THE TRIGGERING FACTORS OF THE FLOOD WAVES FROM THE RIVERS IN THE GILORT HYDROGRAPHIC BASIN

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ABSTRACT – The triggering factors of the flood waves from the rivers in the Gilort hydrographic basin. This case study makes an analysis of the main factors responsible for the manifestation of high waters and flood waves in the area using data from the period between 1982-2007 (26 years), provided by the six hydrometric stations from the basin. Studies included maximum 24-hour rainfall, and Probable Maximum Precipitation (PMP), precipitations intensity and various parameters for the snow cover (duration, thickness, layer melting). The interpretations were made on a multi-annual, annual, seasonal or monthly scale, depending on their relevance or the method used in the study. The main conclusions were that the most significant precipitation quantities in 24 hours appear in the summer, and that the liquid precipitations in the winter are more important comparative to other regions, due to the Mediterranean influence.

Key words: trigerring factors, flood waves, Gilort, probability

1. Introduction

Gilort is located in the south-western part of the country, ranging entirely on the territory of Gorj county, being the most important tributary on the left side of the Jiu river.

The length of Gilort's course is 126 km, the hydrographic basin having an average altitude of 590 m and an area of 1358 km^2, being located between the following coordinates: to the west – 23^{0}20´13″ eastern longitude (Balta Neagră Hill, 386 m), to the east – 23^{0}47´04″ eastern longitude (Muierii Hill, 650 m), to the north – 45^{0}21´12″ northern latitude (Coasta lui Rus Peak, 2300 m), to the south – 44^{0}35´36″ northern latitude (confluence with Jiu). Between these geographical coordinates the studied basin is extended on 45´36″ latitude and 26´51″ longitude.

The present study used data from the 6 hydrometric stations located in the Gilort's hydrographic basin (figure 1). The common activity period of the 6 hydrometric stations in the Gilort's hydrographic basin covers the interval 1982 – 2007 (26 years).

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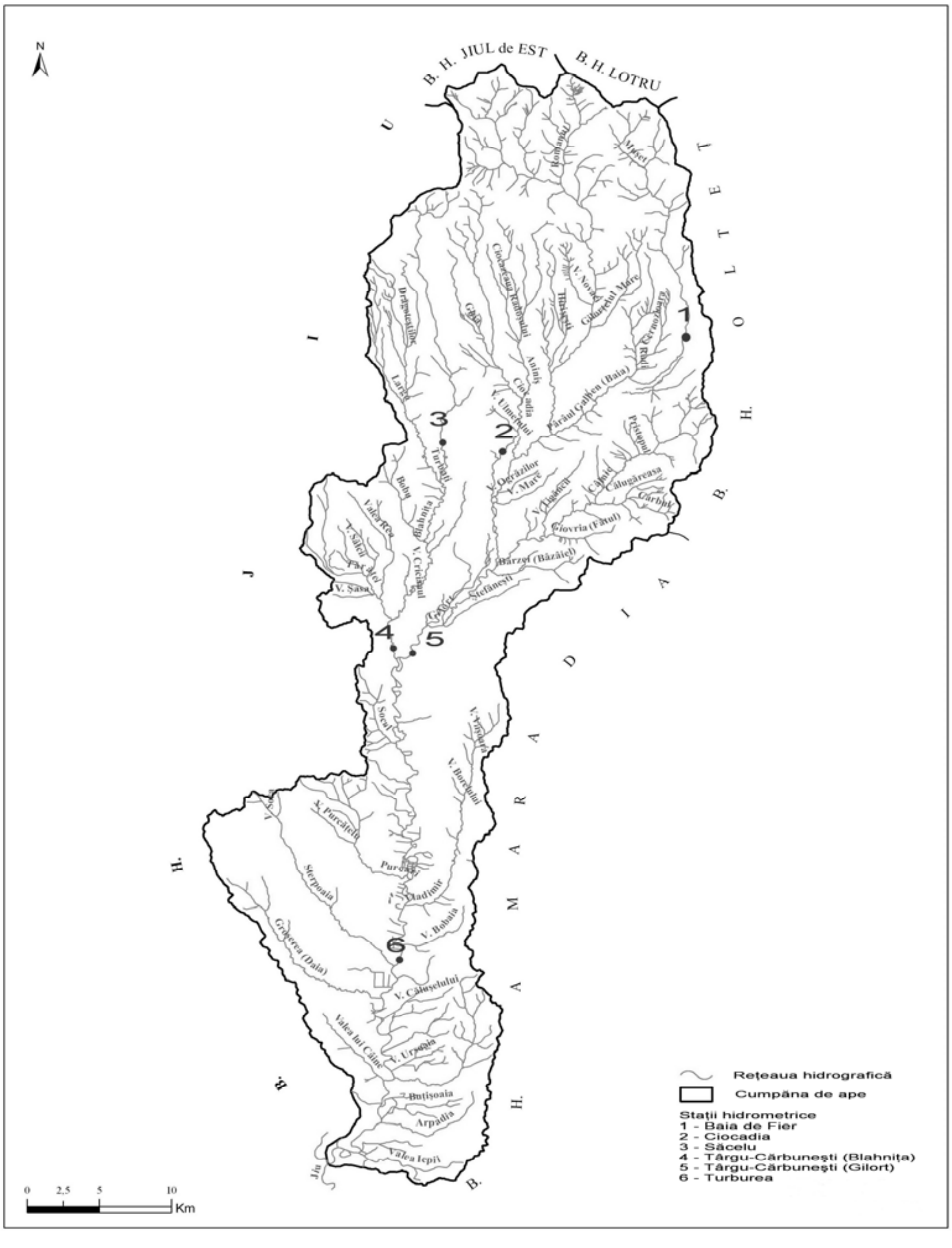

