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THE USE OF THE TEMPORAL OSCILLATION MODEL TO ASSESS VARIABILITY OF PRECIPITATION

Abstract: The article presents the variability of precipitation based on the temporal oscillation model. Series of monthly precipitation totals from the years 1955–1980 were used for the analysis. The detailed research referred to the selected 10 measurement stations in central Poland and 17 in southern Poland. Data series from all the measurement stations were verified in terms of their statistical homogeneity. Furthermore, in accordance with the model guidelines, the tendency was assessed. This was followed by calculation of seasonal and accidental oscillations of precipitation. The results were used to present the variability of precipitation in the two areas studied. The measurement stations in southern Poland showed a much higher mean variation of seasonal oscillations of monthly precipitation. Accidental precipitation, however, is much more significant for the total variability of precipitation in southern Poland.

Key words: precipitation, variability of precipitation, temporal oscillation model, precipitation tendencies, seasonal oscillations, accidental oscillations

Introduction

Randomness is a characteristic feature of precipitation. For this reason, it is extremely difficult to foresee the place and time of a precipitation occurrence as well as its volume and intensity. Although precipitation variability in Poland is not large, "any change in the precipitation total results in profound disturbances in the environment" (Kożuchowski et al. 1990, p. 359). From the hydrological point of view, water excess or deficit[1], i.e. dry, average or wet years, are predominantly dependent on the precipitation volume in a given area (river basin). Volume and intensity of precipitation influence random hydrological occurrences, such as high or low water stages.

Thus, in order to meet the needs of human population and prevent extreme phenomena, it is necessary to know the processes connected with water circulation, especially the volume and variability of precipitation in time in a given area. This kind of knowledge is indispensable for proper planning and balancing available water resources, from the scale of a basic hydrological unit of a river basin to the global scale.

The basic aim of this paper is to present in a detailed way variability in precipitation based on the temporal oscillation model. Special attention is paid to present the method used for the analysis. The time aspect of the research is also analysed. The data, however, were selected in order to minimise the mean error of the arithmetic mean (Byczkowski 1999).

Materials and the methods used for analysing precipitation

In order to analyse the variability of precipitation the following two test areas were selected (Fig. 1):

- Central Poland, for which the following monthly series of precipitation totals were selected: a 26-year-long (1955–1980) series from 10 precipitation stations,
- Southern Poland, for which a 26-year-long (1955–1980) series of monthly precipitation totals from 17 precipitation stations was selected.

All the data used for the analysis were taken from the Yearbooks of Precipitation for the years 1955–1980, published by the Institute of Meteorology and Water Management in Warsaw. The data series from the precipitation stations were verified in terms of their statistical homogeneity. To

[1] Definitions of precipitation excess or shortage according to Z. Kaczorowska (1962)

