Philobiblon Vol. XIV-2009

Analysis of the Maximum Precipitations in the East of the Apuseni Mountains

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Keywords: maximum precipitations, statistical analysis, frequency, probability, intensity, Apuseni Mountains

Abstract
The great majority of geographic hazards developed in the East of the Apuseni Mountains (flash floods, floods and inundations, land instability phenomena, and the pollution of watercourses) are caused by heavy rainfalls. In order to study and statistically analyze the maximum precipitations (monthly and seasonal frequency, quantities with different probabilities of exceedance, maximum intensity) we collected data referring to the highest annual daily amounts of precipitation recorded in a series of raingauge stations in a period of 28 years (1978–2005). The results obtained from the analysis of the maximum precipitations are important starting points for the evaluation of environmental risks.

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1. Introduction
Situated in the central-western part of Romania, north of the Mureş River, the Apuseni Mountains constitute the northern unit of the Western Carpathians. The east of the Apuseni Mountains, including in the present study the drainage basins of the Arieş and Someşul Mic Rivers (Figure 1), is a representative region of the Apuseni Mountains both from a geological (high petrographic complexity) and a geomorphic (low altitudes, highly fragmented mountains) point of view with specific particularities associated, however, with the climatic conditions (a region affected by foehn processes) and implicitly with the runoff regime of the watercourses. The analyzed region is one of the most densely populated areas of the Carpathians (78,612 inhabitants living in 32 communes and

3 towns to which belong no less than 421 smaller localities[1]) including localities along the valleys, in depression areas and on smooth and sunlit mountain tops where permanent settlements are to be found approximately to an altitude of 1600 m.

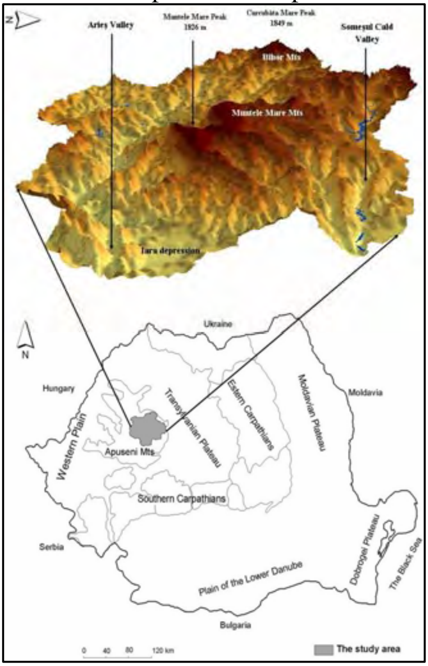

Fig. 1. Location of the study area (below) and 3D terrain map of the same region (above)

The rich natural resources (non-ferrous metals, various raw materials for construction industry, woods, pastures and hayfields and last but not least rich water resources) attracted inhabitants to this region already in antiquity. For a long time mankind lived in harmony with nature using its resources mainly to satisfy his basic needs. With the beginning of the communist era, in the second half of the 20th century a process of fast industrialization began in the localities with a more numerous population by establishing and developing food, textile mining or wood-felling and -working units. Moreover, the tide of tourism has lately increased excessively numerous pensions and holiday homes having been built. In these conditions the pressure on nature has also increased (deforestation, the sometimes excessive pollution of water resources, the extended built-up areas and constructions isolated in narrow valleys, increasing density of the road network etc.), and the inhabitants as well as the social-economic bodies of the region have become more and more exposed to environmental hazards.

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[1] *Recensământul populaţiei şi al locuinţelor* (Population and Houses Census), 2002.

The majority of the natural hazard phenomena occurring in the east of the Apuseni Mountains are triggered directly or indirectly by heavy precipitations (especially in liquid form). We can mention:

- floods, flash floods and inundations which were catastrophic in some cases in the last 50 years (1975, 1981, 1995) resulting in the loss of human lives as well as important material damages affecting especially the road system;
- rockfalls, debris flow and shallow landslides affecting buildings and mainly the road system;
- draining of mineral waste dumps and discharging wastewater into main watercourses affecting especially the fluvial ecosystems (Figure 2).

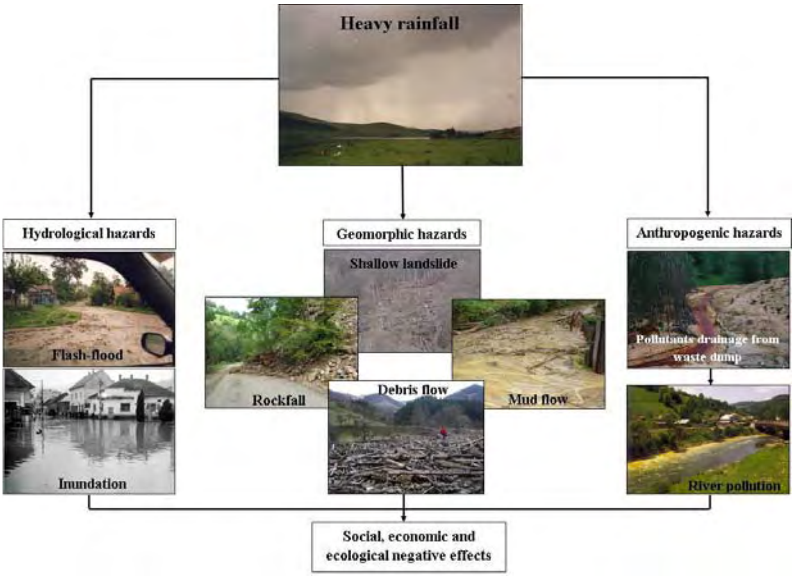

Fig. 2. Hazards triggered by rainfall in the east of the Apuseni Mts.