Figure.1. The location of the hydrometric stations from Gilort hydrographic basin.

The hydrographic basin does not have any meteorological station or post; consequently, the reference was made to the data recorded at the meteorological stations from Parâng, Târgu-Jiu and Târgu-Logreşti.

2. Triggering factors of the flood waves

An outstanding role in triggering the flood waves is held by the maximum 24-hour rainfall and the snow cover characteristics.

2.1. Maximum 24-hour rainfall quantities

Precipitations, regardless they are liquid or solid, have a direct influence on the flood waves. Those which are liquid have an immediate effect, while in the case of a solid form, their influence becomes perceptible after a certain lapse, when the temperatures move in the positive scale, leading to melting the cumulated snow or ice.

According to the maximum 24-hour rainfall quantities, taking into account the data set from the same hydrometric stations, covering the same common time period as for the average precipitations, we will find out that the exceptional quantities recorded on 22-23 January 1998, 23 October 2007 and 25 November 1985 generated maximum quantities, for the analyzed period, at all the hydrometric stations in the basin. Also having a general character, but producing, however, maximum quantities at only 4 hydrometric stations, where those from 23 March 2007 and 7 June 1989. The complete situation for each station, on a monthly basis, is presented in table 1.

Table 1. Maximum 24-hour rainfall quantities, at monthly scale, over a multi-annual period

Hydrometric station	Month											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Baia de Fier	35,4	40,1	30,5	35,3	41,6	74,5	81,1	98,2	52,5	51,2	51,9	51,8
Ciocadia	39,5	39,9	44,2	36,0	51,4	68,7	76,4	65,4	74,5	67,6	57,5	38,9
Săcelu	31,4	61,9	35,2	36,4	36,2	68,6	56,5	49,7	48,0	34,6	70,0	26,6
Tg.-Cărbuneşti	32,5	41,1	39,3	40,9	41,5	55,9	75,2	74,5	50,5	94,5	42,6	35,4
Turburea	53,8	31,5	30,2	45,9	36,7	58,9	70,1	79,3	62,8	65,1	44,0	34,6

The situation of all time maximum 24-hour rainfall quantities for the period covering the years 1982-2007 is presented as follows: Baia de Fier – 98,2 mm on 17 August 1991; Ciocadia – 76,4 mm, quantity recorded on 16 July 1998; Săcelu – 70,0 mm, on 25 November 1985; Târgu-Cărbuneşti – 94,5 mm, on 23 October 2007; Turburea – 79,3 mm, on 29 August 1985.

So, *the absolute maximum* for the studied hydrographic basin is 98,2 mm, recorded on 17 August 1991, at Baia de Fier hydrometric station. Of more recent occurrence are the exceptional precipitations recorded at basin level on 16 August 2005, oscillating between 28,3 mm at Săcelu and 77,5 mm at Turburea. In this case it was obvious, from a synoptic perspective, the great development of the Azores Anticyclone, within Central Europe. At the periphery of the mentioned anticyclone appears a broad depression area, formed by the association of the air masses of the Icelander Cyclone with those came from Arabian Peninsula.

