PROBABLE MAXIMUM PRECIPITATION (PMP) FOR A 1-, 2-, 3-, 4- DAYS DURATION OVER THE KIELCE UPLAND (POLAND)

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The PMP is defined as the greatest depth of precipitation for a given duration that is physically possible over a particular area and geographical location at a certain time of year (WMO 1986). There are different methods of evaluating PMP in various regions of the world (for example Hansen *et al.* 1982, WMO 1986, Foufoula-Georgiou, 1989; BOM, 1994; Collier, Hardaker, 1996; Svensson, Rakhecha, 1998; Rakhecha, Clark 2000). In Poland the researches in this field began at the beginning of XXI century. Meteorological and statistical analysis done for catchments in southern part of Poland (Western Carpathien) contributed to the appearance of a modified PMP calculation called probable credible precipitation (Ozga-Zielińska *et al.*, 2002).

In the above-mentioned study, there attempted to calculate PMP with the use of statistical method in 1-, 2-, 3-, 4- days in rain-gauges in Kielce Upland for durations and showed their spatial distribution.

Kielce Upland is macroregion located in the central part of Poland. It is a part of Małopolska Upland and includes a few mesoregions (Figure 1) of varied landscape in the form of low and medium hummock, with flattened plateau (Iłża Plateau and Gielniów Hummock in the north, Sandomierz Upland in the east, Szydłów Plateau in the south, Suchedniów Plateau in the north-west) surrounding Holy Cross Mts. – with the highest peak of 611 m a.s.l., the area is drained by the river network confluence Kamienna, Czarna Nida, Opatówka, Koprzywianka, Czarna Staszowska and Czarna Maleniecka catchments. The northern part of the area is drained by upper parts of rivers: Radomka and Iłżanka (Figure 1). The area is 6,8 thousand square kilometers (Kondracki, 2002).

In the study there were used daily sums of precipitation registered in the summer term (V–X) from 1961 to 2006 in 23 rain-gauges (Figure 1). The monthly observation sequences were examined homogeneously. Wald-Wolfowitz and Mann-Whitney tests were used. The results show that you cannot reject hypothesis about homogeneity of tested sequences.

For each rain-gauge there considered maximum yearly sum of rainfalls: from day, from consecutive two, three and four calendar days. The highest sum of rainfall in the rain-gauges – was registered in Kielce-Suków (155.2 mm) – in 2001. The rainfalls more 100mm/day were registered in few rain-gauges mostly located in Holy Cross Mts. It should also be mentioned that there appeared extremely high rainfall connected with the moving of thunderstorm cells, that resulted in high rainfalls beyond analysed rain-gauge. On 17 July 1967 in Mroczków (the western part of the Upland) there was a thunderstorm with the rainfall of 121.3 mm registered in 1 hour and 45 minutes (the day sum – 133.9 mm). Low maximum sum day in analysed time (no higher then 70 mm), was registered in Grabowiec, Kurzacze (Iłża Plateau) and in Łaziska.

