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Methodology for the selection of 10-day maximum precipitation totals and their statistical analysis in the upper Hron region

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Abstract: In the paper 10-day maximum precipitation totals from 23 rain gauges over the period 1961 to 2000 in the Upper Hron River basin in Slovakia were analysed. A combined method, based on statistical criteria and on the evaluation of evaporation and runoff conditions during long precipitation events, has been used for the selection of the 10-day precipitation totals. N-year values of the 10-day annual maximum precipitation totals were estimated at-site separately for the summer and winter season using several distribution functions and parameter estimation methods. The distribution functions involved the Gumbel, Generalized Extreme Value, Pearson III, logPearson III, the General Logistic, Rossi, Pareto, Weibull and the Log-normal distribution functions. The parameters of distribution functions were estimated by the method of moments, the maximum likelihood method, probability-weighted moments and L-moments. The number of statistically acceptable distribution functions was tested and found rather high. A comparison

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of the resulting N-year rainfall estimated from these distribution functions showed that in the warm season they did not exhibit significant differences from a practical point of view.

Key words: extreme precipitation, L-moments, at-site frequency analysis, 10-day maximum precipitation totals

1. Introduction

Flood risk assessment often incorporates the need for the estimation of heavy rainfall for different durations. N-year several-day maximum precipitation totals (design rainfall) are usually estimated for engineering hydrology in order to provide hydrometeorological input for design flood estimation. In the past, only daily maximum precipitation totals were usually evaluated in Slovakia (*Šamaj et al., 1985*). Recently, intensive efforts to develop complex statistical methods for design rainfall estimation were reported in national meteorological offices of the world. In Great Britain, the Flood Studies Report (*FSR, 1975*) and then later the Flood Estimation Handbook (*FEH, 1999*), which aimed at methods of estimation of extraordinary flood events, included procedures for the estimation of the design precipitation. The German KOSTRA project (*Malitz, 1999; Bartels et al., 1997*), the Italian VAPI project (*Ferrari, 1994*), the HIRDS system in New Zealand (*Thompson, 2002*) and the Australian Guide to Rainfall and Runoff (*Institution of Engineers, 1987*) are other examples of such complex national studies on heavy precipitation risk assessment.

The objective of the UK Flood Estimation Handbook (*FEH, 1999*) was to develop a method for estimation of rainfall depth-duration-frequency relationships for durations between 1 hour and 8 days and for return periods up to 1000 years for arbitrary locations in Great Britain. The Focused Rainfall Growth Extension method (FORGEX) was developed to estimate the growth curve (*Reed et al., 1999; Faulkner et al., 1999*).

HIRDS (High Intensity Rainfall Design System) is a software package developed in New Zealand for estimating design rainfall values (*Thompson, 2002*). The system involves mapping of index rainfall (the median value of the annual maximum rainfall) and regional growth curves, respectively.

Design rainfall values in HIRDS are computed for 10 standard durations ranging from 10 minutes up to 72 hours.

Regionalization of extreme precipitation totals has been of interest in Switzerland as well. Rainstorms were investigated by *Geiger et al. (1986)*. This analysis resulted in the construction of several maps, which permitted the estimation of design rainfall values up to a duration of 5 days in any locality of the country. *Grebner (1995)* analysed summer precipitation totals of various durations (from 3 to 72 hours) in the northern parts of the Alps.

Within the KOSTRA project (*Malitz, 1999; Bartels et al., 1997*) input data for rainfall frequency analysis were maximum short-duration rainstorm intensities (from 5 minutes) and extreme precipitation totals of longer durations (up to 72 hours). The regionalization of the N-year design rainfall values (N = 0,5 … 100 years) was achieved by means of geostatistical methods with a grid resolution of 8.5 km × 8.5 km.

Analysis of annual maximum precipitation in the State of Washington (USA) (*Schaefer, 1990*) was carried out using the index rainfall methodology. The parameters of the Generalized Extreme Value distribution function were estimated by probability-weighted moments. In South Africa, L-moment-based regionalization method (*Hosking and Wallis, 1997*) was successfully applied to estimate design rainfalls (*Smithers et al., 2001*). For annual maximum precipitation totals of duration of 1, 3, 5 and 7 days *Gellens (2002)* has investigated k-day precipitation totals from one to 30 days over Belgium. In the Czech Republic regional frequency analysis of several-day precipitation totals was reported recently by *Kyselý et al. (2004)*.

