Baltic Coastal Zone No. 13	
(53-65) 2009	Institute of Biology and Environmental Protection Pomeranian Academy Słupsk

EXTREME TWENTY-FOUR-HOUR PRECIPITATION SUMS IN NORTH-WESTERN POLAND

Małgorzata Kirschenstein

Institute of Geography, Pomeranian Academy in Słupsk,
ul. Partyzantów 27, 76-200 Słupsk, Poland
e-mail: mjk67@tlen.pl

Abstract

The paper presents an analysis of the extreme precipitation recorded in north-western Poland between 1951 and 1995. The author of the present paper selected a day with a maximal twenty-four-hour precipitation sum out of each month. The author also selected intervals characterized by specific twenty-four-hour values: 0.1-9.9 mm, 10.0-19.9 mm, 20.0-29.9 mm, 30.0-49.9 mm, 50.0-99.9 mm and ≥100 mm. The author selected frequencies of their occurrence and a monthly average and annual maximums' sum of precipitation. A concept of an extreme precipitation relates to twenty-four-hour sums 50.0-99.9 mm and ≥100 mm. Moreover the author selected the days with extreme twenty-four-hour sums ≥100 mm and specified the atmospheric circulation types, distinguished by B. Osuchowska-Klein (1975).

Key words: extreme precipitation sums, atmospheric circulation, north-western Poland

INTRODUCTION

Examining of the meteorological elements' extreme values remains one of the most important issues in climatology. The results of such occurrences might cause severe economic, social and environmental loses. According to Ozga-Zielińska and Ozga-Zieliński (2006) extreme occurrences are recorded quite rarely and they are characterized by extremely high (extreme maximums) or extremely low values (extreme minimums). This is a kind of occurrence that happens unexpectedly. It often means that people in the face of such occurrence are technically, economically or psychically unprepared (unprotected). The threshold value of the described occurrence classifying it as an extreme event might vary in relation to various situations, people, objects, regions etc. This kind of attitude demands specifying the threshold value above which an event might be regarded as the extreme one. Usually safety regulations specify the threshold values.

There is no definition that explains a concept of an extreme precipitation. The most popular topic connected with the described issue remains the one concentrating on torrential rains. According to Smosarski (1952) a torrential rain is characterized by an interrupted, continuous fall with a straight line or one part of a broken line running very steeply on a pluviograph. The Chomicz (1951) scale allows to compare the torrential rains in regard of their length of time and frequency. Olechnowicz-Bobrowska (1968) defines 6 categories corresponding with specific defined periods of time (in this case twenty-four-hour sums). The mentioned author also uses the following terms: a day characterized by very scant (0.1-1.0 mm), scant (1.1-5.0 mm), moderate (5.1-10.0 mm), moderately intensive (10.1-20.0 mm), intensive (20.1-30.0 mm) and very intensive precipitation (≥ 30.0 mm).

According to Cebulak and Pyrc (2006) an extreme precipitation in the Upper Vistula River Basin is characterized by a twenty-four-hour sum equal or exceeding 100 mm/24 h. They took into consideration the Chomicz (1951) scale when the threshold of 100 mm is exceeded by precipitation lasting 21 hours and is defined as an "intensive torrential rain".

The analysis presents problems connected with the issue of an extreme precipitation recorded in north-western Poland. The present paper includes the twenty-four-hour precipitation sums recorded in 14 research stations between 1951 and 1995 (Fig. 1). The purpose of the present paper is to determine whether an extreme precipitation might occur in the region of north-western Poland. The author selected a day with a maximal twenty-four-hour precipitation sum out of each month. The author also selected intervals characterized by specific twenty-four-hour values: 0.1-9.9 mm, 10.0-19.9 mm, 20.0-29.9 mm, 30.0-49.9 mm, 50.0-99.9 mm and ≥100 mm. The first interval includes all twenty-four-hour sums below 10 mm that is intervals 0.1-0.9, 1.0-4.9 and 5.0-9.9 mm. It was generalized, because the purpose of the present analysis is to define a structure of high (twenty-four-hour sum is ≥ 10 mm) and extreme precipitation. A concept of an extreme precipitation for the north-western regions of Poland refers to twenty-four-hour sums of 50.0-99.9 mm and ≥ 100 mm. Afterwards the author analyzed the selected days with extreme twenty-four-hour precipitation sums of ≥100 mm and determined the types of atmospheric circulation, defined by Osuchowska-Klein (1975).

