METHODOLOGIES OF ESTIMATION OF PERIODICITIES OF RIVER FLOW AND ITS LONG RANGE FORECAST. THE CASE OF TRANSBOUNDARY DANUBE RIVER

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Danube River is the second by its extent river in Europe (after Volga). Its length is equal to 2857 km. Danube has origin in the Black Forest Mountains of western Germany. Along its course, it passes through nine countries: Germany, Austria, Slovakia, Hungary, Croatia, Serbia, Bulgaria, Romania, and Ukraine.

The discontinuous time series (TS) of Danube River runoff are available from 1840, Orsova, Romania (Fig. 1). The runoff of the river is significantly variable. Its minimum of 1863 was equal to 105 km^3/year. Its maxima of 1915 and 1941 approached the value of 250 km^3/year. So the diapason of the changes of the annual runoff of Danube River is equal to 145 km^3/year.

Figure 1. Location of Orsova

The variation of runoff of Danube River impacts to different branches of modern economy, such as fishery, water transport and tourism, industrial and communal water consumption (Pencev, 2008). The development of the methodology of analysis of TS of Danube River runoff for its long range forecasting is actual problem of modern hydrology closely related with the problems of the development of local and regional economy and integrated transboundary water resources management.

The present study is aimed for the development of the method of periodicities for the analysis, modeling and forecasting of TS of Danube River runoff. Annual time series were analyzed and modeled in the time interval from the beginning of instrumental observations up to 1978, the training forecasts for 1979 – 1988, and for the intervals of 1979 – 1983 and 1984 – 1988, were computed and tested by the new data. The annual forecast is considered as true if the difference between the real and forecasted runoff is not exceeded the 67,4% from the standard deviation of its TS (Apollov et al., 1974).

The analysis of TS of Danube River runoff shown that for 1840 – 1978 its mean value (Q_m) and standard deviation are equal to 171,7 km^3/year and 30,1 km^3/year. So, the annual long range forecast of runoff of the Danube River is successful if its mistake is no more than 20,3 km^3/year.

The method of periodicities is based on the approximation of TS by the sine functions. The observation data are approximated successively with the unitary period step by the method of the least squares (Linnik, 1962). For every period the parameters of the best approximated sine and its sum of square differences with TS were computed. The local minima of least sums of square differences between the TS and their approximation were marked near some periods. The availability of periodicities may be indicated there. So the periods of 30, 22 and 5 years were revealed.

The sinusoids with revealed periods were successively summed and their sum was developed into the forecast equation. The TS of runoff of Danube River, the 30 year sine and the sum of periodicities are illustrated on the Fig. 2.

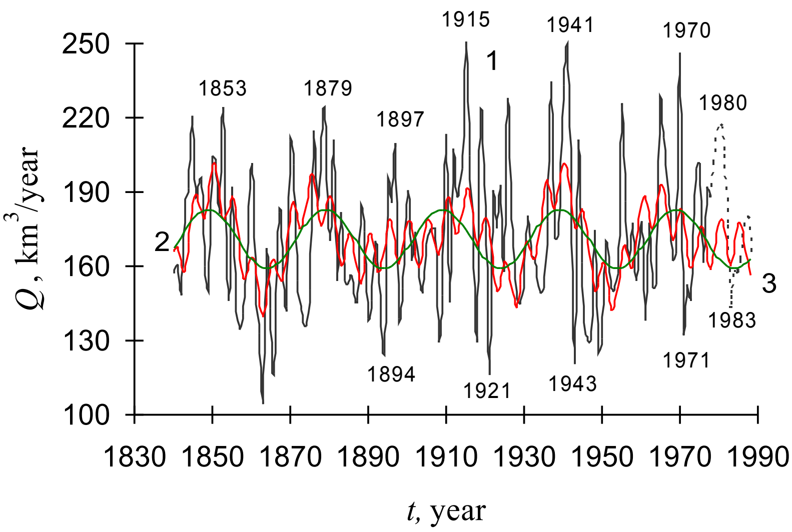

Figure 2. Variation of runoff of Dunabe River (Orsova): 1 – time series (dotted line – training forecast interval, 1979 – 1988), 2 – approximating sine with the period of 30 years, 3 – the sum of periodicities of 30, 22 and 5 years

The results of forecast of runoff of Danube River for 1979 – 1988 are also analyzed in the Table 1. The first column of the table presents the years of the training forecast interval, second and third column – the real water runoff of Danube River (Q) and its values computed by the sum of periodicities of 30, 22 and 5 years (Q_s). The last rows illustrate the mean values of the real and predicted runoff for the five years and ten year intervals.

The difference (Q_s-Q), presented in the forth column, permits to estimate the number of true forecasts for the first five years, second five years and for the all forecasting interval. Fifth column illustrates the squared annual mistakes of forecasts which were summed for the first and second five years and for all ten years. The last two columns reflect the forecast results computed by the mean value.

We may see (Fig.2, Table 1) that 7 values of Danube River runoff from 10 were predicted true (2 true values for the 1979 – 1983 and 5 true values for 1984 – 1988). The forecast results of Danube River runoff computed by the method of periodicities are some better comparing with the forecast by the mean value. The forecasting of runoff of Danube River for the same years by its mean value for 1840 –

1978 produced 6 true values from 10 (1 true value for the 1979 – 1983 and 5 true values for 1984 – 1988). The sum of square mistakes of forecast of the method of periodicities is some smaller than the sum of square mistakes of forecast received by the mean value for the first five years and all ten year interval.

The shortcoming of the forecast is that for 1979 – 1983 the mean value of predicted runoff is significantly lower its real mean value. The real mean runoff for 1979 – 1973 is much larger, while computed runoff is a bit smaller, than it mean value for 1840 – 1978. However, the years of maxima of Danube River runoff (1980 and 1981), causing its increased mean value, and the year of its minimum (1983) were successively predicted by the respective maxima and minimum of the sum of periodicities. So the result of the training forecast by the method of periodicities may be estimated no worse than satisfactory.

Table 1. Estimation of results of training forecast of the runoff of Danube River

t, years	Q, km^3/year	Q_s, km^3/year	Q_s-Q, km^3/year	$(Q_s-Q)^2$, (km^3/year)^2	Q_m-Q, km^3/year	$(Q_m-Q)^2$, (km^3/year)^2
1979	201,5	166,4	-35,1	1233	-29,8	887
1980	216,9	177,9	-39,0	1523	-45,2	2046
1981	205,4	178,0	-27,4	754	-33,7	1136
1982	177,2	167,0	-10,2	104	-5,4	29,7
1983	144,0	160,3	16,3	267	27,7	770
1984	157,7	167,1	9,4	88	14,1	197
1985	157,1	177,3	20,2	407	14,6	213
1986	163,3	175,9	12,6	160	8,5	71,4
1987	180,6	163,6	-17,0	289	-8,9	79,4
1988	164,0	156,0	-8,0	64	7,7	59,3
	Mean	Mean	N. of true forecasts	Sums of squares of mistakes	N. of true forecasts	Sums of squares of mistakes
1979 – 1983	189,0	169,9	2	3882	1	4869
1984 – 1988	164,6	168,0	5	1010	5	621
Total	176,8	169,0	7	4892	6	5489

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