In Slovakia the 2-day and 5-day precipitation totals were analysed in the upper Hron Region in *Stehlová et al. (2001), Jurčová (2002). Gaál and Lapin (2002)* analyzed k-day precipitation totals in the 100-year series from Hurbanovo, and in *Lapin et al. (2003)* the 1-, 2-, and 5-day precipitation totals were analysed for the whole territory of Slovakia.

A broad segment of rainfall frequency analysis methods is based on L-moments. Superiority of L-moments over the conventional moments has been suggested in a number of studies. For example, L-moments do not have sample size related bounds and are less sensitive to the presence of extraordinary values ("outliers") in the data sample than the conventional moments (*Hosking, 1990*). *Vogel and Fenessey (1993)* and *Peel et al. (2001)* showed that the L-moments ratio diagrams are better tools to identify the parent statistical distribution than the conventional moment ratio diagrams because the L-moment ratios are nearly unbiased. A detailed overview of regional frequency analysis based on L-moments can be found in the handbook of *Hosking and Wallis (1997)*.

In the past, only the daily maximum precipitation totals were usually evaluated in Slovakia (*Šamaj et al., 1985*). As the previous examples illustrate, it is necessary to deal with rainfalls of various durations. Issues involving testing new methodologies used for rainfall frequency analysis and acquiring experience concerning their applicability under various physical/geographic conditions of Slovakia are also of interest. The number of new types of acceptable probability distribution functions and parameter estimation methods implies, that the use of a single distribution function (for instance, the almost exclusively used Gumbel or Pearson3 distributions (*Šamaj et al., 1985*) may not be appropriate in the future.

In this paper, we will discuss problems of selecting 10-day precipitation totals and present a case study on fitting of appropriate distribution functions to 10-day maximum precipitation values in the upper Hron region.

2. Methodology for the selection of 10-day maximum precipitation totals

In the previous studies (e.g. *Stehlová et al., 2001; Jurčová et al., 2002*), the selection of k-day precipitation totals (k = 2, 3, 4, 5-days) was based on the requirement of recording daily precipitation totals higher than 0.0 mm in *each day* of the selected k-day period (and not on a k-day moving window). However, when calculating k-day precipitation totals for k higher than 6 days from several locations in Slovakia we came to the conclusion, that especially in lowlands, the number of such continuous events dramatically decreases with increasing k.

For instance at the Hurbanovo Observatory (SW Slovakia, 115 m a.s.l.), only 2 events in the warm half year (the season from April to September (WS)) and 11 events in the cold half year (from October in the previous year to March in the current year, CS) of 10-day precipitation totals have been found during the 1951-2001 period. On the other hand, at the Telgart station (901 m a.s.l., near the Low Tatras) already 88 such events in the WS and 97 such events in the CS have been identified. The possible explanation of this fact is, that long lasting precipitation events are usually caused by the cyclonic synoptic situations with mean duration of about 6 days. That means that in the case of the 10-day precipitation events, probably two consecutive synoptic situations divided by a one day or two day "dry gap" in precipitation are connected. The effects of these gaps are more pronounced in lowlands and less in the mountains.

Therefore a revision of the basic selection criterion has been suggested and implemented in this study. According to this, in the process of selecting of 10-day precipitation totals, *at most two (separate or consecutive) "dry days"* (i.e. days with 0 mm or 0.0 mm precipitation) were allowed during the selected 10-day period.

In the CS the 2-day evapotranspiration total is usually lower than 1 mm, so (especially in the case of maximum events) these gaps do not play any important role for selecting 10-day precipitation totals. In the WS, dry day gaps in precipitation could be connected with sunny and quite warm weather, causing two-day evapotranspiration to rise even well above 10 mm. Moreover, the preceding precipitation may have caused runoff from the catchment. In such case we believe, that next precipitation event cannot be connected with the previous rainy days. Therefore, if a 10-day precipitation event was interrupted by two consecutive dry days in the WS, attention had to be given to potential evapotranspiration and runoff during these two days.

Additional analysis was introduced in order to identify events with small (negligible) decrease of the catchment saturation during the two consecutive dry day precipitation gap.

