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LONG-TERM DYNAMICS OF THE MAIN HYDROMETEOROLOGICAL CHARACTERISTICS OF SPRING FLOOD IN THE DESNA RIVER'S BASIN

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Abstract

This paper presents the results of the long-term variations complex analysis of the spring flood hydrometeorological characteristics in the Desna river basin. Research based on an assessment of homogeneity, stationarity and cyclical fluctuations of the observations data. Analysis were carried out for the following data: maximum spring flood water discharges, the maximum water equivalent of snow cover, the sums of negative and positive air temperatures in winter and the sums of precipitation for the spring floods period. The stationarity of the hydrometeorological characteristics was researched on the base of the estimation of the linear trends significance at the 5% significance level. Phases of cyclical fluctuations of hydrometeorological characteristics based on the difference-integral curves were analyzed. The homogeneity of the observations data was determined by the total integral curve.

Keywords: stationary, cyclical fluctuations, integral curves, long-term dynamics, spring flood

1 INTRODUCTION

In the conditions of global and regional climate changes especially important to know about their impact on the rivers water regime, because its formation depends from such climatic factors as temperature, precipitation, evaporation, etc. Redistribution of these factors in space and time leads to the changes in the hydrological regime of rivers. It is especially important to have knowledge about changes in the maximum river runoff, because high floods lead to negative consequences such as flooding of settlements, the destruction of hydraulic structures, bridges, etc., which causes considerable material damages for the states and public.

The estimation of the homogeneity and stationarity of hydrometeorological observations for the long-term period is one of the central problems of modern researches in the world. Such researches allow to reveal the causes of the observational data stationarity that is allows to apply appropriate methods of the statistical analysis of the observational data, develop forecasting methods, such as the characteristics of the spring flood (maximum water discharge, volumes and depth of runoff, etc.). In many papers the stationarity of the observations data based on the estimation of the statistical significance of the linear trends was researched. At the same time, other methods of the homogeneity estimation of the observation series and cyclical fluctuations of the hydrometeorological characteristics are not considered. For this reason, the purpose of this research is a complex analysis of the long-term fluctuations of the hydrometeorological characteristics of the spring flood in the basin of the Desna river based on the estimation of homogeneity, stationarity and cyclical fluctuations of the observational data.

The object of this research was the basin of the Desna River. The subject of research was the long-term data of the hydrometeorological characteristics of the Desna river basin. The characteristics of the research area were described in details in the work (Gorbachova & Kolianchuk, 2012).

2 METHODS

Long-term changes of the maximum discharges, the maximum water equivalent of snow cover, the sums of precipitation during the spring floods period, the sums of the negative and positive temperatures during the winter period were analyzed for the Desna river basin. This research was based on materials of stationary hydrological observations of 6 gauges (Desna river - Chernihiv city, Desna river – Rozlety village, Ivotka river - Ivot village, Snov river - Schors village, Seim river - Mutin village, Kleven river - Sharpivka village) and 10 meteorological stations (Bilopillya, Hluhiv, Druzhba, Konotop, Nizhyn, Oster, Pokoshychi, Semenivka, Chernihiv, Schors) on the territory of Ukraine and 2 gauges (Desna river – Briansk city, Seim river – Rylsk city) and 9 meteorological stations (Bogoroditske-Fenino, Briansk, Zhukovka, Kursk, Oboyan, Ponyri, Rylsk, Spas Demensk, Trubchevsk) on the territory of the Russian Federation (Figure 1).

Figure 1. Location of the hydrological gauges and meteorological stations in the Desna river basin

The estimation of the stationarity of the long-term fluctuations of the hydrometeorological characteristics in the basin of the Desna River was carried out by an assessment of the statistical significance of the linear trends (MRAH, 2010). The statistical significance of the trends is defined by the statistical significance of the correlation coefficient (R). The correlation coefficient of this dependence is estimating on the relation to the standard deviation *(σ_R)*:

$$R / \sigma_R \geq \beta \tag{1}$$

If as a result of the above-stated calculations it will appear that the trend significantly (at the given significance level) differs from zero, i.e. the double of standard deviation of the correlation coefficient is much less than of the correlation coefficient, it indicates no stationarity of the long-term fluctuations of the hydrometeorological characteristics, i.e. the inhomogeneity its at time, and on the contrary, if $\sigma_R > R$ – the homogeneity of the hydrometeorological characteristics at time. For 5 % of the significance level or for 95 % confidential limit $\beta=2$.

