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TERRITORIAL LONG-TERM FORECASTING OF SPRING FLOOD HARACTERISTICS IN THE MODERN CLIMATIC CONDITION UTILIZING GEOGRAPHICAL INFORMATIONAL SYSTEMS

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ABSTRACT

The actual task of research is a spatial long-term forecasting of spring flood characteristics, allowing their predetermination for any rivers on the area in question, including unstudied in hydrology. To find a solution of this problem is vital if we take into account existing conditions of climate change and stream-flow regime of Ukrainian rivers during the spring flood.

Keywords: *climate change, forecasting, spring flood, river flow.*

1. INTRODUCTION

Climate change for the past decades has still been studding by scientists all over the world. The most authoritative international organization today is the Intergovernmental Panel on Climate Change (IPCC), which deals with the assessment of global and local climate change in the past, nowadays and in future. (Climate Change, IPCC, 2013). Modern global climate warming will lead to a reduction of snow and ice levels that greatly impacts on the spring flood runoff. On the other hand increased frequency of adverse meteorological processes leads to the formation of extremely high floods for some years (Air Ukraine, 2003). In this case, it is very significant to develop new approaches for seasonal runoff forecasting or to adapt existing models to actual climate change.

2. MATERIALS OF THE RESEARCH

The exceeded analysis of the natural environment of the spring flood formation on the Ukrainian lowland rivers has shown that it is an important phase in annual regime of rivers. The flood is a result of a snowmelt or of the spring precipitation. This article concerns the analysis of temperature conditions in winter and spring, the maximum water equivalents of snow pack and date of their appearance, precipitation, maximum frost zone of soils, depth of runoff and maximum spring flood discharges (using the example of South Bug River basin). The long course of meteorological factors and characteristics of spring flood runoff indicates that, against the rise in air temperature in winter and spring, there has been a recurrence of air temperature fluctuations in the marked downtrend for the last decade. The coefficients of correlation are important (in the number of years of observation n from 33 to 96) and they reach up to 0,62-0,71.

3. METHOD OF RESEARCH

a. The scientific basis of the method

The method of the territorial long-term forecasting of spring flood characteristics (depth of runoff and maximum water discharges) is based on using of the regional dependence of these values on the amount of snow and rain precipitation in the basin expressed in modular coefficients, i.e. towards their normal annual quantities (Shakirzanova, 2015)

$$k_m = f(k_P), \qquad (1)$$

k_m – modular coefficient of depth of runoff of spring flood ($k_m = Y_m / Y_0$, Y_m and Y_0 – a depth of spring flood runoff and its normal annual value, mm) and maximum water discharges ($k_m = q_m / q_0$, q_m and q_0 – maximum module of spring flood and its normal annual value, m^3/(s·km^2); k_P – modular coefficient of water equivalents in a basin that helps during the period of spring flood

$$k_Д = (S_m + P_1 + P_2)/(S_0 + P_{1_0} + P_{2_0}), \quad (2)$$

S_m and S_0 – maximum water equivalents of snow pack before the beginning of spring flood and its normal annual value, mm;
P_1 and P_{1_0} – precipitation of the period of spring snow-melt and its normal annual value, mm; P_2 and P_{2_0} – precipitation of the period of fall of spring flood and its normal annual value, mm.

The feature of the techniques is that the provisional diagnosis (forecasting) of type of water content of next spring on the sign of the discriminant function (as above, below or near normal) is made. For the rivers of the South Bug basin the equation is next (Shakirzanova, 2015)

$$DF = a_0 + a_1 k_P + a_2 k_{q_{fl}} + a_3 k_L + a_4 \theta_{02}, \quad (3)$$

$k_{q_{fl}} = Q_{fl} / Q_{fl_0}$ – the modular coefficient of index of soil moistening (Q_{fl} and Q_{fl_0} – the mean monthly water discharge before the spring flood and its normal annual value, m³/s); $k_L = L / L_0$ – modular coefficient of a maximum frost zone of soils during the winter (L and L_0 – the depth of the frost zone of soils and its normal annual value, sm); θ_{02} – the mean monthly air temperature in February, ºC.

