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The Variation of the Liquid Monthly Average Flow in the Hydrographic Basin of the Uz River

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THE VARIATION OF THE LIQUID MONTHLY AVERAGE FLOW IN THE HYDROGRAPHIC BASIN OF THE UZ RIVER

Ioana-Delia Miftode[1], Gheorghe Romanescu[1]

Abstract. The study of the characteristics pertaining to the variation of the average monthly flow is based on the calculation of the multi-annual average extracted from the average monthly flows, on the relative and absolute occurrence frequency of the maximum annual average flows, the analysis of the maximum and minimum seasonal average flows, the occurrence probability of the highest flows, the variation amplitude highlighted with modular coefficients (Kmax si Kmin), the ratio between these two modular coefficients (Kmax/Kmin), but also the Cv variation coefficient calculated based on the entire data series relative to the average flows. Also, there were estimated the maximum flows with different insurances: Pearson III distribution, which adjusts the most effectively the empirical insurances. The variation of the average monthly liquid flows is studied in respect with the variation of the average annual rainfall registered between 1980 and 2009. In this respect, there were established correlations between the flow variations and rainfall, as well as the tendencies at the two hydrometric stations (Cremenea and Dărmănești). By analyzing the variation of the average monthly flows it was possible to establish the genesis of the fluctuation of the flows registered during different periods of the year, as well as the complex way of combining the water sources for the Uz river. The liquid average flows from the Uz hydrographic basin present a temporal variation related to the evolution of climatic factors. The maximum values of the liquid average monthly flows occurred in the month of April in 1970 at the Uz valley hydrometric station and at the Cremenea station, while in 1984 they occurred at the Dărmănești hydrometric station. The registration of the maximum values for the average monthly spring flows can be explained by the intensification of the cyclonic activities responsible for the generation of abundant rainfall overlapped over the rising air temperature fostering snow meltdown at ground level.

Keywords: temporal variation, occurrence frequency, variation coefficient, rainfall

1. Introduction

The water volume flow is leaking through a cross-cut section of a river (or channel) in a unit of time presenting variable values in time and space due to the type and drainage system (Romanescu, 2007). The European Environment Agency, through the studies made at a European level, says that in the northern half of Romania the average monthly flows present a rising tendency (EEA, 2012). During the temporal evolution of the average river flows, it can be observed important oscillations generated, mainly, by the non-uniformity and characteristics of the climatic parameters, but also by the physical and geographical conditions which have a direct and indirect influence over the supplying sources and hydrological

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processes. The analysis of the temporal variation of the average flows is usually performed at an annual and multi-annual, seasonal or even monthly scale. In the case of the seasonal analysis of the average flow, variability is the dominant factor.

The hydrologic parameters, in correlation with the climatic parameters, are extremely well studied at a national and international level (Alfieri et al. 2014, Čech and Čech, 2013; Conrad et al., 2015; Loczy et al., 2009; Raška, 2015; Revuelto et al., 2014; Salit et al., 2013; Simonovici, 2010; Yang et al., 2014). The characteristics of the river in the eastern Romania were systematically studied in a series of papers elaborated during 1950-2014 (Cojoc et al., 2015; Corduneanu and Bucur, 2013; Corduneanu et al., 2014; Costache et al., 2015; Crăciun et al., 2011; Giurma et al., 2009; Haliuc and Frantiuc, 2012; Hapciuc et al., 2015a,b; Iosub et al., 2015; Jora and Romanescu, 2010; Mihu and Romanescu, 2011; Minea, 2012; Porcuțan, 2014; Reti et al., 2014; Romanescu, 2008; 2013, 2015; Romanescu et al., 2005, 2011, 2012, 2013, 2014; Romanescu and Romanescu, 2011; Romanescu and Stoleriu, 2013; Sorocovschi and Bătinaș, 2013; Tîrnovan et al., 2014a,b; Tutunaru et al., 2013a,b). The study aims at highlighting a series of characteristics of the average monthly flow variation between 1950 and 2009.