The standard deviation of the correlation coefficient for n >25 was defined according to:

$$\sigma_R = \left(1 - R^2\right) / \sqrt{n-1} \tag{2}$$

where n – the total number of the observation series.

In order to identify patterns in the cyclical fluctuations of the hydrometeorological characteristics are used difference integral curves. To compare the graphics results of the long-term dynamics, and difference integral curves of the hydrometeorological characteristics are created in the modular coefficients (K) according to:

$$K_A = A_i / \overline{A} \tag{3}$$

where A - the value of the hydrological and meteorological characteristics.

The estimation of the observational data homogeneity was carried out on total integral curves.

3 RESULTS

At all meteorological and hydrological stations in the basin of the Desna River synchronous fluctuations of air temperature, the maximum water discharges, precipitation and maximum water equivalent of snow cover were observed, even though they all located in different parts of the research area (Figure 2). This indicates that the conditions of their formation are homogeneous. Long-term dynamics of maximum spring flood water discharges at all observation stations in the basin of the Desna River has statistically significant trends. It indicates a violation of the stationarity of the spring flood runoff formation. Consequently, we can assume that the main meteorological factors in the basin are also having statistically significant trends (Figure 2). However, trend analysis (Table 1) showed that statistically significant trends have only such factors as the sum of negative air temperatures for the winter period and the sum of precipitation during the spring flood.

