

## Estimation of the long-term cyclical fluctuations of snow-rain floods in the Danube basin within Ukraine

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**Abstract.** Floods are a periodic natural phenomenon, often accompanied by negative consequences for the local population and the economy as a whole. Therefore, knowledge of the trends of maximum flow have great practical importance, because it is the basis for planning and designing various hydraulic structures, hydrological forecasting, the mapping of flood risk, etc. In this paper, we analysed the long-term cyclical fluctuations of the maximum flow of snow-rain floods of the Danube basin within Ukraine (5 large rivers, 14 medium and 5 small). The database includes time series (34 gauging stations) of the maximum discharges of the cold period from the beginning of the observations up to 2015. The methodological approaches (developed by Gorbachova) are based on the use of hydro-genetic methods – namely the mass curve, the residual mass curve, and combined graphs. The presented results illustrate that the long-term fluctuations of the maximum flow of snow-rain floods are synchronous at all study gauging stations in the Danube basin within Ukraine, but these fluctuations are not always in the synchronous phase. We found that the maximum flow of snow-rain floods in the Danube basin within Ukraine have four types of long-term fluctuations, each with a different cycle duration.

**Keywords:** cyclical fluctuations, stationarity, homogeneity, snow-rain flood, synchronicity, mountain rivers

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### 1. Introduction

The long-term cyclical fluctuations of streamflow mean that there are instabilities in the streamflow, characterised by alternating wet and dry phases of different durations and different degrees of deviation from the mean of the long-term flow for the review period (Pekarova et al. 2003). The periods of wet years change to dry, and vice versa. In closely located river basins, under the same climatic conditions and similar elements of the geographical landscape, the streamflow fluctuations are usually synchronous. However, as was found in our previous studies (Gorbachova, Bauzha 2012, 2013; Gorbachova, Khrystiuk 2014; Bauzha, Gorbachova 2017), in the case of the synchronous fluctuations of flow, it is often observed that there is asynchronicity in the phase of fluctuations in the various hydrological stations within the same basin.

In the study of the spatio-temporal fluctuations of water flow, a variety of methods are used. Both statistical and genetic methods are more commonly used (WMO 2009). Among the statistical methods, the most frequently used are correlation, regression, cluster, dispersion, and spectral analysis. The genetic method consists of the graphic methods that mainly include various correlation graphs, frequency of values, histograms, mass curves, double mass curves, residual mass curves, chronological

charts, and others (Chow et al. 1988). The methodical approaches to using these methods were developed by Rippl (1883), Merriam (1937), Searcy and Hardison (1960), and others. The guidelines for these methods were developed separately for each method and for solving particular problems. However, with certain graphic (hydro-genetic) methods, we can successfully carry out the assessment of the spatio-temporal fluctuations of runoff. Therefore, in this paper, the methodological approaches for the hydro-genetic methods are used. This approach was developed by Gorbachova (2014, 2015).

In this paper, the maximum flow of the cold period of the Danube River basin (Ukrainian part) was investigated. The study of the current spatio-temporal fluctuations in the dangerous phase of the hydrological regime of this river is our actual task, because snow-rain floods of varying heights repeat 3-8 times a year in the mountain rivers of the Danube basin within Ukraine. These floods are especially dangerous in the wet phase that is caused by global atmospheric circulation. In the wet phase, significant floods are observed predominantly with 3-4 and 6-8 year recurrence intervals. At the same time, Central and Western Europe also suffer from these natural disasters (Susidko, Luk'yanets 2009; Pekarova et al. 2014). Thus, such studies are important for hydrological and water

management calculations. The goal of this paper is the study of the long-term cyclicity fluctuations of maximum flow of the snow-rain floods of the Danube basin within Ukraine based on the use of hydro-genetic methods.

The main tasks of the research are as follows:

- assessment of the spatio-temporal fluctuations of the maximum flow of the snow-rain floods of the Danube Basin within Ukraine;
- analysis of the phases of cyclical fluctuations of the maximum discharges;
- assessment of the stationarity of the observation series with residual mass curves;
- estimation of the homogeneity of the observation series with the mass curves;
- analysis of the largest and smallest maximum discharge of the snow-rain floods of the Danube basin within Ukraine for a long-term period.