The acceptation/rejection of the 10-day precipitation events with consecutive two day "dry gap" without precipitation has been carried out according the following rules:

1. If the sum of precipitation totals from the previous three days was lower than the triple of the calculated sum of evapotranspiration during the evaluated two day "dry gap", the 10-day precipitation event was not included in further analysis;

2. If the sum of precipitation totals from the previous three days was about 3- to 5-times higher than the calculated evapotranspiration dur-

ing the evaluated two day "dry gap", possible runoff and other water losses had also been considered by an antecedent precipitation index W_r. Then, if the calculated evapotranspiration sum was higher than 30% of this index during these three days, the 10-day precipitation event was, again, removed from the dataset.

3. If the sum of precipitation totals from the previous three days was very high (more than 5 times higher) compared to the calculated evapotranspiration sums during the evaluated two "dry day" gap, then no further consideration on the removal of the 10-day event from the series was made.

The cases of non consecutive two dry days were evaluated individually; such cases only seldom had to be removed from the data (*Lapin et al., 2002*).

Because climatological data for evapotranspiration calculation may not always be available, the following simplified method was used here (see also *Lapin et al., 2002*). Daily potential evapotranspiration sums (E_o) were computed using daily means of air temperature (T) and relative air humidity (U), monthly potential evapotranspiration E_{oM} estimated by *Tomlain (1991)*, who published mean monthly potential evapotranspiration sums for 34 stations in Slovakia for the 1951-1980 period and updated these for 1951-2004 recently (unpublished report). Missing inputs were interpolated from the neighbouring stations by regression.

The formula for daily potential evapotranspiration E_o calculation can be written as follows:

$$E_o = E_{oM}/n + k_1.E_{oM}/n/Sd(T).\Delta T - k_2.E_{oM}/n/Sd(U).\Delta U, \tag{1}$$

where E_{oM} is monthly potential evapotranspiration, n is number of days in the given month, $Sd(T)$ and $Sd(U)$ are standard deviations of daily T and U means for the given month, ΔT and ΔU are daily T and U deviations from the given monthly mean, k_1 and k_2 are coefficients determined empirically. Exceptional negative estimates of daily E_o values have been removed by a simple transformation.

Beside the evapotranspiration, an index of the antecedent precipitation was also estimated using the following formula (*Lapin et al., 2002*):

$$W_r = \sum_{t=1}^{N} R_{N-t+1}k^t, \tag{2}$$

where N is the number of days considered in the analysis, R is the daily precipitation total, W_r is the antecedent precipitation index (in fact an estimate of the water amount stored in the basin considering lumped runoff and evapotranspiration losses) and k is a site specific constant. In our case study, the choice $N = 3$ and $k = 0.90$ resulted in W_r values, which are about 75–85% of precipitation during the previous three days (*Lapin et al., 2002)*.

3. Methods of estimating N-year 10 day maximum precipitation totals

In this study, two approaches for estimating design rainfall, the *DVWK/101 (1999)* method and the *FEH (1999)* methodology, were applied.

DVWK/101 (1999) methodology, designed for at-site estimation of design values from annual maximum data is supported by the HQ-EX statistical computer program *Wasy Gmbh., 1997*. The plotting positions of the maximum annual precipitation totals are estimated according to Cunnane, (*WMO (1989)*) as:

$$P = \frac{m - 0.4}{n + 0.2}, \tag{3}$$

where:

- P is the probability of exccedance,
- n is the sample size and
- m is the rank of the observations sorted in descending order.

To estimate the parameters of theoretical distribution functions three methods were used alternatively:
- the method of moments (MOM),
- the maximum likelihood method (MLM),
- the method of probability weighted moments (PWM).

The following theoretical distribution functions were tested for their applicability: E1 – (Gumbel) with the parameter estimation methods MOM, MLM, PWM, GEV – (Generalized Extreme Value) (MOM, MLM, PWM), ME – (Rossi) (ML), LN3 – (3-parameter Lognormal) (MOM, MLM, PWM), P3 – (Pearson III) (MOM, MLM, PWM), LP3 – (logPearson III) – (MOM, MLM, PWM) and WB3 – (3-parameter Weibull) (MOM, MLM, PWM).

In order to select the most appropriate fitted distributions, the following statistical test is used by DVWK (1999). The testing criterion has two components and is computed from the relationship:

$$D + n\omega^2 + (1 - r_p)\,, \tag{4}$$

where:

- D is the value of the Kolmogorov test,
- ω^2 is the value of the omega-squared test (*Dyck, 1980*),
- r_p is the correlation coefficient between the values of the descendingly sorted values and their respective distribution quantiles.