Considering the situation mentioned above it is easy to understand that the results obtained from the analysis of maximum precipitations are an important starting point for the evaluation of environmental risks.

2. Outstanding precipitation events recorded in the study region

Having collected and analyzed the data[1],[2],[3],[4],[5] recorded over a long period (1890–2005) at the raingauge stations of the region and its close vicinity (Figure 3), we observed the fact that the absolute daily precipitation fallen in 24 hours was 244 mm (Neagra, 26-07-1964),[6] this being one of the ten highest quantities of precipitation recorded in a single day in Romania and, therefore, with a very low probability of exceedance. According to the discussions we had with specialists working at the Câmpeni meteorological and hydrological station, this value must be regarded, however, with some reserve.

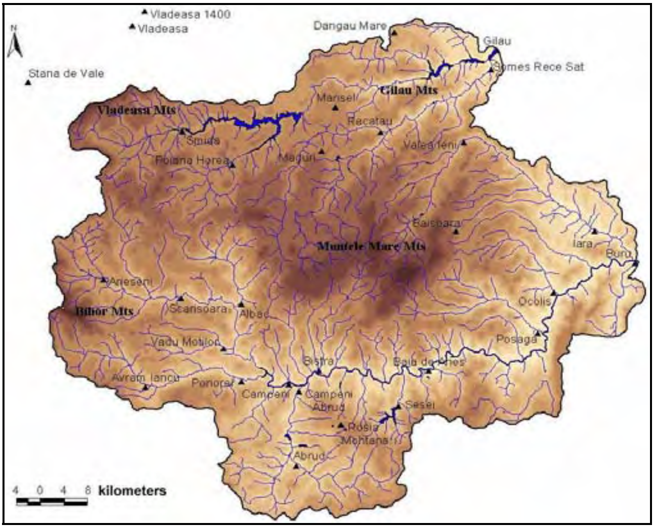

Fig. 3. Raingauge station sites

[1] *Anuar meteorologic* (Meteorological Yearbook) (Bucharest: Institute of Meteorology, 1961–1972).

[2] *Atlasul climatologic al României* (The Climatologic Atlas of Romania) (Bucharest: Institute of Meteorology, 1966).

[3] *Buletin meteorologic anual* (Annual Meteorologic Bulletin) (Bucharest: Institute of Meteorology, 1902–1959).

[4] *Buletin meteorologic zilnic* (Daily Meteorologic Bulletin) (Bucharest: National Waters Council, Institute of Meteorology and Hydrology, 1972–1996).

[5] *Tabele anuale de precipitații* (Annual Precipitation Tables) (Bucharest: INMH Archives, 1978–2005).

[6] *Tabele anuale...*, 548.

Among the precipitations with exceptional values are those fallen in Roşia Montană (19 mm/15 minutes, 16-07-2002), Măguri (34 mm/32 minutes, 13-06-1942), Valea Ierii (154 mm/48 hrs, July 2005), Arieşeni (265 mm/96 hrs, December 1995) and Mărişel where in less than a month (14-07–12-08-2002) 476.7 mm/m² were accumulated (Table 1).

Table 1. Extreme precipitation registered in the east of the Apuseni Mountains between 1890–2005

No.	Raingauge stations	D* (mm)	D** (min)	Month, Year	No.	Raingauge stations	D* (mm)	D** (min)	Month, Year
1	Răcătău	40.7	6	Jul, 1953	36	Vlădeasa	88.2	1440	Jun, 1975
2	Stâna de Vale	44.6	15	Jul, 1945	37	Buru	86	1440	Jul, 2005
3	Roşia Montană	19	15	Jul, 2002	38	Arieşeni	86	1440	Mar, 2001
4	Roşia Montană	27	30	Jul, 2002	39	Scărişoara	85.6	1440	May, 1954
5	Măguri	34	32	Jun, 1942	40	Valea Ierii	85.5	1440	Jul, 2004
6	Abrud	55	90	Jul, 1949	41	Poşaga de Sus	84.7	1440	Jun, 1939
7	Poşaga de Sus	70.5	120	Jun, 1944	42	Vlădeasa 1400	82.4	1440	Jul, 2005
8	Măguri	54	120	Jun, 2005	43	Vlădeasa	82	1440	Jul, 1978
9	Poşaga de Sus	90	130	May, 1937	44	Măguri	82	1440	Sep, 1912
10	Măguri	62.7	240	Jul, 1939	45	Poiana Călineasa	80.9	1440	Aug, 2002
11	Arieşeni	103	360	Mar, 1981	46	Vlădeasa	80.8	1440	Jun, 1974
12	Băişoara	105	600	Jul, 1975	47	Baia de Arieş	80.8	1440	Jun, 1979
13	Neagra	244	1440	Jul, 1964	48	Ocoliş	80.3	1440	Jul, 2005
14	Vlădeasa 1400	130	1440	Sep, 1968	49	Baia de Arieş	80.1	1440	Jul, 1988
15	Avram Iancu	116	1440	Dec, 1995	50	Valea Ierii	154	2880	Jul, 2005
16	Crăieşti	112	1440	Aug, 2007	51	Mărişel	124	2880	Jul, 2003
17	Valea Ierii	112	1440	Jul, 2005	52	Vlădeasa	124	2880	Jun, 1974
18	Băişoara	108	1440	Jul, 1975	53	Băişoara	117	2880	Apr, 1977
19	Arieşeni	105	1440	Apr, 2000'	54	Baia de Arieş	114	2880	Jul, 1988
20	Avram Iancu	104	1440	Dec, 2001	55	Smida	108	2880	Apr, 2004
21	Arieşeni	104	1440	Dec, 1995	56	Băişoara	108	2880	Jul, 1975
22	Vidra	102	1440	Jul, 1964	57	Câmpeni	159	4320	Apr, 2004
23	Avram Iancu	102	1440	Feb,.1970'	58	Smida	149	4320	Mar, 2001
24	Iara	100	1440	Jul, 1975	59	Iara	138	4320	Jul, 1975
25	Dângău Mare	97.5	1440	Sep, 1941	60	Băişoara	137	4320	Jul, 1975
26	Mărişel	96.2	1440	Apr, 2004	61	Arieşeni	132	4320	Dec, 1967
27	Abrud	95	1440	Dec, 1925	62	Arieşeni	265	5760	Dec, 1995
28	Vlădeasa 1400	94.2	1440	May, 1962	63	Arieşeni	221	5760	Mar, 2004
29	Valea Ierii	93.2	1440	May, 1979	64	Vlădeasa	200	5760	Jul, 1980'
30	Roşia Montană	93	1440	Jul, 1911	65	Avram Iancu	198	5760	Dec, 1995
31	Arieşeni	92.2	1440	Dec, 1967	66	Arieşeni	316	10080	Dec, 1995
32	Baia de Arieş	91	1440	Aug, 1942	67	Mărişelu	477	43200	Jul-Aug, 2002
33	Poşaga	89.7	1440	Jun, 1979	68	Mărişelu	395	43200	Jul, 2005
34	Luna de Sus	89.5	1440	Aug, 1938	69	Poiana Călineasa	461	43200	Sep, 2001
35	Scărişoara	89.2	1440	Jun, 1951					