2. Regional setting

The hydrographic basin of the Uz river is situated in the eastern part of Romania, in the southern part of the Oriental Carpathian mountains (Figure 1). The river Uz is the right tributary of the river Trotus. It springs from the Ciucului mountains and the hydrographic basin has a surface of 475 km^2. The river Uz has a length of 46 km. From a mathematical standpoint the surface of the hydrographic basin of the river Uz is situated between 26˚00’16”, 26˚30’56” eastern longitude and 46˚08’44”, 46˚23’27” northern latitude. The average altitude of the hydrographic basin is of about 982,345 m.

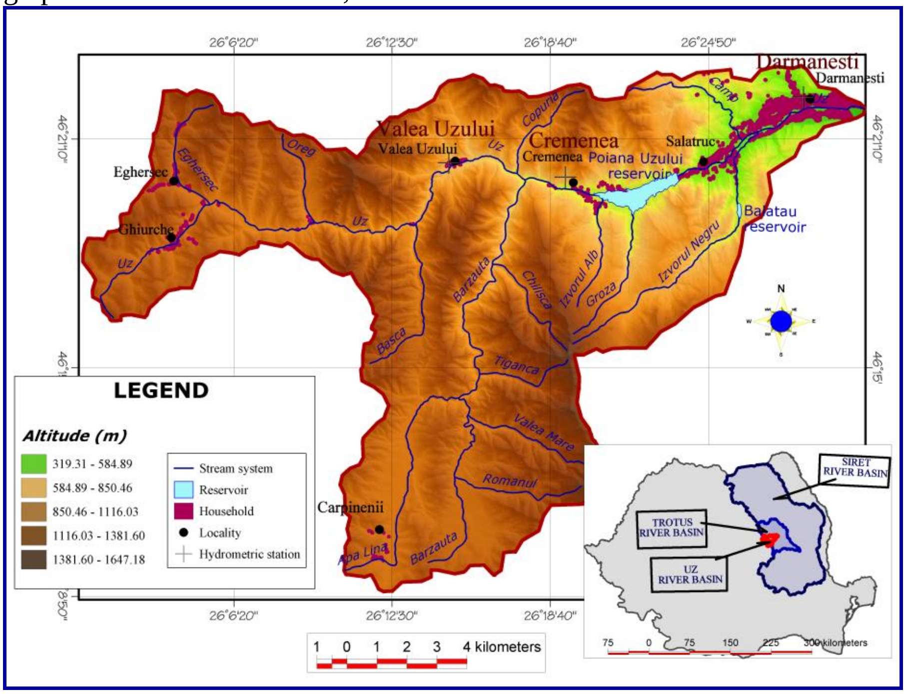


Figure 1: Geographical positioning of Uz hydrographic basin

The biggest heights can be found in the Nemira mountains : Nemira Mare (1648 m), Nemira Țiganca (1626 m), Șandru Mare (1639 m), Osoiul (1553 m), Cărunta (1517 m). The North-South orientation of the Nemira-Șandru Mare peak influences the flowing direction of the water. The lower terraces are separated by the medium ones by sharp slopes. The declivity of the mountain sides varies between 5 and 50 degrees, for the meadows between 1 and 3 degrees and for the interfluves and the bridge terraces between 0 and 6 degrees. From a geological standpoint in the hydrographic Uz basin the following areas can be distinguished: the zone of the Cretaceous and Paleogene flysch in the mountainous sector; the Neogene zone in the depression sector; the post-tectonic zone, but also the transversal profile of the river valley which contributed to the formation of gorge-like narrow sectors which alternate with the small erosion basin. The main characteristic of the Uz valley is represented by the small depression basin and the gorge-like sector where the detritus reach important heights. The hydrographic basin of the river Uz has in its component the accumulation at Poiana Uzului. The climate is one specific to the medium heights in the Eastern Carpathian mountains from the depression, shelter areas (Dărmănești depression).

3. Materials and methods

In order to highlight the variation of the average monthly flow in the hydrographic basin of the river Uz, the registered data from Valea Uzului, Cremenea and Dărmănești, hydrometric stations situated along the Uz river were used and processed. The hydrometric stations Valea Uzului and Cremenea are situated upstream of the Poiana Uzului accumulation lake, while Dărmănești station is situated downstream. Based on the data centralized by the Siret Water Basin Administration in Bacău, we analytically calculated multi-annual average flows, annual average flows, as well as annual maximums and minimums of the average monthly flows.