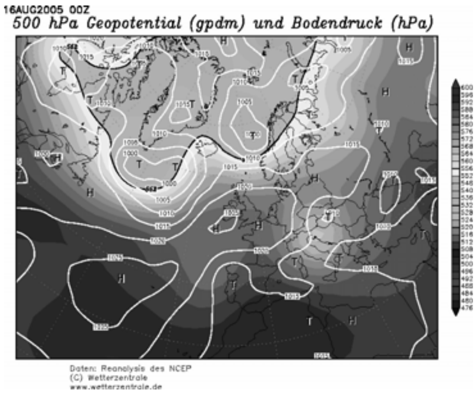

Fig.2. Geopotential map at 500 hPa/mb for 16.08.2005
(source: www.wetterzentrale.de)

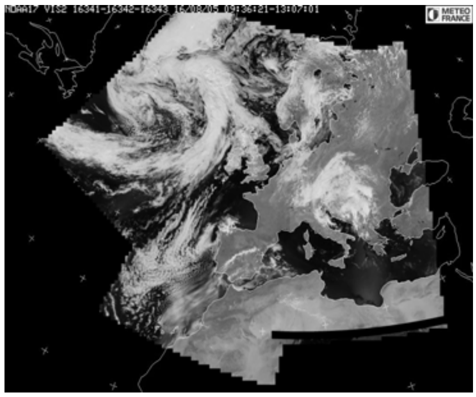

Fig.3. Cloud formations distribution for 16.08.2005
(source: www.satmos.meteo.fr)

The given situation encourages the advection of air masses from southeast, from above Mediterranean Sea, hot and wet air. In this context, it was recorded also a slight decrease of the temperature, increasing the condensation process ratio.

2.1.1. The monthly and seasonal frequency of maximum 24-hour rainfall and the climatic conditions involved in the genesis

Hereinafter we will present the situation referring to another important aspect connected to the maximum 24-hour rainfall quantities, namely their occurrence frequency, at various time scales.

For each hydrometric station in the analyzed basin was extracted the maximum 24-hour value for each month at the time, resulting a number of 312 values for each station, corresponding to the total number of months from the interval between 1982-2007. Next, these values were grouped in 3 categories: above 20 mm, between 10-20 mm and between 0-10 mm (table 2).

Calculating the percentages, at the scale of the whole basin, 38,5 % from the number of values were above 20 mm, 33,2 % covered the interval 10-19,9 mm and 28,3 % that of 0-9,9 mm.

Table 2. Number of days corresponding to different thresholds of the maximum 24-hour rainfall (1982-2007)

No. rainy days	Baia de Fier	Ciocadia	Săcelu	Tg.-Cărbuneşti	Turburea
≥20 mm	132	111	103	135	121
10-19,9 mm	94	118	112	96	97
0-9,9 mm	86	83	97	81	94

The next stage consisted in calculating the monthly frequency of maximum 24-hour rainfall, taking into account only the values higher than 20 mm, the quantitative aspect being determinant in triggering the flood waves. The results are displayed in table 3:

Table 3. Maximum and minimum monthly frequency and seasonal freqency of the maximum 24-hour rainfall (for the period 1982-2007)

Hydrometric station	H (m)	Monthly. max. freq.		Monthly. min. freq.		Biannual freq. (%)	
		Freq. (%)	Month	Freq. (%)	Month	V-X	XI-IV
Baia de Fier	1230	13,6	VIII	3,0	III	68,2	31,8
Ciocadia	848	16,2	VI	1,8	I	69,4	30,6
Săcelu	725	15,5	VII	2,9	I	68,9	31,1
Tg-Cărbuneşti	749	14,0	VI	2,2	I, III	67,4	32,6
Turburea	590	13,3	V, VI	3,3	I	64,2	35,8

Generally, the main baric centers that influence the appearance of the precipitations in the studied territory are the Azores anticyclone, oceanic cyclones and the depression area from the Mediterranean Sea, represented by the Mediterranean cyclones, which, according to their evolution in time and especially in space are tightly connected to the quantity of precipitations recorded in the analyzed area. These last ones develop alongside 9 general trajectories (Şorodoc, 1962), a major importance for Romania having the classic trajectory 1 and the classic transbalkanic trajectories 2a, 2b and 4a. Generally, this type of cyclonic activity is associated with heavy rainfalls in the studied area, even in the warm season, an important role in this case having the Parâng Mountains. This sector determines an ascending circulation of air-masses, leading to the accentuation of the thermic convection process and to the Cumulonimbus clouds. The situation showed is not general, having, however, a high frequency (Ion-Bordei, 1983).