## 2. The study area

The Danube River is the second largest water course in Europe (after the Volga River), with a total catchment area of 817 000 km<sup>2</sup>. It is the world's most international river basin and includes the territories of 19 countries (including Romania, Hungary, Austria, Serbia, Germany, Slovakia, and Bulgaria) (Pekarova et al. 2003). The river originates in the central-western part of Europe (Schwarzwald), runs through the central part of the continent, crosses the Pannonian Depression to the confluence with the Drava, then pierces the Carpathian Mountains through the Iron Gate Gorge. Farther down, it separates the southern part of the Romanian Plain from the Prebalkan Tableland, and the eastern part of the Plain from the Dobrogea Plateau and Mountains. The last sector of the river, up to the Black Sea, encompasses the Delta area (Gastescu, Tuchiuc 2012). The Danube River has a total length of 2 857 km,

Table 1. Characteristics of rivers of the Danube River Basin

Name of river	Catchment area [km <sup>2</sup> ]	Catchment area [km <sup>2</sup> ] (within Ukraine)
Danube	817 000	32 350
Tysa	153 000	11 300
Siret	47 600	2 070
Prut	27 500	17 400
Latorytsya	7 680	4 900
Uzh	2 750	2 010

and approximately one third of its basin is mountainous. The Danube Basin can be subdivided into three main parts (the Upper, Central and Lower Danube regions), in addition to the Danube delta (Pekarova et al. 2014). Within Ukraine, the Danube River flows only in its lower part, with a length of 174 km (6% of the total length), and the catchment area is 32 350 km<sup>2</sup> (Table 1). It occupies the southern and south-eastern slopes of the Eastern Carpathians, Transcarpathia, and the southwestern outskirts of the Black Sea Lowland.

In this paper, the main rivers and their tributaries in the Danube Basin within Ukraine are investigated (Fig. 1). These are 5 large rivers (Tysa, Prut, Latorytsya, Uzh, and Cheremosh) ( $F_{basin} = 1\ 000\text{--}10\ 000\text{ km}^2$ ), 14 medium rivers (Siret, Chorny Cheremosh, Teresva, Bilyi Cheremosh, Rika, Putyla, Turia, Borzhava, Chorniava, Vicha, Stara, Chorna Tysa, Bila Tysa, and Kosivska) ( $F_{basin} = 100\text{--}1\ 000\text{ km}^2$ ), and 5 small rivers (Iltzia, Holiatyinka, Pylypets, Studenyi, and Kamianka) ( $F_{basin} = 10\text{--}100\text{ km}^2$ ) according to the classification of the EU Water Framework Directive (2000/60/EC). Such a classification was carried out according to the area of the catchment of the river from river springs to locking post within Ukraine.

The Tysa River Basin is the largest sub-basin in the Danube Basin (Table 1). It is also the Danube's longest tributary (966 km). In the territory of Ukraine, there is the upper, mostly right bank part of the Tysa basin.

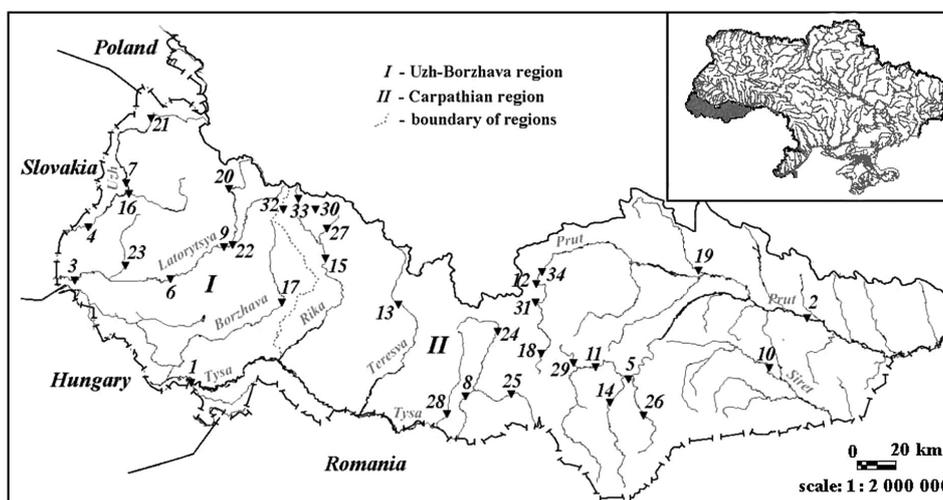


Fig. 1. Location of the 34 water gauges in the Danube basin within Ukraine (the numbering of stations is based on Table 2)

The river at the upper part is a typical mountain river. It has a narrow valley, and it sometimes looks like a gorge with relatively steep slopes. The right bank tributaries of the Tysa River cover the southern slope of the Ukrainian Carpathians. The average altitudes of these catchments within the mountains are 800–1200 m, and the average slopes are 200–400 m/km. The long-term average water discharge near Vylok village is  $207 \text{ m}^3 \text{ s}^{-1}$  (1954–2013).