The selected region includes the Southern Coastal Districts Border and the Pomeranian Lake District up to the Toruńska-Eberswaldzka Proglacial Stream Valley in the south and adjoining from the east the Lower Vistula River Valley (Fig. 1). According to Kirschenstein (2004) the analyzed area is influenced by an atmospheric circulation from the Baltic Sea that is not limited to a narrow coastal zone but its influence affects the whole area of north-western Poland. An atmospheric precipitation recorded in the analyzed area is also influenced by an atmospheric circulation from the Baltic Sea. Furthermore the area of the Baltic Sea is influenced by frequent low pressure media migrations, moving from the North Atlantic Ocean to the north-eastern regions of Europe, that are directly responsible for an intensive precipitation on the coast and the north-western incline of the Pomeranian Lake District. Coastal convergence observed in this area remains characteristic oddity of the coastal zone. It causes a considerable increase of precipitation sums in the vicinity from the coast (especially from August till November). Moreover a characteristic location of the northern part of the lake districts within range of influence of a secondary zonal pre-

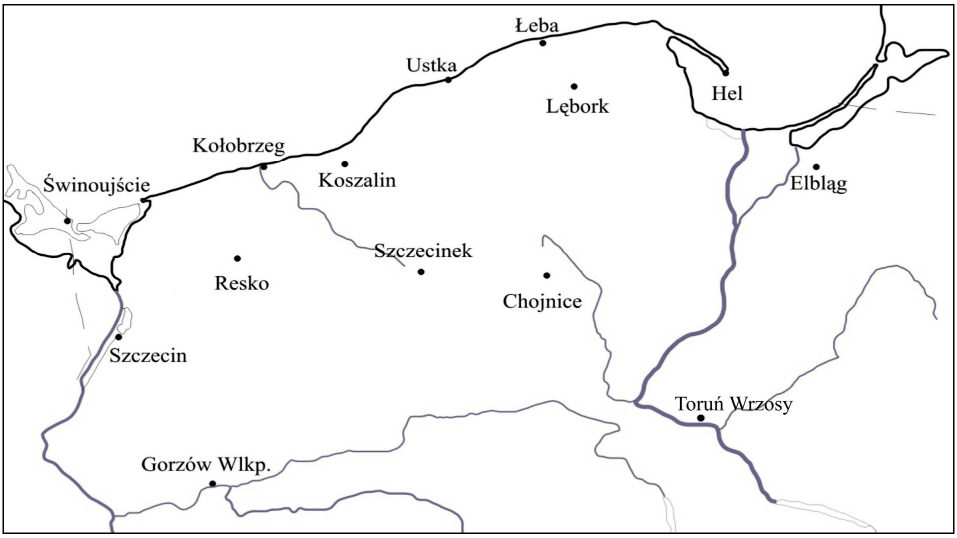

Fig. 1. Stations selected for this study

cipitation maximum, recorded in Europe at 60-70°N latitude, remains one of the most important features of the north-western Poland region.

The mentioned maximum is one of the effects of heat advection in the ocean, that moves the media of low pressure towards higher latitudes. Another important factor influencing the described region is its relief. Since it is very versatile and its highest elevations run from southern-west towards northern-east and are located parallel to the Baltic coast. Absolute heights of Lakeland elevations increase to the north-east from below 100 m to over 300 m above the sea level. In effect of this situation the conditions influencing precipitation on the north-western slope of the Pomeranian Lake District are considered more favorable than those on the south-eastern slope.

FREQUENCY OF MAXIMAL TWENTY-FOUR-HOUR PRECIPITATION SUMS

Frequency of precipitation in intervals with a specific twenty-four-hour sum allows to determine a structure of precipitation and their changes during the year. The collected data compared in a table (Tab. 1) and maps allow to draw a conclusion that the precipitation sums in particular intervals were characterized by the following features (Fig. 2):

1) The sums of 0.1-9.9 mm were recorded with a frequency of 41.3% during a year and varied from 51.9% in the south-eastern part of the analyzed region to 33.1% in the north-western part of the area. The maximum was recorded in February (78.5%), the minimum in August (14.8%). Precipitation was recorded with a high frequency in the cold season of a year (Tab. 1), usually from January to April (above 55% of frequency). During the analyzed period water ability of clouds and intensity of con-

Table 1

Frequency of maximal twenty-four-hour precipitation (in %)
in intervals in north-western Poland (1951-1995)

Intervals	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
0.1-9.9	64.1	78.6	66.8	55.1	29.8	17.1	16.2	14.8	24.1	37.9	44.1	46.5	41.3
10.0-19.9	33.2	19.5	30.5	36.8	48.9	42.7	38.1	40.0	42.9	43.1	45.8	49.2	39.2
20.0-29.9	2.7	1.6	2.5	7.1	15.8	23.7	22.8	23.1	22.2	13.5	7.9	3.0	12.2
30.0-49.9			0.2	1.0	5.2	13.8	16.5	16.7	9.2	5.2	2.2	1.3	6.0
50.0 -99.9		0.2			0.3	2.5	6.2	5.2	1.6	0.3			1.3
≥100						0.2	0.2	0.2					0.04
Average sum	100	100	100	100	100	100	100	100	100	100	100	100	100