Regarding the climatic conditions that influence the maximum 24-hour rainfall formation in the studied basin, it was determined the existence of 5 synoptic situations that generate heavy rainfalls in the southwestern part of the country (Marinică and others, 1984; Marinică, 2006). Therefore, the heavy rainfalls might be situated in one of the following types:

- type I – due to Mediterranean Cyclones;
- type II – determined by cyclones originated in the Pannonian Plain;
- type III – issued on a depressionary couloir between the Icelandic Cyclone and another cyclone from the eastern basin of the Mediterranean Sea;
- type IV – issued at the periphery of an anticyclonic field;
- type V – of thermoconvective origin.

2.2. Maximum rainfall intensity

In order to calculate the medium rainfall intensity with 1% probability, it is recommended to use the following relation:

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

where :
- $S_{1\%}$ - instantaneous rainfall intensity with 1% probability of occurrence;
- n – reduction index of the rainfall intensity;
- t_c –concentration time (rain duration).

For the studied area, according to the generalization of $S_{1\%}$ and n parameters, were adopted the following values (Diaconu, Şerban, 1994):
- $S_{1\%}$ – has values between 10,5 and 15 mm/min;
- n – has the value of 0,60.

The results are given in the table below (table 4).

Table 4. The rainfall intensity with 1% probability of occurrence, for different durations

t_c (minutes)	5'	10'	15'	30'	60'
I_{max} (mm/minute)	3,58	2,49	1,99	1,34	0,89
I_{min} (mm/minute)	5,12	3,56	2,84	1,91	1,27

2.3. The statistical analysis for maximum 24-hour rainfall

To cover this stage, first of all was necessary to establish the common period of functioning of the hydrometric stations; for the next step, for each year were extracted the 12 maximum monthly values. By applying an arithmetic average was obtained a medium monthly value of maximum 24-hour rainfall. The situation is presented in figure 4.

For further analysis, regarding the probabilities of occurrence and implicitly the return periods was used Gumbel repartition (although it underestimates the values in case of long return periods, it is recommended in case of shorts data series), to the detriment of Gamma repartition with 2 parameters (Pearson type III – applied usually in the analysis of data that imply mean values of a parameter and which in this case did not furnish cogent results).

