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# CHARACTERISATION OF VARIABILITY OF ATMOSPHERIC PRECIPITATION AT SELECTED STATIONS OF THE MAZURY LAKE DISTRICT IN THE YEARS 1951-2000

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A b s t r a c t. The paper presents a study on the variability of atmospheric precipitation at selected stations of IMGW (Institute of Meteorology and Water Management) – Elbląg, Olsztyn, Mikołajki and Suwałki – located within the Mazury Lake District. The study covered a period of 50 years (1951-2000). The analysis was 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.

K e y w o r d s: atmospheric precipitation, Mazury Lake District

## INTRODUCTION

Atmospheric precipitation is an element of weather that is characterised by notable variation from year to year. The observed variability of precipitation conditions causes continued interest in research on the problem (Żmudzka 2002). The Mazury Lake District is also characterised by considerable differentiation of the level and distribution of precipitations in particular years, and the precipitation conditions of that area for the years 1951-2000 have not, so far, been the object of detailed analysis (Hutorowicz *et al*. 1996, Nowicka and Grabowska 1989, Szwejkowski *et al*. 2002).

## MATERIAL AND METHOD

The source material was data concerning monthly sums of atmospheric precipitations originating from meteorological stations at Elbląg, Olsztyn, Mikołajki

and Suwałki, located within the area of the Mazury Lake District. The study spanned the period of 50 years (1951-2000). The analyses were made with the use of 30-year moving sample, for monthly and seasonal values – spring (March-May), summer (June-August), autumn (September-November), winter (December-February), warm half-year (April-September), cold half-year (October-March), and year. It was assumed that the variables had gamma distributions with parameters $\alpha$ and $\beta$. Distribution parameters of each of the created series were estimated with the method of greatest credibility according to formulae given by Johnson and Kotz (Otop, Kuchar 2004 after Johnson and Kotz, 1970). For each of the obtained distributions of precipitation sums the critical values *(Xo)* were calculated according to the formula $P(X>X_O) = p_O$, where $X$ is the monthly (or seasonal) sum for various values of probability ($po$ = 0.99, 0.95, 0.90, 0.10, 0.05 and 0.01).

Variability of precipitations was calculated with the use of the precipitation standard according to Mrugała 1997, the upper and lower limits of the norm being determined, respectively, as mean values of deviations (positive and negative) from the mean 50-year precipitation total. For the determined precipitation standards the probability of negative and positive anomalies was calculated. The mean values, series of critical values of precipitation sums, and values of probability of anomalies were described by means of linear trends.

## RESULTS AND DISCUSSION

Analysis of monthly values of coefficients of regression of linear trend (Tab. 1) showed that in successive 30-year periods, at all of the stations under study, significantly increasing trends of atmospheric precipitation occurred in January, March, June and December. In September the increase was statistically significant in Olsztyn, Mikołajki and Suwałki, in May in Mikołajki, and in October in Elbląg. The increasing trends of precipitations were the highest in March, and amounted to 0.3-0.5 mm/year in the localities under study. Significant decreasing trends, on the other hand, occurred in July in Elbląg, Olsztyn and Mikołajki, and in August at all stations, in February in Suwałki, and in April and May in Elbląg. Significant decrease in precipitations was the highest in July and amounted to from 0.6 mm to 1 mm $year^{-1}$.

Atmospheric precipitations calculated for the seasons (Tab. 2) showed significant increasing trends at all localities in spring, winter, in the cold half-year, and in autumn (only in Elbląg and Olsztyn). Significant decreasing trends in precipitations occurred at all the stations under study in the summer season and in the warm half-year (with the exception of Mikołajki). Annual precpitations in successive 30-year periods showed significant increasing trends only in Mikołajki. The trends of changes in precipitations during the successive 30-year periods are simi-

lar (in terms of direction) to changes in precipitation sums for the Mazury Lake District in the years 1951-1995, studied by Banaszkiewicz *et al*. (2002), and to trends of averaged values of precipitation sums for Poland for the years 1951-2000 analysed by Żmudzka (2002).

