CHRONOLOGICAL STRUCTURE OF LONG-TERM ALTERATION OF RIVER FLOW OF BELARUS

A.A. Volchak, V.V. Luksha

Department of Problems of Polesie NAS of Belarus
Brest State Technical University
Brest, Belarus

Analysis of the hydrological information permits to determine the parameters (period and amplitude) for the nearly 5-year period in perennial variability of a river flow for the territory of the Republic of Belarus. Statistic characteristics of the period's values and peculiarities of the annual amplitude of perennial variability of the average month river flow have been received.

As is known, authentic parameters of chronological structure of natural processes are two basic cycles: daily and annual. The physical basis of these major natural rhythms is made by an electromagnetic interaction of the Sun with natural shells of the Earth. Besides, in various natural processes the hidden periodicity defined in the result of analytical research, in particular of time series, for example, by methods of harmonic or spectrum analysis.

In the literature there are numerous references on existence of a hidden periodicity in various natural processes, first of all in climatic, which, in its turn, render complex influence on creation of a river flow. The main characteristic of the detected rhythms in nature – period – varies in a wide range of values. The most researched and described is a quasi-two-year rhythm, practically, which has no doubt in its existence in nature [1,2]. For definition of the concrete characteristics of this rhythm during the formation of a river flow we carried out statistical research of perennial variability of modules of a river flow (liter per second from km^2 – l/s km^2), as most carefully reflecting a spatial distribution of the river flow on the territory of Belarus and enabling possibility of quantitative comparison of river flow on various areas of water collection rivers.

The basis of research was made by the arrays of values of amount of a river flow on 164 river ranges of Belarus for a long-term (with 1877 for 2000 year) period of tool observations, published in the references books on water resources, and also in other normative sources and materials. The amount of the river ranges on basins of the large rivers are: the Pripyat – 39, the Neman – 41, the Western Dvina – 23, the Dnieper - 48, the Bug – 13, which basically, corresponds to an even distribution of the researched rivers on the territory of Belarus.

We made an analysis of 12 time series for each of 164 river ranges, the appropriate for separate months of the year (consisting from one-two continuous series), which were generated by sequential in time values of average monthly river flow modules. On the present analysis stage of modules of a river flow the filter eliminating a series, containing less than 15 units was used. As a result of usage of this filter 12 river ranges, having continuous length of a row in one series from 7 till 14 years were eliminated. 180 series, containing 2028 data in total, are eliminated, that has made 2,69 % from total amount of analyzed modules of a river flow (75374). The total array included 1884 continuous series of values of average monthly modules of a river flow. Length of series varied from 15 till 123 years at average value 38,93 years.

Accepting time series for stationary (the stationary series has constant in time average value), we have used the following method of their research. First of all transition from amount of average river flow to modules under the formula $q = Q \cdot 10^3 / F$, where Q – monthly average river flow, $м^3/s$; F – area of water collection of a river, km^2 was realized. Further, in the limits of one river range for a separate month value of the average long-term module of a river flow (as average arithmetic for a considered collection) was defined. Then this value se-

quentially subtracted from actual values of modules of a river flow in a long-term row. As a result, for separate months in every river range the sign-changing functions (concerning average long-term value of the module of a river flow of the given month) were obtained. Then we were defining an amount of changes of the sign of this function for each month in a long-term row. Further we were defining a quotient from division of all time interval into a number of changes of the sign, which we accepted for the average value of a halfcycle of changing of the monthly average module of a river flow. The value of period, thus, was determined by the formula

$$T = 2 \cdot \frac{N_k - N_1}{k - 1},$$

where N_1 – the first year, and N_k – the last transition through average long-term value; k – amount of transitions through average long-term value on the given temporary interval.

Quotient from division of the sum of deviations modules from average value on a number of these values we accepted for variation amplitude of the average monthly module of a river flow, i. e. amplitude was determined according to the formula

$$A = \frac{\sum |Z_f - Z_m|}{n},$$

where Z_m and Z_f – average long-term and actual value of the module of a river flow for the given year, accordingly; n – amount of years.