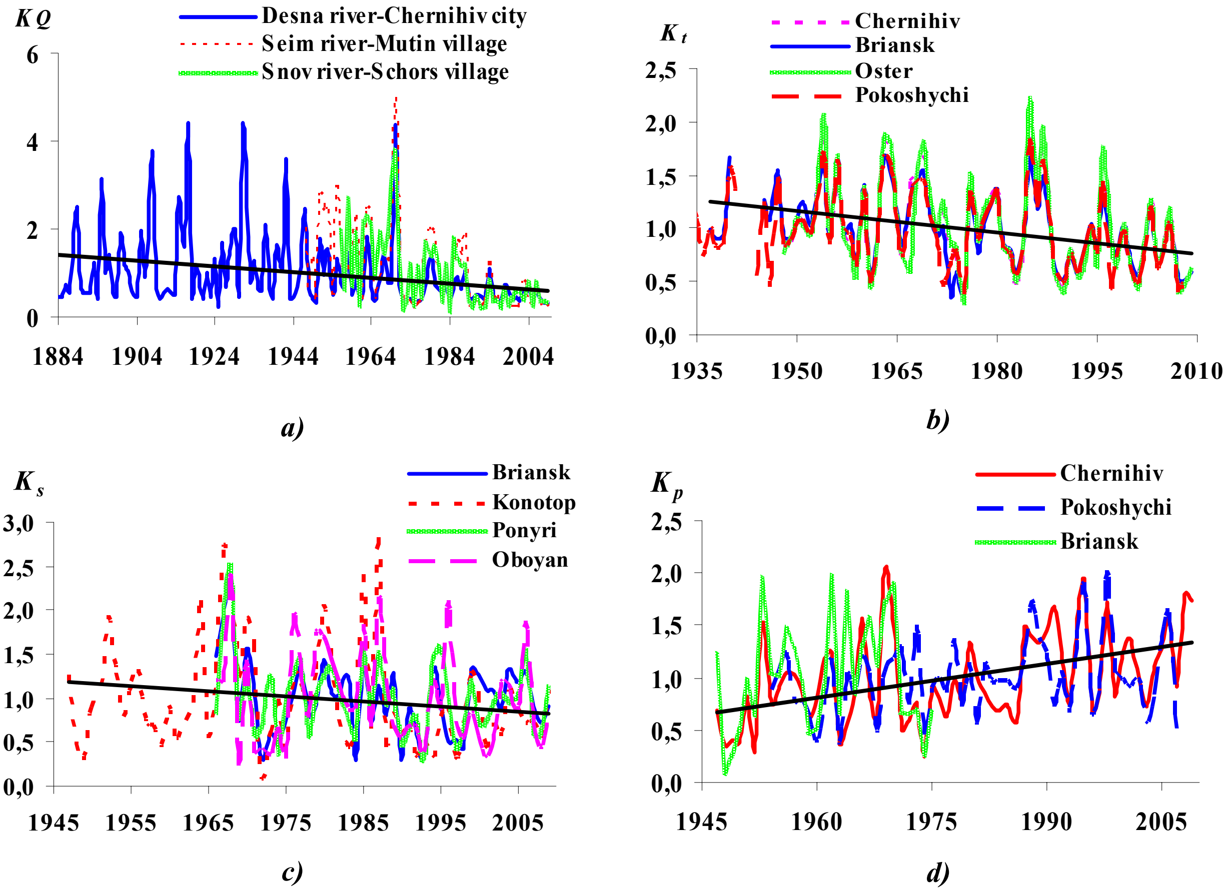


Figure 2. Long-term dynamics, and linear trends of the maximum water discharges (*a*), sum of negative air temperatures in winter (*b*), the maximum water equivalent of snow cover (*c*), the sum of precipitation during the spring flood (*d*) in the basin of the Desna river

At the same time, analysis of homogeneity of the hydrometeorological parameters was carried out using total integral curves. It is showed that all observational data are homogeneous, because of any significant points of curves trends fractures are not detected (Figure 3). Analysis of the difference integral curves of maximum spring flood water discharges showed that for all rivers in 1970 was a transition from high to low water phases of the hydrological cycle. This phase continues today and it is impossible to predict its ending (Figure 4 *a*). As a consequence the observational data of the maximum runoff does not have a full closed cycle. Hydrological gauge Desna River - Chernihiv city also does not have a full hydrological cycle, although has an observational data in 128 years (Figure 4 *b*). For indicators such as maximum water equivalent of snow cover and the sums of negative temperatures in winter observed a decreasing phase of the cyclical fluctuations starting from 70 years of the last century, (Figure 4 *c, e*). That is, decreases of the sums of negative temperatures leads to the decrease of solid precipitation, and as a result to the decrease of the maximum water equivalent of snow cover. All this causes the reduction of the maximum water discharges in the basin of the Desna River since 1970.

Table 1. The estimation of the significance linear trends of the spring flood hydrometeorological characteristics in the basin of the Desna river