The Prut River is a left tributary of the Danube (Table 1). The river springs from the northeastern slope of the Chornohora Massif at an altitude of approximately 1600 m. The basin of the Prut River, being a transboundary basin, is located in the territory of three countries (Moldova, Ukraine, and Romania). The average slope of the catchment in the upper reaches is 285 m/km, whereas it is much smaller in the lower reaches. The average meandering ratio is 2.1. The largest tributary of the Prut River is the Cheremosh River. The long-term average water discharge near Chernivtsi city is  $67.7 \text{ m}^3 \text{ s}^{-1}$  (1945–2013).

The Siret River is a left tributary of the Danube, starting from the confluence of the Bursuky and Lustun mountain sources next to Dolysnyi Shepit village in Chernivtsi Oblast (Table 1). In its upper section (to the Beregomet settlement), it is a typical mountain river, but downstream it gains submountain and lowland features with a wide valley, which is swampy in some places. The Siret flows into the Black Sea. In the upper part, it flows through the territory of Ukraine (110 km) and then Romania (596 km). The general fall is 435 m. The slope of the river is 4.4 m/km. The meandering ratio is 1.92. The long-term average water discharge near Storozhynets town is  $6.63 \text{ m}^3 \text{ s}^{-1}$  (1953–2013).

The Latorytsya River is a left tributary of the Bodrog River (tributary of the Tysa River) (Table 1). The river springs from the Ukrainian Carpathians (Eastern Carpathian Mountains) near the village Latorka. It flows from Ukraine (156.6 km) to Slovakia (31.4 km). Its slope varies from 80 m/km in the upper reaches to 0.2 m/km in the lower reaches. The long-term average water discharge near Chop town is  $35.9 \text{ m}^3 \text{ s}^{-1}$  (1957–2013).

The Uzh River is a left tributary of the Laborec River (tributary of the Latorytsya River) (Table 1). The river springs in the mountains in the northwest of Transcarpathia. It flows from Ukraine (107 km) to Slovakia (26 km). The slope of the river is 7.2 m/km. The long-term average water discharge near Uzhhorod city is  $29.3 \text{ m}^3 \text{ s}^{-1}$  (1947–2013).

The temperature regime in the Danube basin is determined mainly by the nature of the circulation of air masses and the features of the terrain. The long-term average annual air temperature within the Ukrainian part

of the basin is  $8.1^\circ\text{C}$  for the Chernivtsi weather station and  $9.6^\circ\text{C}$  for the Uzhhorod weather station. The coldest month is January, with average temperatures ranging from  $-0.3$  to  $-3^\circ\text{C}$  in the lowlands and  $-8$  to  $-9^\circ\text{C}$  at the highest points, and in some places even lower. In July, the average air temperatures rise to  $17$ – $24^\circ\text{C}$  (Pekarova et al. 2014). The long-term annual average precipitation total at the Uzhhorod weather station is 785 mm, and it is 652 mm at the Chernivtsi weather station.

The Ukrainian Carpathians are characterised by significant heterogeneity of the territory, which results in different conditions of flow formation. Thaws are observed in the mountain rivers of the Carpathians due to the unstable thermal regime and frequent transitions in the winter period from negative to positive air temperatures in December to February. During these thaws, a flow of mixed origin (from the melting of snow and liquid precipitation) is formed. In this case, high floods occur, which are characterised by the highest water discharges per year in the long-term period. Sometimes, such floods become catastrophic and threaten not only the economy of the region but also human life. The Carpathians are the region with the most danger of flooding in all of Ukraine (Susidko, Luk'yanets 2009).

According to hydrological regionalisation by the intra-annual distribution of the flow, the Tysa, Prut and Siret Rivers within Ukraine belong to two hydrological regions, namely the Uzh-Borzhava and Carpathian regions (Gorbachova 2015). For the rivers of the Carpathian region (the upper reaches of the Tysa River to the Rika River, including the Prut and Siret rivers), the wet period lasts from March to July, the autumn period is characterised by floods, and winter is characterised by the smallest discharges in the year. The rivers of the Uzh-Borzhava region are characterised by intense floods in the cold period of the year. Thus, the lowest discharges are observed from August to October.