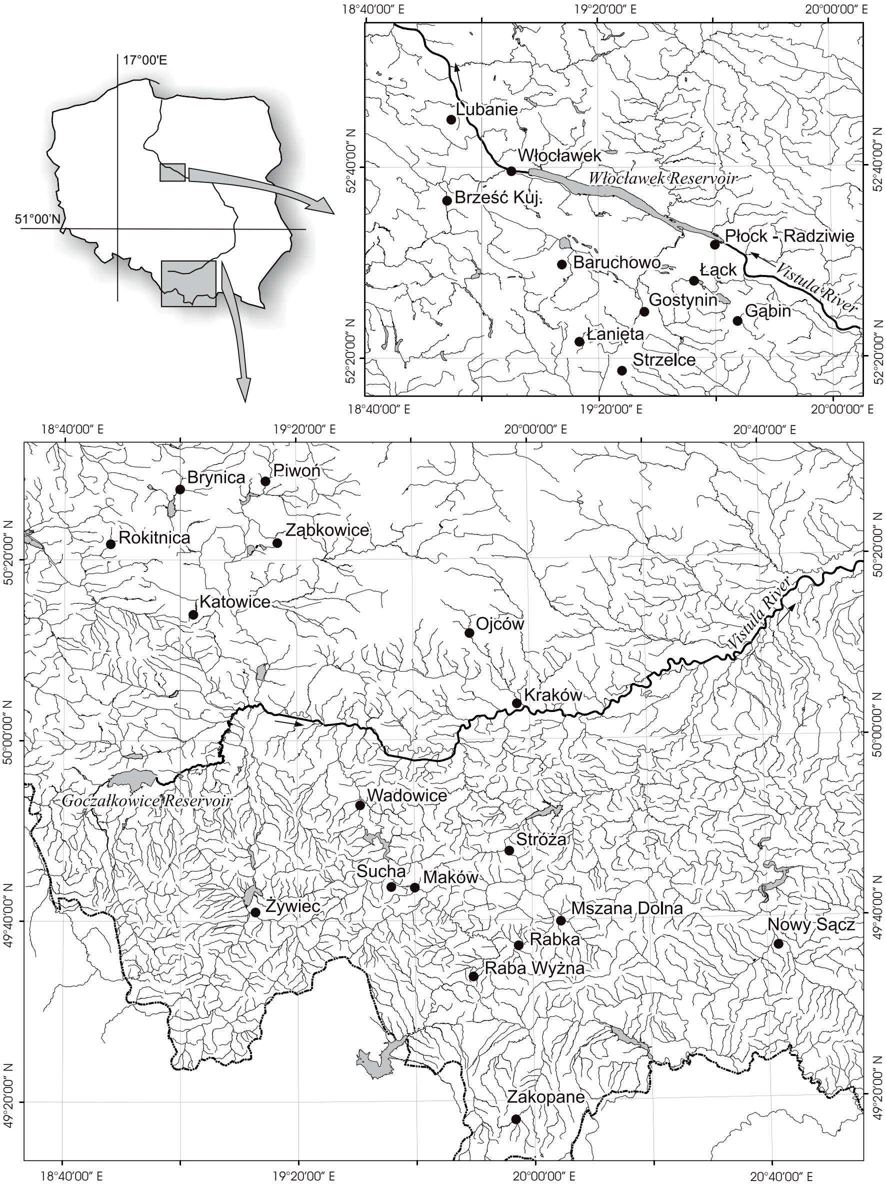

Fig. 1. Location of precipitation stations in the researched areas

do this, a test was conducted based on the Spearman rank-order correlation coefficient (Ozga-Zieliński 1987).

In most cases, to describe precipitation variability specialist literature uses the variation coefficient (Cv) of the precipitation annual totals, which is a relation of standard deviation to the mean. Such a measure was used by Kożuchowski (1981, 1986), Wójcik and Marciniak (1993), Twardosz (1999), and others. Moreover, precipitation variability was presented with the use of the irregularity index (W), which is a quotient of maximum and minimum annual precipitation total in a multi-annual period of time.

The temporal oscillation model, the method selected by the authors, was introduced to analysis and description of hydrological occurrences by Jankowski and Czaja (Jankowski 1986; Czaja 1988; Czaja and Jankowski 1989) followed by Bartczak (2007). The method was also used by Czaja and Radosz (1989) in order to estimate the variability of precipitation within the area of the Katowice Region (Voivodeship). In accordance with the definition by Sobczyk (2002), the temporal oscillation model is a theoretical construction which describes a given phenomenon as a function of time variable, and periodical and accidental (irregular) oscillations. The advantage of such a method is the fact that both numerical and graphic representation of seasonal and accidental oscillations can be assessed in the background of precipitation tendencies. Taking the above into consideration, the analysis was divided into three stages.

In Stage One the tendency (trend) of precipitation was described with the analytical method. This is the most frequently used and the easiest method, which shows the development of a studied phenomenon as a linear function of the trend in the following form:

$$\hat{y} = a_0 + a_1 t, \text{ where:}$$

$\hat{y}$ – theoretical value of the function of the precipitation trend during the period t, a_0 – value of the trend of the function during the month which precedes the period of time studied [mm], a_1 – value of the growth of the trend from month to month [mm], t – the following number of the observation. Parameters a_0 and a_1 of the function were determined using the method of least second powers.

In Stage Two the volume of periodical oscillations, of which seasonal oscillations are a specific case, was determined. The value of seasonal oscillations was presented with the use of seasonality indexes given either in percent or in absolute levels of seasonal oscillations given in absolute values. In order to select seasonal oscillations the method based on mean one-type (monthly) periods of time was used. In this situation, the calculation of seasonality indexes was based on the following formula:

$$S_i = \frac{\bar{y}_i \times d}{\sum \bar{y}_i} \times 100 \text{ [\%], where:}$$

S_i – seasonality index for the i^{th} sub-period (Octobers, Novembers, Decembers, etc.), $\bar{y}_i$– mean precipitation total [mm] during a one-type research sub-period, d – number of months in a year.