Based on the average monthly flow values, it was possible to establish the relationship between the average monthly flows and the average multi-annual flows, the K modular coefficient and the Cv variation coefficient. Also, an analysis of the average seasonal flows for the entire study period was performed, flow variation diagrams being made in correlation with the multiannual variation of the atmospheric rainfall, as well as the tendencies, the frequencies, the standard deviation. In order to fulfill the objectives of the study, a modern conception approach was used, as well as methods and instruments: GIS, the graphic method and the analytical method. The graphic part had as support the topographic maps at a 1:5000 scale. For the elaboration of the MNT a program called TNTMips was used. The data were processed in Ms Excel, from which a chart resulted.

4. Results and Discussions

The variation of the average monthly liquid flow was studied based on the average multi-annual monthly values of the flows registered at the hydrometric stations from the hydrographic Uz basin : the Valea Uzului and Cremenea stations are situated upstream of Poiana Uzului lake; Dărmănești station is situated downstream. The average of the medium monthly values between 1950 and 2009 was calculated: 1,661 m^3/s for the Valea Uzului hydrometric station, 4,051 m^3/s for Cremenea and 4,801 m^3/s for Dărmănești.

The multi-annual maximum values for the annual average flows vary between 3,102 m^3 at Valea Uzului in 1970 and 9,313 m^3/s at Dărmănești in 1984. The calculation of the minimum multiannual values of the annual average flows for the same period indicates the fact that these are contained within the interval 0,609 m^3/s at Valea Uzului in 1950 and 1,703 m^3/s at

Dărmănești in 1990. Starting from the average annual flows and multi-annual average flow the Ki modul coefficient and Cv variation coefficient were established (Table 1).

Table 1: Kmax module coefficient – S.h. Valea Uzului, Cremenea si Dărmănești

	Valea Uzului			Cremenea			Dărmănești		
Period	**1970**	**1950-2009**	**Ki**	**1970**	**1950-2009**	**Ki**	**1984**	**1950-2009**	**Ki**
I	0.73	0.54	**1.37**	1.67	1.31	**1.27**	4.69	1.83	**2.56**
II	0.93	0.65	**1.44**	2.13	1.54	**1.38**	1.29	2.19	**0.59**
III	4.24	1.69	**2.51**	9.66	4.00	**2.42**	4.56	4.82	**0.95**
IV	5.98	4.02	**1.49**	13.63	9.63	**1.42**	31.90	11.11	**2.87**
V	13.23	3.29	**4.02**	30.16	8.13	**3.71**	34.20	9.63	**3.55**
VI	4.06	2.53	**1.60**	9.26	6.24	**1.48**	11.50	7.16	**1.61**
VII	2.71	2.19	**1.24**	6.19	5.32	**1.16**	7.74	6.00	**1.29**
VIII	2.17	1.57	**1.38**	4.95	3.97	**1.25**	4.68	4.47	**1.05**
IX	0.96	1.12	**0.86**	2.19	2.75	**0.80**	2.45	3.23	**0.76**
X	0.88	0.88	**1.00**	2.01	2.14	**0.94**	2.75	2.57	**1.07**
XI	0.73	0.77	**0.95**	1.65	1.91	**0.87**	2.76	2.37	**1.17**
XII	0.61	0.69	**0.89**	1.40	1.67	**0.84**	3.23	2.23	**1.45**
I-XII	*3.10*	*1.66*	***1.56***	*7.07*	*4.05*	***1.46***	*9.31*	*4.80*	***1.58***

By interpreting the modular Ki coefficient, the average monthly flow in the month of May of the year 1970, for the stations Valea Uzului and Cremenea, and also for the year 1984 at Dărmănești station, is approximately four times higher than the average multiannual monthly flow (Table 1). For 1970, it was registered at the stations Valea Uzului and Cremenea, the annual Qmed being approximately two times higher than multiannual Qmed. For Dărmănești station in 1984, the average annual flow was two times higher than multiannual Qmed. It was made a Pearson III distribution that adjusts empirical insurances (Figure 2). The maximum flow with the insurance of 1% has a value of 1,397 m^3/s for Dărmănești station, 1,302 m^3/s for Cremenea station and 0.929 m^3/s for the Valea Uzului station.