In case of the absence of annual data of hydrometeorological observations and their normal annual values in individual river basins or regions the spatial fields of hydrometeorological characteristics are restoring. For this purpose geographically linked characteristics which depend on latitude of measurement points and the catchment area of the river basins are built and their determination is performed using the maps of their distributions on the area in question.

There was discovered that for river systems which are in the similar conditions concerning generation of spring floods discriminant equations are stable and can be used for all rivers within homogeneous areas.

Dependencies for forecasting of depth of runoff and maximum water discharges of the form (1) have been obtained in accordance to the sign of the discriminant functions (more or less than zero), and are described by next equations

$$k_m = b_0 + b_1 k_P + b_2 k_P^2 + b_3 k_P^3, \quad (4)$$

b_0, b_1, b_2, b_3 – the coefficients determined within the homogenous areas.

b. Frequency of predicted values

The method of long-term territorial forecasts of spring flood characteristics provide the determining of probability of predicted values in the long-term-period. That probability is set by the forecast modular coefficient of depth of runoff or maximum water discharges and their statistical characteristics using a three-parameter gamma distribution by S. Kritsky and M.Menkel as an interval $P_1\% < P_{Y(Q)}\% < P_2\%$ ($P_1\%$ and $P_2\%$ – the upper and the lower limits of frequency).

c. The presentation of the forecast

The forecasting values (in the form of modular coefficient of depth of runoff and maximum water discharges) are designated in the map (designed utilizing geographical informational systems) of stream-gauging network and generalized on the area in question. Forecast modular coefficients are calculated using a map for any river basin and can be used to assess the depth of runoff, Y_m mm, according to the equation

$$Y_m = k_m \cdot Y_0; \quad (5)$$

for the maximum water discharges, Q_m, m³/s, according to the equation

$$Q_m = k_m \cdot q_0 \cdot A \quad (6)$$

A – river catchment areas, km².

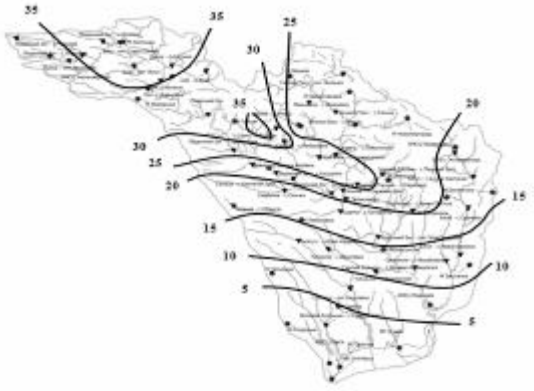

Figure 1. Normal annual averages of spring flood depth of runoff distributed on the territory of the South Bug basin ($\grave{A}_{for}=0$, $\grave{A}_{bogs}=0$), mm.

In the formula (5) normal average values of depth of runoff of spring flood Y_0, mm, can be determined for any rivers of territory using their maps (the example for the South Bug river basin is shown in Fig. 1). Influence of the forest and bogs on the depth of spring runoff Y_0 is taken into account using coefficients $k_{for}=1-0{,}082\lg(\grave{A}_{for}+1)$ and $k_{bogs}=1-0{,}24\lg(\grave{A}_{bogs}+1)$, $\grave{A}_{for}$, % and $\grave{A}_{bogs}$, % – forest and bogs areas in a river basin. In the formula (6) normal average values of the maximum modules of spring flood q_0, m^3/(s·km^2), are calculated for the rivers, unstudied in hydrology according to a model of typical reduction hydrographs of flood (Gopchenko, 2005) according to equation

$$q_0 = q'_0\psi(t_p/T_0)\varepsilon_F \cdot r \text{ ,} \tag{7}$$

q'_0 – normal average module of maximum water discharge from surface inflow, m^3/(s·km^2); $\psi(t_p/T_0)$ – transformation function of flattening of the flood waves which is influenced by the channel lag-time; ε_F – the coefficient of the channel-floodplain regulation; r – the coefficient of flood transformation which is influenced by lakes and river-bed type storage reservoirs.