In order to calculate the absolute level of seasonal oscillations for the individual sub-periods of the seasonal cycles, the following formula was used:

$$g_i = \left[\frac{S_i}{100} - 1\right] \times \bar{y} \text{ [mm], where:}$$

g_i – absolute levels of oscillations of seasonal precipitation, S_i – seasonality index for the i^{th} sub-period of a given cycle of the precipitation oscillation [%], $\bar{y}$ – monthly mean of the precipitation total during the period of time studied [mm].

The standard deviation of the absolute seasonality indexes (absolute levels of seasonal oscillations) is understood in the following way:

$$s(g_i) = \sqrt{\frac{\sum g_i^2}{d}} \text{ [mm], where:}$$

$s(g_i)$ – standard deviation of the absolute levels of seasonal oscillations, g_i – absolute levels of seasonal oscillations of precipitation, d – number of months in a year.

In Stage Three accidental oscillations were separated; besides both main and seasonal factors they influence the character of precipitation. In the temporal oscillation model the accidental oscillations are represented by the remaining elements, which can be calculated according to the following formula:

$$z_t = y_t - \hat{y}_t - g_{it} \text{ [mm], where:}$$

z_t – accidental oscillations in the absolute values, y_t – monthly precipitation totals [mm], $\hat{y}_t$ – theoretical value of the function of the precipitation trend [mm] during the period t, g_{it} – absolute level of seasonal oscillations of precipitation [mm] during the ith sub-period of the cycle.

The standard deviation of the remaining element is a synthetic measure of the accidental oscillations, which can be put in the following way:

$$s(z_t) = \sqrt{\frac{\sum z_t^2}{n - 2}} \text{ [mm], where:}$$

$s(z_t)$ – standard deviation of the remaining element, z_t – accidental oscillations in the absolute values, n – number of months in a time sequence.

In order to determine the share of accidental oscillations in the mean annual total of precipitation during a multi-year period of time, the so-called coefficient of the remaining variability was used in the following formula:

$$V = \frac{s(z_t)}{\bar{y}} \times 100 \text{ [\%], where:}$$

V – coefficient of the remaining variability, $s(z_t)$ – standard deviation of the remaining element of precipitation [mm], $\bar{y}$ – mean monthly total of the precipitation during the multi-year period of time.

Results and discussion

Variability of annual totals of precipitation

The two areas under comparison differ from each other in terms of all the calculated parameters (Table 1). Most of all, they are different as far as mean annual total of precipitation is concerned. Such a distribution of precipitation is mainly dependent on geographical location as well as the altitude of the measurement stations. Moreover, the role of local factors is significant in the case of the volume of precipitation; they include the closeness of large water bodies, compact forest complexes, urban and industrial centres, and others (Paszyński 1955). During the period of time analysed, precipitation in central Poland ranged from 469 mm in Brześć Kujawski to 593 mm in

Łąck. According to Wójcik and Marciniak (1993), the minimum mean annual totals of precipitation in the research area is the result of both the lowness and the flatness of the area, as well as the influence of the rain shadow created by the Lakeland Plateaus.

As far as southern Poland is concerned, however, the dependence of the annual precipitation totals on the altitude of the measurement stations is much more visible. Mean annual precipitation totals in the area ranged from 711 mm in Kraków (206 m a.s.l.) to 1,145 mm in Zakopane (857 m a.s.l.). Such a dependency was closely analysed and proved by Czaja and Radosz (1989) for the area of the Upper Silesian Conurbation. The case of Zakopane and its multi-annual variability of the precipitation totals were closely described by Kożuchowski (1981). In accordance with his analysis, the annual mean of the precipitation totals for the years 1896–1978 was 1,136 mm. This value is similar to the mean for the years 1955–1980. The range of the extreme annual totals, though, was much higher; it amounted to 793 mm (the maximum annual total was 1,564 mm in 1913, while the minimum annual total was 771 mm in 1917) in relation to 589 mm for the years 1955–1980 (the maximum annual total was 1,436 mm in 1980, while the minimum annual total of 847 mm was in 1956). The above differences mainly result from the length of the time period considered for the study. This same factor influenced the visible differences between the calculated variability coefficients for the annual precipitation totals. In accordance with Kożuchowski (1981), the variability coefficient is 16%, while it was 14% for the years 1955–1980 (Table 1).

