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EXTREME PRECIPITATION EVENTS ON THE NORTHERN SIDE OF THE TATRA MOUNTAINS

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ABSTRACT: This article reviews the occurrence and variability of extreme precipitation on the northern slope of the Tatra Mountains (southern Poland), using rainfall amounts of duration from 1 to 30 days. Daily data from 76 years (1927-2002) are used for the Hala Gąsienicowa meteorological station at 1520 m a.s.l. This is the place with the heaviest rainfall in Poland. The highest daily precipitation total (300 mm) was recorded on 30 June 1973 during a northern cyclonic situation. For longer durations extreme values of precipitation were observed during different years. In July 1934 the highest 3-day total reached 422 mm, and during the 11 days between 16 to 26 July 2001 the total amount of rainfall reached 500 mm. In the last 7 years the precipitation totals and the number of extreme events are distinctly greater than in the previous part of the analysed 76 years period, although a strong influence on the results may be the data from the extreme year 2001. However, an earlier period saw extreme precipitation concentrated during the years 1958-1978. A transition to a rather wetter phase of climate has been noted since 1995. However, there is no sign for any of the elements studied of any departure that has exceeded the values typical for fluctuations of climate in the 20th century, and which could therefore be taken as indication a permanent change in the climate.

KEY WORDS: climatic change, extreme precipitation events, Tatra Mountains, Poland.

INTRODUCTION

The Tatra Mountains are the highest part of the Western Carpathians and are influenced strongly by the heavy precipitation in southern Poland (Niedźwiedź 1992). Sometimes, especially during the summer season, extreme rainfall

amounts cause catastrophic floods in the large area of the upper Vistula basin. During the 20th century more than 41 significant flood events occurred in this region caused by the strong precipitation in Carpathian Mountains (Cebulak 1998, Cebulak and Niedźwiedź 2000). The best known events took place in July 1934, 1970 (Niedźwiedź 1972) and 1997 (Niedźwiedź 1999). According to the orographic effect the northern slope of the Tatra range is especially affected by extremely high precipitation with daily totals achieving 300 mm (Cebulak 1983, 1992a), which is the highest value ever measured in the whole of Poland (Paszyński and Niedźwiedź 1999).

Since 1995 the frequency of local heavy rains connected with thunderstorms has probably increased in southern Poland (Cebulak and Niedźwiedź 1997). After prolonged rains in July 1997 the new record level of summer precipitation occured in summer 2001. All these extreme precipitation events play an important role on morphogenetic processes (Klapa 1980), and in intensifying the denudational system in the mountains (Kotarba et al. 1987) causing large amounts of erosion even in the form of debris-flows (Kotarba 1998). The intensity of these phenomena seems be as large as those during the Little Ice Age (Starkel 1996, 1999). There are some suggestions that the increase in the number of extreme events in the mountains is connected with a general acceleration of energy and mass circulation (Starkel 1999) caused by the increasing greenhouse effect (Obrębska-Starkel and Starkel 1991, Bednarz et al. 1994).

The main aim of this paper is investigation of the variability of selected extreme precipitation events in the Tatra Mountains during the last 76 years. I hope that a preliminary assessment is possible, about whether precipitation increased and whether extreme events have become more frequent during recent years or not.

MATERIALS AND METHODS

The most representative place for the northern side of the Tatra Mountains with a relatively long precipitation data series is selected for analysis to meet the aims of this paper. Daily data from 76 years (1927-2002) are used for the Hala Gąsienicowa meteorological station (49° 15'E, 20° 00'E) located at 1520 m a.s.l., strictly near the upper tree line. This is the place with the heaviest rainfall in Poland. The station is operated by the Institute of Meteorology and Water Management, as well as by the Institute of Geography and Spatial Organization, and data quality is very good. Measurements of daily precipitation total started in December 1926. But during the war there are breaks in the data: August-December 1939, January 1940, July-August 1944, and the whole year 1945.

Statistical analysis was possible for 27565 days. For each year were calculated the extreme values of precipitation totals for durations from 1 to 30 consecutive days. Also standard monthly and annual totals, as well as the winter (December-

February), spring (March-May), summer (June-August) and autumn (September-November) precipitation sums were analysed. Frequency, empirical probability and standard time series analyses of data were performed.