For typical hydrographs the value q'_0 is determined according to the next equation (Gopchenko, 2005):

$$q'_0 = 0{,}28\frac{n+1}{n}\frac{1}{T_0}Y_0 \text{ .} \tag{8}$$

The value of the coefficient of temporal unevenness of surface inflow $(n+1)/n$ for the Ukrainian lowland rivers basins (including the South Bug basin) can be put equal to 8,1 (Shakirzanova, 2015).

In a formula (8) duration of surface inflow of snow melt and rain water T_0, hours is determined for any rivers of territory on a map (for the South Bug river basin it is shown on Fig.2). Influence of the forest and bogs on duration T_0 is considered based on the coefficients $k'_{for}=1+0{,}34\lg(\grave{A}_{for}+1)$ and $k'_{bogs}=1+1{,}23\lg(\grave{A}_{bogs}+1)$.

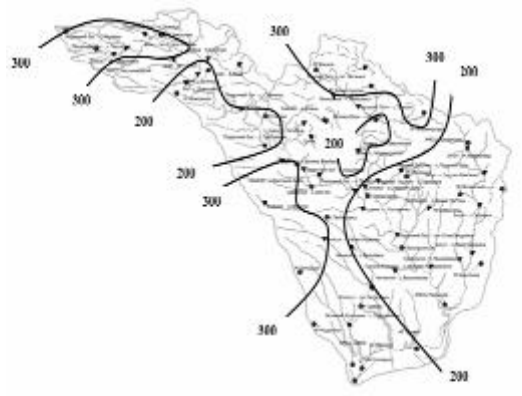

Figure 2. Duration of snow melt and rain water inflow from the slopes distributed on territory of the South Bug basin ($\grave{A}_{for}=0$, $\grave{A}_{bogs}=0$), mm.

d. Got results

In the offered method of the territorial long - term forecasting of spring flood characteristics base maps and equation parameters must be precised according to the conditions of modern changes of climate and stream-flow regime of the lowland rivers in Ukraine. For that purpose regional coefficients are added to the values Y_0 and q_0, in a scheme of the forecast considering the present decrease of depth of runoff and maximum water discharges of spring flood. It is recommended to precise that coefficients every decade, because the orientation of modern changes can change a sign to the opposite. Verification of the method of the forecasting of spring flood characteristics is carried out for modern period from 2001 to 2010 for 10 supporting catchment areas in the South Bug river basin. The quality control of efficiency and quality of methods (according to the data of 800 forecasts) using the quality criterion S/σ (S – is a normal quadratic forecast error, σ – is a normal quadratic deviation of forecast value from a norm) according to a scale of the quality control of methods for the depth of runoff and maximum water discharges have shown good results: for the depth of runoff the error equals 0,44-0,48 (according to the assessment scale of operational forecast the forecast is good), at *P*=89-91% and maximum water discharges – 0,21-0,25 (the forecast is excellent), at *P*=95-96%.

e. Further prospects of model development

This research considers the possibility of using the forecast model including the vector-forecaster of discriminant function of hydrometeorological factors of spring flood, got from the data of climatic scenarios. The cross-correlation connections are discovered between the spring flood factors, values of temperature of air and precipitations for different periods (according to the data of climatic scenario). Coefficients of correlation of these connections are important and vary in the range from 0,69 to 0,95. That fact allows using meteorological characteristics of scenario in the scheme of the forecast for the assessment of spring flood characteristics of the lowland rivers in future.

4. CONCLUSIONS

The offered method of territorial long-term forecast of depth of runoff and maximum water discharges of spring flood on the lowland rivers in Ukraine allows carrying out forecasting of these characteristics using the complex of hydrometeorological factors and the method of discriminant analysis. The possibility of current territorial forecasting of spring flood characteristics for any rivers of territory, including unstudied in hydrology is justified.

It is recommended to precise the base characteristics of the scheme of the forecast in the modern conditions of changes of climate and stream-flow regime of spring flood. The possibility of using the hydrometeorological factors of spring flood which have been got from data of climatic scenarios is justified.

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