Another paper worth mentioning at this point is Twardosz's (1999) work on precipitation in Kraków. While analysing the multi-annual variability of the annual precipitation totals for the years 1812–1992, he paid attention to three years of maximum precipitation totals (1855, 1912, 1966), which occurred at approximately 55-year intervals. The lowest annual precipitation total was noted in 1819, amounting to 429 mm. Significant information on the precipitation volume in Kraków in the earlier half of the 16th century is found in a paper by Limanówka (2001). Based on the number of days with precipitation, she reconstructed both monthly and annual precipitation totals for the following periods: 1503–1507, 1527–1531 and 1535–1540. According to her estimates, the lowest annual precipitation totals occurred during the last of these periods and amounted to 382 mm in 1538, 363 mm in 1536, and only 253 mm in 1540. The maximum annual total was recorded in 1505:

Table 1. The characteristics of the variability of the annual precipitation totals in Central Poland (a) and South Poland (b)

No.	Station	Data sets	Mean annual precipitation [mm]	Minimum annual precipitation [mm]	Maximum annual precipitation [mm]	Coeffiicient of variation (Cv) [%]	Coefficient of irregularity (W) [-]	Amplitude (A) [mm]
a)								
1	Włocławek	1955–1980	533	343	731	20.1	2.1	388
2	Baruchowo	1955–1980	528	377	725	17.6	1.9	348
3	Brześć Kuj.	1955–1980	469	261	642	19.3	2.5	381
4	Gostynin	1955–1980	551	390	775	18.4	2.0	385
5	Łanięta	1955–1980	535	397	703	17.0	1.8	306
6	Lubanie	1955–1980	544	378	877	21.9	2.3	499
7	Łąck	1955–1980	593	368	877	19.5	2.4	509
8	Gąbin	1955–1980	588	406	786	16.2	1.9	380
9	Płock–Radziwie	1955–1980	568	379	819	18.0	2.2	440
10	Strzelce	1955–1980	557	352	767	19.6	2.2	415
b)								
1	Katowice	1955–1980	743	522	1 011	15.6	1.9	489
2	Ząbkowice	1955–1980	735	552	1 098	15.9	2.0	546
3	Brynica	1955–1980	768	608	1 092	15.8	1.8	484
4	Rokitnica	1955–1980	730	570	928	14.8	1.6	358

Table 1. cont.

5	Ojców	1955–1980	713	499	1 017	17.6	2.0	518
6	Piwoń	1955–1980	745	595	1 066	15.5	1.8	471
7	Kraków	1955–1980	711	517	996	15.7	1.9	479
8	Stróża	1955–1980	950	766	1 218	12.9	1.6	452
9	Mszana Dolna	1955–1980	892	644	1 163	16.0	1.8	519
10	Zakopane	1955–1980	1 145	847	1 436	14.3	1.7	589
11	Nowy Sącz	1955–1980	750	543	1 054	15.7	1.9	511
12	Wadowice	1955–1980	812	623	1 081	12.5	1.7	458
13	Sucha	1955–1980	1 021	754	1 268	13.5	1.7	514
14	Żywiec	1955–1980	952	718	1 271	16.6	1.8	553
15	Maków	1955–1980	982	660	1 327	14.8	2.0	667
16	Rabka	1955–1980	923	768	1 187	12.5	1.5	419
17	Raba Wyżna	1955–1980	914	666	1 175	14.5	1.8	509

Source: The author's calculations based on *Opady atmosferyczne*…

623 mm. An interesting analysis of the variability of annual precipitation totals for the meteorological stations in Warsaw, Kraków and Wrocław for the years 1901–1993 was presented by Lorenc (1994). In order to estimate the variability, she used the index introduced by Kaczorowska (1962), which is the percentage deviation of the precipitation total in a given year in relation to the multi-annual mean total. In this way, Lorenc classified the years in terms of either shortage or excess of precipitation. Thanks to the results of this research it was possible for her to conclude that normal years, with the precipitation totals being 90–110% of the norm, took place 45 times, i.e. in 48% of the years in the time period under investigation. The years with *in plus* deviation, i.e. with precipitation totals over 110% of the norm, were recorded 24 times, which makes 26% of the years of the time period in question. Similarly, the years with *in minus* deviation, i.e. with a precipitation total lower than 90% of the norm, were also recorded 24 times (26% of the years).