The name of gauge	The observation period	The equation of the trend	R^2	R	σ_R	$2\sigma_R$	$3\sigma_R$	The result
Maximum water discharges								
Desna river - Chernihiv city	1884-2009	y = -0.0064x + 1.4092	0.07	0.271	0.08	0.165	0.25	“A”
Seim river - Mutin village	1947-2009	y = -0.0241x + 1.7704	0.23	0.480	0.10	0.194	0.29	“A”
Kleven river - Sharpivka village	1956-2009	y = -0.0246x + 1.6766	0.23	0.480	0.10	0.210	0.31	“A”
Snov river - Schors village	1956-2009	y = -0.0306x + 1.8418	0.33	0.574	0.09	0.182	0.27	“A”
Sum of negative air temperatures in winter								
Chernihiv	1948-2009	y = -0.0067x + 14.281	0.09	0.298	0.12	0.231	0.35	“A”
Briansk	1937-2009	y = -0.0067x + 14.283	0.16	0.400	0.10	0.197	0.29	“A”
Rylsk	1960-2009	y = -0.0089x + 18.672	0.12	0.346	0.12	0.249	0.37	“A”
Sum of positive air temperatures in winter								
Chernihiv	1948-2009	y = 0.0068x - 12.449	0.04	0.200	0.12	0.244	0.37	“0”
Pokoshychi	1925-2008	y = 0.0053x - 9.3337	0.03	0.179	0.11	0.211	0.32	“0”
Briansk	1937-2009	y = 0.0044x - 7.7479	0.02	0.128	0.12	0.230	0.35	“0”
Rylsk	1960-2009	y = 0.0054x - 9.7033	0.02	0.150	0.14	0.276	0.41	“0”
Maximum water equivalent of snow cover								
Hluhiv	1947-2009	y = -0.0059x + 12.654	0.03	0.179	0.12	0.244	0.37	“0”
Druzhba	1947-2009	y = 0.0005x + 0.0038	0.0003	0.017	0.13	0.252	0.38	“0”
Briansk	1966-2009	y = -0.0072x + 15.269	0.04	0.211	0.14	0.288	0.43	“0”
Ponyri	1966-2009	y = -0.0076x + 16.037	0.05	0.222	0.14	0.287	0.43	“0”
Sum of precipitation during the spring flood								
Chernihiv	1947-2009	y = 0.0106x + 0.6601	0.20	0.451	0.10	0.201	0.30	“A”
Pokoshychi	1954-2009	y = 0.8459x + 131.02	0.06	0.240	0.13	0.257	0.38	“0”
Oster	1947-2009	y = 0.0111x + 0.6444	0.19	0.433	0.10	0.205	0.31	“A”
Briansk	1947-1975	y = 0.0066x + 0.9016	0.01	0.104	0.18	0.367	0.55	“0”

«A» – the statistically significant trend, i.e. inhomogeneous; «0» – the statistically insignificant trend, i.e. homogeneous

