# Changes of elements of water balance and their forecast against global climate fluctuation

A Volchek A.A. and Sheshko N.N.

Brest, Belarus, volchak@tut.by, optimum@tut.by

## 1. Data and methods

Materials of stationary hydrological and climatic supervision by the hydro-meteorological centre of the Ministry of natural resources and the environment of the Republic of Belarus were used for an estimate of transformation of water parameters of the rivers caused by climatic fluctuations and anthropogenic influences.

Water-balance investigations of river basins are executed with a hydrology-climatic calculation method developed by V.S. Mezentsev (1980, 1986) based on the joint solution of the equations of water and heat-and-power balances.

The equation of water balance of a river basin for a certain time interval looks like:

$$Y_K(I) = H(I) - Z(I)\text{, (1)}$$

where $Y_K$ ($I$) – a total climatic drain, mm; $H$ ($I$) – total resources of humidifying, mm; $Z$ ($I$) – total evaporation, mm; $I$ – an averaging interval.

Total evaporation can be calculated:

$$Z(I) = Z_m(I)\left[1 + \left(\frac{\frac{Z_m(I)}{W_{HB}} + V(I)^{1-r(I)}}{\frac{X(I)+g(I)}{W_{HB}} + V(I)}\right)^{n(I)}\right]^{-\frac{1}{n(I)}}\text{, (2)}$$

where $Z_m(I)$ – the greatest possible total evaporation, mm; $W_{HB}$ – the least moisture capacity of soil, mm; $V(I) = \frac{W(I)}{W_{HB}}$ – relative soil humidity at the beginning of the reference period; $X$ ($I$) – sum of an atmospheric precipitation, mm; $g$ ($I$) – a soil component of water balance, mm; $r$ ($I$) – parameter depending on water-physical properties and mechanical structure of the soil; $n$ ($I$) – parameter considering physiographic conditions of a drain.

Relative humidity of soil at the end of the reference period is determined from relations:

$$V(I+1) = V(I)\cdot\left(\frac{V_{cp}(I)}{V(I)}\right)^{r(I)}\text{, (3)}$$

$$V_{cp}(I) = \left(\frac{\frac{X(I)+g(I)}{W_{HB}} + V(I)}{\frac{Z_m(I)}{W_{HB}} + V(I)^{1-r(I)}}\right)^{\frac{1}{r(I)}}\text{, (4)}$$

The greatest possible total evaporation can be estimated by the procedure described by Volchek A.A. (1986). Total resources of humidifying are defined as follows:

$$H(I) = X(I) + W_{HB}(V(I) - V(I+1))\text{, (5)}$$

The solution of combined equations (1) – (5) is carried out by iteration procedure until the value of relative soil humidity at the beginning of a reference interval is equal to the value of the relative humidity at the end of the last interval. The initial value of humidity is considered equal to the value of the lowest moisture capacity, i.e. $W(1) = W_{HB}$, from which $V(1) = 1$. Convergence of the outcome of the hydrology-climatic calculation method is reached already on the fourth step of calculation.

The climatic drain value is updated by means of coefficients considering the influence of various factors on formation of channel flow, i.e.

$$Y_P(I) = k(I)\cdot Y_K(I)\text{, (6)}$$

where $Y_P$ ($I$) – total channel flow, mm; $k$ ($I$) – the coefficient considering hydrographic characteristics of a river basin.

## 2. Analysis of the results

The hydrology-climatic calculations method is realized in the computer program "Balans". Modeling of water balance of the river in question is carried out in two stages: adjustment of the model and modeling.

In the first stage it is necessary to set co-ordinates of the centre of gravity of the basin of the investigated river and the basic hydrographic characteristics of the basin. Then the program selects the river-analogue from the built-in data bank of hydro-meteorological information taking into account similarity of formation of a water mode of the rivers. Further changing parameters $W_{HB}$, $r$ and $n$ and solution of combined equations (1) – (5) permits adjustment of the model for the river-analogue. The least moisture capacity of soil $W_{HB}$ varying within the limits of 60 to 220 mm, parameter $r$ – 1 to 2.5, parameter $n$ – 2 to 3.4. When the model is adjusting the aim is to reach the greatest conformity of the calculated climatic drain and channel flow of a river-analogue. The first stage ends after the diagrams of climatic drain and channel flow are plotted and the error of modeling is estimated.

The second stage represents direct calculation of the water balance of the river investigated, using the parameters obtained when modeling a drain of the river-analogue. Calculation of elements of the water balance takes features of the river basin considered into account.

For construction of forecasting models on the basis of the hydrology-climatic calculations method the future values of changes of the basic climatic characteristics are necessary. For this purpose we will use earlier obtained values of changes in temperature, atmospheric precipitations and deficiencies of air humidity, resulting in Table 1.

Using these data and the computer program «Balans», the model of a climatic drain of the river Narev (station Nemerzha) is constructed. Possible changes of a climatic drain connected with changes of components of water balance for 2015 are calculated by the model. Figure 1 shows the diagrams of model adjustments to a natural drain of the river Narev (station Nemerzha).