*D= Depth ; D**= Duration

Analyzing the data presented in Table 1 we may observe the fact that the maximum values of precipitation fallen in different periods of time are specific to the western part of the region, with great absolute altitudes (Bihor-Vlădeasa Mountains), and, somewhat paradoxically, to the eastern and southern part of the Muntele Mare Massif, a region situated in precipitation shadow where the continental character of the climate increases and downpours reach high quantities in the summer.[1]

3. Monthly and seasonal frequency of 24-hours precipitation events and the atmospheric conditions involved in their genesis

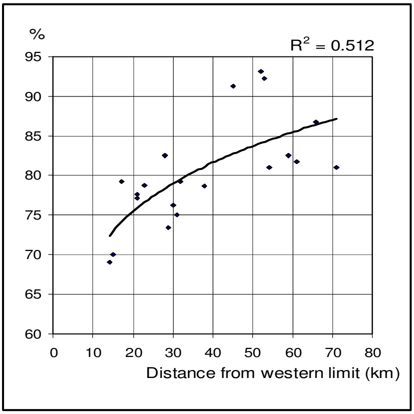

Fig. 4. The frequency of 24-hours maximum precipitations fallen in the warm season (%) increasing with the distance from the western limit of the territory

In order to determine the yearly critical intervals with maximum precipitations we collected data from 21 raingauge stations scattered on a representative area of over 3000 km^2. Every rainfall registered in the period 1978–2005[2] during which the 24 hrs amount exceeded the yearly maximum daily precipitation with the smallest depth recorded at the raingauge stations of the region has been taken into consideration.

Analyzing the values centralized in Table 2 we can observe the uneven distribution of precipitations, the great majority of the events taken into consideration being specific to the *warm season* of the year (May–October) when, besides frontal precipitations, strong convective processes are developed. This situation is more clearly expressed in the

[1] Viorel Arghiuş, *Studiul viiturilor de pe cursurile de apă din estul Munţilor Apuseni şi riscurile asociate* (The Study of Flash Floods from the Watercourses of the Eastern Apuseni Mountains and the Related Hazards) (Cluj-Napoca: Editura Casa Cărţii de Ştiinţă, 2008), 51.

[2] *Tabele anuale...*

south-eastern side of the Muntele Mare Massif and at great altitudes. (Figure 4)

Table 2. Monthly and seasonal frequency of 24-hours maximum precipitation (1978–2005)

No	*Raingauge stations*	Altitude (m)	Monthly maximum frequency		Monthly minimum frequency		Seasonal frequency (%)	
			F (%)	Month	F (%)	Month	Hot (V-X)	Cold (XI-IV)
1	Vlădeasa	1836	25.8	VII	0	I. II. III	93.5	6.5
2	Băişoara	1361	24.1	VI	0	I. III	93.1	6.9
3	Roşia Montană*	1198	23.2	VIII	0	III. XI	75	25
4	Poiana Horea**	1008	19	VII	0	II. XI	79.3	20.7
5	Smida**	998	20.9	VI	1.5	IV. XI	69	31
6	Scărişoara	763	18.3	VIII	1.7	III. XI	70	30
7	Valea Ierii	740	29.7	VII	0	I. III	92.2	7.8
8	Albac	616	19	VII	0	II. XI	77.6	22.4
9	Vadu Moţilor**	605	25.7	VIII	0	II. XI	77.1	22.9
10	Abrud	599	20.3	VII	0	XI	73.4	26.6
11	Ponorel	580	19.7	VIII	0	IV. XI	78.7	21.3
12	Abrud-Câmpeni	550	22.2	VII	0	XI	76.2	23.8
13	Bistra	546	20.7	VII	0	XI	79.3	20.7
14	Câmpeni	542	24.6	VII	0	II. XI	82.5	17.5
15	Muşca	530	23.2	VI	0	I. XI	78.6	21.4
16	Poşaga	510	28.1	VII	0	I. III	82.5	17.5
17	Baia de Arieş	485	26.3	VI. VIII	0	III. XI	91.2	8.8
18	Iara	460	28.3	VI	0	I. III	86.7	13.3
19	Ocoliş	440	25	VII	1.7	I. II. III	81.7	18.3
20	Someş Rece Sat**	430	30	VII	0	II	81	19
21	Buru	380	29.3	VII	0	I	81	19