### 3. Methodology and data

Available and reliable flood observation data help to improve understanding of flood processes and associated changes in flood characteristics and regimes (Hall et al. 2015). The analysis of the cyclicity of water flow depends on the availability of long-term observation data. The longer the duration of the observation series, the more it is possible to reliably determine the decrease and increase in the phases of cyclic fluctuations of water flow for each river.

This study of the long-term fluctuations of the maximum flow of snow-rain floods is conducted at 34 gauging

Table 2. List of selected water gauges along the Danube River Basin within Ukraine

No.	River	Water gauge	Catchment area [km <sup>2</sup> ]	Study period
1	Tysa	Vylok village	9140	1954-2015
2	Prut	Chernivtsi city	6890	1895-1911, 1919-1924, 1926-1935, 1945-2015
3	Latorytsya	Chop town	2870	1957-2015
4	Uzh	Uzhhorod city	1970	1947-2015
5	Cheremosh	Usteriky village	1500	1958-2015
6	Latorytsya	Mukachevo town	1360	1947-2015
7	Uzh	Zaricheve village	1280	1947-2015
8	Tysa	Rahiv city	1070	1947-2015
9	Latorytsya	Svaliava town	680	1962-2015
10	Siret	Storozhynets town	672	1953-2015
11	Chorny Cheremosh	Verhovyna village	657	1958-2015
12	Prut	Yaremche town	597	1950-2015
13	Teresva	Ust-Chorna village	572	1949-1976, 1978-1982, 1986-2015
14	Bilyi Cheremosh	Yablunytzia village	552	1958-2015
15	Rika	Mizhhiria village	550	1946-2015
16	Turia	Simer village	464	1958-2015
17	Borzhava	Dovhe village	408	1947-2015
18	Prut	Tatariv village	366	1959-2015
19	Chorniava	Lyubkivtsi village	333	1985-1989, 1991, 1993-1997, 1999-2007, 2009-2015
20	Latorytsya	Pidpolozzia village	324	1947-2015
21	Uzh	Zhornava village	286	1952-2015
22	Vicha	Nelipyne village	241	1958-2015
23	Stara	Zniatseve village	224	1952-2015
24	Chorna Tysa	Yasinia village	194	1956-2015
25	Bila Tysa	Luh village	189	1955-2015
26	Putyla	Putyla village	181	1963-1993, 1996-2015
27	Rika	Verhnii Bystryi village	165	1954-1994, 1999-2015
28	Kosivska	Kosivska Poliana village	122	1963-2015
29	Iltsia	Iltsi village	86.1	1959-2015
30	Holiatynka	Maidan village	86	1956-1994, 1999-2015
31	Prut	Vorohta village	48.3	1978-2015
32	Pylypets	Pylypets village	44.2	1956-2015
33	Studenyi	Nyzhnii Studenyi village	25.4	1954-1994, 1999-2015
34	Kamianka	Dora village	18.1	1946-2015

stations situated in the Danube River basin within Ukraine. The maximum discharges in the cold period are analysed in the study. The cold period is characterized by a steady decrease in air temperature below 0°C. During this period, the floods are of mixed origin, namely snow-rain (Kosovets et al. 2005). The maximum discharge data of the cold period are obtained from the archive of the Central Geophysical Observatory of Ukraine. The analyses are carried

out for the data series at all stations from the beginning of the observations to 2015 inclusive. The period of observation of these water bodies is from 27 (Chorniava River – Liubkivtsi village) to 104 (Prut River – Chernivtsi city) years (Table 2).

In terms of the hydro-genetic analysis, including concepts such as change and variability, the homogeneity and stationarity of the hydrological series were defined.

The homogeneity of the time series is the absence of unidirectional changes of the hydrological characteristic (this refers to one genetic series: floods, rain floods, etc.) over time against the backdrop of its variability due to long-term cyclical fluctuations. The stationarity of the time series is the constancy of average value hydrological characteristic over time if the time series has at least one full closed cycle (dry and wet phase) of long-period fluctuations. The change of the time series is the unilateral deviation from a straight line of the hydrological characteristic, which is in such a state that the hydrological characteristic moves to a new quality, due to the state of factors that are formed by the hydrological characteristic or human activities. The variability of the time series is a temporary deviation from a straight line of the hydrological characteristic that is in such a state that the hydrological characteristic acquires a new quality only for a period. In the case of long-term cyclical fluctuations, this period can last for decades; but at the same time, the hydrological characteristic from time to time returns to its “old” state. This same scenario is relevant for short-term cyclical fluctuations, but the period is much shorter and is usually considered to be a few years.