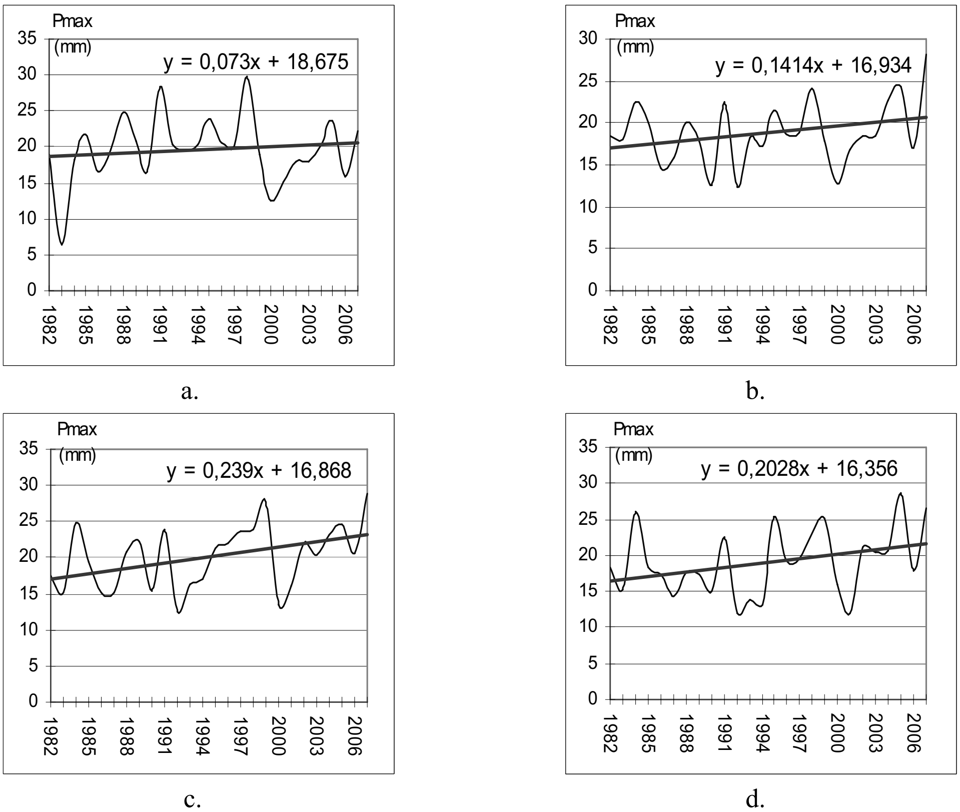

Fig. 4. – The variation and the trend of maximum 24-hour rainfall
(a. Baia de Fier; b. Ciocadia; c. Târgu-Cărbuneşti; d. Turburea)

Next were calculated the parameters for the empirical distribution curves, using the following formulas:

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

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

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

where:
- $\overline{P}_{24h}$ – arithmetic average of maximum rainfall;
- P_i – the maximum rainfall corresponding to the number *i* from the sequence of terms;
- *n*- number of terms;
- C_v –coefficient of variation;
- C_s – asymmetry coefficient;
- k_i – module coefficient.

The values of the coefficients of variation calculated for the period 1982-2007 were oscillating between 0,20 (Ciocadia) and 0,25 (Turburea).

The next step was represented by the calculation of maximum 24-hour rainfall values with different probabilities of occurrence / return periods (table 5)

Table 5. The maximum 24-hour rainfall values with different probabilities of occurrence (for the period between 1982-2007)

Hydrometric station	Maximum 24-hour rainfall values with different probabilities of occurrence / return periods					
	1	2	5	10	20	50
	100	50	20	10	5	2
Baia de Fier	103,9	93,9	80,7	70,5	59,8	43,7
Ciocadia	102,9	93,3	80,6	70,8	60,5	45,0
Săcelu	89,2	80,8	69,6	61,0	51,9	38,3
Tg.Cărbuneşti	108,7	98,3	84,4	73,7	62,5	45,7
Turburea	111,3	100,3	85,5	74,1	62,2	44,2

2.4. The estimation of PMP values

The probable maximum precipitation was defined as "the greatest theoretic height of precipitations for a given duration, which is physically probable on a given surface, in a certain geographic location and in a particular time of the year" (O.M.M., 1986).

According to Hershfield (1965), the probable maximum precipitation at a hydrometric station might be calculated by using the following formula:

$$X_{PMP} = X_n + K \cdot S_n, \text{ where:}$$

- X_{PMP} – the extreme precipitation at one station;
- X_n – average of the range of *n* annual maximum;
- S_n – standard deviation for the range of *n* annual maximum;
- *K* –variable of frequency, depending on the statistic distribution, the number of years taken in consideration and the return period.

In 1961, Hershfield defined the formula used to obtain the *K* parameter:

$$K = \frac{X_1 - X_{n-1}}{S_{n-1}},$$

where:
- X_1 – the greatest value from the range of *n* annual maximum;
- X_{n-1} – the average of the ranges of *n* annual maximum, neglecting the greatest value from the range;
- S_{n-1} – the standard deviation of the ranges of *n* annual maximum, neglecting the greatest value from the range;

Using the 2 suggested formulas, were obtained the sets of values that are presented in table 6.

Table 6. The values for *K* and X_{PMP} parameters

Hydrometric station	***K***	X_{PMP}
Baia de Fier	18,1	104,8
Ciocadia	16,0	79,1
Săcelu	12,5	70,2
Târgu-Cărbuneşti	18,5	101,5
Turburea	12,4	76,9

3. Snow cover melt

Taking into consideration the fact that in the Gilort hydrographic basin there is not operating any meteorological station, in the study were used data coming from the meteorological stations located in the adjacent basins, as it follows. So, for the mountain area were used the data from Parâng meteorological station (1548 m) and for the subcarpathian and piedmontan area were taken into account the data from Polovragi meteorological station (532 m) and Târgu-Jiu meteorological station (205 m).

3.1. The characteristic parameters of the snow cover

3.1.1. The duration of the snow cover

Temporally, the snow cover presents variations, influenced mainly by the air temperature and the altitude. The slow melting process of the cover, associated with the passage of the temperatures at positive values, produces an additional water input (superposed or not over a series of liquid precipitation), which leads to the augmentation of drainage coefficients. In these conditions, the rivers are due to produce flood waves with mixed origin. As a matter of fact, in the analyzed basin, the situation is very frequent, due to the heat waves in the winter, issued as a consequence of the Mediterranean influences.