*1983–2006 **1989–2005

In the warm period of the year the advection of masses of cold air from the western, northern and, especially, north-western part of the continent is responsible for the appearance of heavy rainfalls with high intensity, associated with an intense atmospheric instability. In these situations the 500 hPa isohypses are rather close to one another indicating a high baric gradient and, consequently, favouring the fast advance of maritime polar air masses from the direction of the Atlantic Ocean. Fast advection maintains the freshness of the cold air masses, which lend a sudden ascending movement to the pre-existent warm air with a high water vapour content, this leading to the rapid condensation of vapour and to high precipitation amounts fallen in a relatively short time.[1]

Studying maps of 500 hPa geopotential height and those which give the 850 hPa air temperature we observed that whenever there were heavy rainfalls, a height trough was extended over the country developed from the baric depression localized above the Arctic Ocean, or, more frequently, cut-off cyclones. These cold nucleuses maintain the cyclonic activity at ground level and accentuate the instability grade of the air in the lower and middle troposphere leading to intense lifting movements on the anterior part of the height troughs, capable to develop frontal cloud systems with a high precipitation potential.[2] The situation at the ground level indicates in such conditions a field of high atmospheric pressure (the Azores High) developed from South-Western to Central Europe and a depression field in the south-east of Romania, in which conditions the circulation of the air masses is realized from a predominantly north-western sector (Figure 5).

On the other hand, on the southern and eastern sides of the Muntele Mare Massif, situated in rain shadow, powerful thermal convection processes are developed (often on the days following the passing of atmospheric fronts) which cause significant downpours.

When the Mediterranean cyclones stagnate over Transylvania for days, sometimes until occlusion (e.g. 10–13-07-2005), heavy rainfalls are to be expected in the east of the Apuseni Mountains as well.

During the events of the *cold season* as well, the circulation of air masses from the western sector are predominant, but an increase has been observed in advection from the south-western sector. The heaviest precipitations specific to the cold season are related to the interstream area formed by the ridges of the Bihor-Vlădeasa Mountains. Especially at the beginning of winter and spring, in favourable thermobaric conditions, these areas are affected by the relatively warm air coming from the direction of the Atlantic Ocean or the Mediterranean Sea, which bring significant quantities of precipitation, often in liquid form. However, on the eastern part of the Muntele Mare Massif precipitations lose intensity and duration consequently to the development of foehn processes.

Analyzing the atmospheric situation at the ground level in the case of heavy precipitations recorded in the cold season, we observed the

[1] Arghiuş, *Studiul viiturilor...,* 54.

[2] Atanase Mustăţea, *Viituri excepţionale pe teritoriul României, Geneză şi efecte* (Exceptional Flash Floods in the Territory of Romania, Genesis and Effects) (PhD diss., Romanian Academy, Institute of Geography, Bucharest, 1996), 43.

existence of a large depression, extended almost all over the continent, formed by several cyclonic nucleuses which move in general from the western part of Europe to the east with high speed, as the effect of the high thermobaric gradients in the heights (Figure 6).

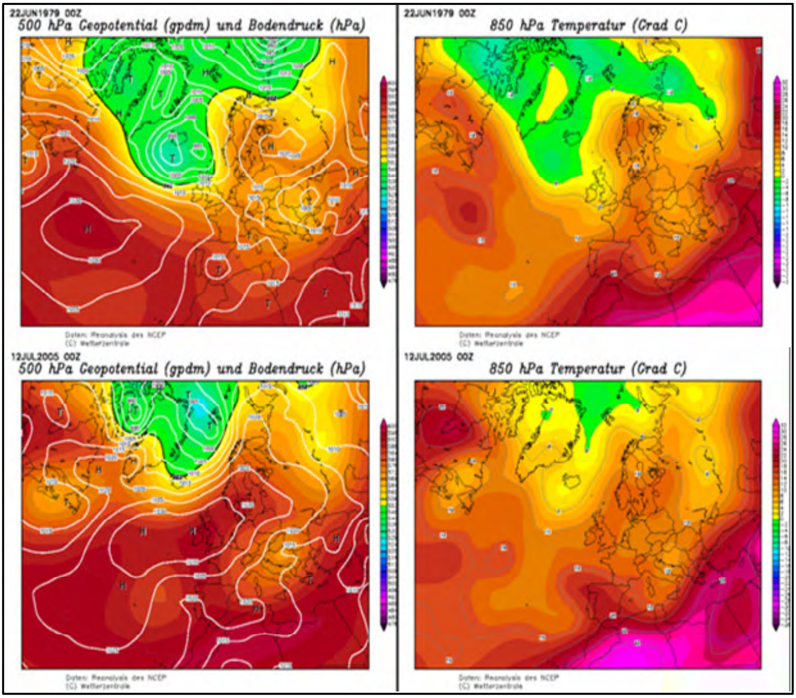

Fig. 5. 500 hPa Geopotential Height and 850 hPa Temperature Level linked to heaviest rainfall fallen in the hot season[1]