Table 3 presents the values of the upper and lower limits of precipitation standards at the stations under study. The values of the lower limit of the standard were low in the months from January to April (14-25 mm), and in October and December (24-31mm); in the summer months the corresponding values were 39-53 mm. The values of the upper limit of the standard varied from 36-50 mm in Fabruary and March to 109-130 mm in July. In the months from July to December the values of the upper limit of the precipitation standard were the highest in Elbląg. Among the seasons of the year, the highest ranges of normal precipitation values were recorded for the summer - from 172-315 mm in Elbląg to 164-277 mm in Suwałki. The range of the lower limit of the standard for the year was from 502 mm in Mikołajki to 557 mm in Elbląg. The upper limit of the standard was the highest in Elbląg (776 mm) and decreased in the eastern direction (to 667 mm in Suwałki). The broadest ranges of values of normal annual precipitations were recorded for Elbląg, and the smallest for Suwałki. Normal precipitations of the summer and of the warm half-year decreased within the area under study in the direction from the west to the east. The values of the presented monthly and seasonal precipitation standards are similar to the standard values for the Mazury Lake District for the period of 1951-1990 given by Mrugała (2001).

After the determination of critical values from the gamma distributions for various values of probability and their trends for the monthly and seasonal standards, the probability of occurrence of positive and negative anomalies was calculated.

The probability of occurrence of precipitations exceeding the upper limit of the standard (positive anomaly) showed significant increasing trends (Tab. 1) in August (at all the stations), and in most of the localities in May, July, November and February (with the exception of Elbląg, where insignificant decreasing trends were observed). Increasing trends were also observed, usually at a significant level (Tab. 2), at all the localities in summer, in the warm half-year, and in the year (with the exception of Mikołajki).

Decreasing, mostly significant trends of occurrence of high precipitations were found for all the localities under study in January, March, April, June, September and December. In the studied seasons, significant decreasing trends of the probability of occurrence of high precipitations (Tab. 2) were recorded for winter and the cold half-year (for all the localities), autumn (in Elbląg and Olsztyn), and spring (in Olsztyn and Mikołajki).

**Table 1.** Monthly coefficients of regression of linear trend (mm year$^{-1}$) of the precipitation in the Mazury Lake District in successive 30-year sequences of moving sample from 1951-2000

| Station | Characteristics | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elbląg | Average precipitation[1] | 0.31*** | 0.10 | 0.47*** | -0.13** | -0.13** | 0.46*** | -1.02*** | -0.47*** | 0.18 | 0.35** | 0.10 | 0.25*** |
| | Probability[2] | -0.003*** | -0.004*** | -0.008*** | 0.006*** | -0.004** | -0.003** | 0.006*** | 0.001 | 0.002*** | 0.002 | -0.007*** | -0.007*** |
| | Probability[3] | -0.005*** | -0.001 | -0.009*** | -0.000 | 0.004*** | -0.003*** | 0.006*** | 0.004*** | -0.003*** | -0.003** | 0.002* | -0.001 |
| Olsztyn | Average precipitation[1] | 0.32*** | -0.03 | 0.39*** | 0.06 | 0.06 | 0.23* | -0.99*** | -0.78*** | 0.20* | -0.00 | 0.08 | 0.22*** |
| | Probability[2] | -0.003*** | -0.002** | -0.008*** | 0.003*** | -0.006*** | -0.001 | 0.008*** | 0.004** | 0.002* | 0.001 | -0.006*** | -0.005*** |
| | Probability[3] | -0.005*** | 0.001** | -0.005*** | -0.003*** | 0.002*** | -0.002* | 0.007*** | 0.007*** | -0.004*** | -0.000 | 0.002 | -0.002** |
| Mikołajki | Average precipitation[1] | 0.24*** | 0.01 | 0.44*** | -0.05 | 0.15** | 0.35*** | -0.61*** | -0.19** | 0.35*** | -0.01 | -0.16 | 0.10* |
| | Probability[2] | -0.005*** | -0.002** | -0.008*** | 0.006*** | -0.008*** | -0.001 | 0.004*** | 0.001 | -0.000 | -0.001* | 0.002 | -0.005*** |
| | Probability[3] | -0.004*** | 0.001 | -0.007*** | -0.002*** | 0.001 | -0.003*** | 0.004*** | 0.002** | -0.006*** | 0.001 | 0.002* | -0.000 |
| Suwałki | Average precipitation[1] | 0.20*** | -0.13*** | 0.31*** | 0.04 | -0.09 | 0.16** | -0.00 | -0.77*** | 0.14** | -0.04 | -0.13 | 0.19*** |
| | Probability[2] | -0.001* | 0.000 | -0.006*** | 0.004*** | -0.003* | 0.000 | 0.002* | 0.004*** | -0.000 | -0.001 | -0.003* | -0.005*** |
| | Probability[3] | -0.004*** | 0.003*** | -0.005*** | -0.002** | 0.003* | -0.002*** | 0.001 | 0.005*** | -0.002** | 0.001 | 0.005*** | -0.002** |