The assessment of the homogeneity and stationarity of the hydrological series necessitated the following:

- In the hydrological series, there is a need to restore the gaps in observations and bring them to a long time period, thus allowing the tracing of the temporal dynamics of hydrological characteristics over a longer time interval.
- The homogeneity of the hydrological characteristic over time is researched with a mass curve.
- The stationarity of the hydrological characteristic is researched with a residual mass curve.

To clarify the results obtained (if necessary), other hydro-genetic methods and approaches can be used (the analysis of meteorological factors of the runoff formation, the combined graphics, etc.)

For the assessment of the homogeneity of the observation series, the mass curve was used. In 1883 Rippl developed the mass curve and the residual mass curve methods. Now, the mass curve is used to detect the influence of anthropogenic factors (hydraulic structures, canals) and of climate change (the presence of trends in the data series). If “jumping” on the mass curve is not found, and neither are “emissions” or unidirectional deviation, then the generation of runoff in the study area is homogeneous, and vice versa. The mass curve is defined with the following formula:

$$W = \sum_{t=1}^T w(t) \quad (1)$$

where:  $W$  – the total runoff of the river for time period  $T$ ;  $w(t)$  – the runoff of  $t$ th year.

For the assessment of the spatio-temporal fluctuations of the maximum flow of the snow-rain floods of the Danube basin within Ukraine, the residual mass curve and combined graphs were used. The analysis of the residual mass curve allows the definition of the stationarity of data series, namely the sustainability of the average value of the hydrological characteristic in the course of time. The average value of the time series is stable in the presence of at least one full closed cycle (dry and wet phase) of long-period fluctuations. The residual mass curve is defined according to (Andreyanov 1959):

$$f(t) = \frac{\sum_{t=1}^T (k(t) - 1)}{C_v} \quad (2)$$

where:  $C_v$  – the variation coefficients of runoff;  $k(t) = Q(t)/Q_0$  – the modulus coefficients;  $Q(t)$  and  $Q_0$  – the discharge of the  $t^{\text{th}}$  year and the average discharge for the period of time  $T$ .

According to Andreyanov’s formula (2), the dry and wet phases were identified. The wet phase is characterized by an increasing tendency, and the dry phase is characterized by a decreasing tendency.

Combined graphs of characteristics allow the definition of the synchrony/asynchrony of long-term fluctuations in different rivers within the one hydrologically homogeneous area. In turn, the synchronous fluctuations are indicated on the homogeneous climatic conditions for the formation of runoff.

#### 4. Results

Graphs of the mass curves and residual mass curves of the maximum flow of the snow-rain floods in the Danube Basin within Ukraine were created for 34 catchments.

The analysis of these graphs shows that the series of observations are homogeneous, because no significant points of fracture in direction (“jumpings” or unidirectional deviation) were found on any mass curves (Gorbachova, Bauzha 2012, 2013; Bauzha, Gorbachova 2017). Examples of such curves are shown in Figure 2.

Some of these may raise doubts about the homogeneity of the hydrologic characteristics, e.g., the observation series in Figure 2c. However, the shape of the sum curve is determined by the structure of the observation series, namely the presence of only phases of prolonged increase and decrease in the cyclical fluctuations (Fig. 3).

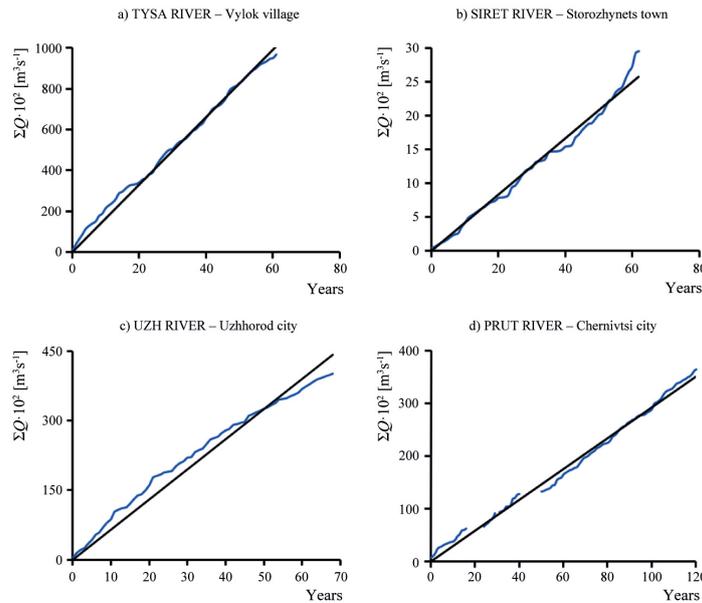


Fig. 2. Some mass curves of the maximum flow of snow-rain floods in the Danube River basin within Ukraine