In accordance with the estimations, annual precipitation totals for the years 1955–1980 recorded at the measurement stations in central Poland show much greater variability than those recorded in southern Poland (Table 1). The values of the variability coefficient (Cv) are between 16.2 % in Gąbin and 21.9 % in Lubanie. Variability coefficients calculated by Wójcik and Marciniak (1993) for the years 1951–1990 take similar values, and amount to 21.8% for Włocławek, 18.9% for Płock, 22.7% for Bydgoszcz and 22.2% for Toruń. In southern Poland this coefficient is from 12.5% in Wadowice to 17.6% in Ojców. However, Kożuchowski (1986) showed the growing tendency of the precipitation variability in Poland in the last century and, according to him, it is “a characteristic feature of the evolution of precipitation relations in Poland during the last century” (p. 452). He supposes the reasons for this variability to be general changes in the global circulation of the atmosphere, which is a shift from a zonal to a meridian form of circulation.

Precipitation tendencies

Prior to the analysis of the precipitation variability courses, the values of the determinant coefficient R^2 were calculated on the basis of the determined linear regression. Moreover, the statistical significance of the tendencies was estimated; this was based on the statistical value t_{n-2} resulting from the following formula:

$$t_{n-2} = \frac{R}{\sqrt{1-R^2}}\sqrt{n-2}, \text{ where:}$$

R^2 – value of the determinant coefficient in a linear regression, n – amount of the measurement data in a sequence, which was compared to the critical value t_α of the *t*-Student distribution for the statistical significance $\alpha = 0.05$ and *n*-2 of the degrees of freedom. In the case when the $t_{n-2} > t_\alpha$ relation was recorded, the measurement sequence in question showed a tendency which is statistically essential.

A characteristic feature of precipitation recorded at the measurement stations in central Poland is their significant positive development during the study period. The only station which showed a negative tendency was the Strzelce measurement station located in the south-eastern part of the area. Linear regression for all the remaining stations is not statistically essential (Table 2). Concerning the above, the dependencies recorded between the real and theoretical values should be treated only as approximate.

In southern Poland significant diversities in precipitation tendencies were recorded. All the measurement stations located in both the Upper Silesian Conurbation and Zakopane showed a distinct positive tendency in annual precipitation totals. At all the remaining measurement stations, however, a negative tendency of insignificant value predominated. Nevertheless, the calculated precipitation tendencies at all the measurement stations in southern Poland were not statistically essential.

Seasonal oscillations of precipitation

Sobczyk (2001) describes seasonal oscillations as "regular quantitative changes in the course of mass phenomena repeated during the same calendar unit, year in, year out" (p. 349). Seasonal oscillations make it possible to define the role of cyclical factors in shaping precipitation. This issue is essential, as

Table 2. Precipitation tendencies in Central Poland (a) and South Poland (b)

No.	Station	Data sets	Annual sums of precipitation			Monthly sums of precipitations		
			Trend	Coefficient of determination R^2	Statistically significant trend for $\alpha = 0.05$	Trend	Coefficient of determination R^2	Statistically significant trend for $\alpha = 0.05$
a)								
1	Włocławek	1955–1980	y = 0.2814x + 528.7	0.0004	Non-Essential	y = 0.0043x + 43.705	0.0001	Non-Essential
2	Baruchowo	1955–1980	y = 0.7897x + 517.03	0.0042	Non-Essential	y = 0.0075x + 42.796	0.0005	Non-Essential
3	Brześć Kuj.	1955–1980	y = 3.4899x + 422.04	0.0871	Non-Essential	y = 0.0263x + 34.976	0.0064	Non-Essential
4	Gostynin	1955–1980	y = 0.2168x + 548.46	0.0003	Non-Essential	y = 0.0036x + 45.386	0.0001	Non-Essential
5	Łanięta	1955–1980	y = 1.5426x + 514.56	0.0168	Non-Essential	y = 0.0125x + 42.664	0.0015	Non-Essential
6	Lubanie	1955–1980	y = 3.7251x + 493.48	0.0574	Non-Essential	y = 0.0281x + 40.91	0.0055	Non-Essential
7	Łąck	1955–1980	y = 4.0017x + 538.78	0.07	Non-Essential	y = 0.0297x + 44.747	0.0063	Non-Essential
8	Gąbin	1955–1980	y = 1.9374x + 561.5	0.0241	Non-Essential	y = 0.0154x + 46.554	0.0018	Non-Essential
9	Płock Radziwie	1955–1980	y = 2.1863x + 538.37	0.0269	Non-Essential	y = 0.0172x + 44.628	0.0023	Non-Essential
10	Strzelce	1955–1980	y = -2.1682x + 586.19	0.0231	Non-Essential	y = -0.0129x + 48.426	0.0013	Non-Essential
b)								
1	Katowice	1955–1980	y = 4.0889x + 687.42	0.0726	Non-Essential	y = 0.0301x + 57.18	0.0048	Non-Essential
2	Ząbkowice	1955–1980	y = 3.5969x + 686.4	0.0554	Non-Essential	y = 0.0266x + 57.083	0.004	Non-Essential