Values significant at the level of: * 0.05; ** 0.01;*** 0.001,
[1]Average precipitation totals,
[2]Probability of precipitation below lower limit of norm,
[3]Probability of precipitation above upper limit of norm.

**Table 2.** Seasonal coefficients of regression of linear trend (mm/year) of precipitation in the Mazury Lake District in successive 30-year sequences of moving sample from 1951-2000

| Station | Characteristic | III-V | VI-VIII | IX-XI | XII-II | IV-IX | X-IV | Year |
|---|---|---|---|---|---|---|---|---|
| Elbląg | Average precipitation totals | 0.21* | -1.03*** | 0.64*** | 0.66*** | -1.11*** | 1.59*** | 0.48 |
| | Probability[1] | -0.002*** | 0.002* | -0.002* | -0.006*** | -0.001 | -0.007*** | -0.005*** |
| | Probability[2] | -0.001 | 0.004*** | -0.004*** | -0.004*** | 0.005*** | -0.008*** | 0.002** |
| Olsztyn | Average precipitation totals | 0.51*** | -1.55*** | 0.27* | 0.51*** | -1.23*** | 0.98*** | -0.26 |
| | Probability[1] | -0.006*** | 0.007*** | -0.001 | -0.004*** | 0.002** | -0.004*** | -0.002** |
| | Probability[2] | -0.002** | 0.005*** | -0.002** | -0.004*** | 0.005*** | -0.005*** | 0.002** |
| Mikołajki | Average precipitation totals | 0.55*** | -0.44** | 0.19 | 0.35*** | 0.02 | 0.62*** | 0.64*** |
| | Probability[1] | -0.001*** | 0.002* | -0.002** | -0.006*** | -0.002* | -0.005*** | -0.004*** |
| | Probability[2] | -0.003*** | 0.001** | 0.000 | -0.003*** | 0.001 | -0.002* | -0.000 |
| Suwałki | Average precipitation totals | 0.25** | -0.61*** | -0.03 | 0.26*** | -0.52** | 0.40*** | -0.12 |
| | Probability[1] | -0.004*** | 0.002* | -0.002** | -0.004*** | -0.003** | -0.003*** | -0.004*** |
| | Probability[2] | -0.001 | 0.003** | 0.001* | -0.002** | 0.005*** | -0.001* | 0.004*** |

Values significant at the level of: * 0.05; ** 0.01;*** 0.001;
[1]Probability of precipitation below lower limit of norm,
[2]Probability of precipitation above upper limit of norm.

