

CHARACTERISATION OF ATMOSPHERIC PRECIPITATION OF IŁAWA  
AND CHEŁMIŃSKO-DOBRZYŃSKIE LAKE DISTRICTS  
IN THE YEARS 1951-2000\*

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**Abstract.** The paper presents selected characteristics of atmospheric precipitation in the Iława and Dobrzyńsko-Chełmińskie Lake Districts determined on the basis of data from four stations of IMGW (Institute of Meteorology and Water Management) – Prabuty, Biskupiec on Osa, Brodnica and Lubawa. The study covered a period of 50 years (1951-2000). The analyses were made with the use of a 30-year moving sample. Critical values of monthly and seasonal sums of precipitations for various levels of probability were calculated from the gamma distribution, and then their trends were determined. Also, probability of occurrence of precipitation anomalies was calculated. The probability of occurrence of precipitations below the lower limit of the norm at all the stations displayed a significant increasing trend in August and in July, however the probability of occurrence of precipitations exceeding the upper limit of the norm generally displayed significant decreasing trends at all stations in July and August, in the summer season and in the year period.

**Key words:** atmospheric precipitation, north-eastern Poland

#### INTRODUCTION

Analyses of precipitation conditions, due to their notable variability in time and space, constitute a standard element of climatic research (Mrugała 2001, Żmudzka 2002). Differentiation in the level and distribution of precipitation in individual years applies also to north-eastern Poland. This creates the possibility of obtaining a variety of precipitation characteristics, concerning e.g. its anomalies, multi-year trends, or spatial distribution (Banaszekiewicz *et al.*, 2008, Hutorowicz *et al.*, 1996, Nowicka and Grabowska 1989, Szwejkowski *et al.*, 2002). The study presented here is a continuation of research on the precipitation conditions of the region in the

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\*The work was grandet by research project No 2P06S06828 in years 2005-2008.

period of 1951-2000, and focuses on the area of the Iława and Chełmińsko-Dobrzyńskie Lake Districts.

#### MATERIAL AND METHODS

The study was made on the basis of data obtained from four meteorological stations, covering the period of 1951-2000. The analyses were based on values of diurnal sums of precipitation from the stations at Prabuty and Brodnica, and on monthly precipitation values from the stations at Biskupiec on Osa and Lubawa.

The characterisations developed concerned the monthly sums of precipitations, vegetation season (April-Sept.) and sums for one-year periods (Jan.-Dec.), using a 30-year moving sample, i.e., based on the data for the period of 1951-2000, 21 series of variables were created for the successive 30-year periods. The first 30-year period comprised the years 1951-1980, the second – 1952-1981, and so on until the last one covering the years 1971-2000. It was assumed that the variables have gamma distribution with parameters  $\alpha$  and  $\beta$ . The distribution parameters of each of the created series were estimated with the method of the greatest credibility according to formulae given by Johnson and Kotz (Otop and Kuchar 2004 after Johnson and Kotz 1970). For each of the obtained distributions of precipitation sums the critical values ( $X_0$ ) were calculated, according to the formula  $P(X > X_0) = p_0$ , where  $X$  is the monthly (or seasonal) sum for various values of probability ( $p_0 = 0.99, 0.95, 0.90, 0.10, 0.05$  and  $0.01$ ).

Also calculated were the values of precipitation norms according to Mrugała (1997), determining their upper and lower limes, as mean values of deviations (positive and negative), respectively, from the mean 50-year sum of precipitations. The tendencies of precipitation sums and values of probability of positive and negative anomalies were developed and described by means of linear trends.

Additionally, for Brodnica and Prabuty, calculations were made of the numbers of days with precipitations ( $\geq 0.0$  mm,  $\geq 1.0$  mm,  $\geq 10.0$  mm,  $\geq 20.0$  and  $\geq 30.0$  mm), and of the numbers of non-precipitation day series (lasting for more than 10, 15 and 20 days) during the vegetation season (April-Sept.) and in the individual months of that season. Analysis was also made of the frequency of occurrence of seasons with rainfall excess or deficit according to the Kaczorowska criterion (1962).