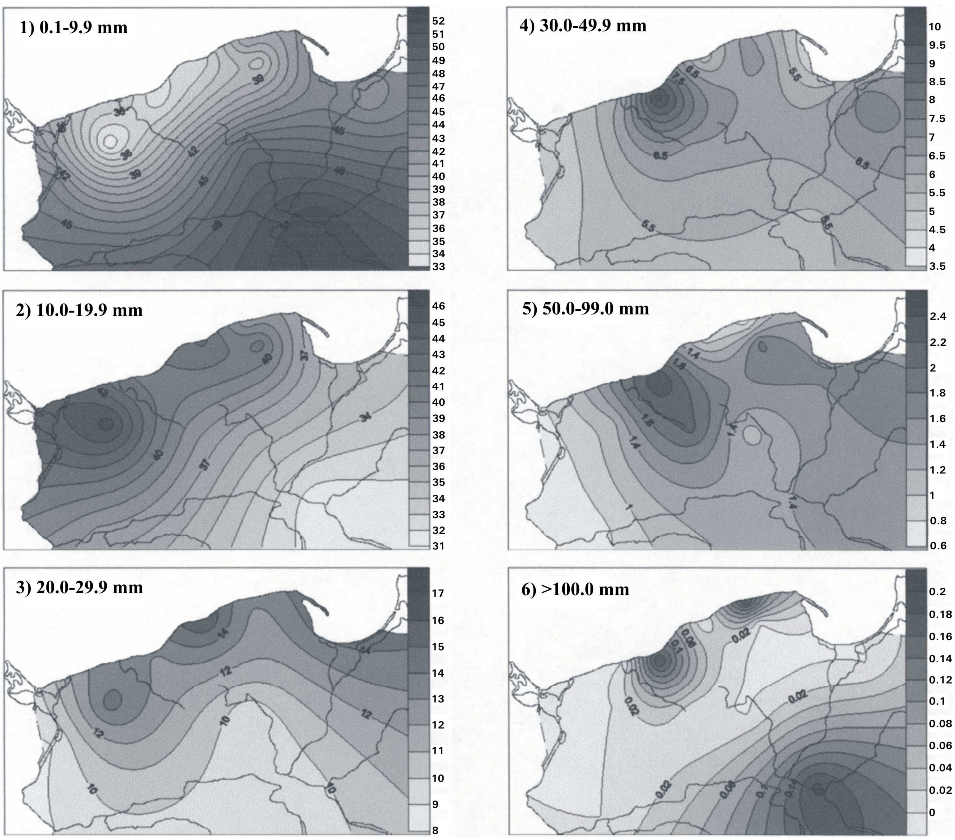

Fig. 2. Average annual frequency of maximal twenty-four-hour precipitation (in %) in intervals in north-western Poland (1951-1995), (Kirschenstein 2008)

vection was decreased and inflow of warm air from the Baltic Sea and the Atlantic Ocean to a colder land created favorable conditions to form clouds of a stratified type, that became a source of a frequent however not intensive precipitation. In summer months their frequency dramatically decreases, because the warmed up subsoil causes development of convection and it effects with precipitation characterized by twenty-four-hour sums exceeding 10 mm.
2) Twenty-four-hour sums 10.0-19.9 mm are classified as low precipitation. Their frequency was very high – 39.2% and their amount, on the contrary to the sums 0.1-9.9 mm increased from south-east to north-west (from 31.3% to 45.6%). The amount of these sums is considerably higher from May to December (with the maximum in December – 49.2%) than the one from January to April (with the minimum in February – 19.5%).
3) Twenty-four-hour sums 20.0-29.9 mm occurred with an annual frequency 12.2%. Their amount increases from the south to the north (from 9.1% to 16.1%). Most often they occur from June till September (above 20% of frequency). The maximum is recorded in June (23.7%), the minimum in February (1.7%). From this interval we can observe a considerable decrease of precipitation frequency in the cold season of a year.
4) The sums 30.0-49.9 mm made 6% of an annual frequency and most often occurred from June till August (the maximum 16.7% was recorded in August). The sums did not occur in January and February. They seldom occurred in March, April, November and December. In the north-western region of Poland the amount of the sums increases, approximately from the west to the north and north-east (from 4.4% to 9.8%).
5) The sums 50.0-99.9 mm occurred very seldom (1.3%). Precipitation might occur from May till October (with the maximum in July – 6.2%) and it was recorded only once in February (in Koszalin). The least amount of precipitation was recorded in the western part and gradually (similarly to the sums 30.0-49.9 mm) increases to the north and north-east direction.
6) The highest precipitation sums, exceeding 100 mm were recorded only three times: in Łeba (in July – 141.0 mm), Koszalin (in August – 101.3 mm) and Toruń (in June – 101.6 mm).
The results show that the twenty-four-hour sums below 10 mm occurred more frequently in the south part of north-western Poland than in the north one, while intensive precipitation above 10 mm most often occurred in the research centers located in the area of the South Baltic coast, especially in the region of Koszalin and Gdańsk coast. However according to the results concerning the precipitation frequency, the author managed to determine periods characterized by their most intensive frequency:

- the sums 0.1-9.9 mm most often occurred in the cold period of a year – usually from January till April;
- the sums 10.0-19.9 mm – from May till December;
- the sums 20.0-29.9 mm – from May till October;
- the sums 30.0-49.9 mm – from June till September;
- the extreme sums 50.0-99.9 and ≥100mm – from June till August.