The best fit is given by the lowest values of ω^2, D and the highest values of r_p.

The *FEH (1999)* methodology is based on L-moment statistics. L-moments are summary statistics for probability distributions and data samples. They are analogous to ordinary moments; they provide measures of location, dispersion, skewness, kurtosis, and other aspects of the shape of the probability distributions or data samples, but are estimated from linear combinations of the ordered data values (*Hosking and Wallis, 1997*).

Probability weighted moments defined by *Greenwood et al. (1979)*, are precursors of L-moments. Sample probability weighted moments, estimated from data values $x_1, x_2, ...x_n$, sorted in increasing order, are given by:

$$b_o = n^{-1}\sum_{j=1}^{n} x_{(j)}, \tag{5}$$

$$b_1 = n^{-1}\sum_{j=2}^{n} \frac{(j-1)}{(n-1)} x_{(j)}, \tag{6}$$

$$b_2 = n^{-1}\sum_{j=3}^{n} \frac{(j-1).(j-2)}{(n-1).(n-2)} x_{(j)}, \tag{7}$$

$$b_3 = n^{-1}\sum_{j=4}^{n} \frac{(j-1).(j-2)(j-3)}{(n-1).(n-2)(n-3)} x_{(j)}. \tag{8}$$

L-moments are linear combinations of probability weighted moments. The first L-moments are defined by:

$$l_1 = b_0, \tag{9}$$

$$l_2 = 2b_1 - b_0, \tag{10}$$

$$l_3 = 6b_2 - 6b_1 + b_0, \tag{11}$$

$$l_4 = 20b_3 - 30b_2 + 12b_1 - b_0, \tag{12}$$

The first L-moment is the measure of location, the second L-moment is a measure of the dispersion of the data values about their mean. By dividing the higher-order L-moments by the dispersion measure, we obtain the L-moment ratios, which are dimensionless quantities.

$$L - Cv : t_2 = l_2/l_1, \tag{13}$$

$$L - Cs : t_3 = l_3/l_2, \tag{14}$$

$$L - Ck : t_4 = l_4/l_2, \tag{15}$$

where t_2 is the measure of dispersion, t_3 is a measure of skewness and t_4 is a measure of kurtosis – these are respectively named L-skewness and L-kurtosis.

According to *Hosking (1990)*, L-moments have the following theoretical advantages over ordinary moments:

- For L-moments of a probability distribution to be meaningful, it is only required that the distribution have finite mean; no higher-order moments need be finite (*Hosking, 1990,* Theorem 1).

- For standard errors of L-moments to be finite, it is only required that the distribution has finite variance; no higher-order moments need be finite (*Hosking, 1990,* Theorem 3).

For the estimation of N-year 10-day maximum precipitation totals using L-moments the following distribution functions were applied: GLO – (Generalized Logistic), LN3 – (Lognormal III), GEV – (Generalized Extreme Value), GPA – (Generalized Pareto) and PE3 – (Pearson III). For selecting the appropriate distribution function the *L*-moment ratio diagrams were used, which are a widely used tools for the graphical interpretation and comparison of the sample *L*-moment ratios *L-Cs* (skewness) and *L-Ck* (kurtosis) of various probability distributions (*Hosking, 1990*).

4. Input data

The 10-day maximum annual precipitation totals were analysed separately in two seasons within the year – the warm season (covering the season from April to September), and the cold season for the remaining part of the year (from October in the previous year to March in the current year). This selection was primarily based on the similarity of the physical conditions for precipitation occurrence and on seasonal analysis. Fig. 2 shows the frequency of 10-day maximum precipitation totals occurrence in different months at the Banská Bystrica station.

Twenty three precipitation stations in the upper Hron basin to the gauging station Banská Bystrica were selected. The observation period ranged from 1961 to 2000, 2 stations had longer observation periods from 1951 to

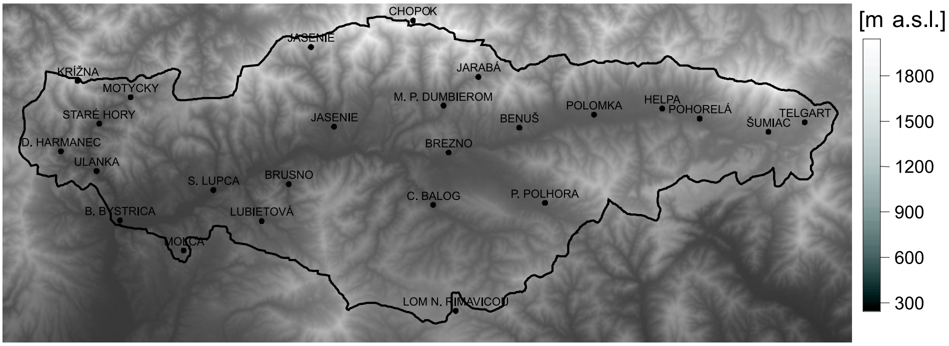

Fig. 1. The site map of the analysed precipitation stations in the upper Hron region.