EXTREME PRECIPITATION

Hala Gąsienicowa has an average annual precipitation of 1690 mm which varied from 1038 in 1946 to 2626 mm in 2001 (Table 1). Above 42 percent of the annual total is observed during the summer, what is typical for this part of Europe. Spring precipitation (23 percent) is slightly above that of autumn (22 percent), and the winter precipitation is the least (13 percent). Variability of the presented element is greatest during the autumn season. Maximum monthly precipitation occurs in July (250 mm) with a relatively large coefficient of variability (55 percent). Extreme monthly totals varied from 38 mm in July 1928 to the exceptional value of 743 mm in July 2001. The highest monthly value for the whole of the Carpathians was 812 mm measured at the Lysa Hora peak in the Silesian Beskid Mountains in the territory of the Czech Republic in July 1997 (Niedźwiedź 1999). Amounts exceeding 500 mm were noted on four occasions: in July 1934 (684 mm), 1980 (622 mm), 1997 (560 mm) and 1960 (518 mm).

Table 1. Average and extreme precipitation totals (in mm) in Hala Gąsienicowa (1927-2002).

Element	Winter (DJF)	Spring (MAM)	Summer (JJA)	Autumn (SON)	Annual	Daily Maximum
Average	220	387	714	368	1689	90,0
Coeff. of variation (%)	32	27	30	32	17	51
Maximum	469	675	1439	672	2626	300,0
Year	1948	1940	2001	1931	2001	1973
Minimum	92	94	381	160	1038	34,7
Year	1997	1946	1990	1986	1946	1935

The highest daily precipitation total (300 mm) was recorded on 30 June 1973 during a northern cyclonic situation. This is the highest 24-hour amount of rainfall ever observed in the Carpathian Mountains (Cebulak 1983) as well as in the whole of Poland. The highest daily value for Central Europe was 345,1 mm on 30 July 1897 (Paszyński and Niedźwiedź 1999) in the Isera Mountains (Sudetes) at the Nova Louka (Neuwiese) station in the Czech Republic, and 313 mm in the Zinnwald (Erzgebirge) near the Czech-German border on 12 August 2002. Such large and prolonged rains are influenced by the orography, when the humid air masses are flowing perpendicularly to the mountain chain. All investigations indicate that such events are connected with the northern, north-eastern, and north-western cyclonic situations or cyclonic troughs (Cebulak 1992b, Lapin and Niedźwiedź 1984, Niedźwiedź 1972, 1999).

For longer durations, extreme values of precipitation were observed during different years. In July 1934 the highest 3-day total reached 422 mm. During 11 days between 16 and 26 July 2001 the total amount of rainfall reached 500 mm. Another wet period was observed on 26 June – 18 July 1934 with 685 mm during 23 days. The extreme value of 700 mm was exceeded on 26 days and 779 mm on 30 consecutive days (Table 2).

Table 2. Extreme precipitation totals (in mm) in Hala Gąsienicowa (1927-2002) for duration 1-30 days.

Duration days	Precipitation mm	Period	Duration days	Precipitation mm	Period
1	300,0	30 June 1973	16	592,0	25 July – 9 August 1991
2	392,5	16-17 July 1934	17	614,0	11-27 July 2001
3	422,4	16-18 July 1934	18	634,0	1-18 July 1934
4	438,7	15-18 July 1934	19	647,4	30 June – 18 July 1934
5	462,3	14-18 July 1934	20	656,9	29 June – 18 July 1934
6	465,3	13-18 July 1934	21	662,3	28 June – 18 July 1934
7	467,2	12-18 July 1934	22	679,0	27 June – 18 July 1934
8	473,2	11-18 July 1934	23	684,7	26 June – 18 July 1934
9	473,2	10-18 July 1934	24	685,1	22 July – 14 August 1980
10	482,7	14-23 July 1934	25	696,5	21 July – 14 August 1980
11	499,5	16-26 July 2001	26	700,1	21 July – 15 August 1980
12	561,6	16-27 July 2001	27	740,1	1-27 July 2001
13	570,2	15-27 July 2001	28	744,9	1-28 July 2001
14	575,8	14-27 July 2001	29	772,3	20 June – 18 July 1934
15	575,8	13-27 July 2001	30	779,4	19 June – 18 July 1934

Apart from prolonged extreme events sometimes the greatest erosion consequences have followed violent heavy rains caused by local thunderstorms. In the Tatra Mountains the maximum rainfall of 60 minutes duration exceeded 40-50 mm with a probability 1 percent (return period 100 years), and 30 mm with a probability 10 percent (once in 10 years). However, the maximum values for rainfall duration exceeded 60-80 mm with 1 percent frequency, and 40 mm with 10 percent frequency (Cebulak et al. 1986, Niedźwiedź 1986c, 1992).