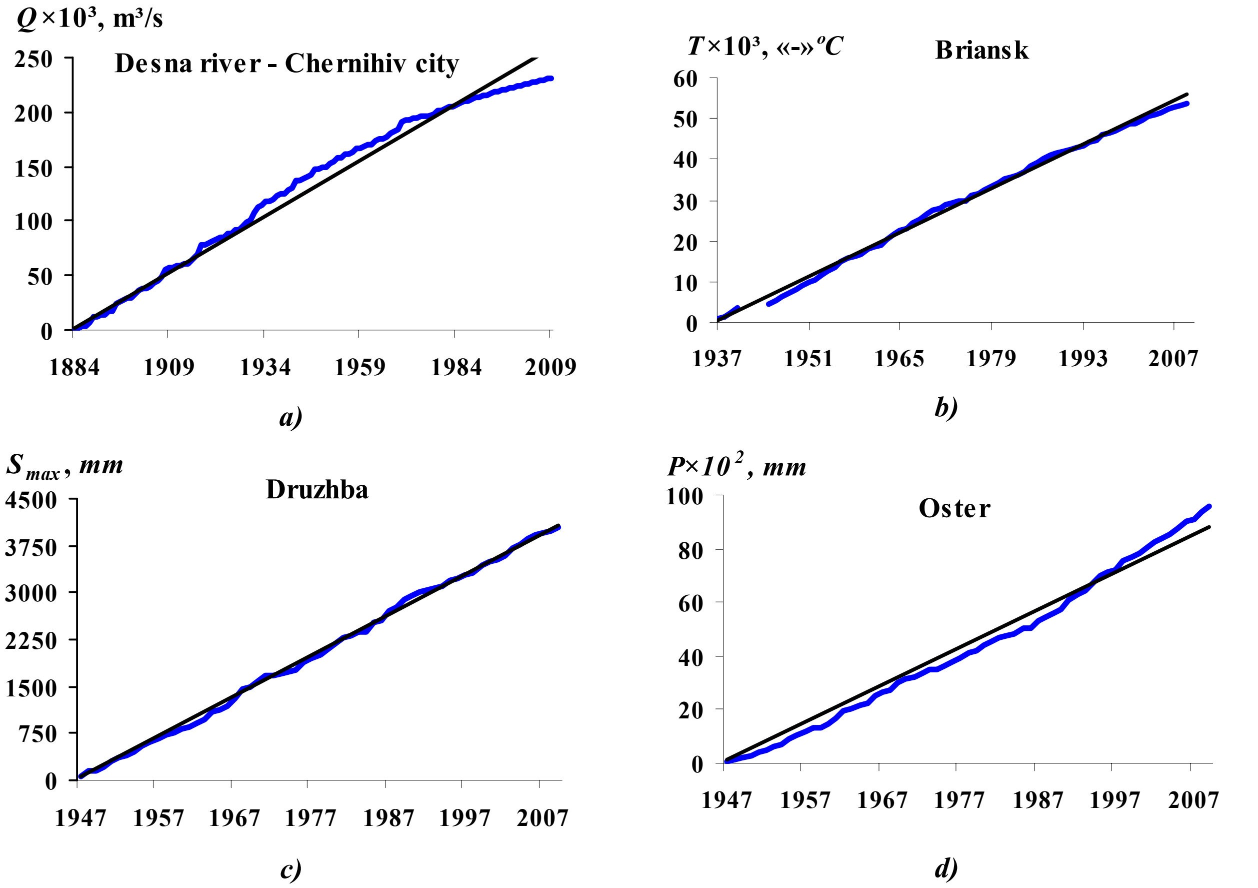
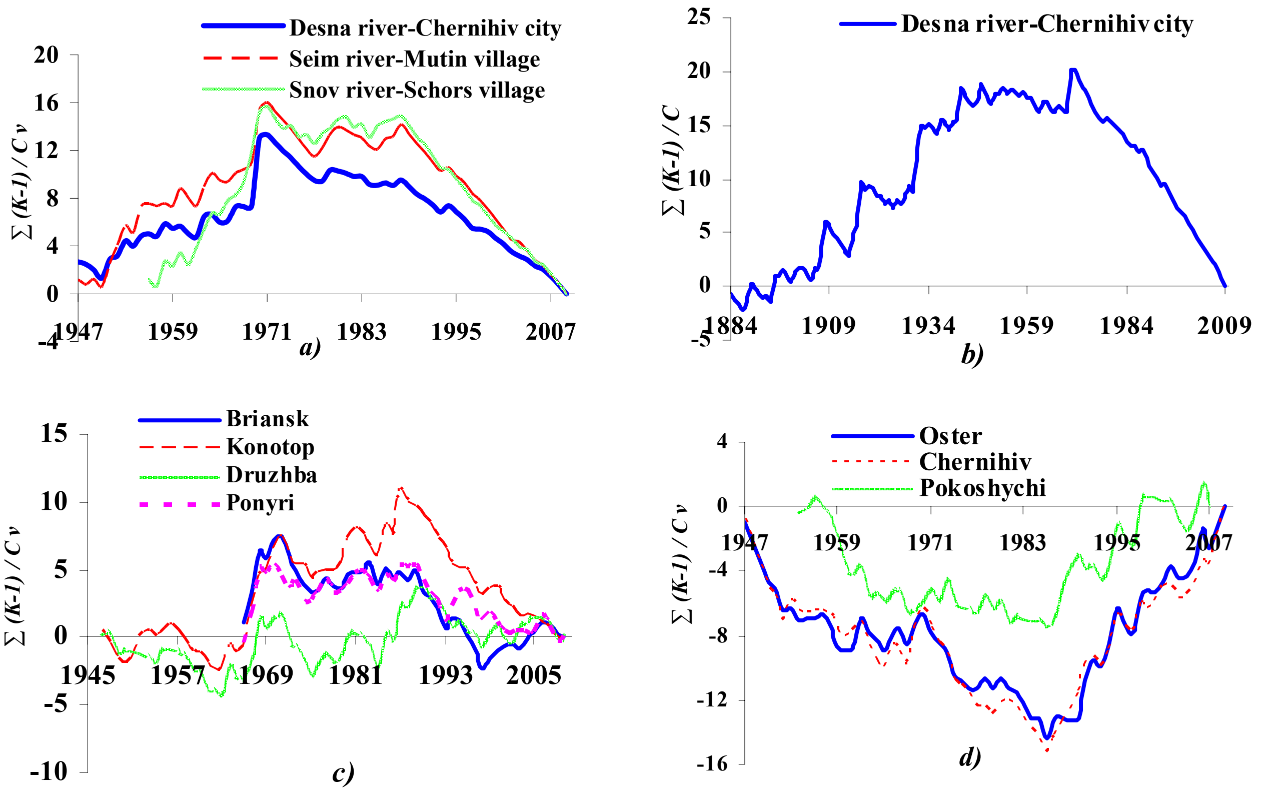