AN AVERAGE SUM OF PRECIPITATION MAXIMUM

An average annual maximum sum in an interval 0.1-9.9 mm is 6.7 mm. Its monthly variations are small – from 5.8 mm in February to 7.9 mm in November (Tab. 2). The maxima and minima recorded in the remaining intervals occurred in various months:

– 10.0-19.9 mm – the maximum occurred in July (14.9 mm), the minimum in February (12.8 mm);
– 20.0-29.9 mm – the maximum in March and April (25.0 mm), the minimum in December (22.7 mm);
– 30.0-49.9 mm – the maximum in March (43.5 mm), the minimum in December (32.6 mm);
– 50.0-99.9 mm – the maximum in June (62.7 mm), the minimum in February (50.2 mm);
– ≥100 mm – the maximum in July (141.0 mm).

Table 2

Average maximum's sum (in mm) in intervals in north-western Poland (1951-1995)

Intervals	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
0.1-9.9	6.8	5.8	6.7	6.9	7.2	7.1	7.4	7.3	7.5	6.8	7.9	7.8	6.7
10.0-19.9	13.6	12.8	13.3	13.6	14.0	14.8	14.9	14.0	14.6	13.8	13.8	13.2	13.9
20.0-29.9	24.8	23.4	25.0	25.0	23.6	24.5	24.7	24.1	23.9	23.4	23.8	22.7	23.7
30.0-49.9			43.5	33.9	36.0	37.2	36.6	37.2	36.2	35.5	34.8	32.6	36.1
50.0 -99.9		50.2			54.3	62.7	62.5	61.1	61.0	62.4			61.3
≥100						101.6	141.0	101.3					114.6
Average sum	14.2	23.0	22.1	19.8	27.3	41.5	48.0	41.0	28.8	28.5	20.2	19.1	42.9

The differences between the average maximal and minimal sums are small (about 2 mm) in the intervals: 0.1-9.9 mm; 10.0-19.9 mm; 20.0-29.9 mm. As for the remaining intervals – the higher twenty-four-hour sum the higher difference: 30.0-49.9 mm – 10.9 mm, 50.0-99.9 mm – 12.5 mm, ≥100 mm – 39.4 mm. Furthermore, the average maximum sum recorded in these intervals considerably increases in the warm season of a year, especially from June to August (Tab. 2).

A general atmospheric circulation and local conditions remain the most important reasons influencing high precipitation, including extreme precipitation in summer months. The contents of steam in the air increases, and warmed up subsoil conditions developing of convection. Moreover the thermal contrasts recorded on the border of a land and the sea increase in the coastal zone of the Baltic Sea. Frequent, an intensive precipitation in August is considered a characteristic feature of the coastal zone. The occurrence is caused by cooling influence of the sea that might retard temperature increase and result with moving the maximum to August. The extreme sums above 100 mm are a very good example illustrating this occurrence. They were recorded in various months: in Toruń in June, in Łeba – in July, and in Koszalin only in August.

After comparing the maps of a twenty-four-hour precipitation sums' frequency (Fig. 2) to an average maximum sum (Fig. 3) the author of the present paper discovered that an increase of frequency does not mean an increase of precipitation sums. It is particularly noticeable in three intervals: 0.1-9.9 mm, 10.0-19.9 mm and 50.0-99.9 mm. In the interval 0.1-9.9 mm – precipitation recorded in the northern part occurred rarely in comparison to those recorded in the southern part but their average maxima were higher. Precipitation of 10.0-19.9 mm most often occurred in the north-western part, and their average maxima were lowest in comparison to the remaining area. However the author noticed that in the particular case of sums 50.0-99.9 mm recorded in the southern part of the analyzed area precipitation occurred rarely in comparison to those recorded in the northern part but their average maxima were high.

Geographic divisions show that high average maximum's sums occur in all intervals in the northern part of the analyzed area (Fig. 3). The eastern regions – in intervals