Such a situation is temporary. With the extension of the duration of observations, the data series will have several phases of cyclical fluctuations. For example, the mass curve looks similar to that in Figure 2d for the gauging station Prut River – Chernivtsi city. The observation series at the gauging station Prut river – Chernivtsi city is the longest and has several decreasing and increasing phases of long-term cyclical fluctuations. The durations of full cycles are approximately 15-20 years (Fig. 3). Therefore, the observation series of the maximum flow of snow-rain floods in the Danube Basin within Ukraine are homogeneous and quasi-homogeneous.

An analysis of the stationarity of the maximum flow of snow-rain floods of the Danube River Basin and its cyclical fluctuations was carried out using the residual mass curves of the data series of 34 gauging stations. According to the analysis, these curves have similar and distinctive features in their configuration. The long-term fluctuations of the maximum flow at all gauging stations are synchronous, but they are not always in synchronous phase (Fig. 4).

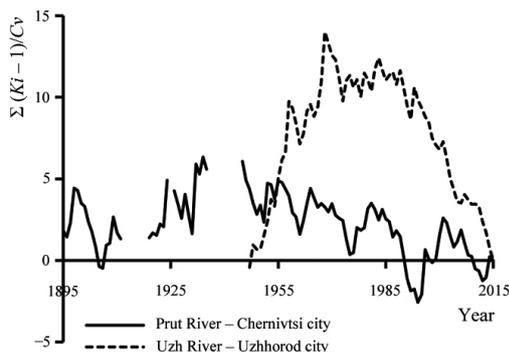


Fig. 3. The residual mass curves of the maximum flow of snow-rain floods in the Danube River basin within Ukraine

Thus, several types of cyclical fluctuations were identified (Fig. 5). The first type of long-term cyclical fluctuations includes the observations series that have only two phases: decreasing and increasing. Such fluctuations in the maximum flow of snow-rain floods are characteristic of the Uzh River. The increase phase began from the beginning of the observation and continued until 1968. The decrease phase began after 1968 and continues to this day (Fig. 5a). For some rivers in other basins, which can also be attributed to the first type of fluctuation (e.g., the Holyatynka river – Maidan village, and the Turia River – Simer village), the increasing phase continued until 1989 (Fig. 5a).

The second type of cyclical fluctuation includes the observation series, which are characterized by an increasing phase from the beginning of the observations to the end of the 1960s. After this, such phases changed to the decreasing

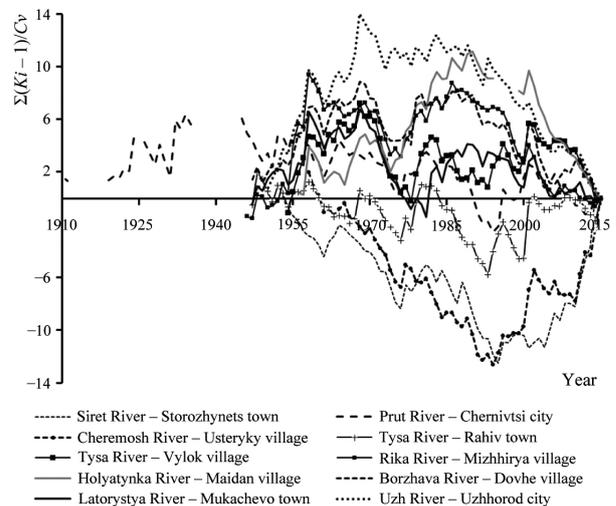


Fig. 4. Some residual mass curves of the maximum flow of snow-rain floods in the Danube River Basin within Ukraine