According to the described algorithm the calculation blocks for the PC in Microsoft Excel 2000 were composed, but thus each stage was visually inspected. Usage of the automatic calculations allowed to handle considerable in size the rows of the hydrological data and to gain statistically well-grounded results.

As a result 73346 interannual differences in the array of monthly average modules of a river flow were analyzed. The average value of period (arithmetic mean) changes of monthly average modules of a river flow for all array has appeared equal to 5,30 years, average amplitude – 2,36 l/s km^2. Thus, the usage of filters on the length of a series (from not less than 15 up to 20, 30, 40 and more than 50 units) essentially (difference less than 5 %) did not influence on the result, that allows to consider the obtained values statistically well grounded. The dispersion of values of period is 1,86, standard deviation – 1,36, coefficient of a variation – 0,35. The coefficients of skewnesses and kurtosis are 1,16 and 1,30 accordingly, i. e. the allocation is characterized by positive asymmetry and kurtosis concerning to normal distribution.

Then we shared the initial array on the river ranges of the basins of the Pripyat and the Bug and remaining river ranges with the purpose of the analysis of a flow of the rivers of Belarusian Polesie and for two obtained arrays the periods and amplitudes of variability of monthly average modules of a river flow were obtained. Thus the average value of period is 5,38 years for the rivers of Belarusian Polesie and 5,25 years for the remaining rivers, amplitude – 2,24 l/s km^2 and 2,42 l/s km^2.

The histograms of allocation of values of periods are represented in figure 1. From the considered histogram there is an apparent absolute maximum of values of period appropriate to approximately 5-year's variations. The changes in accordance with this period in three analyzed arrays occur rather frequently (21–22 %). In both sides from value of period equal to 5 years, the frequency of meetings decreases, that as a whole corresponds to characteristics of allocation, close to normal. Thus about 90 % of all obtained values of period are concentrated in an interval 5,30±1,96 years for all arrays of the rivers, 5,38±1,95 for the rivers of Polesie and 5,25±1,98 for the remaining rivers of Belarus.

The amplitude-periodic characteristics, obtained as a result of research, of changing of monthly average modules of a river flow for various months of the year concerning average long-term values for all territory of Belarus, Polesie and remaining territory are stated in the table.

The Table. The amplitude-periodic characteristics quasi-five-year variability of monthly average modules of a river flow

Parameter/Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
All Belarus rivers												
Amplitude, l/s km^2	0,81	0,83	0,51	0,94	0,23	0,48	0,54	0,33	0,33	0,68	0,96	0,74
Period, years	0,86	0,44	0,15	0,34	0,76	0,06	0,27	0,64	0,99	0,54	0,94	0,57
Mean monthly modules, l/s km^2	0,95	0,92	0,22	6,59	0,85	0,97	0,46	0,13	0,22	0,91	0,66	0,46
Belarusian Polesie rivers												
Amplitude, l/s km^2	0,02	0,02	0,49	0,56	0,83	0,53	0,54	0,33	0,18	0,52	0,98	0,9
Period, years	0,48	0,20	0,59	0,52	0,08	0,15	0,17	0,78	0,92	0,63	0,32	0,75
Mean monthly modules, l/s km^2	0,44	0,48	0,49	1,09	0,86	0,14	0,64	0,28	0,30	0,84	0,59	0,76
Other rivers												
Amplitude, l/s km^2	0,71	0,74	0,52	0,60	0,42	0,45	0,55	0,33	0,40	0,75	0,94	0,67
Period, years	0,04	0,55	0,94	0,25	0,60	0,01	0,32	0,56	0,02	0,50	0,76	0,48
Mean monthly modules, l/s km^2	0,17	0,12	0,54	9,04	0,74	0,35	0,83	0,50	0,63	0,39	0,13	0,77