#### RESULTS AND DISCUSSION

The mean annual sums of atmospheric precipitation for the multi-year period of 1951-2000 in the area of the Iława and Chełmińsko-Dobrzyńskie Lake Districts varied from 589 mm in Brodnica to 656 mm in Lubawa (Tab. 1). At the stations under study, the highest annual sums of precipitations were observed in 1970, and the lowest in 1951. Their values had runs typical for the climate of Poland; in July

they generally exceeded 80 mm, while monthly minima occurred in February, amounting to from 29 to 34 mm. Distribution of precipitations is related with the relief of the terrain; in numerous climatic studies, e.g. concerned with the multi-year periods of 1951-1970 (Nowicka and Grabowska 1989) and 1951-1995 (Szwejkowski *et al.* 2002), the region under study, i.e. north-western and western parts of the Mazury Lake District, is indicated as a zone receiving greater sums of precipitations as compared to the central and eastern parts of the region.

**Table 1.** Sums of atmospheric precipitation (mm) in the Iława and Chełmińsko-Dobrzyńskie Lake Districts in the years 1951-2000

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	IV-IX	I-XII
Biskupiec n/Osą	41	31	32	36	50	68	82	65	54	44	47	47	356	598
Brodnica	36	29	34	36	48	69	83	68	55	40	47	46	358	589
Lubawa	43	34	37	40	56	72	86	77	62	47	52	51	392	656
Prabuty	35	29	31	36	54	72	85	80	61	47	44	44	388	618
Max	43	34	37	40	56	72	86	80	62	47	52	51	392	656
Min	35	29	31	36	48	68	82	65	54	40	44	44	356	589

Analysis of monthly values of regression coefficients of linear trend (Tab. 2) showed that in the successive 30-year sequences, at all stations under study, there occurred significantly increasing trends of sums of atmospheric precipitations in March, June, September and December (with the exception of Brodnica). In January the increase was statistically significant in Lubawa and Prabuty, and in October – in Brodnica, Lubawa and in Prabuty. The increasing trends of precipitations were the highest in June, and amounted to 0.7-0.8 mm year<sup>-1</sup> at the localities under study. Whereas, significant decreasing trends occurred at all the stations in July, August and May (non-significant at Prabuty). The highest significant decrease in precipitations occurred in July and amounted to from 0.4 mm to 1.2 mm year<sup>-1</sup>. The sums of atmospheric precipitations calculated for the vegetation season generally displayed insignificant decreasing trends (with the exception of Brodnica, where a significant opposite trend occurred). The annual sums of precipitations in the successive 30-year periods revealed significant increasing trends only at Prabuty. Those trends in precipitation changes in the successive 30-year periods are similar (in terms of their direction) to the changes in precipitation sums of the Mazury Lake District in the years 1951-1995 and 1951-2000 studied by Banaszekiewicz *et al.* (2002, 2008), and to trends of averaged values of precipitation sums for Poland for the years 1951-2000 analysed by Żmudzka (2002).

**Table 2.** Monthly and seasonal coefficients of regression of linear trend (mm/year) of precipitation in the Iława and Chełmińsko-Dobrzyńskie Lake Districts in successive 30-year sequences of moving sample from 1951-2000

Station	Characteristics	I	II	III	IV	V	VI	VII	VIII
Biskupiec n/Osą	1	-0.23***	-0.28***	0.12**	-0.16***	-0.33***	0.70***	-0.44***	-0.44***
	2	0.006***	0.003***	-0.001*	0.003**	0.000	-0.007***	0.005***	0.008***
	3	-0.000**	-0.006***	0.003*	-0.002***	-0.005***	0.004***	-0.001*	-0.001
Brodnica	1	-0.15***	-0.01	0.07*	0.02	-0.08**	0.82***	-0.34***	-0.73***
	2	0.006***	-0.000***	-0.002	0.003**	-0.000	-0.006***	0.000	0.005***
	3	-0.001	-0.002***	0.001	0.002***	-0.002	0.006***	-0.002***	-0.006***
Lubawa	1	0.40***	0.17***	0.33***	0.07*	-0.30***	0.77***	-1.24***	-0.55***
	2	-0.000***	-0.000***	-0.007***	-0.000	-0.001	-0.000***	0.009***	0.003**
	3	0.006***	0.000**	0.004***	0.000***	-0.005***	0.007***	-0.006***	-0.004***
Prabuty	1	0.21***	-0.04	0.26***	-0.01	-0.07	0.77***	-0.98***	-0.48***
	2	-0.001	-0.004***	-0.007***	0.005***	-0.003***	-0.003*	0.007***	0.003***
	3	0.004***	-0.002***	0.004***	0.002**	-0.003***	0.007***	-0.005***	-0.003***