[1] http://www.wetterzentrale.de

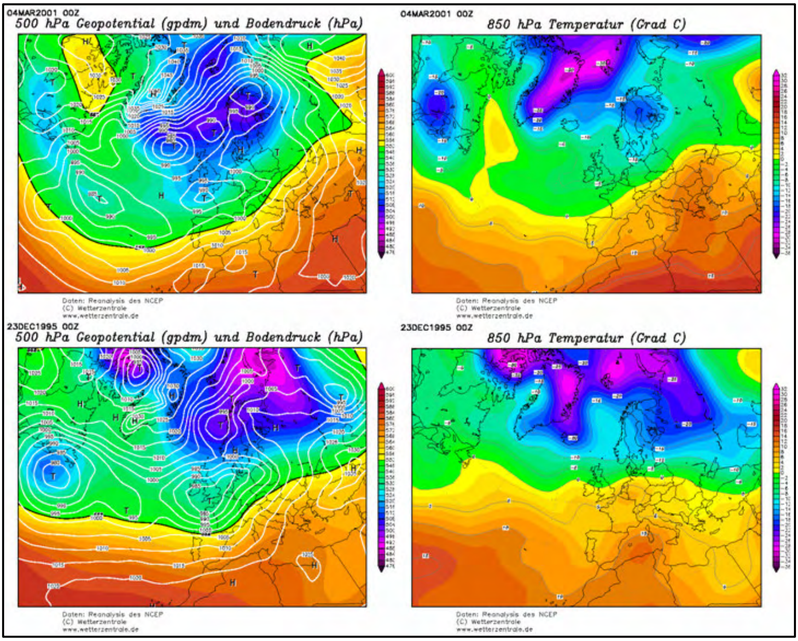

Fig. 6. 500 hPa Geopotential Height and 850 hPa Temperature Level linked to heaviest precipitations fallen in the cold season[1]

4. Probability of exceedance assessment for 24 h – maximum precipitation events

4.1. Methodology

In order to realize this study we collected data referring to the highest annual daily precipitations recorded in 19 raingauge stations (Table 3). The majority of these are placed in the bottom of valleys, while few stations are situated on the slopes and in the interstream areas. In the lack of a station situated at a great height we analyzed the data recorded at the Vlădeasa station, situated north-west from the analyzed area, in its immediate proximity.

[1] http://www.wetterzentrale.de

Rainfall observations were made in the east of the Apuseni Mountains already in the 19th century (1890, Baia de Arieş station), but the majority of the present day stations have been functioning only since 1978. The activity of the older stations was interrupted for different periods having gaps in the time series. In these conditions, to obtain a common period of records which would make possible to compare the results obtained from the statistic analysis, we have chosen a uniform interval of 28 years (1978–2005) for every station. The period of study can be considered sufficiently long and representative with a significant variation in the annual maximum precipitations.

In what follows we are going to describe the methodology used in the statistic analysis of the data.

In the first stage we calculated the parameters of the empirical distribution curves using the formulas:[1]

$$\overline{P}_{24h} = \sum \frac{P_i}{n}$$

$$C_v = \sqrt{\frac{\sum (k_i - 1)^2}{n-1}} \quad \text{where } k_i = \frac{P_i}{\overline{P}_{24h}}$$

$$C_s = \frac{\sum (k_i - 1)^3}{n \cdot C_v{}^3}$$

where: $\overline{P}_{24h}$ is the mean of the series of *n* annual maxima; P_i is the maximum precipitation corresponding to the order number i from the series of terms; n is the number of terms; C_v is the variation coefficient; C_s is the asymmetry coefficient; k_i is the module coefficient.

Since great errors might have occurred in the statistic calculation of the C_s parameter (even for 100 terms the error was calculated at 25%), we chose a more precisely determined value in function of the variation coefficient whose calculated values are within the admitted error limits (to 10%) even for a smaller number of 25 terms.

[1] M. Constantinescu et al., *Hidrologie* (Hydrology) (Bucharest: Editura Tehnică, 1956), 40, 43, 49, 52.

Thus, taking into consideration the recommendations of some scientific works,[1] we chose a unique value, $4C_v$ for every station.

In order to obtain as pertinent results as possible for the raingauge stations where higher quantities of the 24-hour precipitations were measured before the period 1978–2005, we used the following formula:[2]

$$\overline{P}'_{24h} = \frac{1}{N}\left(P_N + \frac{N-1}{n}\sum P_i\right);$$

$$C_v' = \sqrt{\frac{1}{N}\left[(k_N - 1)^2 + \frac{N-1}{n}\sum (k_i - 1)^2\right]}$$

where: $k_N = \frac{P_N}{\overline{P}'_{24h}}$

The empirical probabilities of exceedance were calculated with *Chegodaev's formula*:

$$p = \left(\frac{i-0.3}{n+0.4}\right)\cdot 100$$

where: i is the order number of the maximum precipitation from the series of terms ordered decreasingly; n is the number of terms.

In order to determine the theoretical exceedance probabilities of the 24-hour precipitations we used an adequate repartition, as well as the Two-Parameter Gamma Distribution (*Pearson type III*).

The value of maximum precipitations with different probabilities of exceedance ($P_{p\%24h}$) were determined on the basis of the relation:

$$P_{p\%24h} = \overline{P}_{24h}(Cv \cdot \phi_i + 1)$$

The values corresponding to the ϕ_i coefficient were extracted from tables,[3] these varying in function of the *Cs* value and the value of the exceedance probability.

[1] Radu Drobot, *Bazele statistice ale hidrologiei* (The Statistic Bases of Hydrology) (Bucharest: Editura Didactică şi Pedagogică, 1997), 61–75.
[2] Constantinescu, *Hidrologie*, 50, 44–45.
[3] http://www teaching.ust.hk/~civl253/notes/Chap-03-freq_analy

We compared the results of the maximum precipitations with different probabilities of exceedance for the analyzed stations obtained from the application of the Pearson Type III distribution with the probabilities calculated by applying a Gumbel distribution (we used the Geostru – Hydrologic Risk, 2007 software), the differences between the values obtained with the aid of the two distribution types being within the acceptable limits.