Daily precipitation exceeding 200 mm was recorded three times during the 76 years (Table 3), but more than 100 mm was observed 25 times. Long term variability of daily maximum precipitation (Figure 1) indicates a small increasing trend (1,5 mm for 10 years) from 84 mm in 1927 to 95 mm in 2002, but the highest values occurred during the 1958-1978 period.

The most evident is variability of the number of days with precipitation above selected thresholds (Figure 2). For example the number of days with precipitation >10,0 mm changed from 49 in 1927 to 53 in 2002 with the small increasing trend of 1 day for a 20 years. The maximum number of such days was observed in 1948 (74), with a secondary maximum in 2001 (67 days).

Table 3. The number of days (n) with precipitation above particular thresholds in Hala Gąsienicowa, in relation (percent) to 27565 days of observation (1927-2002).

Threshold mm	Number of days	Percent	Threshold mm	Number of days	Percent
0,1	16161	58,6	80,0	61	0,2
1,0	12481	45,3	90,0	38	0,14
5,0	6821	24,7	100,0	25	0,09
10,0	3840	13,9	110,0	17	0,06
20,0	1543	5,6	120,0	12	0,04
30,0	754	2,7	130,0	10	0,04
40,0	404	1,5	140,0	7	0,03
50,0	239	0,9	150,0	4	0,015
60,0	150	0,5	200,0	3	0,011
70,0	96	0,3	300,0	1	0,004

For days with larger precipitation amounts the highest number was noticed in 2001. In this particular year the number of days with precipitation above 50 mm exceeded 13, and above 30 mm exceeded 22 days.

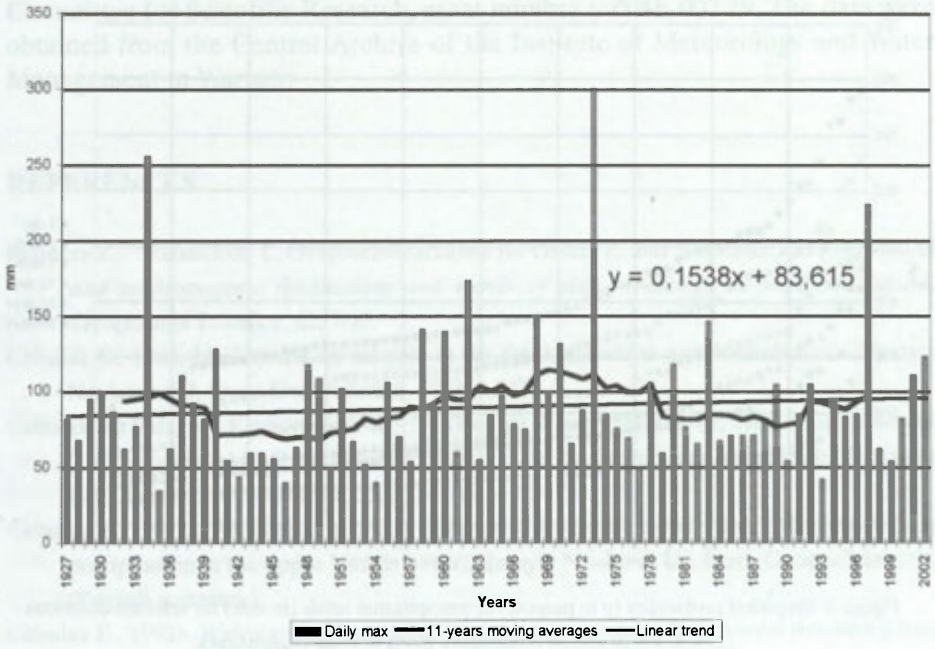

Figure 1. Long-term variability of daily maximum of precipitation in Hala Gąsienicowa.