Station	Characteristics	IX	X	XI	XII	IV-IX	I-XII
Biskupiec n/Osą	1	0.52***	0.06	-0.12	0.11*	-0.10	-0.50
	2	-0.004***	-0.000	-0.005	-0.003***	0.000	-0.002*
	3	0.006***	0.001	-0.004***	0.000	-0.001	-0.003***
Brodnica	1	0.74***	0.11**	0.08	-0.00	0.53**	0.51
	2	-0.003***	-0.000	-0.003	0.002	-0.002**	-0.003***
	3	0.008***	0.001*	0.000	0.001	0.001	-0.000
Lubawa	1	0.27***	0.13**	-0.01	0.29***	-0.84***	0.34
	2	-0.000	0.001	-0.007***	-0.004***	0.002**	-0.003***
	3	0.000***	0.002***	-0.004***	0.003***	-0.003***	-0.001
Prabuty	1	0.39***	0.37***	0.14*	0.26***	-0.02	0.81***
	2	-0.000	-0.000	-0.008***	-0.006***	-0.002*	-0.005***
	3	0.005***	0.004***	-0.001	0.002***	-0.003***	-0.001

Values significant at the level: \* 0.05; \*\* 0.01; \*\*\* 0.001;

<sup>1</sup>Average precipitation totals, <sup>2</sup>Probability of precipitation below lower limit of norm, <sup>3</sup>Probability of precipitation above upper limit of norm.

Calculated values of precipitation norms are given in Table 3. The values of the lower limit of the norm were low for the months from January till April (16-27 mm), somewhat higher in October and December, and up to 43-54 mm in the summer months. The values of the upper limit fell within the range from 40 to 63 mm in the months from January to April, and 130-142 mm in July. The lower limit of the norm in the warm half-year (April-September) assumed values from 283 to 314 mm, while the values of the upper limit of the norm varied within the range from 443 to 482 mm. For the twelve-month period, the lower limit of the norm varied from 528 mm in Prabuty to 499 mm in Brodnica, while the upper limit of the norm was the highest in the Iława Lake District and at Garb Lubawski (above 740 mm). The values of the presented monthly and seasonal precipitation norms are similar to those for north-eastern Poland in the period of 1951-1990 given by Mrugała (2001).

The probability of occurrence of precipitations below the lower limit of the norm (Tab. 2) in the 30-year sequences of the moving sample displayed a significant increasing trend in August, at all meteorological stations included in the study. Increasing trends, mostly significant, were also observed in July and in April (with the exception of Lubawa). The analysis revealed also that the decreasing, most frequently significant, trend of occurrence of negative anomaly concerned a majority of the studied localities from September to March, in May, June, and in the warm half-year and the twelve-month period.

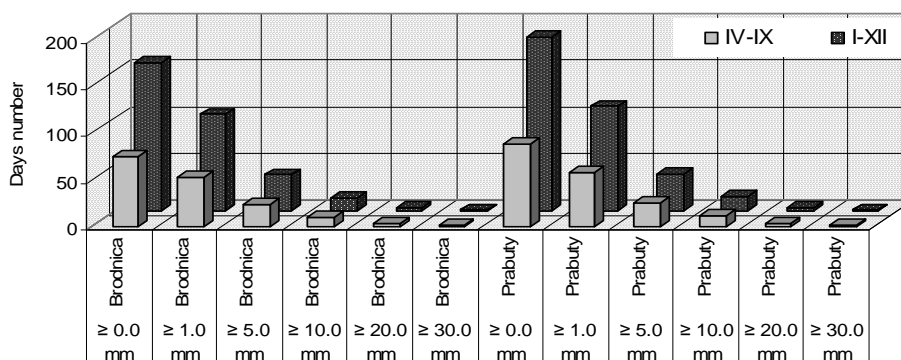
The probability of occurrence of precipitations above the upper limit of the norm usually revealed significant decreasing trends in July, August (at all stations), in May and February (with the exception of Lubawa), and in November, with the exception of Brodnica. A decreasing trend of positive anomaly occurred also, usually significantly, in most of the localities in the summer season (with the exception of Brodnica) and in the twelve-month period. An increasing, mostly significant, trend of occurrence of high precipitations was noted at all of the localities in March, April (with the exception of Biskupiec on Osa), June, September, October and in December.