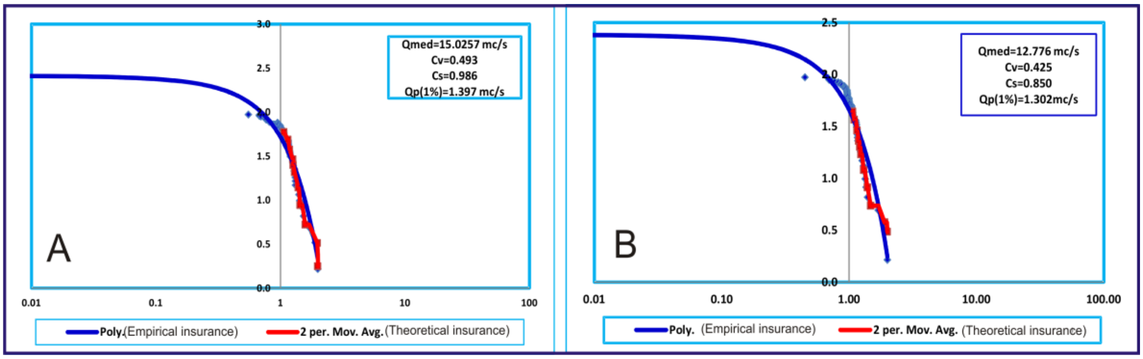


Figure 2: Empirical and theoretical Pearson III empirical probability – Cremenea and Dărmănești station

For the average per month of the mean flows between 1950 and 2009 the following were found: in the month of April the maximums of the average multi-annual monthly flows were registered at the three hydrometric stations (Valea Uzului – 3.98 m^3/s, Cremenea – 9,564 m^3/s and Dărmănești – 11,033 m^3/s). The minimums of the average multi-annual monthly flows between 1950 and 2009 were registered at the three hydrometric stations in the month of January: Valea Uzului – 0.54 m^3/s, Cremenea – 1.32 m^3/s and Dărmănești – 1.93 m^3/s. This hydrologic parameter is represented by the flow hydrograph (Figure 3). The average multi-annual monthly values are in a continuous decrease in the month of April until January. In the month of January and February the values keep a low record followed by a sharp increase in March and April.

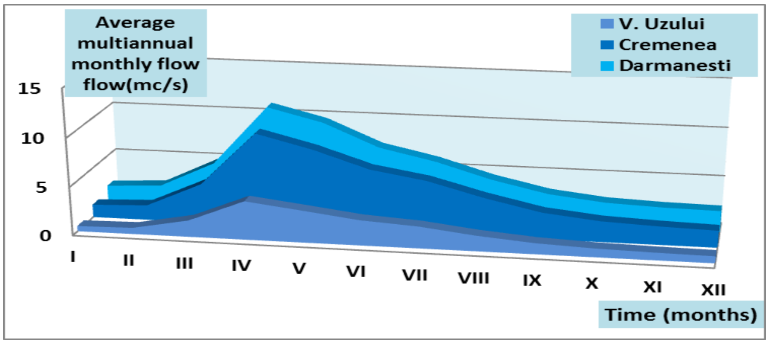


Figure 3: The variation of average multiannual monthly flows (1950-2009)

The variation of the average seasonal flows shows that the average multi-annual monthly maximum flows occur in spring (April). The supplying of the river is made through rainfall and snow melting. The minimums of the average multiannual monthly flows, occurred during winter, are due to the quantitatively reduced rainfall, i.e. snow trapped in ice. To this we add the negative air temperatures that not only last long time, but also foster freezing (Figure 4 A).

In the hydrographic basin of the river Uz, at all three hydrometric stations, in the evolution of average flows four characteristic periods corresponding to the seasons can be differentiated during the entire year. The highest liquid flow passes during spring (45%) and the lowest during winter (9%). During summer, the percentage of the average monthly flows is of about 32%, while during autumn it is of about 14% (Figure 4 B). The flow variation is due to the intake of water supply which influences seasonally the water quantity transported by the river Uz. This intake is highly influenced by the physical and geographical condition in the hydrographic basin. The seasonal average flows present variations in time and space.