Figure 3. Total integral curves of the maximum water discharges (*a*), sum of negative air temperatures in winter (*b*), maximum water equivalent of snow cover (*c*), sum of precipitation during the spring flood (*d*) in the basin of the Desna river

At the same time the sum of precipitation for the period of spring flood and the sum of positive air temperatures in winter has the increasing phase of cyclical fluctuations from 1986-1988 (Figure 4 *d, f*).



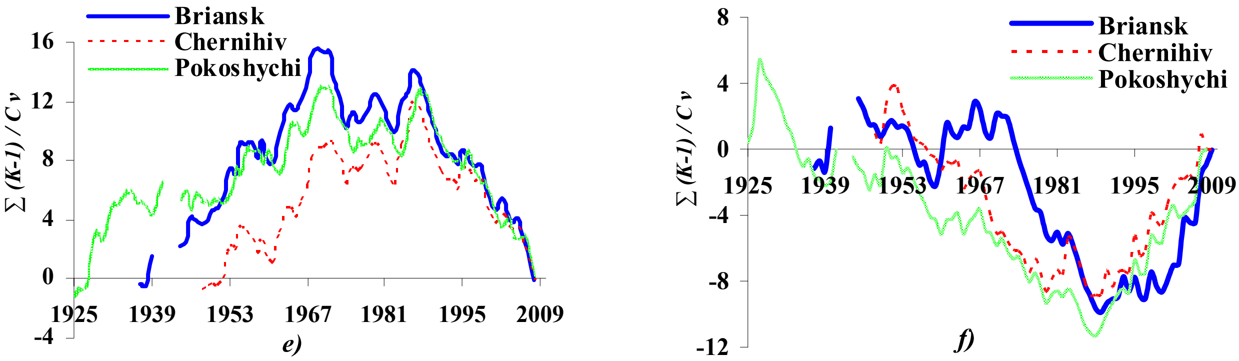


Figure 4. Difference-integral curves of the maximum water discharges (*a, b*),), maximum water equivalent of snow cover (*c*), sum of precipitation during the spring flood (*d*), sum of negative (e) and positive (*f*) air tempratures in the basin of the Desna river

However, the growth of these parameters does not have a significant impact on the spring flood formation, as, for example, the proportion of rainfall during the spring flood in the general flood runoff is only a 12-20% (Fomenko&Nikolaev, 1976).

Observational data of the sum of precipitation for the period of spring flood and the sum of negative air temperature in winter period does not have a full closed cycle (Figure 4 *d, e*). It can be assumed that the presence of statistically significant or insignificant trends in the meteorological observational data has periodic character, which depends not only from the duration of the observational data, but also from the duration of individual phases of cyclical fluctuations. Thus, the observational data can be considered as quasistationary.

CONCLUSIONS

Long-term dynamics of the maximal water discharges, sum of negative temperatures during the winter period and sum of precipitation for the spring flood period in Desna river basin has statistically significant trends at the 5% significance level. However, analysis of the total integral curves showed that all the data of the hydrometeorological characteristics are homogeneous, so as they don't have any points of the fracture in the directions. This indicates the absence of influence of anthropogenic factors and global climate changes.

Statistically significant trends are temporary and are caused by cyclical fluctuations. Observational data on the hydrological post Desna River - Chernihiv city has a complete cycle, even though it has a series of observations in 128 years.

Since 70th of the last century the sums of negative temperatures are decreased. It leads to a decrease of solid precipitation and as consequence to the decreasing of the maximum water equivalent of snow cover. All this causes a decrease of the maximum water discharges in the basin of the Desna River from 1970 (decreasing phase of the cyclical fluctuations).

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