The additional analyses showed that the average annual number of days with precipitations  $\geq 0.0$  and  $\geq 1.0$  mm was higher at Prabuty than at Brodnica, with the vegetation season accounting for an average of ca. 50% of the days with precipitations within those categories (Fig. 1). The mean annual number of days with precipitation  $\geq 5.0$  mm at both stations was ca. 39, and with precipitation  $\geq 10.0$  mm 14-15 days. Very high precipitations, i.e.  $\geq 20.0$  and  $\geq 30.0$  mm, occurred on average about three times a year at Brodnica and one time at Prabuty. Those values were similar to those obtained for the western part of the Mazury Lake District in the multi-year period of 1951-1970 (Nowicka and Grabowska 1989).

**Table 3.** Lower and upper limits of precipitation norm (mm) in the Iława and Chełmińsko-Dobrzyńskie Lake Districts in the years 1951-2000

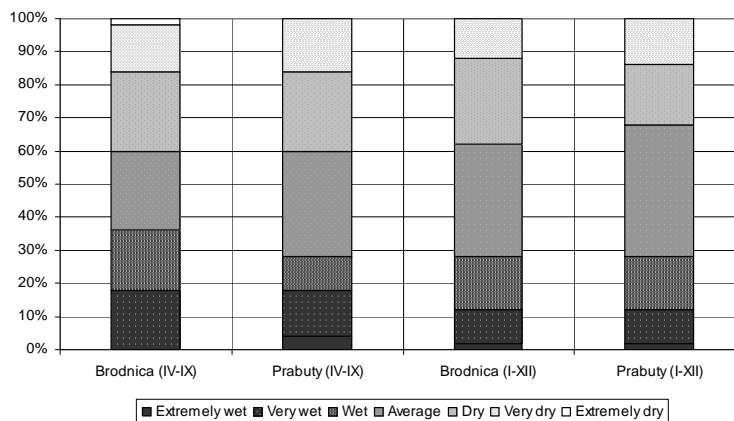
Station	Norms	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	IV-IX	I-XII
Biskupiec n/Osą	1	24	20	23	23	32	43	51	44	33	25	32	27	290	507
Brodnica	1	21	19	23	23	35	46	49	41	33	22	32	29	283	499
Lubawa	1	25	20	23	27	36	45	53	46	38	26	38	35	296	541
Prabuty	1	19	16	20	22	33	46	54	50	37	27	30	29	314	528
Biskupiec n/Osą	2	62	45	50	56	73	106	137	104	80	70	66	66	448	720
Brodnica	2	51	40	55	53	72	107	142	96	88	75	69	65	443	710
Lubawa	2	63	48	52	61	83	108	134	113	98	76	74	74	479	762
Prabuty	2	50	41	43	56	78	106	130	118	84	79	60	62	482	742

1 – lower limit of norm, 2 – upper limit of norm.



**Fig. 1.** Number of days with precipitation  $\geq 0.0$  mm,  $\geq 1.0$  mm,  $\geq 5.0$  mm,  $\geq 10.0$  mm,  $\geq 20.0$  mm,  $\geq 30$  mm in periods of April-Sept. and Jan.-Dec. in Brodnica and Prabuty in the years 1951-2000

The mean frequency of occurrence of precipitations on average level in the vegetation seasons of the multi-year period under study (acc. to Kaczorowska classification) was 24% in Brodnica and 32% in Prabuty (Fig. 2); very wet and wet seasons occurred more frequently in Brodnica (18%), and very dry constituted 14-16%. At both localities, vegetations seasons were classified as dry at the frequency of 24%. Extremely dry vegetation seasons were recorded only in Brodnica (2%), and particularly wet in Prabuty (4%).



**Fig. 2.** Average frequency (%) of occurrence of vegetation seasons (IV-IX) and years (I-XII) with deficiencies and excess of precipitation according to the Kaczorowska criterion in Brodnica and Prabuty in the years 1951-2000



In terms of precipitations, the year period (January-December) in the studied multi-year period was estimated at both stations as average (34-40%). The frequency of years classified as very dry was 12-14% and was greater than the frequency of very wet years (10%). Also the frequency of dry years was higher than the frequency of wet years; extremely wet years (with frequency of 2%) were noted for both localities, while particularly dry years did not occur at all.