2000. The list of stations is presented in Tab. 1. Ten-day annual maximum values in each season were used in the statistical analysis, selected using the methodology described in part 2 of the paper.

Tab. 1. The list of analysed precipitation stations

Station	**Code**	**Elevation (m a. s. l.)**	**Observation Period**	**Length of observation (years)**
Chopok	21 080	2008	1961-2000	40
Telgárt	33 020	901	1951-2000	50
Pohorelá	33 060	764	1961-2000	40
Polomka	33 120	586	1961-2000	40
Beňuš	33 140	550	1961-2000	40
Pohorelská Polhora	33 160	637	1961-2000	40
Brezno	33 200	487	1961-2000	40
Čierny Balog – Krám	33 240	530	1961-2000	40
Mýto pod Ďumbierom	34 040	610	1961-2000	40
Brusno	34 080	406	1961-2000	40
Ľubietová	34 100	477	1961-2000	40
Slovenská Ľupča	34 120	370	1951-2000	50
Môlča	34 140	459	1961-2000	40
Harmanec	34 160	481	1961-2000	40
Motyčky	34 180	688	1961-2000	40
Staré Hory	34 220	468	1961-2000	40
Banská Bystrica – Uľanka	34 240	398	1961-2000	40
Banská Bystrica	34 260	427	1961-2000	40
Lom nad Rimavicou	54 120	1015	1961-2000	40
Jasenie pred Suchou	34 060	507	1961-2000	40
Jasenie na Bankovej	34 070	543	1961-2000	40
Heľpa	33 080	695	1961-2000	40
Krížna	34 200	1150	1961-2000	40

5. Selection of the appropriate distribution functions according to the DVWK and *L*-moment methods

The three best distribution functions for the estimation of 10-day maximum precipitation totals in each station were selected based on the two com-

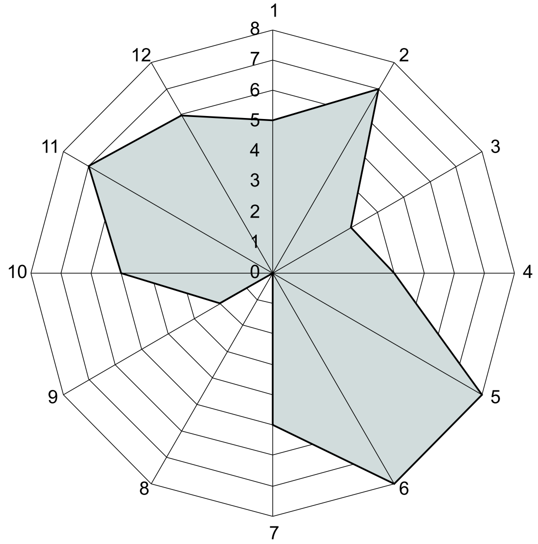

Fig. 2. Frequency of 10-day maximum precipitation totals occurrence in different months at the Banská Bystrica station.

ponent statistical test according to the procedure described in the DVWK (1999) method. In Tabs 2 and 3, the numbers of stations with their station codes belonging to the selected distribution function for the cold and warm seasons are presented.

Using the software *RFFA*, (developed at the Dept. of Land and Water Resources Management, SUT Bratislava (*Čunderlík, 1999*)), the values of *L-Cs*, and *L-Ck* at all stations were estimated, and subsequently the *L*-moment ratio diagram was used to compare the *L*-skewness and *L*-kurtosis relations of different distributions and data samples. The *L*-moment ratio diagram gives a visual indication which distribution may be expected to give a good fit to a data sample or samples. Figs 3 and 4 show the *L*-moment ratios for all analysed stations for the cold and warm seasons.