The highest sum of rainfall in the region from 2 consecutive days was registered in 1970 and 2001. The maximum value was registered in rain-gauge Końskie. During two days (17 and 18 July) in 1970 the rainfall was 200.9 mm.
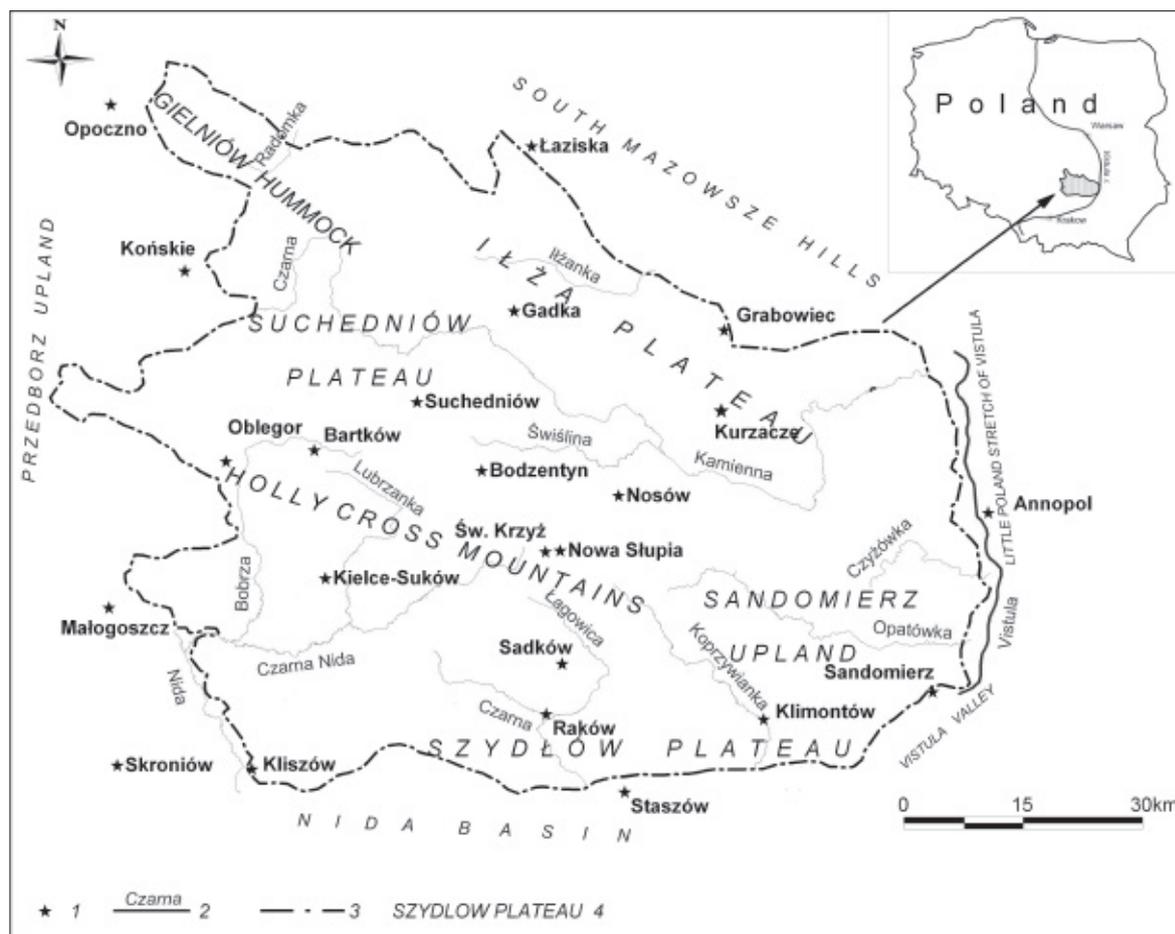
Figure 1. The study area with rain-gauge location (1- rain-gauge, 2- river, 3- Kielce Upland boundaries, 4- mesoregion)

The appearance of maximum sum of rainfall was connected with the moving (from west to east) of cold fronts or cyclones with well developed system of clouds (July 1970, August 1972, July 1997) or coming of warm and humid tropical air from Black Sea and its corvergence zone with polar maritime air over Kielce Upland (23-25 July 2001).

The calculation of PMP was done with the use of statistical method based on frequency equation (Hershfield, 1965):

$$PMP = P_n + k_m S_n$$

where:

P_n – mean of n maximum annual rainfalls,
S_n - standard deviation series n maximum annual rainfalls,
k_m - regional parameter.

A very important element of the equation is k_m – regional parameter:

$$k_m = \frac{P_{max} - P_{n-m}}{S_{n-m}}$$

The values of P_{n-m} and S_{n-m} are calculated in a standard way, but after eliminating from calculations the maximum observed value in a series for each rain-gauge (WMO 1986). To calculate k_m the metod was slightly modified – it eliminated all maximum yearly sum of rainfall higher than threshold value. Value which is based on five-time standard variation of calculating series.

The calculated value of k_m parameter in observed area varies independently on time period in the boundaries of 2.29 – 8.42. The highest value for one day – $k_m = 8.42$ was calculated on the basis of data from Kielce-Suków meteorological station, in the group of 2-day rainfall was in Końskie ($k_m = 6.91$), 3-day in Gadka ($k_m = 6.69$), 4-day in Klimontów ($k_m = 6.43$). The given values are much lower than obtained in identical time period of rainfalls in USA, Canada ($k_m(_{max}) = 25$) (WMO 1986), in Asia especially in Indochin peninsula or in China ($k_m(_{max}) = 19$) (Feng, He 1987). There are incredibly high values resulting in unrealistic PMP values. The calculated values k_m correspond with values obtained in Western Carpathien (Ozga-Zielińska et al. 2002, Suligowski 2005), but are much lower (especially in many-day durations) than in Kłodzka Basin (Suligowski, Kupczyk 2006). It is interesting that similar values of k_m parameter in one day are calculated for meteorological stations located in southern part of Malaysia peninsula (Desa et al., 2001; Desa, Rakhecha 2007), with a humid equatorial climate, with a low coefficient of variability in a series of maximum yearly sum of 24 h rainfall.

The calculation of PMP for each rain-gauge was done on the basis of highest value of k_m in a given period of time in any rain-gauge with the use of equation (1).