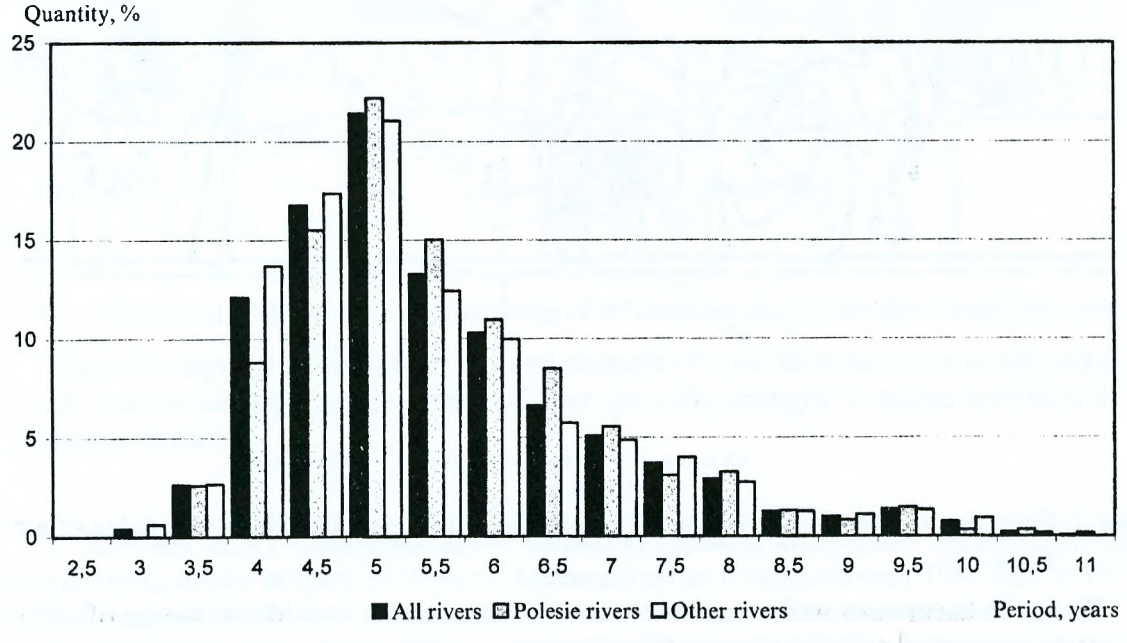

Figure 1. The allocation histograms of changes values (periods) of river flow modules.

The amplitudes of monthly changes average modules of a river flow form an exact course. Thus annual changes of amplitudes of monthly average modules of a river flow for the territory Belarusian Polesie have a little less expressed amplitude in a spring high water, which maximum, as a whole, occurs in April (figure 2).

The maximal values of amplitude of interannual variability of modules of a river flow are considered for spring months, and minimum – for summer, that corresponds to a spring high water and summer low water in hydrological year.

So, the research of interannual variability of monthly average modules of a river flow according to the explained above technique allows the establishing of statistically authentic periodic changes, close by 5 years. For the hydrological regime of the rivers quasi-five-year changes mean, that approximately once per 5 years the positive anomaly (maximal increase of

river flow concerning average for the given month) and once in the same approximately 5 years – negative is noticed. The period of repetitions of the same anomalies is approximately 5 years, different – about 2,5 years. Approximately everyone 2,5 years the monthly average modules of a river flow comes nearer to average long-term value. Here with a period, with close to 2,5 years, not function (monthly average unit of a river flow) and its amplitude in this case varies.

