Estimations of the periodic regularities in time series of water runoff of Neman River for its long range forecasting

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Neman River is one of the largest rivers in Europe. Its length is equal to 937 km. Neman has origin in the Minsk Upland, Belarus, and flows west through a broad, swampy basin. It then turns north and passing through the territories of Lithuania and Russia discharge its water into the Baltic Sea.

The discontinuous time series (TS) of Neman River runoff are available from 1859. Observations are made near Smalininkai, Lithuania. The runoff of the river is chaotic and significantly variable. Its minimum of 1969 was equal to 11,2 km^3/year, while the maximum of 1916 approaches the value of 25,2 km^3/year. So, the diapason of the changes of the annual runoff of Neman River is equal to 14 km^3/year.

The variation of runoff of Neman River impacts to different branches of modern economy, such as fishery, water transport and tourism, industrial and communal water consumption.

The development of the methodology of analysis of TS of Neman River runoff, revealing their regularities for long range forecasting are actual research and practical tasks closely related with the problems of development of the regional economy and integrated water resources management. Long range forecasts should account the hidden periodicities in runoff dynamics.

The present study is aimed for the development of the method of periodicities for the analysis, modeling and forecasting of TS of Neman River runoff. Annual time series were analyzed and modeled in the time interval from the beginning of instrumental observations up to 1995, the training forecasts for 1996 – 2005, and for the intervals of 1996 – 2000 and 2001 – 2005, were computed and tested by the new data. The forecast computed by the method of periodicities was compared with the mean value forecast.

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 Neman River runoff shown that for 1859 – 1995 its mean value (Q_m) and standard deviation are equal to 17,1 km^3/year and 2,69 km^3/year. So, the annual long range forecast of runoff of the Neman River is successful if its mistake is no more than 1,81 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, Iu.V., 1962; Babkin A.V., 2005). 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 8, 16, 26 and 124 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 Neman River, the 26 year sine and the sum of periodicities are illustrated on the Fig. 1.

The results of forecast of runoff of Neman River for 1996 – 2005 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 Neman River (Q) and its values computed by the sum of periodicities of 8, 16 and 26 and 124 years (Q_s). The last rows illustrate the mean values of the real and predicted runoff for the five years and ten year intervals.

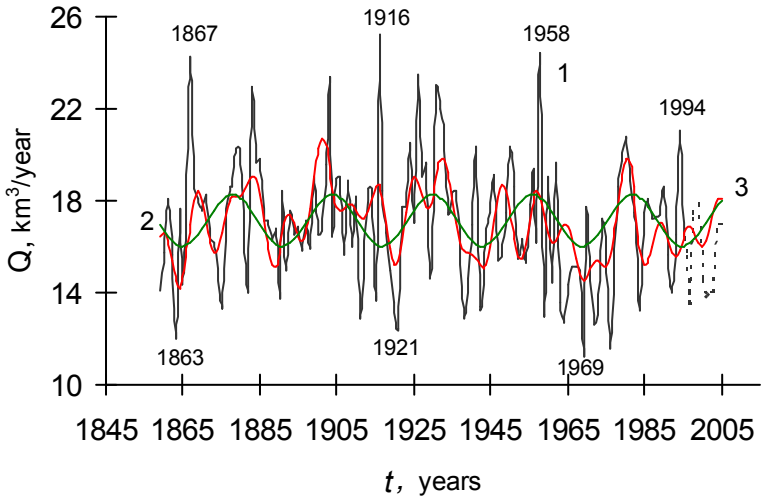

Figure 1. Variation of runoff of Neman River (Smalininkai): 1 – time series (dotted line – training forecast interval, 1996 – 2005), 2 – approximating sine with the period of 26 years, 3 – the sum of periodicities of 8, 16, 26 and 124 years

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

t, years	Q_f, km^3/year	Q, km^3/year	$Q-Q_s$, km^3/year	$(Q-Q_s)^2$, (km^3/year)^2	$Q-Q_m$, km^3/year	$(Q-Q_m)^2$, (km^3/year)^2
1996	15,6555	16,7912	1,1357	1,289814	1,4529	2,110918
1997	13,4505	16,8783	3,4278	11,74981	3,6579	13,38023
1998	17,3565	16,6098	-0,7467	0,557561	-0,2481	0,061554
1999	17,892	16,2147	-1,6773	2,813335	-0,7836	0,614029
2000	14,5845	16,0253	1,4408	2,075905	2,5239	6,370071
2001	13,7655	16,2634	2,4979	6,239504	3,3429	11,17498
2002	14,0175	16,8919	2,8744	8,262175	3,0909	9,553663
2003	13,986	17,6258	3,6398	13,24814	3,1224	9,749382
2004	16,9785	18,101	1,1225	1,260006	0,1299	0,016874
2005	16,9155	18,1018	1,1863	1,407308	0,1929	0,03721
	Mean	Mean	N. of true forecasts	Sums of squares of mistakes	N. of true forecasts	Sums of squares of mistakes
1996 – 2000	15,7878	16,50386	4	18,48643	3	22,5368
2001 - 2005	15,1326	17,39678	2	30,41714	2	30,53211
Total	15,4602	16,95032	6	48,90357	5	53,06891

The difference (Q-Q_s), 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.1, Table 1) that 6 values of Neman River runoff from 10 were predicted true (4 true values for the 1996 – 2001 and 2 true values for 2001 – 2005). The computation based on the 26 sine produces 5 true points with the sum of square mistakes for ten year interval is equal to 52,2

The forecast results of Neman River runoff computed by the method of periodicities are some better comparing with the forecast by the mean value. The forecasting of runoff of Neman River for the same years by its mean value for 1859 – 1995 produced the 5 true forecasts true values from 10 (3 true value for the 1996 – 2005 and 2 true values for 1996 – 2005). 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, second five years and for all ten year interval.

The shortcoming of the forecast is that for 2001 – 2005 the mean value of predicted runoff is significantly larger its real mean value. However, in general the result of the training forecast by the method of periodicities may be estimated no worse than satisfactory.

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