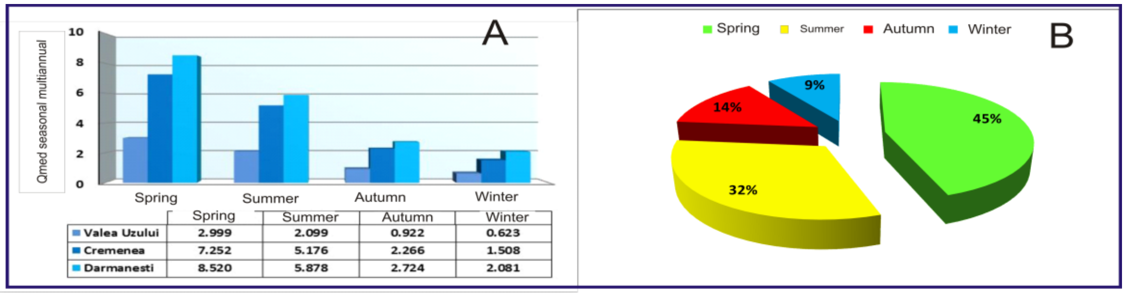
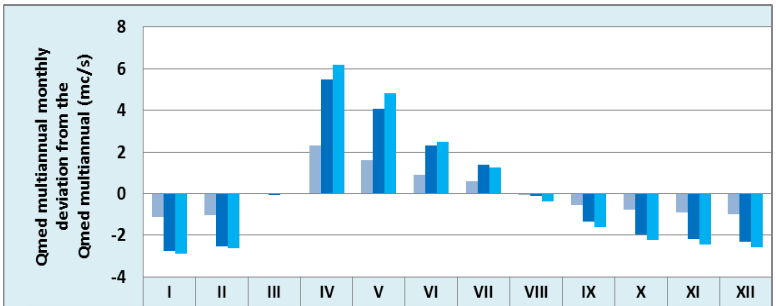


Figure 4: The variation of the average multiannual seasonal flows (1950-2009)

For summer (June-August) the values of the average flows drop in comparison to those registered during spring. The drop is due to the water losses manifested through evapotranspiration and seepage (Sorocovschi and Bătinaș, 2013). In autumn (September-November) the values of the average monthly flows are reduced due the subterranean supply of the rivers. An important cause is represented by the summer-autumn anticyclone with low rainfall. During winter (December-February) the values are low due to the rainfall dropped as snow and to the very low temperatures.

The standard deviations of the average monthly flows from the multiannual average and from the average multiannual monthly flows show that at Valea Uzului and Dărmănești, during August-March, the deviations from the multiannual average are negative. For Cremenea station, the period with negative deviations extends until March (Figure 5).



	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Valea Uzului	-1.1	-1.0	0.03	2.3	1.6	0.9	0.6	-0.1	-0.5	-0.8	-0.9	-1.0
Cremenea	-2.8	-2.5	-0.04	5.5	4.1	2.3	1.4	-0.1	-1.3	-1.9	-2.2	-2.3
Darmanesti	-2.9	-2.6	0.04	6.2	4.8	2.5	1.3	-0.4	-1.6	-2.2	-2.5	-2.6

Figure 5: Standard deviation of the average monthly flows from the multiannual average (1950-2009)

The deviations for April, May, June and July are positive due to the rise in the air temperature that favors snow meltdown in the mountainous region, as well as quantitatively significant rains. The standard deviations of the average multiannual monthly flows (Figure 6) and of the specific multiannual monthly flows show that the hydrometric stations of Valea Uzului and Dărmănești are negative during August-March. The period with negative deviations from Cremenea station extends for March as well. For April, May, June and July it can be ascertained that the standard deviations are positive due to a rise in air temperature that favors not only snow meltdown in the mountainous region, but also quantitatively significant rainfall.