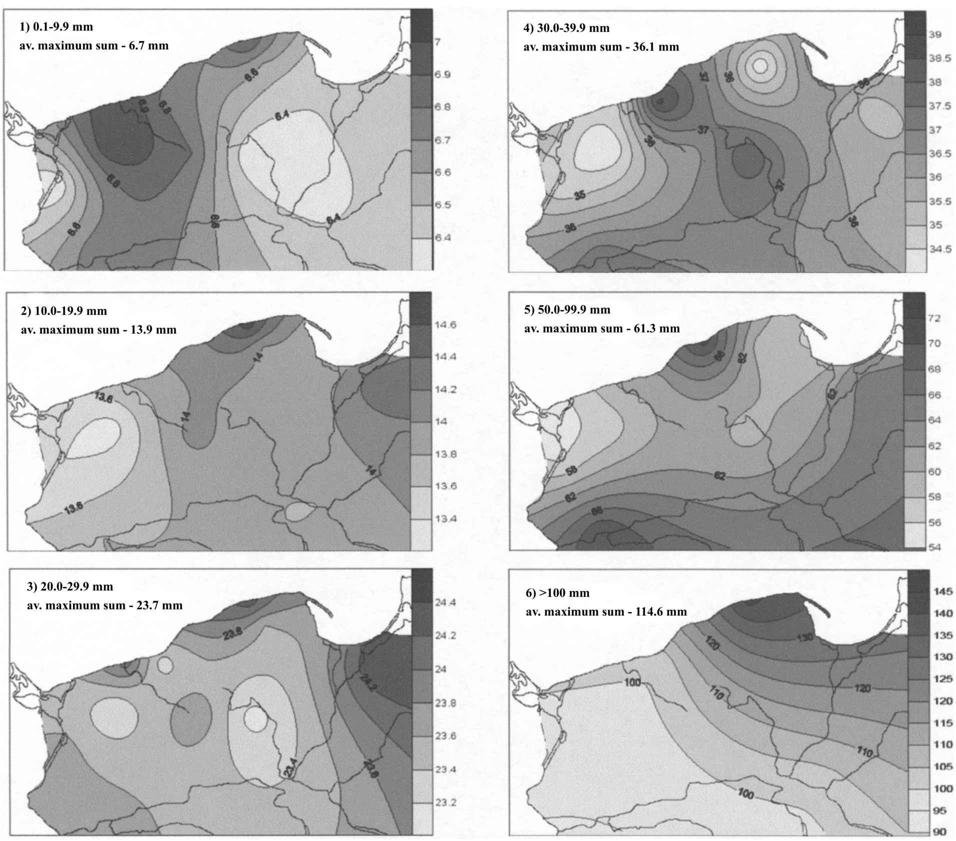

Fig. 3. Average annual maximum's sum (in mm) in intervals in north-western Poland (1951-1995), (Kirschenstein 2008)

10.0-19.9 mm, 20.0-29.9 mm and 50.0-99.9 mm and the southern regions – in intervals 30.0-49.9 mm and 50.0-99.9 mm are also characterized by high maxima. Whereas maxima in the western part are characterized by lower average in comparison to the records from the remaining parts of the analyzed area.

DAYS OF EXTREME PRECIPITATION SUMS

The author analyzed selected days with extreme twenty-four-hour precipitation sums ≥100 mm and determined atmospheric circulation types, defined by B. Osuchowska-Klein (1975): A – western cyclonal circulation, CB – north-western cyclonal circulation, Eo – north-eastern and eastern cyclonal circulation, F – south-eastern cyclonal circulation, B – southern cyclonal circulation, D – south-western cyclonal circulation, C_2D – western anticyclonal circulation, E_2C – north-western anticyclonal circulation, E – north-eastern anticyclonal circulation, E_1 – south-eastern and eastern anticyclonal circulation, D_2C – south-western and southern anticyclonal circulation, G – central anticyclonal circulation, BE – south transitional between cyclonal and anticyclonal circulation; X – situations of small similarity to the model types.
Such extreme precipitation were recorded three times: in Łeba (24/07/1988), Koszalin (18/08/1991) and Toruń (15/06/1980) during the analyzed many years' period 1951-1995, taking into account 14 research centers located in the region of north-western Poland. However M. Kirschenstein (2004) – the author of the present paper – compared twenty-four-hour precipitation sums collected in 185 research stations located in the region of north-western Poland and recorded between 1961 and 1980. The results show that during the analyzed time extreme precipitation occurred in 14 different research stations. The data will be used in further research, because it is important to determine the circulation types influencing extreme precipitation. The author prepared 8 maps (Fig. 4 – the maps were divided into categories according to dates). The maps include information about circulation type recorded on a previous day, and a type determining the analyzed day with extreme precipitation. Additionally the isohyets 50 and 100 mm were made thicker. The results show that an extreme precipitation occurred with circulation types: cyclonal – Eo, F and CB and anticyclonal – E_1 and C_2D. The maps allow to determine the characteristic features of precipitation distribution structure with the defined circulation types.

1) North-eastern and eastern cyclonal circulation type Eo caused an extreme precipitation 3 times:
   - 19/07/1975 – extreme sums above 50 mm occurred in the Chełmińskie and Dobrzyńskie Lake District, and precipitation ≥100 mm was recorded in one of the research stations. Western anticyclonal circulation C_2D was recorded on a previous day. A precipitation distribution confirms that circulation Eo influenced occurring of an extreme precipitation.
   - 08/08/1978 – extreme precipitation were recorded in 5 research centers located in the north-western and western parts of the analyzed area. Intensive precipitation were also recorded almost on the whole area of the coast. Precipitation distribution shows that circulation Eo influenced intensity of pre cipitation ho-