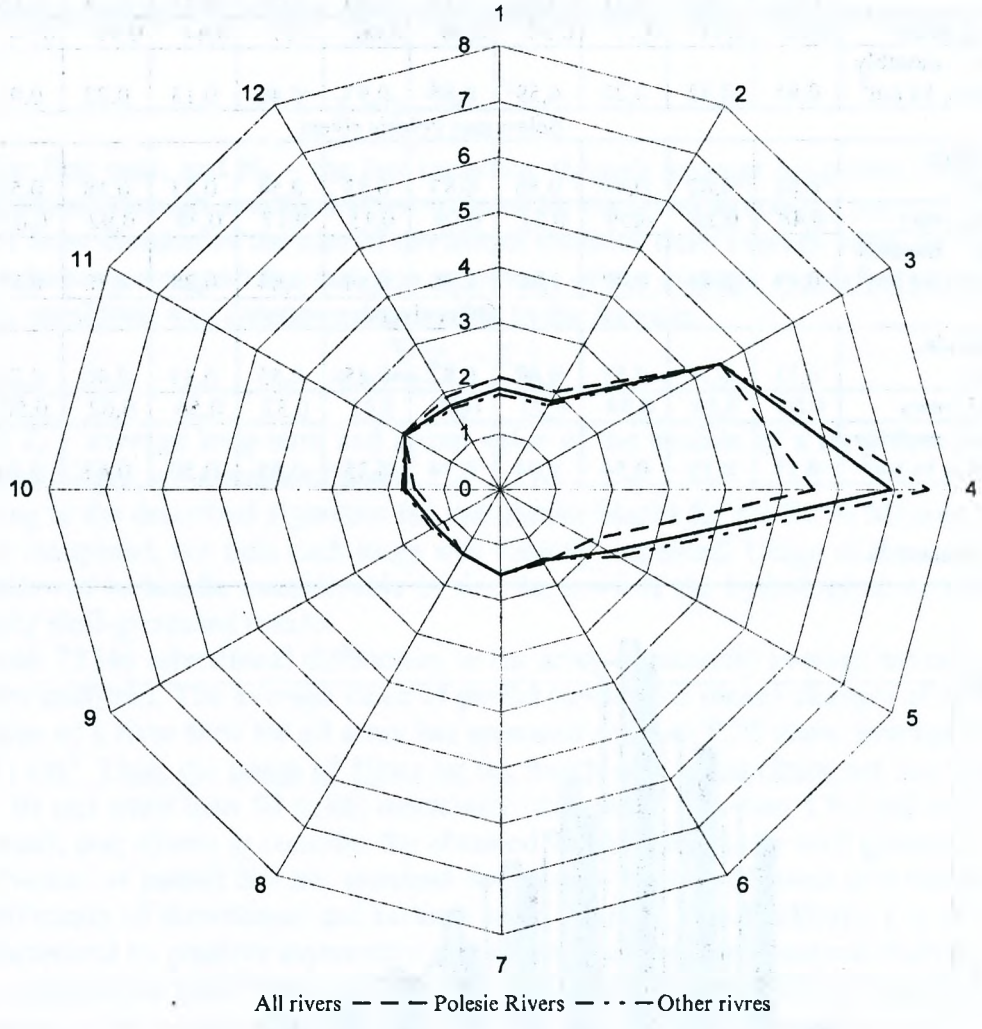

Figure 2. Graphics of the annual course of amplitude of periodic variability modules of a river flow.

Thus, the harmonics with a period close to 5 years can be considered as one of authentic parameters of chronological structure of Belarus rivers and be taken into account while developing the long-term prognoses of monthly average river flow (modules of a flow).

The obtained values of parameters of long-term changes of monthly average river flow modules – period and amplitude – have allowed mapping their space structure. The maps of changing of period and amplitude of monthly average modules of a river flow for 12 months (24 maps in all) on the all territory of Belarus were constructed. As an example in figure 3 the map of allocation of period of long-term fluctuations of average values of July river flow modules is stated.

V.M. Fedorov [3, 4] has allocated quasi-four-years fluctuations of interannual variability of average monthly temperature and sums of precipitates and has justified this periodicity by electromagnetic effect, which can be realized in a nature through the mechanism of a parametric resonance and operation of tidal or perturbing forces proximate to the Earth of celestial bodies. As the river flow is the integral characteristic of a set of the climatic factors, it is possible to assume, that allocated by us it 5 years periodicity alongside with 4 years tempera-

tures and precipitates can be explained by some inertness of processes of river flow creation, i.e. the processes happening in an atmosphere, not at once are reflected on a river flow, and there is some additional transition period (about 0,5 years) between positive and negative anomalies in relation to atmospheric phenomena. As it was stated above, within this period, close to 2,5 years, not function (monthly average unit of a sink) but its amplitude varies.