The average annual flows during the years 1950-2009, when extreme and medium flows occurred, presented maximum values in 1970: 13.2 m^3/s at Valea Uzului station and 30.2 m^3/s at Cremenea station. In 1984 the maximum annual flow that was registered at Dărmănești was of 34.2 m^3/s. All maximum values resulted from the calculation can be found in the month of April, but in different years. Noteworthy is the fact that at Dărmănești station in 1984 a secondary maximum of 31.9 m^3/s was registered in the month of April. The values of the main maximum flow are very close to that of the secondary one. The lowest liquid flow for the entire studied period is of about 0.1 m^3/s and it was registered at Dărmănești in 1990. In January 1950, at Valea Uzului station, the minimum flow was of about 0.3 m^3/s, and at Cremenea station the minimum flow was of about 0.8 m^3/s in January 1950.

The variation of the average monthly flows in the years with extreme and medium flow between 1950 and 2009 proves that the years with a humidity deficit were 1950 (Valea Uzului and Cremenea stations) and 1990 (Dărmănești station) (Figures 6).

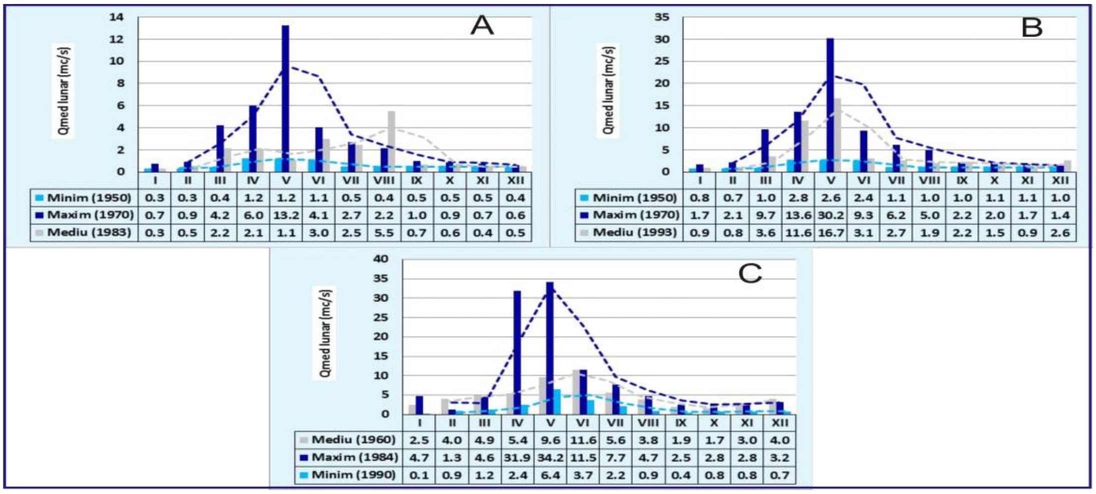


Figure 6: The variation of the average monthly flows for the years when extreme and medium flows were registered (1950-2009)

The graph of the correlations between the average annual flows and the average annual rainfall quantities for 1980-2009 from Cremenea and Dărmănești stations shows that in the years when the average annual rainfall quantities have high values, high average annual flows are also registered (Figure 7).

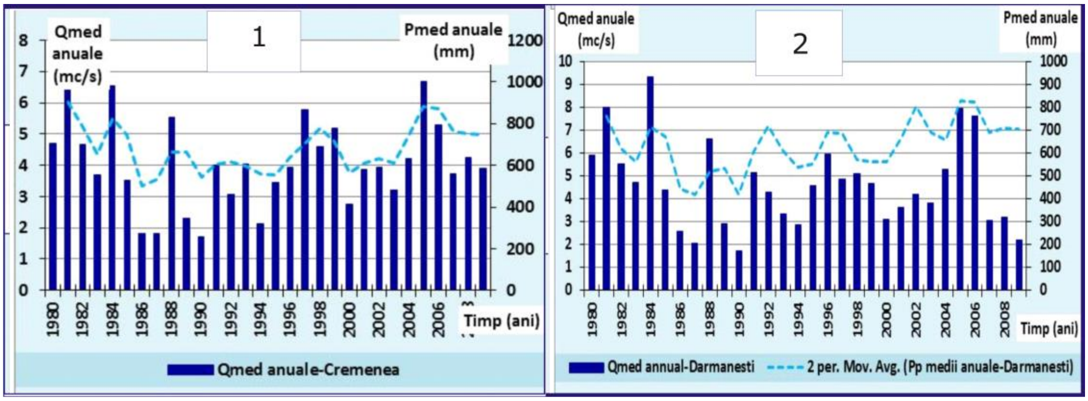


Figure 7: Correlation between average annual flows and average annual rainfall quantities (1980-2009) – hydrometric stations Cremenea (1) and Dărmănești (2)