Table 2. cont.

3	Brynica	1955–1980	y = 2.52x + 734.33	0.0253	Non-Essential	y = 0.019x + 61.055	0.0021	Non-Essential
4	Rokitnica	1955–1980	y = 3.1268x + 687.56	0.0493	Non-Essential	y = 0.0228x + 57.247	0.0032	Non-Essential
5	Ojców	1955–1980	y = 5.9566x + 632.7	0.1314	Non-Essential	y = 0.0428x + 52.726	0.0108	Non-Essential
6	Piwoń	1955–1980	y = 1.8995x + 719.28	0.0158	Non-Essential	y = 0.0146x + 59.787	0.0013	Non-Essential
7	Kraków	1955–1980	y = -1.7005x + 734.34	0.0136	Non-Essential	y = -0.0104x + 60.916	0.0006	Non-Essential
8	Stróża	1955–1980	y = -1.5274x + 970.33	0.0091	Non-Essential	y = -0.0095x + 80.63	0.0003	Non-Essential
9	Mszana Dolna	1955–1980	y = -1.3197x + 909.74	0.005	Non-Essential	y = -0.0076x + 75.51	0.0002	Non-Essential
10	Zakopane	1955–1980	y = 3.3675x + 1099.3	0.0249	Non-Essential	y = 0.0262x + 91.3	0.0012	Non-Essential
11	Nowy Sącz	1955–1980	y = -2.9303x + 789.21	0.0363	Non-Essential	y = -0.0187x + 65.399	0.0014	Non-Essential
12	Wadowice	1955–1980	y = -1.5053x + 832.44	0.0129	Non-Essential	y = -0.0093x + 69.135	0.0004	Non-Essential
13	Sucha	1955–1980	y = 0.0462x + 1020.8	0.00001	Non-Essential	y = 0.0016x + 84.871	0.00001	Non-Essential
14	Żywiec	1955–1980	y = 2.2793x + 921.65	0.0121	Non-Essential	y = 0.0178x + 76.589	0.0009	Non-Essential
15	Maków	1955–1980	y = -2.0321x + 1009.4	0.0114	Non-Essential	y = -0.013x + 83.865	0.0004	Non-Essential
16	Rabka	1955–1980	y = -0.0458x + 923.39	0.00001	Non-Essential	y = 0.0011x + 76.722	0.000004	Non-Essential
17	Raba Wyżna	1955–1980	y = -2.3665x + 945.87	0.0187	Non-Essential	y = -0.015x + 78.5	0.0007	Non-Essential

Source: The author's calculations based on *Opady atmosferyczne*…

solving it enables specialists to foresee the volume of precipitation happening at specific periods of time or months of an annual or multi-annual cycle.

The course of seasonal oscillations in monthly precipitation totals in an annual cycle was similar at the two study areas. In central Poland monthly precipitation totals were above the multi-annual mean in the period between May and August (Fig. 2). Only at the measurement stations at Strzelce and Gąbin was this period of time one month longer. In this area one distinctive seasonal culmination of monthly precipitation totals was recorded; at all the measurement stations it was noted in July (Table 3). The maximum precipitation above the multi-annual mean ranged from 70.6% at the Łanięta measurement station to 93.5% in Włocławek and 95.4% in Brześć Kujawski. During all the other months precipitation was seasonally lower than the multi-annual mean. Minimum monthly totals were recorded in February at almost all the measurement stations; the only station which recorded them in January was Łanięta. The largest deviation *in minus* from the multi-annual mean is a characteristic feature of the precipitation in Brześć Kujawski, while the smallest is recorded at the measurement stations in the south-western section of this study area (Gąbin, Łanięta, Strzelce and Łąck). The range between the seasonal maximum and minimum deviations of the monthly precipitation totals from the multi-annual mean is from about 107% (Łanięta) to about 145% (Brześć Kujawski) (Table 3). The ranges become characteristically 'flattened' at measurement stations in the western part of the area in question; their values there do not exceed 120%.