**Table 3.** Lower and upper limits of precipitation norm (mm) in the Mazury Lake District in the years 1951-2000

| Station | Norms | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | III-V | VI-VIII | IX-XI | XII-II | IV-IX | X-IV | I-XII |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elbląg | 1 | 23 | 19 | 18 | 23 | 35 | 44 | 45 | 50 | 48 | 31 | 37 | 29 | 87 | 172 | 141 | 89 | 326 | 207 | 557 |
| Olsztyn | 1 | 22 | 17 | 21 | 25 | 34 | 41 | 53 | 45 | 41 | 27 | 37 | 28 | 95 | 172 | 129 | 87 | 309 | 195 | 521 |
| Mikołajki | 1 | 18 | 14 | 20 | 24 | 36 | 50 | 43 | 45 | 35 | 26 | 33 | 24 | 103 | 167 | 112 | 65 | 311 | 176 | 502 |
| Suwałki | 1 | 20 | 15 | 20 | 24 | 32 | 47 | 49 | 39 | 35 | 28 | 36 | 27 | 94 | 164 | 108 | 77 | 300 | 191 | 510 |
| Elbląg | 2 | 53 | 44 | 40 | 57 | 74 | 105 | 130 | 124 | 112 | 94 | 76 | 68 | 149 | 315 | 237 | 145 | 520 | 307 | 776 |
| Olsztyn | 2 | 53 | 40 | 50 | 60 | 72 | 112 | 116 | 103 | 92 | 85 | 71 | 65 | 172 | 297 | 210 | 139 | 477 | 302 | 724 |
| Mikołajki | 2 | 45 | 36 | 47 | 60 | 70 | 116 | 109 | 102 | 73 | 92 | 70 | 52 | 158 | 293 | 205 | 108 | 440 | 274 | 683 |
| Suwałki | 2 | 50 | 37 | 47 | 54 | 68 | 98 | 122 | 106 | 79 | 83 | 70 | 54 | 159 | 277 | 202 | 117 | 423 | 282 | 667 |

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

The probability of occurrence of precipitations below the lower limit of the standard in the 30-year series of the moving sample (Tab. 1) displayed a significant increasing trend in April and July at all the stations under study. Significant increasing trends were also observed in August - in Olsztyn and Suwałki, and in September – in Elbląg and Olsztyn. In the studied seasons, the probability of occurrence of negative anomaly (Tab. 2) showed significant increasing trends in summer (at all the localities) and in the warm half-year – in Olsztyn. These trends indicate increasing probability of the occurrence of precipitation deficits in those periods and localities.

The analysis showed also that significantly decreasing trend of the occurrence of negative anomaly applies to all of the localities under study in May. In the months from November to March such a trend occurred most frequently at a significant level at all stations under study. Decreasing trends of negative anomaly, at all stations under study, were usually significant in spring, winter, in the cold half-year, and in the year. The observed trends indicate decreasing probability of the occurrence of precipitation deficit in those periods (and localities).

## CONCLUSION

Analysis of average monthly and seasonal sums of precipitations for the years 1951-2000 from selected meteorological stations of the Mazury Lake District (Elbląg, Olsztyn, Mikołajki, Suwałki), with the use of 30-year moving sample, showed that the sums of precipitations, at all of the stations studied, were characterised by significant increasing trends in January, March, June and December, and in spring, winter, and in the cold half-year. Significant decreasing trends occurred in July (with the exception of Suwałki), in August and in summer, and in the warm half-year (with the exception of Mikołajki).

Analysis of the probability of occurrence of precipitations below the lower and above the upper limits of the precipitation standard permitted the identification of four types of variability of their trend directions:

Type 1. Probability of occurrence of precipitations below the lower and above the upper limits of precipitation standard in the studied months and seasons displayed decreasing trends, indicating decreasing variability of precipitation sums in those periods.

This type of variability was characteristic (at all the localities) of precipitations of January, March and December (except for the upper limit of the standard in Mikołajki). Regression coefficients attained the highest values in March, from –0.005 to –0.009 mm year$^{-1}$. Also precipitations of spring, winter and the cold half-year most frequently showed, at all the localities under study, significantly

decreasing trends of the probability of occurrence of positive and negative anomalies. Such trends were also observed in autumn, in Elbląg and Olsztyn.