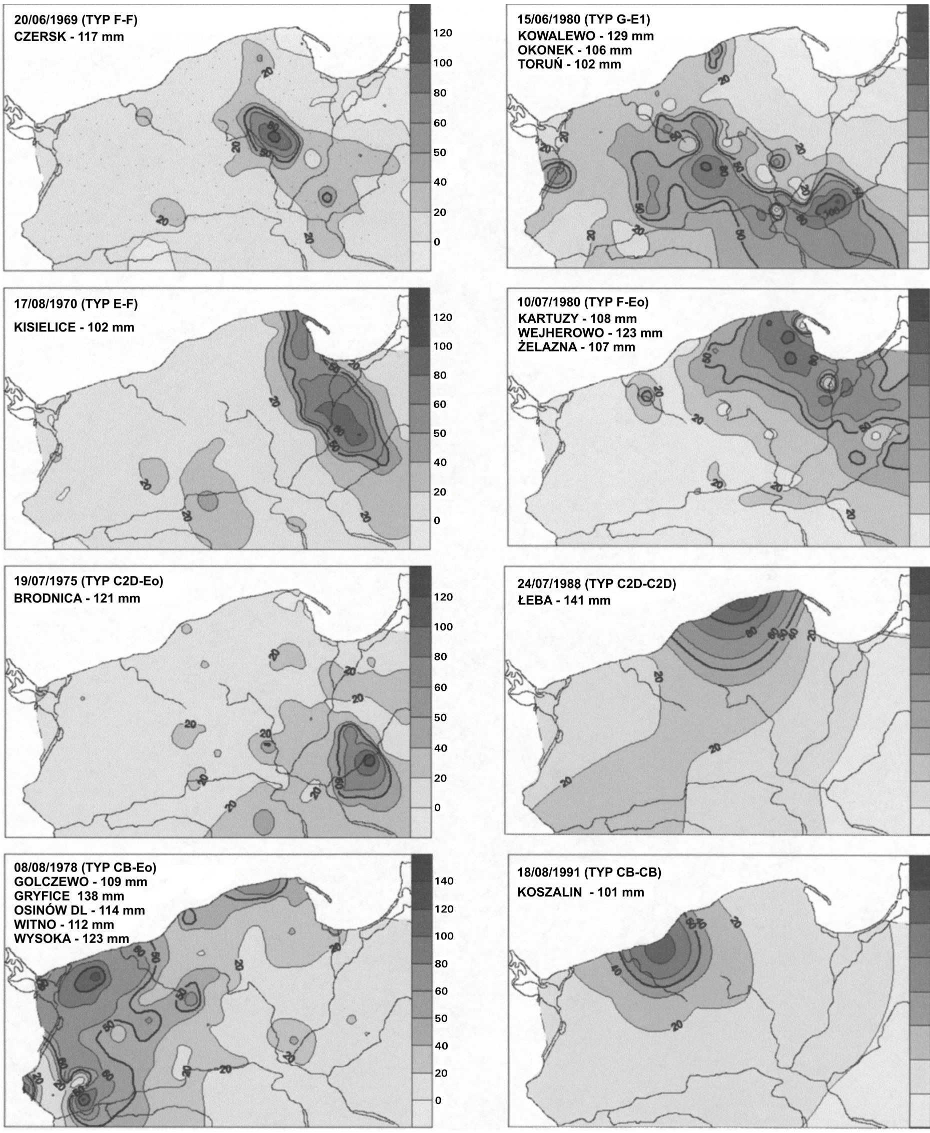

Fig. 4. Distribution of extreme sums of precipitation in north-western Poland in selected days. The maps include circulation type recorded on a previous day and a type determining the analyzed day with extreme precipitation. Additionally the isohyets with precipitation sums of 50 and 100 mm were made thicker (Kirschenstein 2008)

wever north-western cyclonal circulation CB, recorded on a previous day was also an important factor influencing precipitation patterns.

– 10/07/1980 – very intensive precipitation sums, above 50 mm were recorded in the north-eastern part. Extreme precipitation were recorded in three research centers. South-eastern cyclonal circulation F was recorded on a previous day. Precipitation distribution patterns shows that the rain fall was an effect of circulation Eo.

2) North-western cyclonal circulation type CB caused extreme precipitation on the 18/08/1991 in Koszalińskie Coast region, with the maximum in Koszalin.
3) South-eastern cyclonal circulation type F caused extreme precipitation twice:
   - 20/06/1969 – precipitation recorded on the Charzykowska Plain, in the Tucholskie Forests and the Chełmińskie Lake District.
   - 17/08/1970 – extreme precipitation occurred in an area stretching from the Iławskie Lake District, through the Starogardzkie Lake District, Żuławy Wiślane, the Kaszubskie Lake District, Gdańsk coastal region till the Helska Spit. North-eastern anticyclonal circulation E recorded on a previous day might also influence precipitation patterns.
4) South-eastern and eastern anticyclonal circulation type E_1 brought about extreme precipitation (15/06/1980) over a vast area including the Chełmińskie Lake District, the Brda River Valley and also the Krajeńskie, Wałeckie, Drawskie Lake Districts, Słowińskie coastal regions and the districts located in the vicinity of Szczecin.
5) Western anticyclonal circulation type C_2D caused an intensive precipitation on 24/07/1988 in the eastern part of the South Baltic coastal regions and the northern part of the Polanowska Upland and the Kaszubskie Lake District.