In terms of the differences between the maximum and minimum values of seasonal oscillations, the measurement stations in southern Poland can be divided into two categories. The first group contains the measurement stations located in the north-eastern part of the area (Fig. 1), i.e. within the Upper Silesian Conurbation, where one distinct maximum of seasonal oscillation was recorded in June. The fact that there is one July maximum was proved by Czaja and Radosz (1989) at all the measurement stations in the Upper Silesian Conurbation. Minimum values of seasonal oscillation of precipitation are recorded in February; the only second minimum of similar importance in January is recorded in Katowice. The February minimum does not compose a characteristic feature of the entire Upper Silesian Conurbation. In this area minimum seasonal precipitation totals are also recorded in January and March. Czaja and Radosz (1989) delimited the meridional zonality of the minimum precipitation occurrence. According to them, however, "precipitation minimums do not show chronology, while the precipitation zones do not show homogeneity" (p. 184). In the set of measurement stations analysed, seasonal oscillations range from 117.4% in Brynica and Rokitnica to about 131% in Katowice.

The second group of stations includes those which record two similar maximums in July and June. It is only at the measurement stations in Zakopane and Sucha that the maximums are recorded in a diverse order. Minimum values of the seasonal oscillations of precipitation are recorded from January till March. In this area the difference between the extreme values of the seasonal oscillations is high, ranging between 119.4% in Kraków and 157.7% in Zakopane (Table 3). The average variability of the seasonal oscillations of the monthly precipitation is much higher at the measurement stations located in southern Poland. The standard deviation of the absolute levels of seasonal oscillations ranges from 22 mm to about 25 mm at the measurement stations within the Upper Silesian Conurbation, and from about 26 mm to 52 mm in the remaining part of the area. In central Poland this index does not exceed about 18 mm.

Accidental oscillations of precipitation

The remaining elements estimated for the individual months make it possible to assess how intense the influence of the meteorological oscillations over precipitation in a given year is. The remaining element, therefore, explains the influence of the elements which cannot be treated as a tendency or seasonal oscillations of precipitation.

The October maximum of accidental oscillations, a feature of precipitation totals in an annual cycle, is a phenomenon common to both analysed areas (Fig. 2). This means that at all the measurement stations of the area in question October is the month in which the seasonal rhythm of precipitation is broken by accidental precipitation of the highest deviation from the multi-annual mean for this month. Only the measurement stations at Mszana Dolna and Rabka recorded a higher level of accidental deviation, in February and January respectively. For the measurement stations in central Poland maximum accidental deviations of precipitation in its annual cycle amounted from 71% in Baruchowo to about 85% in Lubanie. Similarly, in southern Poland the range of maximum values is from 62% in Rabka to 82% at the Piwoń measurement station.

Table 3. Seasonal and accidental variations of precipitation in Central Poland (a) and South Poland (b)

No.	Station	Altitude of the measurement station [m asl]	Mean monthly precipitations [mm]	Maximum values of the seasonal oscillations		Minimum values of the seasonal oscillations		Amplitude seasonal oscilations A [%]	The level of variation (diversity) of seasonal oscillations S(gi) [mm]	The volume of coefficient of the remaining variability V [%]
				month	level [%]	month	level [%]			
a)										
1	Włocławek	62	44.4	VII	193.5	II	58.9	134.7	17.51	63.3
2	Baruchowo	89	44.0	VII	171.3	II	58.5	112.8	15.31	58.2
3	Brześć Kuj.	86	39.1	VII	195.4	II	50.1	145.3	17.21	61.9
4	Gostynin	90	46.0	VII	186.3	II	59.4	127.0	17.84	60.1
5	Łanięta	125	44.6	VII	170.6	I	63.5	107.1	15.31	56.3
6	Lubanie	76	45.0	VII	185.3	II	56.9	128.4	17.63	64.5
7	Łąck	85	49.4	VII	175.4	II	61.8	113.6	17.39	58.6
8	Gąbin	102	49.0	VII	175.3	II	63.6	111.7	16.03	58.4
9	Płock–Radziwie	63	47.3	VII	183.7	II	58.6	125.1	17.68	57.1
10	Strzelce	130	46.4	VII	172.6	II	62.9	109.7	15.64	59.4
b)										
1	Katowice	284	61.9	VII	190.7	I / II	59.5 / 59.6	131.1	25.2	48.4
2	Ząbkowice	314	61.2	VII	190.3	II	60.3	130.1	24.3	47.2

Table 3. cont.