6. Discussion of results

The percentage of the preferred distribution functions was calculated. From Tabs 2 and 3 we can conclude, that the possibility of finding one

Tab. 2. Number of stations with their station codes belonging to the selected distribution function for the cold season - DVWK method

Distribution function	No. of stations	Precipitation station code
E1	2	34140 (2×)
GEV	11	54120 (2×); 21080; 33020 (3×); 33040; 33060; 34160; 33080; 34120
ME	8	54120; 33160; 33240; 34040; 33080; 34140; 34180; 34120
LN3	10	33040 (2×); 33060; 33160 (2×); 34020; 34160; 33080; 34070; 34120
P3	15	34220; 33200 (2×); 33060; 33120; 33240; 34020; 34040; 34260; 34080; 34160; 34060 (2×); 34070; 34180
LP3	1	21080
WB3	22	34200 (3×); 21080; 33200; 33120 (2×); 33140 (3×); 33240; 34020; 34040 34260 (2×); 34080 (2×); 34060; 34070; 34180; 34220 (2×);

Tab. 3. Number of stations with their station codes belonging to the selected distribution function for the warm season - DVWK method

Distribution function	No. of stations	Precipitation station code
GEV	30	34260 (2×); 34080 (2×); 34160; 34060; 34070(3×); 33080; 34140; 34180; 34120(2×); 34220(2×); 34200; 54120; 21080; 33200; 33040; 33060; 33120; 33140(2×); 33160; 33240 (2×); 34020(2×); 34040
LN3	10	54120; 21080; 33020; 33160; 34260; 34160; 34140; 33240; 34020; 34120
WB3	13	33140; 33160; 34040; 34200; 33040; 33060; 33120(2×); 34260; 33080(2×); 34060; 34180
ME	2	34080; 34220
P3	8	33040; 34040; 21080; 33020(2×); 34160; 34140
LP3	4	34060; 34200;34180; 33200(2×)
E1	1	54120

universal distribution function for the whole region is rather limited. The GEV and WB3 distribution functions were most frequently used.

In the cold season, the prevailing distribution type was WB3 with 24% followed by P3 with 22%. Minimum percentage was achieved by the LP3 (1%) and E1 (1%) distributions. In the warm season, the prevailing distribution type was GEV with 39% followed by LN3 with 16%. Minimum percentage was achieved by the ME (2%) and E1 (1%) distributions. When applying the L-moment method, it was again not possible to reduce the number of acceptable distributions, nor was it possible to recommend one

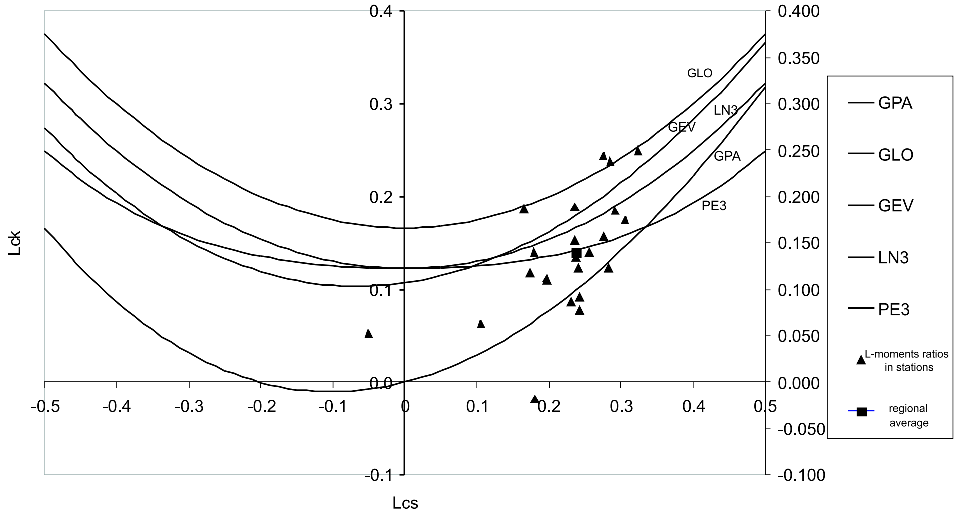

Fig. 3. *L*-moment ratio diagram for the precipitation stations in the upper Hron region; the regional average is marked as a black square. Cold season.
(Legend of the distribution functions: GLO: Generalized Logistic, LN3: Lognormal, GEV: Generalized Extreme Value, GPA: Generalized Pareto, PE3: Pearson III.)