The analysis of selected days with extreme atmospheric precipitation shows clearly that precipitation might occur in any place of the researched area. The analysis of geographic distributions indicate important role of a direction of an air flow over the area of north-western Poland, respectively in cyclonal circulation or anticyclonal circulation. Types of cyclonal circulation CB and Eo and anticyclonal C_2D in the warm season of a year generate inflow of cold air over the warmer subsoil. Warming up of lower layers of the subsoil results in forming of convective currents that bring about cumulus clouds. Intensive warming up might transform the clouds into a cumulus – rainy type and effect with storms and heavy rains. However at cyclonal F and anticyclonal E_1 types one can observe inflowing of warm air from the east and south east that might bring about convection and result in precipitation of stormy character. M. Dubicka (1994) confirms that type F is characterized by very high relative humidity of air (over 80%), while E_1 is characterized by high temperatures (above the standard – positive departures reach even 6°C) and twenty-four-hour temperature's amplitudes often above the standard, relative humidity does not exceed 70%.

CONCLUSIONS

The results of the research show that an extreme precipitation that exceed security standards causing social, economic and environment dangers occur in the areas of north-western Poland, twenty-four-hour sums 50.0-99.9 mm were registered from May till October and in February, whereas sums ≥100 mm were recorded only in summer months.

The author confirms that during the analyzed many years' period 1951-1995, an extreme precipitation 50.0-99.9 mm recorded in 14 research stations located in the area of north-western Poland occurred 102 times (6%), whereas precipitation ≥100 mm – 3 times: in Łeba (24/07/1988), Koszalin (18/08/1991) and Toruń (15/06/1980). However taking into account data from 185 research stations, collected between 1961 and 1980 the author discovered that the sums ≥100 mm were recorded in 14 various stations. The author prepared maps for these days and determined atmospheric circulation type. The analysis shows that extreme precipitation occurred at cyclonal circulation types – Eo (north-eastern and eastern), F (south-eastern) and CB (north-western) and anticyclonal circulation types – E_1 (south-eastern and eastern) and C_2D (western). During 8 selected days extreme precipitation occurred: in June (twice) – at types F and E_1; in July (3 times) – at types Eo (twice) and C_2D and in August (3 times) – at types Eo, F and CB. Cyclonal types caused extreme precipitation at 6 days. During the warm season of a year, at circulation types with northern component one can observe inflowing of cold air over the area of north-western Poland, whereas at south-eastern and eastern types one can observe inflowing of very warm air, most often with high relative humidity. In both cases advection of the air might bring about convection and result in precipitation with extreme sum.

Characteristics of selected days show that extreme precipitation (50.0-99.9 mm and ≥100 mm) might occur almost in any place of the researched area. Both intensity of precipitation and a place of occurrence depend on direction of an air flow, appropriately in cyclonal or anticyclonal circulation and on qualities of inflowing air mass (e.g. temperature, stream contents).

After comparing the maps of a twenty-four-hour precipitation sums' frequency to the average maximum sum the author of the present paper discovered that an increase of frequency does not mean an increase of precipitation sums. In the interval 0.1-9.9 mm – precipitation recorded in the northern part occurred rarely in comparison to those recorded in the southern part but their average maxima were higher. Precipitation of 10.0-19.9 mm most often occurred in the north-western part, and their average maxima were lowest in comparison to the remaining area. However the author noticed that in the particular case of sums 50.0-99.9 mm recorded in the southern part of the analyzed area precipitation occurred rarely in comparison to those recorded in the northern part but their average maxima were high. Moreover high average maximum sums occur in all intervals recorded in the northern part of the researched area. The eastern regions – in intervals 10.0-19.9 mm, 20.0-29.9 mm and 50.0-99.9 mm and the southern regions – in intervals 30.0-49.9 mm and 50.0-99.9 mm are also characterized by high maxima. Whereas maxima in the western part are characterized by lower average in comparison to the records from the remaining parts of the analyzed area.

REFERENCES

Cebulak E., Pyrc R., 2006. Metody opracowania zdarzeń ekstremalnych na przykładzie opadów atmosferycznych o natężeniu >100 mm/dobę w dorzeczu górnej Wisły w XX i XXI wieku. (Methods of extreme events elaboration with precipitation over 100 mm/day as an example in the upper Vistula basin in the 20th and 21st century). Series: *Monografie – Zagrożenie środowiska naturalnymi zjawiskami ekstremalnymi*. IMGW, Warszawa, 9--26, (in Polish).

Chomicz K., 1951. Ulewy i deszcze nawalne w Polsce. (The torrential rains and extreme precipitation). *Wiad. Służby Hydrol. i Meteor*., 2, 3, 177-260, (in Polish).