In the Parâng mountain area, the first day with snow cover appears ordinarily in September; in the hills and piedmont area, this day is in general in November, existing however frequent cases when the apparition is made in December. The last day with consistent snow cover in the mountain area is recorded ordinarily in May and in the other areas in the studied basin in March.

Regarding the multi-annual average number of days with snow cover, it presents large range variations, remarking however their decreasing trend from north to south, according to the altitude. The actual situation recorded at the meteorological stations taken into account is presented in table 7.

Table 7. The multi-annual average number of days with snow cover ≥ 5 cm (after Savin, 2008)

Meteorological station	**Record period**	**The multi-annual average number of days with snow cover**
Parâng	1958-1982	120,8
Polovragi	1974-1996	36,8
Târgu-Jiu	1958-1982	24,0

3.1.2. The thickness of the snow cover

The thickness of the snow cover is bound up mainly with the water volume stored, which will contribute at the spring high waters and flood waves formation. This parameter is connected to the forestation degree of the land, to the altitude, slope exposure etc.

Therefore, the greatest thickness at a multi-annual scale is recorded in the mountain area, at Parâng meteorological station, in February (the multi-annual average exceeding 50 cm). In the sheltered areas, with predominantly northern exposure, the snow cover can reach even 7-8 m thickness. For the hill and piedmont regions, the greatest thickness of the snow cover is recorded in January-February, the multi-annual average is not exceeding however 15 cm at Polovragi meteorological station and 10 cm at Târgu-Jiu. The detailed situation regarding the thickness of the snow cover is presented in table 8.

Table 8. The medium multi-annual thickness of the snow cover (after Savin, 2008)

Meteorological station	**I**	**II**	**III**	**IV**	**V**	**X**	**XI**	**XII**
Parâng	40,8	55,7	47,2	13,7	0,7	0,7	5,8	20,7
Polovragi	11,5	11,7	9,4	0,03	-	-	0,4	4,6
Târgu-Jiu	6,8	3,8	1,0	-	-	-	0,1	1,7

3.1.3. The snow cover melting

For estimating this parameter was used the degree-day method (Drobot, Şerban, 1999), for the average daily temperature, based on the formula:

$$h = M' \cdot (T_{med} - T_e) \approx M' \cdot T_{med},$$

where:

- T_{med} – average daily temperature;
- T_e – equilibrium temperature (which is considered in general equal to zero);
- M' – degree-day factor used for T_{med}.

The degree-day factor might be calculated taking into account the density of the snow and the vegetation cover, using the following formula (Rango and Martinec, 1995):

- general – $M'=1,1(\rho_{zăp} / \rho_{apă})$;
- wooded area – $M'=1,04(\rho_{zăp} / \rho_{apă}) - 0,7$;
- open area – $M'=1,96(\rho_{zăp} / \rho_{apă}) - 0,239$.

Bearing in mind the fact that the density of water in normal pressure and temperature conditions is 1 g/cm^3, while the density of the snow presents variations due to wind exposure, freezing-defreezing cycle, compression under its own weight etc., between 0,07 and 0,5 g/cm^3 (passing over this value only when ice is formed), the values of degree-day factor will present variations too (Ursu, Ţilea, 2007). For the study was selected the month of March, because of the more frequent passage of the temperatures in the positive scale, which determines the melting of the snow cover accumulated in the previous months. The data obtained using the general formula for the degree-day factor is presented in table 9.

Table 9. Maximum and minimum values of the melted snow cover, using the degree-day method, for average temperatures

Meteorological station	**$T_{med\ march}$ (°C)**	**h_{min}**	**h_{max}**
Parâng	-2,4	0,18	1,32
Polovragi	3,6	0,28	1,98
Târgu-Jiu	4,9	0,38	2,70

Conclusions

Regarding the triggering factors of the flood waves form the Gilort hydrographic basin, some conclusions are drawn, mentioned as it follows.

Firstly, the most important quantities of 24-hour rainfall appear during the summer, fact confirmed also by the production periods of the 2 most important high floods from each station, for the analyzed period, due to heavy rainfalls.

Another important aspect is related to the fact that even on the one hand, in percentages, the winter months have the lowest frequency, on the other hand, it becomes obvious that liquid precipitations have a much higher weight than in other regions, due to the Mediterranean influence felt in the basin.

Due to the same influence the snow cover also has a lower thickness and duration than other regions, located at the same altitude and latitude.

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