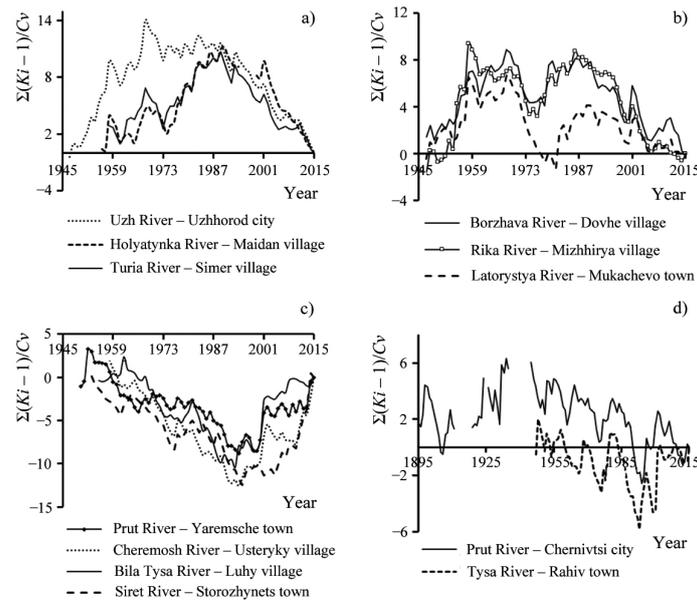


Fig. 5. Types of long-term cyclic fluctuations of the maximum flow of snow-rain floods in the Danube River Basin within Ukraine

phase, which continued until the mid-1970s. The increasing phase began again after the 1970s and continued until the mid-1980s, and it has since then changed to the decreasing phase of cyclical fluctuations. This type of fluctuation is seen in such rivers as Latorysya, Borzhava, and Rika (Fig. 5b).

The third type of fluctuations includes the rivers that, from the beginning of the observation and until the mid-1990s, are characterized by the decreasing phase. After this, the phase changed to the increasing phase, with minor variations in some years. This type of fluctuation is seen in the rivers Upper Tysa, Siret and Upper Prut (Fig. 5c).

The fourth type of fluctuations includes the rivers Tysa and Prut, which have cyclic fluctuations of 15-20 year duration. On Figure 5d, it is seen that the long-term cyclical fluctuations at the gauging stations Tysa River – Vylok village and Prut River – Chernivtsi city have synchronous and in-phase fluctuations.

Generally, the observation series of the maximum flow of snow-rain floods in the Danube Basin within Ukraine are characterised by synchronous fluctuations, which do not always have synchronous phases. It can be assumed that the differences in cyclic fluctuations are caused by factors of the underlying surface of the river basins – namely:

- 1) The mountain relief, which is significantly cut by river valleys (defines peculiar patterns of runoff formation, which manifest in the uneven distribution of precipitation, temperature and humidity in the basin).
- 2) Exposure of slopes (the windward slopes receive considerably more rainfall).
- 3) The presence of large forest areas.

Table 3 provides information on the largest and smallest maximum discharge of the cold period of the year of the 34 water gauges along the Danube River Basin

within Ukraine for long-term periods. During the study period, the largest values of the maximum discharge of snow-rain floods ( $3580 \text{ m}^3 \text{ s}^{-1}$ ) were observed for the water gauges on the Tysa River – Vylok village in 2001. This value is 2.3 times higher than the long-term average of the maximum water discharge (1954-2015). It was the largest flood over the entire observation period (historical flood), and it had catastrophic consequences because it resulted in the loss of human lives and significant economic damage (Boiko, Kulbida 2001).

In general, the maximum runoff of the cold period over the past 10 years is characterised by a decreasing trend in most of the study gauges (Fig. 5a, b, d), with the exception of some hydrological stations (Siret River – Storozhynets town, Cheremosh River – Usteryky village, Iltzia River – Iltzi village, Prut River – Yaremche town, Prut River – Tatariv village, Bila Tysa River – Luhy village, Chorny Cheremosh – Verhovyna village, Putyla River – Putyla village, and Kamianka River – Dora village) (Fig. 5c).

## 5. Conclusion

The study presents results from time-series analyses using hydro-genetic methods for maximum discharges of snow-rain floods in the Danube Basin within Ukraine. The observation series of the maximum flow have different types of long-term cyclic fluctuations. In total, four types of fluctuations were determined, and they are conditioned by the climatic and the orographic features of the research area. Each type of cyclic fluctuation is characterised by a different duration. Only for the rivers Prut and Tysa can the duration of fluctuations be reliably

Table 3. The largest and the smallest of the maximum discharge [ $\text{m}^3 \text{s}^{-1}$ ] of the cold period of the year of the Danube Basin within Ukraine for long-term periods