During the multi-year period under analysis non-precipitation sequences (Tab. 4), of all categories under study, in the vegetation season (April-Sept.) and in the individual months of the season occurred more often in Brodnica than in Prabuty. Periods without precipitations lasting for more than 10 days occurred most often in April, May, August and September, and those lasting for longer than 20 days were recorded in September, only in Brodnica. The number of sequences of all categories was lower in Prabuty in the 50-year period of 1951-2000 than in the period of 1971-2000 studied by Banaszekiewicz *et al.* (2004).

**Table 4.** Long-term (1951-2000) average numbers of non-precipitation day sequences lasting  $\geq 10$   $\geq 15$   $\geq 20$  days in particular months from April to September and in the vegetation period (IV-IX) in Brodnica and Prabuty

Locations	IV			V			VI			> 10
	> 10	>15	>20	> 10	>15	>20	> 10	>15	>20	
Brodnica	0.4	0.2	0.0	0.5	0.1	0.0	0.3	0.1	0.0	0.3
Prabuty	0.3	0.1	0.0	0.4	0.0	0.0	0.3	0.1	0.0	0.2

Locations	VII		VIII			IX		IV-IX			
	>15	>20	> 10	>15	>20	> 10	>15	>20	> 10	>15	>20
Brodnica	0.1	0.0	0.4	0.1	0.0	0.5	0.2	0.1	2.4	0.8	0.2
Prabuty	0.1	0.0	0.3	0.1	0.0	0.4	0.1	0.0	1.8	0.5	0.1

## CONCLUSIONS

1. Mean annual sums of precipitations in the area of the Hława and Chełmińsko-Dobrzyńskie Lake Districts in the multi-year period of 1951-2000 varied from 589 mm in Brodnica to 656 mm in Lubawa; the sums of precipitations in the vegetation season followed an analogous pattern, at 358 and 392 mm, respectively.

2. Analysis of sums of precipitations with the use of 30-year moving sample showed that their values, at all stations under study, were characterised by significant increasing trends in March, June, September and December (with the exception of Brodnica). Whereas, predominantly significant decreasing trends occurred in May, July and in August at all stations studied.

3. The range of normal precipitations for the year period varied from 499-710 mm in Brodnica to 541-762 mm in Lubawa, for the vegetation season it fell within the range of from 283-443 mm in Brodnica to 314-482 mm in Prabuty.

4. The probability of occurrence of precipitations below the lower limit of the norm at all the stations displayed a significant increasing trend in August, mostly significant in April (except for Lubawa) and in July. A decreasing, mostly significant, trend of occurrence of negative anomaly concerned most of the localities under study in the months from September to March, in May, June, and in the warm half-year and in the year period. The probability of occurrence of precipitations exceeding the upper limit of the norm generally displayed significant decreasing trends at all stations in July and August, in the summer season and in the year period. Whereas, predominantly significantly increasing trends of positive anomaly were recorded in March, June, September, October and in December.

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## CHARAKTERYSTYKA WARUNKÓW OPADOWYCH POJEZIERZA IŁAWSKIEGO I CHEŁMIŃSKO-DOBRZYŃSKIEGO W LATACH 1951-2000\*

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**Streszczenie.** W pracy przedstawiono wybrane charakterystyki opadów atmosferycznych Pojezierzy Iławskiego i Dobrzyńsko-Chełmińskiego wykonane na podstawie danych pochodzących z czterech stacji i posterunków meteorologicznych IMGW (Prabuty, Biskupiec n/Osą, Brodnica, Lubawa). Badaniami objęto okres 50-letni (1951-2000). Analizy dokonano z zastosowaniem 30-letniej próby kroczącej. Wartości krytyczne miesięcznych i sezonowych sum opadów dla różnych wartości prawdopodobieństwa wyliczono z rozkładu gamma, a następnie wyznaczono ich trendy. Obliczono również prawdopodobieństwo wystąpienia anomalii opadowych. Prawdopodobieństwo wystąpienia opadów poniżej dolnej granicy normy wykazywało we wszystkich badanych stacjach istotny trend rosnący w sierpniu i w lipcu, natomiast prawdopodobieństwo wystąpienia opadów przekraczających górną granicę normy wykazywało na ogół istotne tendencje malejące we wszystkich badanych stacjach w lipcu i w sierpniu, w półroczu letnim oraz roku.

**Słowa kluczowe:** opady atmosferyczne, północno-wschodnia Polska

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\*Praca finansowana ze środków na naukę w latach 2005-2008 jako projekt badawczy nr 2P06S06828.