4.2. Results

The variation of the maximum precipitations from a year to the other is expressed by means of the variation coefficients. In the studied territory the highest oscillations of the daily maximum precipitations characterize the low situated areas (300–800 m), on the eastern and southern side of the Muntele Mare Massif mountain group and the Iara Depression, where the values of this parameter are generally situated between 0.40 and 0.44. The lowest variation coefficient values are specific to the Arieşului Mountains as well as the highest areas[1] (Figure 7, Table 3).

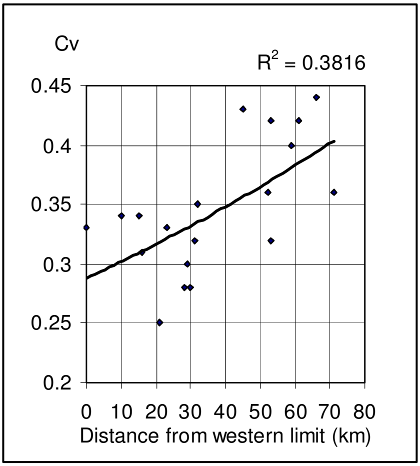

Fig. 7. The variation coefficient values increasing with the distance from the western limit of the territory

Table 3. Values of the absolute daily maximum precipitation and of the distribution curves parameters (Cs= 4 Cv) (1978–2005)

No	*Raingauge stations*	Altitude (m)	Abs. max. value Month, year (mm)	$\overline{P}_{24h}$	Cv
1	Vlădeasa	1838	88.2 - 06.1975	49.5	0.33
2	Băişoara	1361	108 - 07.1975	41.6	0.36
3	Roşia Montană	1198	93.0 - 07.1911	40.3	0.32

[1] Arghiuş, *Studiul viiturilor...,* 64.

4	Poiana Horea**	1008	70.0 – 06.1999	40.7	0.31
5	Scărişoara	763	89.2 - 06.1951	42.0	0.34
6	Valea Ierii	740	112 - 07.2005	48.9	0.42
7	Avram Iancu	680	116 -12.1995	53.5	0.34
8	Albac	616	60.5 - 07.2001	43.7	0.25
9	Abrud	599	95,0 - 12.1925	42.5	0.30
10	Ponorel	580	102 - 07.1964	42.9	0.33
11	Abrud-Câmpeni	550	69.5 - 09.1978	41.4	0.28
12	Bistra	546	65.0 - 07.1982	38.0	0.35
13	Câmpeni	542	73.3 - 09.1978	40.4	0.28
14	Poşaga	510	90.0 - 05.1937	41.5	0.40
15	Baia de Arieş	485	91.0 - 08.1942	41.0	0.43
16	Iara	460	100 - 07.1975	42.1	0.44
17	Ocoliş	440	80.3 - 07.2005	38.5	0.42
18	Someş Rece Sat**	430	89.5 – 08.1938	39.2	0.32
19	Buru	380	86.0 - 07.2005	40.2	0.36

*1983–2006 ** 1989–2005

Depending on the thermobaric situation of the atmosphere and, implicitly, on the circulation conditions of the air masses, the quantity of the annual daily maximum precipitation fluctuated between rather wide limits at the stations of the region. Against the background of these quite natural variations one may observe a slight increase in the mean values of this parameter at the majority of the region's stations, this general trend being accentuated after 2002 (Figure 8).

The mean daily maximum precipitations follow on the whole the two basic laws of the quantitative repartition of rainfalls in Romania, they increase together with the height (49.5 mm, Vlădeasa) and the proximity to the west of the territory (53.5 mm, Avram Iancu).

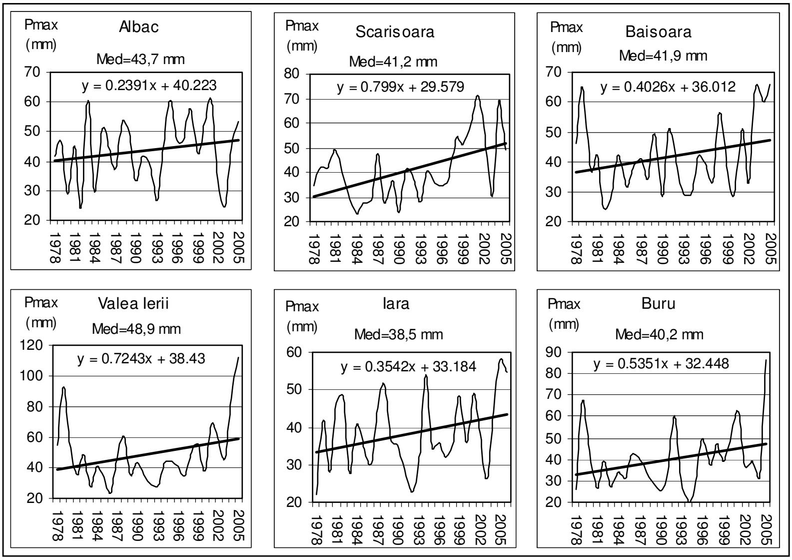

Fig. 8. Variation compared to the mean daily maximum precipitations and the general tendency of the 24-hours maximum precipitation events at some of the raingauge stations in the region (1978–2005)

In what regards the probabilities of exceedance one can observe that the estimated values of 24-hours precipitations with a 100-year return period vary on a rather large scale, between 122 mm at Valea Ierii station and 80 mm at Someş Rece-Sat (Table 4). The Valea Ierii location, as well as the nearby areas with similar topoclimatic characteristics (territory situated between 600 and 1000 m on the southern and eastern side of the Muntele Mare Massif), can be considered the "nucleus areas" of heavy summer rainfalls in the east of the Apuseni Mountains. On the basis of the available precise values and the time series data we can state the same thing regarding this time the frontal precipitations of the cold season in the higher regions of the upper basin of the Arieş as well. One may also observe that the maximum precipitations lessen at a certain interval of height, which is called the optimal condensation level and which was placed in the Western Carpathians between 1200 and 1400 m by Emm. de Martonne.[1]