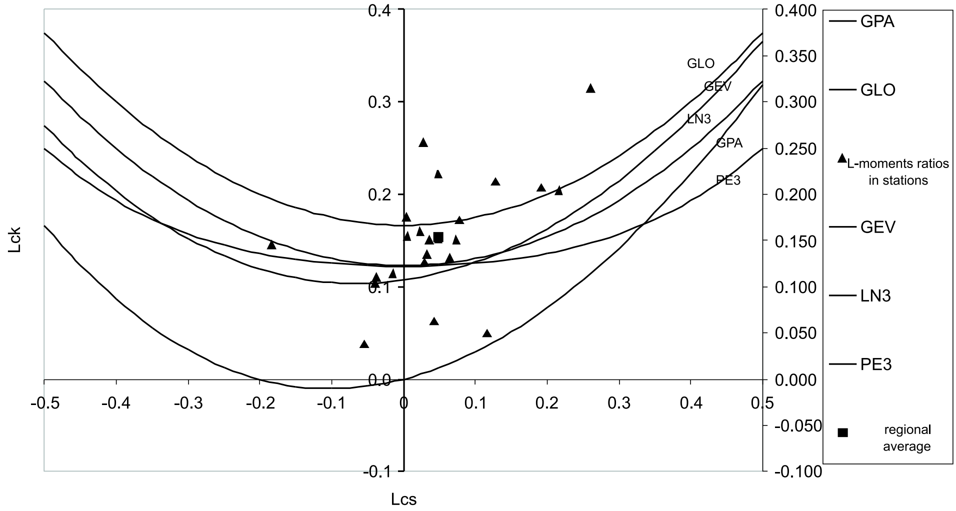

Fig. 4. *L*-moment ratio diagram for the precipitation stations in the upper Hron region; the regional average is marked as a black square. Warm season.
(Legend of the distribution functions: GLO: Generalized Logistic, LN3: Lognormal, GEV: Generalized Extreme Value, GPA: Generalized Pareto, PE3: Pearson III.)

distribution for the whole analysed region. The most frequently applied distribution functions were the PE3 and GLO distribution functions.

In Figs 5 and 6 a comparison of design rainfall values by applying the mentioned methods for $N = 1$, 10, 50, 100 years at the Banská Bystrica station is presented. We can see that the values are very close and comparable up to the return period of $N = 50$ years. For the return period of $N = 100$ years the differences in the design values using various methods could reach up to 20% of the mean value.

To test the consistency of these values for engineering calculations, we have compared the values of N-year 10-day maximum precipitation totals with 1, 2, 5-day maximum precipitation totals at the Banská Bystrica station in the cold and warm season, which were estimated in previous studies (*Jurčová, 2002; Stehlová et al., 2001*). The results are presented in Tab. 4. The distribution functions which gave the highest value of 100-year maximum precipitation totals from the statistically accepted distributions for 1, 2, 5, or 10-day maximum precipitation totals were selected for this comparison.

We can observe that the 100-year values of 1-day maximum precipitation totals, which are predominantly caused by extreme convective rainfall, were higher in the warm season than in the cold season. When we compare the 100-year values of the 2, 5 and 10-day maximum precipitation totals, higher values can be observed in the cold season. What is also important to stress, is that the 100-year values of 10-day maximum precipitation totals are two to three times higher than the estimated values of the 100-year values of the 1-day maximum precipitation totals in the same station. This fact

Tab. 4. Values of N-year 1, 2, 5 and 10-day maximum precipitation totals at the Banská Bystrica station in the cold and warm season in [mm]

Cold season/ N[years]	*2*	*10*	*20*	*50*	*100*
10-day	78.3	164.0	199.0	234.0	278.0
5-day	72.5	110.4	126.7	148.4	164.9
2-day	51.8	81.5	97.2	131.1	142.2
1-day	37.7	57.8	66.4	78.3	87.7
Warm season/N[years]	*2*	*10*	*20*	*50*	*100*
10-day	90.8	123.0	136.1	153.3	166.6
5-day	72.3	106.2	121.3	142.6	159.9
2-day	54.3	73.1	82.5	96.8	109.3
1-day	37.7	55.0	64.0	77.5	88.8