The highest value PMP for 1 day was calculated in Kielce-Suków – 219.9 mm. It is 1,4 times higher than the highest registered sum of rainfall – about 64.7 mm. The highest calculated in few days period was obtained in Końskie (266.1 mm per 2 days, 293.8 mm per 3 days). What is characteristic, it is a small increase of PMP with an increase of time period from 3 to 4 days. Spatial distribution of point PMP values in Kielce Upland in analysed time periods is illustrated by maps (Figure 2).
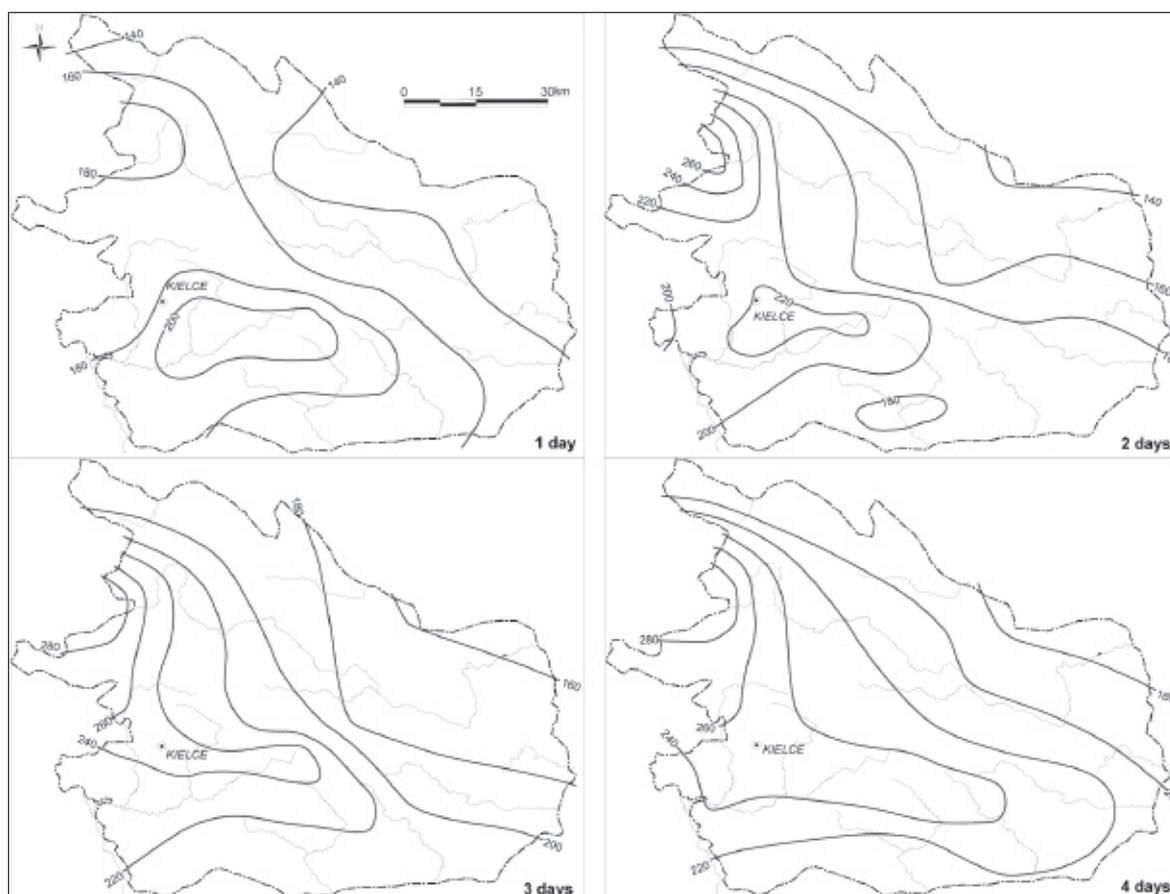

Figure 2. Spatial distribution of PMP (mm) in Kielce Upland

Generally speaking, the highest values of PMP for 1-day are in rain-gauges located in the higher part of Upland (Holy Cross Mts.). They surpass 200 mm and get lower on the verges of this area. The lowest values were in Sandomierz Upland and Iłża Plateau (E and NE part of the study area) (Figure 2). Spatial distribution of PMP in few-day time periods is similar, but from the beginning of 2 days there appears a clear centre of maximum PMP over western part of Kielce Upland (PMP> 260 mm per 3 days).

There is a correlation between the value of PMP and a mean of maximum sum of precipitation in series. There obtained a regression equation significant on alfa=0.05. The smallest relation is in the period of 1- and 4 days (r= 0.71).

Acknowledgements

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