Table 4. Values of 24-hours precipitations with different exceedance probabilities (1978–2005)

No	24-hours precipitations with different annual exceedance probabilities/return periods									
	0.01	0.1	0.5	1	2	3	4	5	10	20
	10000	1000	200	100	50	33	25	20	10	5
1	175	141	118	108	98	91	87	84	73	62
2	156	126	104	95	86	80	76	73	64	54
3	139	112	94	85	77	72	69	67	58	49
4	138	112	93	86	78	73	70	67	59	51
5	148	120	100	91	82	77	73	71	62	52
6	205	163	134	122	109	101	96	92	79	65
7	195	157	130	119	108	101	96	92	80	68
8	127	105	89	82	75	71	69	66	59	52
9	128	104	89	82	76	72	69	67	60	52
10	156	126	104	95	86	80	77	74	64	54
11	130	106	89	82	75	71	68	65	58	50
12	139	112	93	85	77	72	68	66	57	48
13	128	104	88	81	74	69	66	64	57	49
14	165	132	109	99	88	82	78	74	64	53
15	178	141	116	105	94	87	83	79	68	56
16	181	143	117	106	94	87	82	79	67	55
17	163	130	107	97	86	80	76	73	63	52
18	130	105	88	80	73	68	66	63	56	48
19	153	122	101	92	83	78	74	71	62	52

The measurement between fixed hours of the precipitations fallen in 24 hours at the raingauge stations, the different length of the time series by taking into consideration the absolute daily maximum precipitations and the broad spatio-temporal variability of the maximum precipitations can affect the quality of local results. In order to avert these lacks we regionalized this parameter delimiting 3 regions in which we took into consideration all the stations, with close mean values and variation coefficients, adopting for each one the probability of

[1] *Geografia României, geografie fizică* (The Geography of Romania, Physical Geography) (Bucharest: Editura Academiei, vol. 1., 1983), 232.

exceedance values obtained at the representative stations (with a long period of records, high values of mean daily maximum precipitations, absolute daily maximum precipitations and variation coefficients (Figure 9, Table 5).[1]

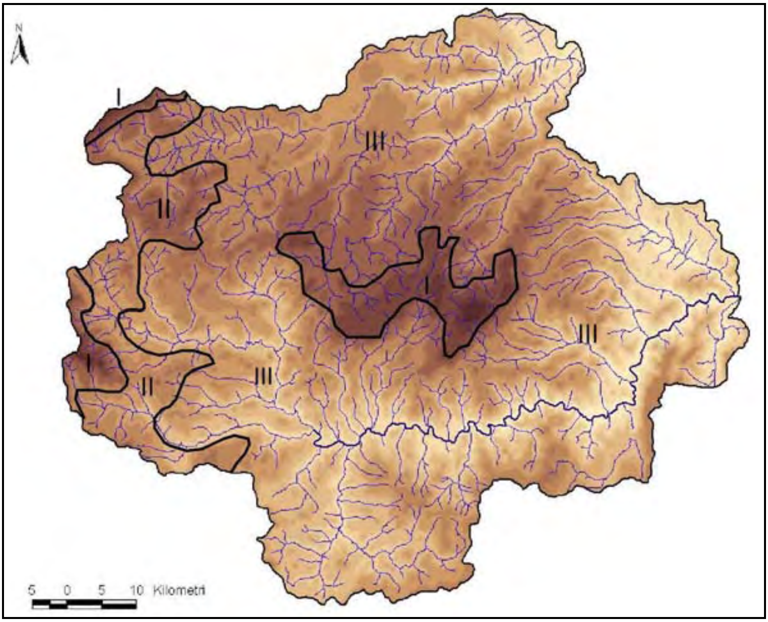

Fig. 9. Regionalization of 24-hours precipitation exceedance probability

Table 5. Estimated regional values for the 24-hour precipitations with different annual exceedance probabilities (1978–2005)

Regi	24-hours precipitations with different exceedance probabilities									
	0.01	0.1	0.5	1	2	3	4	5	10	20
I	175	141	118	108	98	91	87	84	73	62
II	195	157	130	119	108	101	96	92	80	68
III	192	152	125	114	102	94	90	86	74	61

[1] Radu Drobot, *Assessment of Rainfall Intensity, Frequency and Runoff for the Roşia Montană Project* (MWH, Tehnichal Report, 2004), 39 p.

In order to determine the amount of the precipitations with different probabilities for shorter periods than 24 hours we used the method of regionalization since the pluviographical records from the region are not a sufficiently consistent database for a statistic analysis similar to the one made related to the 24-hours precipitations. Thus, the daily precipitations with different probabilities of exceedance for this three regions were converted into precipitations with duration between 15 and 720 minutes by multiplying their values with certain conversion coefficients.[1]

The Table below shows the estimated values of the precipitations with different duration for the 1% annual exceedance probability.

Table 6. The estimated amount of precipitation equivalent to the 1% annual exceedance probability for periods of time between 5 minutes and 12 hours (1978–2005)

Regions	5'	10'	15'	30'	60'	2hrs	6	12
I	22	32	39	52	63	72	84	95
II	24	36	43	57	69	80	93	105
III	23	34	41	55	66	76	89	100

5. Maximum intensity of the rainfalls

The maximum intensity of the rainfalls (mm/minute) varies according to the return period and the duration of the precipitations, altitude, the continentality degree and certain local climatic characteristics, such as the foehn processes present in the east of the Apuseni Mountains in the case of the frontal precipitations with western advection.