Dubicka M., 1994. Wpływ cyrkulacji atmosfery na kształtowanie warunków klimatu (na przykładzie Wrocławia). (Influence of atmospheric circulation on the climate conditions with Wrocław as an example). *Acta Univ. Wratisl., Stud. Geogr.* LX, (in Polish).

Kirschenstein M., 2004. Rola cyrkulacji atmosferycznej w kształtowaniu opadów w północno-zachodniej Polsce. (Role of atmospheric circulation in falls forming in north-west Poland). PAP Słupsk, (in Polish).

Kirschenstein M., 2008. Ekstremalne dobowe sumy opadów w północno-zachodniej Polsce w latach 1951-1995. W: Świadomość ekologiczna a rozwój regionalny w Europie Środkowo-Wschodniej. (Extreme daily precipitation totals in north-western Poland for the 1951-1955 period. In: Ecological consciousness and regional development in Central Eastern Europe). AP Słupsk, 440-452, (in Polish).

Olechnowicz-Bobrowska B., 1968. Rozkład dni z opadem w Polsce. (Distribution of days with precipitation in Poland). *Przegl. Geofiz.*, 13 (21), 4, (in Polish).

Osuchowska-Klein B., 1975. Prognostyczne aspekty cyrkulacji atmosferycznej nad Polską. (Prognostic aspects of atmospheric circulation over Poland). *Prace IMGW*, z. 7, (in Polish).

Ozga-Zielińska M., Ozga-Zieliński B., 2006. Metody oceny zdarzeń ekstremalnych na przykładzie zjawisk hydrologicznych. (Methods of estimation of extreme events based on the example of hydrological events). Seria: *Monografie – Zagrożenie środowiska naturalnymi zjawiskami ekstremalnymi.* IMGW. Warszawa, (in Polish).

Smosarski W., 1952. Bieg dobowy opadów i burz w Poznaniu. (Diurnal cycles of precipitation and storms on Poznań). *PTPN. Prace Komisji Matematyczno-Przyrodniczej*. Poznań, (in Polish).

EKSTREMALNE DOBOWE SUMY OPADÓW W PÓŁNOCNO-ZACHODNIEJ POLSCE

Streszczenie

W pracy przybliżono problematykę ekstremalnych opadów w północno-zachodniej Polsce. Badanie ekstremalnych wartości elementów meteorologicznych to jedno z najważniejszych zagadnień klimatologii. Występowanie tych elementów może spowodować straty ekonomiczne, społeczne czy środowiskowe. W analizie uwzględniono dobowe sumy opadów z 14 stacji, obejmujące lata 1951-1995. Dla obszaru północno-zachodniej Polski za opad ekstremalny przyjęto sumy dobowe 50,0-99,9 mm i ≥100 mm, następnie przeprowadzono analizę wybranych dni, w których wystąpiły ekstremalne dobowe sumy opadów ≥100 mm i określono typy cyrkulacji atmosferycznej, wyróżnione przez B. Osuchowską-Klein (1975).

Z przeprowadzonych analiz wynika, że na obszarze północno-zachodniej Polski występują opady ekstremalne, które przekraczają granice bezpieczeństwa, powodując zagrożenia społeczno-gospodarcze i środowiskowe. Sumy dobowe 50,0-99,9 mm pojawiały się od maja do października oraz w lutym, natomiast sumy ≥100 mm występowały tylko w letnich mie-

siącach. W badanym wieloleciu 1951-1995, przy uwzględnieniu 14 stacji z obszaru północno-zachodniej Polski ekstremalne opady 50,0-99,9 mm wystąpiły 102 razy (6%), natomiast opady ≥100 mm – 3 razy: w Łebie (24.07.1988 r.), Koszalinie (18.08.1991 r.) i Toruniu (15.06.1980 r.). Jednakże, przy uwzględnieniu większej liczby stacji (185 stacji dla okresu 1961-1980) sumy ≥100 mm wystąpiły w 14 innych stacjach. Dla tych dni wykonano mapy i określono typ cyrkulacji atmosferycznej. Otrzymano, że ekstremalne opady występowały przy typach cyrkulacji cyklonalnej – Eo (północno-wschodnia i wschodnia), F (południowo-wschodnia) i CB (północno-zachodnia) oraz antycyklonalnej – E_1 (południowo-wschodnia i wschodnia) i C_2D (zachodnia). W wybranych 8 dniach opady ekstremalne wystąpiły: w czerwcu (2 razy) – przy typach F i E_1; w lipcu (3 razy) – przy typach Eo (2 razy) i C_2D i w sierpniu (3 razy) – przy typach Eo, F i CB. W 6 dniach przyczyną opadów ekstremalnych były typy cyklonalne.

W ciepłym okresie roku, przy typach cyrkulacji ze składową północną na obszar północno-zachodniej Polski napływa chłodne powietrze, natomiast przy typach południowo-wschodnich i wschodnich napływa bardzo ciepłe powietrze, często o dużej wilgotności względnej. W obu przypadkach adwekcja powietrza może prowadzić do rozwoju konwekcji i w rezultacie powstają opady o ekstremalnej sumie.