The results of the forecast are present in Table 2, in which the values of a layer of a drain for the modern period and predicted drain layer for the basin of Narev are also resulted.

## 3. Conclusions

The results of the predicted changes of a layer of a drain on a river Narev basin clearly shows the periods of significant changes of annual distribution of a drain. During the winter period (February) a probable reduction to 25% of a drain is possible, and during the period of summer and autumn mean water redistribution of a drain up to 20% is possible (September →August). In turn, change of an average annual drain is insignificant (0,1 %). The result of possible changes of climatic parameters (warming) will not cause a change of size of annual drain, but there will be a seasonal redistribution of an annual drain.

## 4. References

Mezentsev V.S, Karnatsevich I.V. Moisture of West Siberian plain. – Leningrad: Gidrometeoizdat, 1969. – 168 p. (in Russian)

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**Table 1.** The Basic climatic characteristics

| Belovezhskaya Pushcha | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Year |
| current values | Air temperature, $C^0$ | | | | | | | | | | | | |
| | -2,93 | -2,15 | 1,48 | 8,07 | 13,75 | 16,54 | 18,67 | 17,87 | 12,58 | 7,67 | 1,98 | -1,90 | 7,64 |
| | Atmospheric precipitations, mm | | | | | | | | | | | | |
| | 30,43 | 33,09 | 33,02 | 37,58 | 54,53 | 64,13 | 75,60 | 70,54 | 52,47 | 36,15 | 39,84 | 38,70 | 566,17 |
| | Deficiency of air humidity, mb | | | | | | | | | | | | |
| | 0,73 | 0,99 | 1,82 | 4,11 | 6,20 | 6,53 | 7,33 | 6,96 | 3,74 | 2,17 | 0,97 | 0,66 | 3,52 |
| forecast values for 2015 | Air temperature, $C^0$ | | | | | | | | | | | | |
| | -1,55 | -0,41 | 1,98 | 8,86 | 13,90 | 16,93 | 19,88 | 18,67 | 13,49 | 8,07 | 2,72 | -2,64 | 8,33 |
| | Atmospheric precipitations, mm | | | | | | | | | | | | |
| | 26,26 | 40,93 | 27,99 | 34,73 | 58,98 | 54,11 | 85,75 | 83,61 | 36,73 | 41,78 | 38,71 | 33,24 | 562,97 |
| | Deficiency of air humidity, mb | | | | | | | | | | | | |
| | 0,72 | 1,01 | 2,07 | 4,60 | 6,52 | 7,49 | 8,01 | 7,85 | 4,81 | 2,09 | 1,03 | 0,63 | 3,90 |

**Table 2.** Change of a climatic layer of a drain of river Narev (station Nemerzha)

| Values | Months | | | | | | | | | | | | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | |
| Modern, mm | 4,38 | 5,82 | 21,5 | 32,9 | 9,25 | 4,96 | 3,25 | 2,78 | 1,72 | 2,78 | 5,2 | 3,92 | 98,5 |
| Predicted (2015), mm | 4,68 | 4,59 | 21,5 | 33,1 | 9,24 | 4,93 | 3,28 | 2,33 | 2,23 | 2,81 | 5,15 | 4,8 | 98,6 |
| Relative change of a layer of a drain, % | 6,41 | -26,8 | 0,00 | 0,60 | -0,11 | -0,61 | 0,91 | -19,3 | 22,8 | 1,07 | -0,97 | 18,3 | 0,10 |

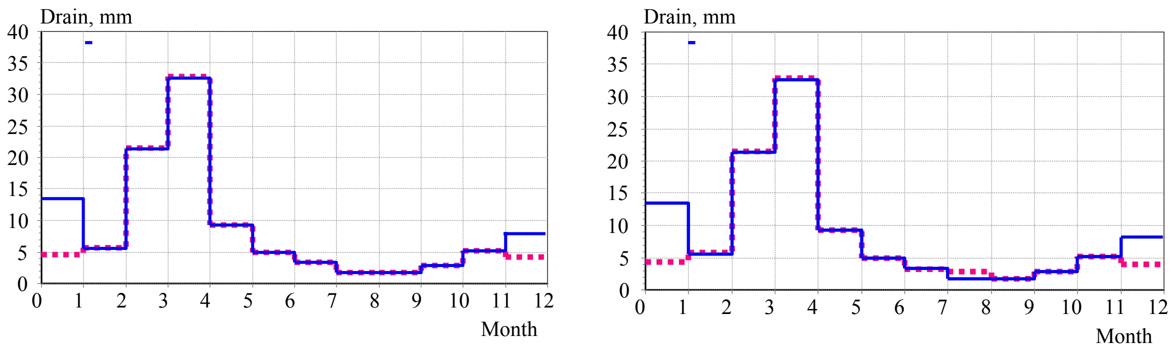


**Figure 1.** Analytical hydrographer of a layer of a drain of river Narev (station Nemerzha)
a) current values climatic drain; b) predicted values of climatic drain