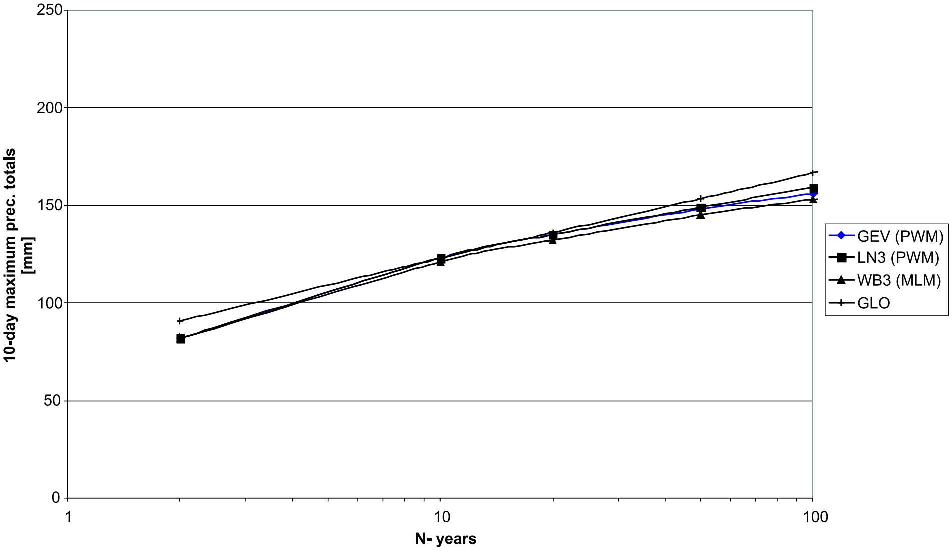

Fig. 5. Comparison of the design values of a 10-day maximum precipitation totals at the Banská Bystrica station – warm season.

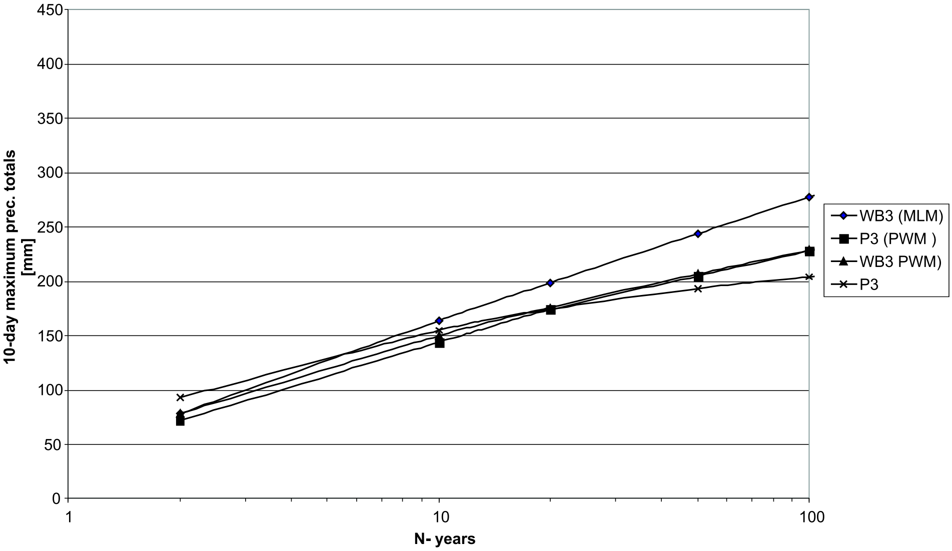

Fig. 6. Comparison of the design values of a 10-day maximum precipitation totals at the Banská Bystrica station – cold season.

should be taken into consideration by practical applications, e.g. designing engineering structures.

7. Conclusions

In this study a combined method, based on statistical criteria and on the evaluation of evaporation and runoff conditions during long precipitation events, has been used for the selection of the 10-day precipitation totals in the upper Hron Region. The 10-day maximum precipitation totals were analysed in two seasons. The precipitation data from 23 stations were used.

For at-site statistical analysis, the DVWK method and the method applied in FEH (1999) were used. Finally, the best distribution functions were selected for each station. According to the results it was not possible to recommend a single distribution for the whole region analysed, what used to be standard practice in Slovakia. A comparison of the resulting N-year rainfall estimated from these distribution functions showed that in the warm season they did not exhibit significant differences from a practical point of view. In the cold season more significant difference could occur, which could partly be attributed to the fact, that precipitation data in this season include both rainfall and snowfall. For flood risk estimation, however, the warm season is decisive, because rainfall induced floods represent the major threat.

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