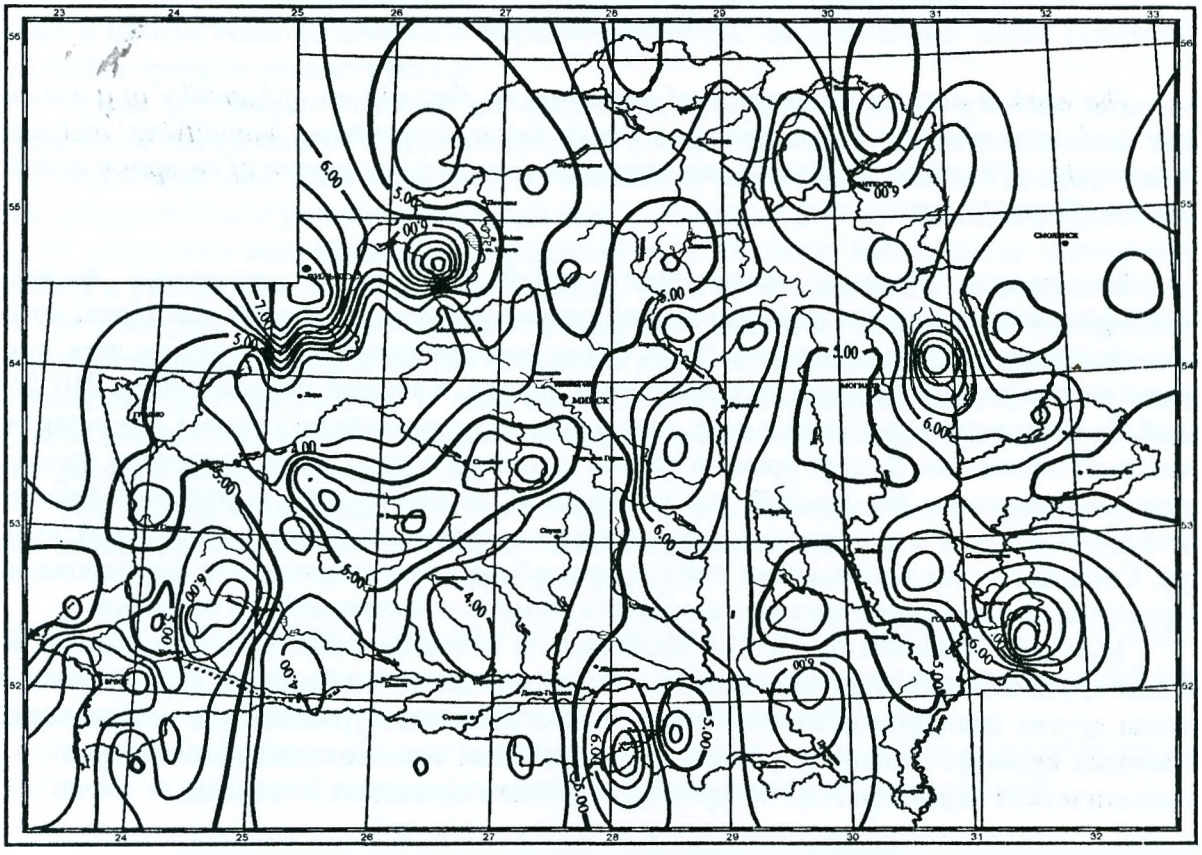

Figure 3. Allocation of long-term fluctuations of an average July river flow modules period.

Thus, the physical nature of the marked changes of river flow modules is not completely clear yet, but the reliability of existence of these periodic changes in nature proves to be true by statistical research.

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