The mean value of the intensity recorded by pluviographs was higher than 1 mm/minute in the case of rainfalls with duration between 15 and 30 minutes (1.27 mm/min, 16-07-2002; 1.06 mm/min, 13-06-1942 – Roşia Montană) and 0.15–0.05 mm/min in the case of those with duration of 24 hours. Isolatedly, for very short periods of time (under 10 minutes), in the eastern half of the region the intensity of the rainfalls was higher than 3 mm/min, reaching even values seldom recorded in

[1] Diaconu and Şerban, *Sinteze şi regionalizări hidrologice* (Hydrological Syntheses and Regionalizations) (Bucharest: Ed. Tehnică, 1994), 251.

Romania (6.78 mm/min at Răcătău raingauge station on 23-07-1953, when in only 6 minutes 40.7 mm were recorded).

In many practical applications it is indispensable to determine the maximum intensity of rainfalls for periods shorter than 24 hours (for example in the calculation of peak discharges in unmonitored small basins by means of the rational or the reductional formula).

In order to calculate the intensity values of heavy rainfalls with a 1% annual exceedance probability ($I_{1\%}$) for short periods of time (5–60 minutes), we used the formula which takes into consideration the relation between the intensity and the duration of the rain.[1]

$$I_{1\%} = \frac{S_{1\%}}{(D+1)^n}$$

where $S_{1\%}$ is the instantaneous intensity for 1% rain (in the east of the Apuseni Mountains the values specific to this parameter were between 10.5 and 14.0 mm/minute) (Figure 10); *n* is the reduction index of the rain intensity (0.50–0.60 for the studied region) (Figure 10); *D* is rain duration (minute).

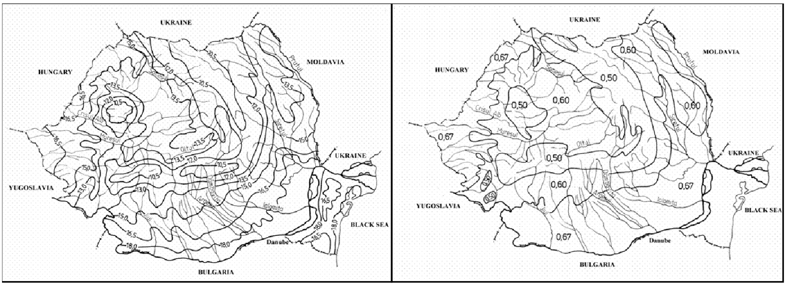

Fig. 10. Regionalization of $S_{1\%}$ *(left) and n (right) parameters*[2]

Table 7 shows the calculated values of the mean intensities of the precipitations with different durations for 1% annual exceedance probability. Analyzing the results, we observed that the mean intensity of

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[1] Şerban et al., *Hidrologie dinamică* (Dynamic Hydrology) (Bucharest: Editura Tehnică, 1989), 32.

[2] Diaconu and Şerban, *Sinteze şi regionalizări...,* 236, 239.

the precipitations has higher values for shorter periods of time (5–15 minutes) in the lower areas in the east of the region, which highlights the less moderate character of the climate, with local, convective summer rainfalls with high depth, but short duration. Contrary to the above mentioned territory, the western region, situated higher (the upper basins of the Arieş and the Someş Cald rivers), receives abundant frontal precipitations, amplified locally by the orographic factor (region situated in the "optimal pluviometric level" of the Apuseni Mountains, at approximately 1000–1400 m), which fall in longer periods of time.

Table 7. Mean intensity of the precipitations with 1% annual exceedance probability calculated by regionalization methods for different durations Eastern

	Western region					Estern region				
D (min)	5'	10'	15'	30'	60'	5'	10'	15'	30'	60'
I (mm/min)	4.29	3.18	2.6	1.89	1.34	4.78	3.32	2.65	1.78	1.19

The values calculated by regionalization methods are quite close to the values calculated directly for each station apart (Table 8). The differences which occur can be attributed to some local climatic features which could not be detected in the regionalization studies, characterized by a certain level of generalization.

Table 8. Mean intensity of the precipitations with 1% exceedance probability, calculated on the basis of local raingauge data for different durations

	Western region					Eastern region				
D (min)	5'	10'	15'	30'	60'	5'	10'	15'	30'	60'
Imax (mm/min)	4.76	3.57	2.86	1.9	1.15	4.88	3.66	2.93	1.95	1.18
Imin (mm/min)	3.24	2.43	1.94	1.3	0.78	3.2	2.4	1.92	1.28	0.77

6. Conclusions

The temperate-continental climatic background specific to the analyzed region does not exclude the possibility of high quantities of frontal, convective or mixed rainfalls. Directly or indirectly, heavy rainfalls (mainly in liquid form) cause most of the geographical hazard phenomena which affect the region (flash floods, floods and inundations, land instability phenomena, and pollution of watercourses).

Consequently to the interpretation of the results we identified two "nucleus areas" in the region where the quantities of precipitations usually reach the highest values:

- the eastern and southern side of the Muntele Mare Massif for convective summer rains generally of short duration and high intensity;
- the western side of the region for long duration frontal precipitations falling in the cold season.

The results obtained from the analysis of the maximum precipitations are important starting points for the evaluation of environmental risks, the value of which is expected to increase in the future since, firstly, the value of the objectives and their exposition degree will become higher, and, secondly, an increase of the intensity and frequency of maximum precipitations is to be expected.

Translated by Ágnes Korondi