There is a correlation between the average annual flow regime and the average annual quantity regime in the hydrographic Uz basin. The strongest rainfalls were registered in 1981, 1984 and 1991. The variability of the curve that represents the values of the annual average rainfall is similarly approximate with those of the average annual flows for the same time period. The average flows of the river Uz oscillated within large limits depending on the pluviometric characteristic of each year.

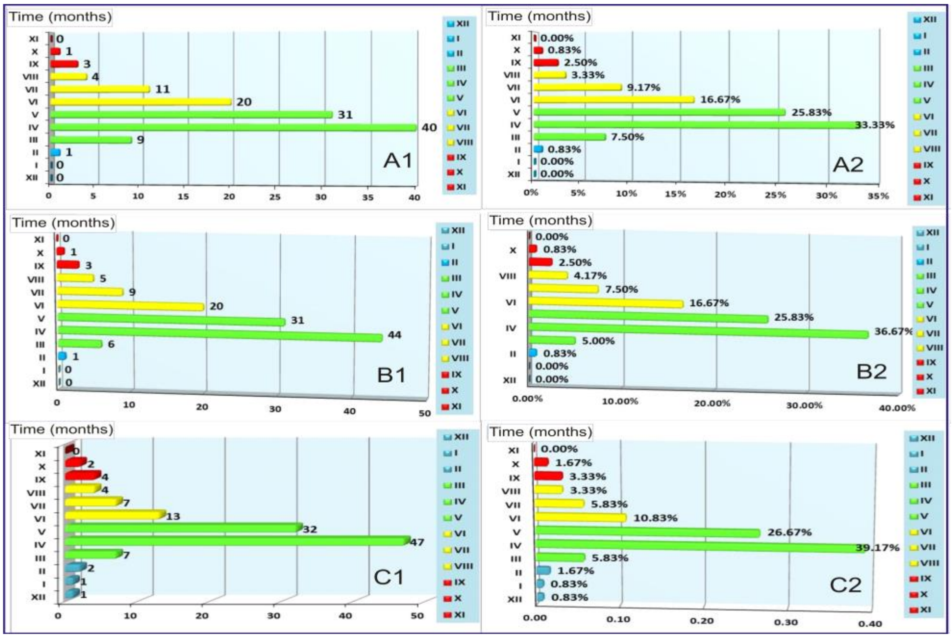


Figure 10: Maximums occurrence frequency for the average monthly flows (1950-2009) – Valea Uzului hydrometric stations (A1,2), Cremenea (B1,2) and Dărmănești (C1,2)

The highest fluctuations of the flows are associated with the flows in the middle of spring, when important floods occur. In the hydrographic Uz basin, the maximum average monthly flow can be found in April at all hydrometric stations, with a cumulated occurrence frequency of 33.3% for the Valea Uzului station, 36.67% for Cremenea station and 39.17% for Dărmănești station. The autumn and winter flows do not lead to the formation of maximum values (the occurrence frequency is reduced). During summer, the highest occurrence frequency for the maximum summer flows is of 16.67% for the Valea Uzului and Cremenea stations and of 10.83% for Dărmănești station. The maximum flows during summer are conditioned by an accentuated rainfall torrentiality, but it does not come close to those in spring (Figure 10)

Conclusions

The carrying out of this study was based on the need to analyze and highlight the variation of the average monthly liquid flow, as well as the genesis of the flow fluctuations registered in different periods of the year on the Uz river. The non-uniformity in time of the climatic conditions is the main cause for the variation in time of the average monthly flows. The maximum and minimum average flows highlight the seasonal, annual and multi-annual temporal fluctuations. The knowledge of the fluctuations related to the average monthly flows highlighted through maximum and minimum present a particular practical importance, because of its negative effects.

The knowledge of the variation for the average monthly liquid flows is important for the security of hydro-technical constructions, of human settlements, of crops etc.

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