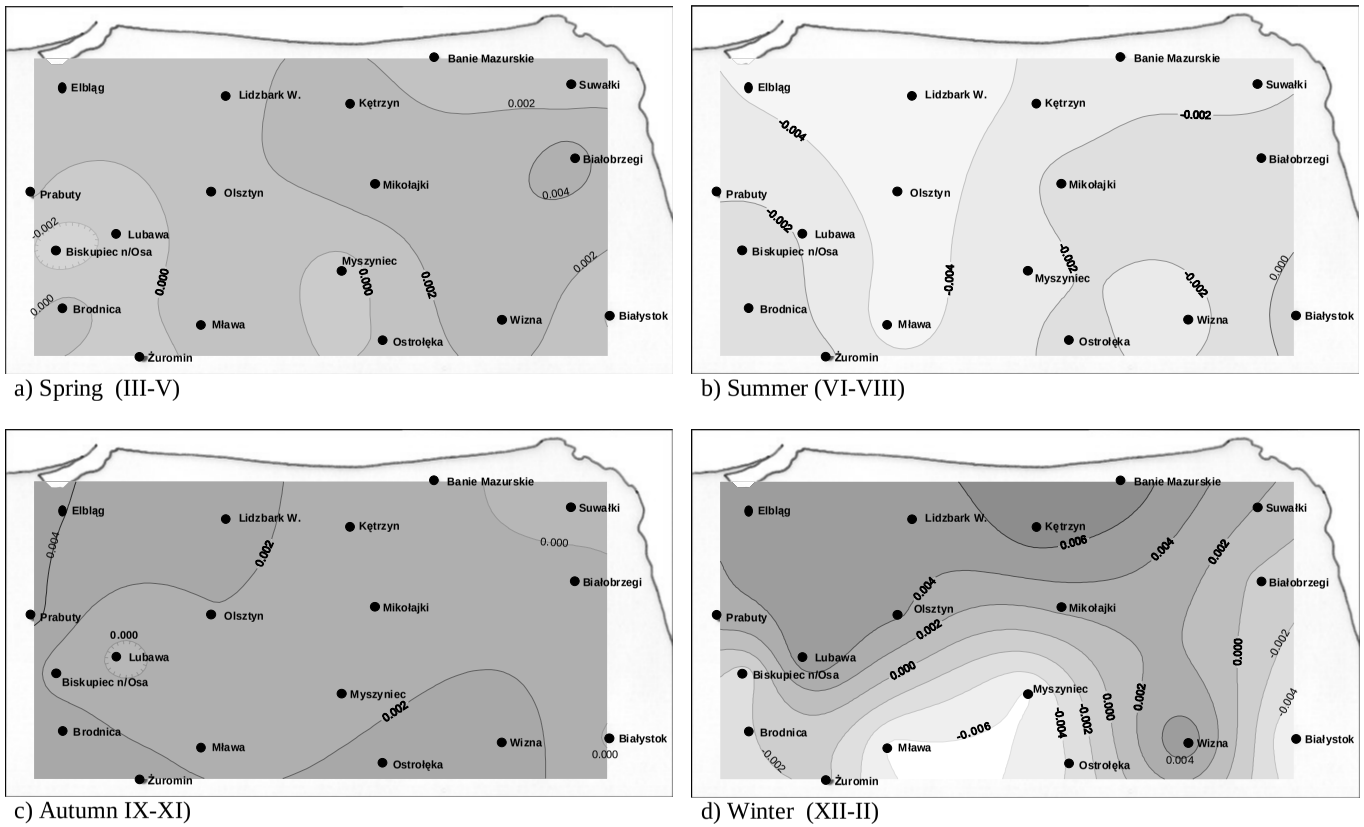

Fig. 3 abcd. Spatial distribution of slope coefficients in linear trend (mm/year) for probability of seasonal precipitation above upper limit of norm in the north-eastern Poland (1951-2000)

The growing tendencies of the negative anomaly, indicating an increasing probability of the deficiency of precipitation in the examined area, were observed in summer in all examined stations. The highest values of regression coefficients (0.004 mm/year) were found in the Olsztyn Lake District. The analysis also demonstrated that a decreasing, most frequently significantly, tendency of the occurrence of the negative anomaly concerned all examined locations in autumn.

It was also found in the majority of the examined locations in spring (except for Biskupiec on the Osa and Brodnica). In winter, generally significant decreasing tendencies (of the values between -0.004 to -0.006 mm/year) occurred in the north of the examined area, in the areas of lake districts and in the vicinity of Wizna, while insignificant increasing trends were established in the southern part (the areas of Mława, Myszyniec and Białystok). The observed tendencies indicate a decreasing probability of precipitation deficiency in those seasons.

The probability of precipitation exceeding the upper limit of the norm showed generally significant decreasing tendencies in spring in all stations except for Białystok. The greatest decreasing tendencies (-0.004 mm/year) were observed in the zone covering the north Elbląg and Lidzbark Warmiński and reaching Mława in the south. On the other hand, significant increasing tendencies (0.004-0.006 mm/year) were found in winter in the north of the region, while decreasing tendencies occurred generally in its southern area: values ranging from -0.004 to -0.006 mm/year concerned the area between Mława, Myszyniec and Ostrołęka and the vicinity of Białystok. In autumn, slight increasing trends of high precipitation covered the entire area under examination, except for the Suwałki Lake District and area around Lubawa and Białystok.

The probability of the occurrence of precipitations below the lower and above the higher limit of the norm demonstrated tendencies similar to changes in precipitation sums for the Mazurian Lake District in 1951-2000 examined by BANASZKIEWICZ *et al.* (2008, 2009ab).

Conclusions

The performed characteristics of sums of precipitation in individual seasons of north-eastern Poland from 1951-2000 in a 30-year moving sample lead to the following conclusions:

1. Seasonal precipitation revealed, in the majority of the examined locations, generally statistically significant increasing tendencies in spring and autumn, while in winter growing tendencies of precipitation were observed usually in the northern part of the region. Mostly significant decreasing trends of precipitation occurred in all examined stations in summer.
2. The probability of precipitation below the lower limit of the norm demonstrated mostly significant increasing tendencies in summer in all locations under examination. A generally significant decreasing tendency of the occurrence of the negative anomaly was characteristic for the majority of the examined locations in spring and autumn. In winter, generally significant decreasing trends

were observed in the north of the examined region, areas of lake districts and the vicinities of Wizna.

3. The probability of precipitation exceeding the upper limit of the norm demonstrated mostly significant decreasing tendencies in summer in all stations except for Białystok. An increasing, mostly significant tendency of the occurrence of high precipitation was observed in winter in the northern part of the examined area, while opposite tendencies occurred generally in its southern part.
4. Examination of seasons as regards direction of tendencies also proved that predominately significant:
   - in the majority of the examined area in spring (except for the south-western part of the region, the area around Myszyniec and Białystok), and in autumn (except for Białystok, Lubawa and Suwałki), the probability of negative anomaly demonstrated a decreasing trend, while the probability of the positive anomaly demonstrated a growing trend;
   - in summer, the frequency of high precipitation decreased and the probability of precipitation deficiency increased, which was characteristic for all examined stations apart from Białystok;
   - in winter, a clear spatial diversity occurred as regards directions of tendencies: in the northern and the central part of the examined area and in the area around Wizna the observed probability of the anomaly was the same as in spring and autumn, and in the most part of the southern area, except for Brodnica and Białobrzegi – the same as in summer..
5. Trends of precipitations and probability of precipitation anomalies in individual seasons demonstrated consistency of the directions of tendencies in the examined locations.

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