3	Brynica	285	64.0	VII	184.4	II	67.0	117.4	22.0	46.7
4	Rokitnica	300	60.8	VII	184.9	II	67.5	117.4	22.2	47.4
5	Ojców	370	59.4	VII / VI	170 / 165.9	II	61.3	108.7	22.8	48.9
6	Piwoń	302	62.1	VII	184.6	II	66.7	117.9	22.0	48.0
7	Kraków	206	59.3	VII / VI	176.9 / 171.7	II	57.8	119.4	26.2	50.4
8	Stróża	307	79.1	VII / VI	190.5 / 172.3	II	60.7	129.8	35.5	48.6
9	Mszana Dolna	410	74.3	VII / VI	192.1 / 186.0	III	53.9	138.2	36.6	50.0
10	Zakopane	857	95.4	VI / VII	203.6 / 193.2	I	45.9	157.7	52.0	46.1
11	Nowy Sącz	292	62.6	VII / VI	197.0 / 182.4	II	49.1	147.9	31.2	52.2
12	Wadowice	260	67.7	VII / VI	189.2 / 171.6	I	55.9	133.3	30.7	48.2
13	Sucha	340	85.1	VI / VII	179.5 / 176.8	II	62.3	117.2	35.8	46.6
14	Żywiec	353	79.4	VII / VI	185.0 / 172.5	III	58.0	127.1	34.3	50.7
15	Maków	350	81.8	VII / VI	195.0 / 178.1	III	55.6	139.4	39.1	52.3
16	Rabka	511	76.9	VII / VI	195.0 / 172.9	III	55.1	139.9	35.2	49.7
17	Raba Wyżna	600	76.2	VII / VI	191.9 / 180.0	III	57.2	134.7	35.8	44.5

Source: The author's calculations based on *Opady atmosferyczne*….

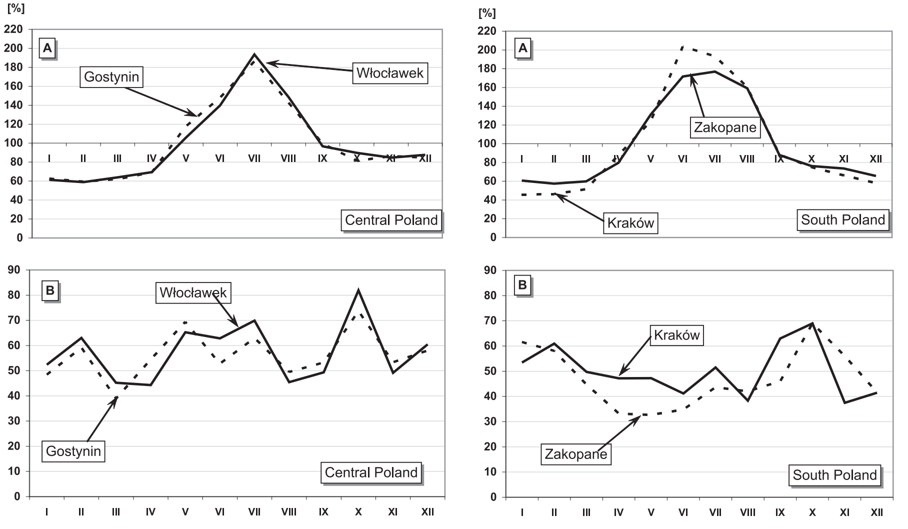

Fig. 2. Seasonally (A) and accidentally (B) changeability of precipitations in the choosing stations in the areas study.

The remaining variation coefficient diversifies the two study areas very well. In the case of precipitation in central Poland, this coefficient ranges from about 56% to about 64%, while in southern Poland it is much lower, ranging from about 44% to about 52% (Table 3). This means that in central Poland the role of accidental precipitation in total precipitation variability is much more important than in southern Poland.

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