Type 2. Probability of occurrence of precipitations below the lower and above the upper limits of precipitation standard displayed increasing trends (increasing probability of occurrence of both positive and negative anomalies), i.e. there was instability of precipitations in the months and seasons.

In the months of July and August (at all the stations studied) and in November (in Mikołajki) mostly significantly increasing trends were found for the precipitation sums of that type. Increasing probability of occurrence of abnormal precipitations was observed also, at a significant level, for the summer season (at all the localities studied) and for the warm half-year in Olsztyn.

Type 3. Probability of occurrence of precipitations below the lower standard *(negative anomaly)* showed an increasing trend, and probability of occurrence of precipitations above the upper limit of the standard *(positive anomaly)* displayed a decreasing trend, i.e. the frequency of high precipitations decreased, and the probability of occurrence of precipitation deficit increased.

Such trends appeared usually, at a significant level, at all the localities under study in April, and were also recorded for September and October in Elbląg and Olsztyn.

Type 4. Probability of occurrence of precipitations below the lower limit of the standard displayed a decreasing trend, and probability of occurrence of precipitations above the upper limit of the standard showed an increasing trend.

Trends of this type occurred mainly, at a significant level, in all the localities under study in May, and in the studied periods were significant for the autumn season in Suwałki, and for the whole year in Elbląg, Olsztyn and Suwałki.

## REFERENCES

Banaszkiewicz B., Szwejkowski Z., Nowicka A., 2002. Climate of Mazury Lake District, Part II, Trends of changes in basic meteorological elements in the region (in Polish), Fragmenta Agronomica, XVIX, 2 (74), 297-303.

Hutorowicz H., Grabowska K., Nowicka A., 1996. Characterisation of climatic conditions of Mazury Lake District (in Polish), Zesz. Probl. Post. Nauk Roln., 431, 21-29.

Mrugała S., 1997. Attempt at determination of natural standard and anomalies of atmospheric precipitations (in Polish). Prz. Geofiz., 42 (2), 169-174.

Mrugała S., 2001. Atmospheric precipitations with normal and abnormal level in the territory of Poland (1951-1990) (in Polish), Wydawn. UMCS, Wydz. Biologii i Nauk o Ziemi, Rozprawy Habilit. LXVI.

Nowicka A., Grabowska K., 1989. Characterisation of major elements of the climate of Warmia-Mazury Lake District, IV. Atmospheric precipitations (in Polish), Acta Acad. Agricult. Techn. Olst. Agricultura, 59, 105-113.

Otop I., Kuchar L., 2004. Variability of atmospheric precipitations of the summer season in Jelenia Góra in the years 1951-2000 (in Polish). Acta Sci. Pol., Formatio Circumiectus 3 (2) 101-111.
Szwejkowski Z., Nowicka A., Dragańska E., 2002. Climate of Mazury Lake District, Part. I, Temperature and atmospheric precipitations in the 45-year period of 1951-1995 (in Polish), Fragmenta Agronomica, XVIX, 2 (74), 285-295.
Żmudzka E., 2002. On the variability of atmospheric precipitations in the area of lowland Poland in the 2nd half of 20th century (in Polish), Wiadomości IMGW, Tom XXV (XLVII) 4, 23-38.

# CHARAKTERYSTYKA ZMIENNOŚCI OPADÓW ATMOSFERYCZNYCH WYBRANYCH STACJI POJEZIERZA MAZURSKIEGO W LATACH 1951-2000

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S t r e s z c z e n i e. Badano zmienność opadów atmosferycznych w wybranych stacjach IMGW (Elbląg, Olsztyn, Mikołajki i Suwałki) zlokalizowanych na Pojezierzu Mazurskim. 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.

S ł o w a k l u c z o w e: opady atmosferyczne, Pojezierze Mazurskie