The empirical probability (Figure 3) of long lasting precipitation enabled the evaluation of risk of occurrence of such precipitation. For example with the

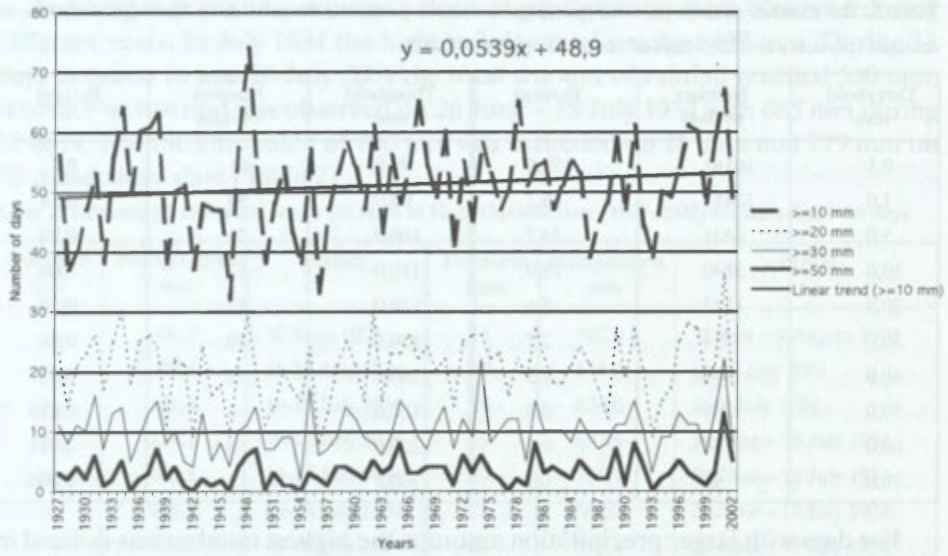

Figure 2. Variability of the number of days with precipitation above selected thresholds in Hala Gąsienicowa.

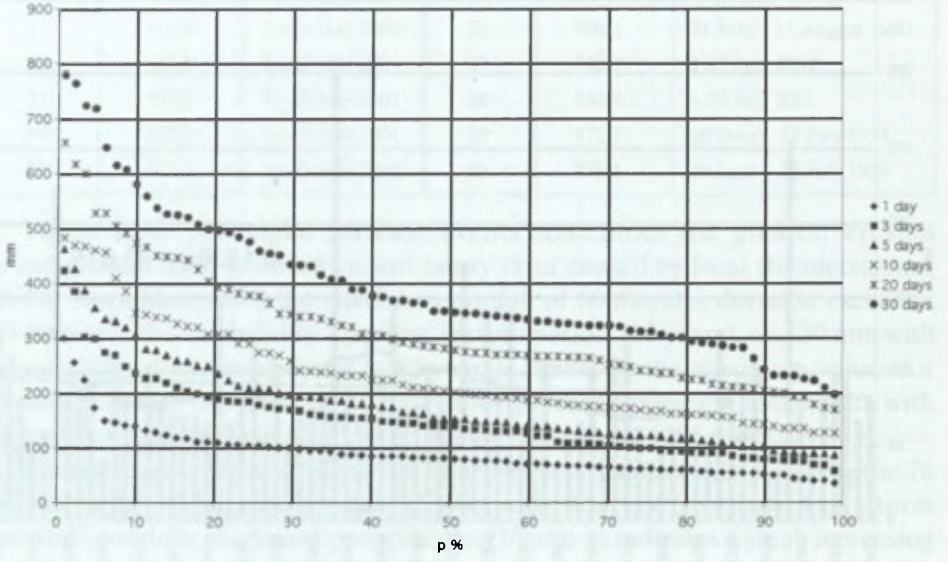

Figure 3. Empirical probability (p in percent) of precipitation totals (in mm) for selected durations (1, 3, 5, 10, 20 and 30 consecutive days) in Hala Gąsienicowa.

return period of 10 years (p=10 percent) daily precipitation exceeded 130 mm, 3 days precipitation exceeded 230 mm, 5 days – 300 mm, and 30 days total of precipitation could be higher than 600 mm.

CONCLUDING REMARKS

The problem of variability of large precipitation totals during the last 76 years on the northern slope of the Tatra Mountains was studied. There exists a large dispersion of extreme events of different duration.Extreme values exceeded 300 mm in 24 hours and near 800 mm on 30 days.

In the last 7 years precipitation totals and the number of extreme events is distinctly greater than in the previous part of the 76 year period analysed. It may be that the the data from the extreme year 2001 has a strong influence on the results. But it is generally evident that the previous period with extreme precipitation was concentrated during the years 1958-1978. A transition to a rather wetter phase of climate has been noted since 1995. However, there is no sign for any of the elements studied of any departure that has exceeded the values typical for fluctuations of climate in the 20th century, and which could therefore be taken as indicating a permanent change in the climate.

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