River	Water gauge	$Q_{\text{average}}$ [ $\text{m}^3 \text{s}^{-1}$ ]	$Q_{\text{max. cold period}}$ [ $\text{m}^3 \text{s}^{-1}$ ] (per year)	
			max	min
Tysa	Vylok village	207 (1954-2013)	3580 (2001)	302 (1973)
Tysa	Rahiv city	25.6 (1947-2013)	938 (2001)	15.4 (1987)
Chorna Tysa	Yasinia village	4.83 (1956-2013)	186 (2001)	5.50 (1963)
Bila Tysa	Luhv village	5.11 (1955-2013)	84 (2001)	5.44 (1969)
Borzhava	Dovhe village	11.0 (1947-2013)	411 (1979)	26.4 (1972)
Kosivska	Kosivska Poliana village	4.60 (1963-2013)	213 (2001)	4.48 (1984)
Teresva	Ust-Chorna village	18.3 (1949-2013)	665 (2001)	22.2 (1963)
Siret	Storozhynets town	6.63 (1953-2013)	195 (2014)	2.69 (1990)
Prut	Chernivtsi city	67.7 (1945-2013)	1316 (1932)	46.2 (1990)
Prut	Vorohta village	1.98 (1978-2013)	82.6 (2001)	2.18 (1991)
Prut	Tatariv village	8.01 (1960-2013)	126 (2001)	13 (1991)
Prut	Yaremche town	12.6 (1950-2013)	299 (1952)	10.5 (1998)
Cheremosh	Usteriky village	27.8 (1958-2013)	392 (2001)	26.3 (1991)
Bilyi Cheremosh	Yablunytzia village	9.38 (1958-2013)	120 (2001)	8.85 (1991)
Chorni Cheremosh	Verhovyna village	14.1 (1958-2013)	219 (2001)	8.05 (1991)
Iltsia	Iltsi village	1.66 (1959-2013)	51.2 (2014)	1.84 (1991)
Kamianka	Dora village	0.36 (1949-2013)	22.6 (2011)	0.17 (1946)
Putyla	Putyla village	2.57 (1963-2013)	74.4 (2012)	1.59 (1974)
Chorniava	Lyubkivtsi village	1.67 (1985-2013)	85.1 (1996)	1.21 (1991)
Latorytsya	Mukachevo town	26.4 (1962-2013)	1480 (1958)	64.1 (1972)
Latorytsya	Pidpolozzia village	9.27 (1947-2013)	537 (1958)	44.2 (2003)
Latorytsya	Svaliava town	14.7 (1962-2013)	540 (1967)	34.4 (1973)
Latorytsya	Chop town	35.9 (1957-2013)	653 (1968)	66.5 (2015)
Vicha	Nelipyne village	6.87 (1958-2013)	249 (1958)	18.6 (1973)
Stara	Zniatseve village	2.27 (1952-2013)	54.7 (1974)	9.0 (2014)
Uzh	Uzhhorod city	29.3 (1947-2013)	1680 (1958)	108 (1973)
Uzh	Zhornava village	6.63 (1952-2013)	284 (1958)	30.9 (1961)
Uzh	Zaricheve village	21.0 (1947-2013)	1210 (1958)	92.8 (1973)
Turia	Simer village	9.26 (1958-2013)	427 (1958)	22.8 (1973)
Rika	Verhnii Bystryi village	4.17 (1954-2013)	142 (1958)	16.2 (2003)
Rika	Mizhhiria village	13.7 (1946-2013)	735 (1958)	54 (1946)
Holiatynka	Maidan village	2.16 (1956-2013)	100 (1958)	7.87 (1961)
Pylypets	Pylypets village	1.44 (1958-2013)	57.1 (1958)	4.74 (2003)
Studenyi	Nyzhnii Studeniyi village	0.61 (1954-2013)	62.6 (1986)	1.54 (1961)

determined, because they have several full cycles of fluctuations. The duration of the cycles on their tributaries and the Siret River will be specified with the extension of the observation series, because such data have incomplete increase and decrease phases of long-term cyclic fluctuations. The observation series of the maximum flow of snow-rain floods in the Danube Basin within Ukraine are characterised by synchronous fluctuations, which do not always have synchronous phases. In general, the maximum runoff of the cold period over the past 10 years was

characterised by fluctuation and has a decreasing trend at most of the study gauges. Some hydrological stations are an exception. Because the results of the analysis of changes of river flow depend on the availability and length of long-term data series, there is a need to continuously carry out estimation of the long-term cyclical fluctuations of the maximum runoff of rivers. This will allow the discovery of new tendencies in fluctuations and the making of forecasts for the future, because the Danube River Basin within Ukraine is characterised by dangerous flood activity.

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