Hydrological and climatic conditions of water resources formation in the South of Western Siberia

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Abstract. Hydrological and climatic features of the formation of water resources in any territory are closely related to the conditions of formation of incoming elements of water and heat balance. The use of the method of hydrological and climatic calculations (GCR) developed by V. S. Mezentsev and tested in most regions of Siberia and adjacent territories involves the determination of flow characteristics by the equations of water and heat energy elements. In the presence of indicators of values of total moisture and heat and power resources of climate, these equations allow calculating values of actually all components of balance equations, both for a year and an intra-annual interval. The application of the GCR method in determining the elements of the water balance in the conditions of flat areas, which include the South of Western Siberia, allows obtaining runoff characteristics with satisfactory accuracy. The paper identifies the features of formation and distribution of elements of water and heat balance in the study area, determines their values for the territory of Western Siberia and checks the calculated values of flow by comparison with the measured ones.

1. Introduction
Water resources of any territory are derived from the interaction of factors, such as climate, topography, geological structure and underlying surface represented by soil and vegetation. The basis for the quantitative assessment of the distribution of space-time characteristics for thermal and water elements is the fundamental provision on the implementation of a complex and continuous process of energy and matter transformation [1, 2]. The intensity of this process is primarily due to the degree of proportionality of the available heat and moisture resources and the structural features of the catchment surface.

Due to the lack of knowledge of the elements of water balance equations as well as the theoretical and practical need to disclose the natural relationships between these elements, factors and conditions of their formation, the solution of the equation of the water balance of the land area is carried out through indirect methods. The use of most indirect methods involves a sufficiently large amount of initial data. Its production requires special measurements and studies, which limits or makes it impossible to use it for mass calculations in conditions of objective lack of knowledge of small river basins.

The method of hydrological and climatic calculations (GCR) developed by V.S. Mezentsev [3] and tested in most regions of Siberia and adjacent territories [4-7] determines the flow characteristics according to the equations of connection of water and heat power elements. The advantage of this method is its applicability with a relatively limited amount of initial data obtained through standard
measurements. Due to the high reliability and informativeness of the calculated parameters and characteristics, the GCR method can be used in various natural conditions, including small river basins.

2. Object, models and method of research

An important stage of water management calculations is the correct registration of runoff resources that characterize the water resources in the study area. In this regard, the most important task of water balance investigation is to match the calculated values with hydrological processes occurring in nature. The degree of such compliance is equally determined both by the objectivity and accuracy of the initial hydrometeorological information, and the validity and reliability of the calculation methods for determining the individual components of the water balance of a land or river basin.

Currently, there are various methods for determining the hydrological characteristics, which within the limits of permissible errors describe the hydrological processes to obtain the water balance characteristics of the territory. In most calculations, morphological and morphometric basin characteristics that characterize the local conditions of runoff formation are used as the source of information. Therefore, the use of such methods is necessary to perform additional field for hydrometeorological services, which limits their use for mass calculations.

The most optimal methods, which do not require a large variety of initial data, include calculation methods based on the joint consideration of the equations of water and heat balances corresponding to the fundamental laws of conservation of matter and energy in the process of global water - heat rotations.

E.M. Oldecop first proposed the expediency of the joint solution of the equations of water and heat balance of the land was first proposed in the early 20th century, and later, it was widely implemented in the works of M.I. Budyko, A.A. Grigoriev, V.S. Mezentsev, I.V. Karnatsevich, and G.V. Belonenko. Numerous studies of water balance, which were carried out subsequently by the method of hydrological and climatic calculations for different regions of Russia, convincingly proved the objective advantages of the joint consideration of the equations of water and heat balance of the land. The joint consideration of the balance of moisture and heat is also of fundamental importance for the assessment of the impact of anthropogenic factors, predicting the possible size and consequences of the economic use of the main components of the natural environment that directly affect the development of hydrological processes within the studied water body [8].

The practice of using this method for studying the laws of the interaction of heat and moisture allows us to specify the calculated stock characteristics of the existing fields of precipitation and heat and power resources of evaporation, taking into account the orographic and soil-geological features of the structure of the watershed.

The advantages of joint consideration of the balance of heat and moisture are obvious. They comprise the objective control of the total evaporation of moisture and heat in the active layer of the land area. The quantitative characteristics obtained from this assessment are a sufficiently reliable guiding basis for the development of recommendations for the hydromeliorative transformation of the natural environment [5]. In addition, the structure of the water balance calculated by the coupling equations most closely corresponds to the zonal conditions for the formation of the components of heat and moisture exchange in the active surface and the surface layer of the atmosphere. In the conditions of constantly increasing influence of human economic activity on hydrological processes and phenomena, this circumstance is of great practical importance, as, due to the comparison of the actual (observed) and calculated values of the components of moisture exchange, it is possible to quantify the impact of anthropogenic or azonal natural factors on the components and structure of the water cycle process within the studied river basin or region [9].

Thus, the equation of connection between water and heat (heat power) balances is called the analytical expression of the dependence of the total evaporation of the thermal and water characteristics on the territory. The basis of these equations, as a rule, is the dependence of the total evaporation of precipitation and thermal energy resources of evaporation expressed in millimeters of
evaporated moisture. In the theoretical aspect, the boundary conditions of this process assume the total consumption of heat resources for the total (maximum possible) evaporation.

3. Result and discussion
In the conditions of insufficient hydrometeorological, heat and water balance study of the South of Western Siberia, quantitative assessment of elements of water and heat exchange in the system "atmosphere – underlying surface" can be implemented on the basis of data on hydrological and climatic calculations (GCR) with extensive use of standard hydrometeorological information and materials characterizing the features of the structure of the earth's surface. In the presence of values of total humidification and heat and power resources of climate, the equations system of connection of water and heat and power balances allows calculating all components of balance equations, both for annual and intra-annual periods. According to the results of studies, in the conditions of flat areas, water consumption and runoff are in general determined by satisfactory accuracy. The spatial and temporal redistribution of water resources mainly depends on the physical and geographical features of the landscape, as well as the conditions for the formation of the drainage surface of the catchment area [8, 9]. Taking this into account, the values of annual runoff and their intra-annual distribution at 104 sites located in the South of Western Siberia were calculated using the equations of connection of heat and water elements [10-14]. Figure 1 shows a graph of changes in water balance characteristics for Omsk.

![Figure 1](image.png)

Figure 1. Graph of annual precipitation (KX), maximum possible evaporation (Zm), total evaporation (Z) and total runoff (Y) for Omsk site calculated by the GCR.

The change in the equivalent of thermal energy resources of evaporation for the year on the territory has a latitudinal character. The highest value of 866 mm in the Pavlodar region reduces to 650 mm to the North (Kenya). The annual distribution of Zm in the absence of data on thermal balance observations was performed, depending on the temperature and relative humidity [5].

Annual sums of total evaporation as a derivative of heat power resources of evaporation and atmospheric precipitation have the minimum values of 280 mm in the South of the territory, and the greatest values (540 mm) are observed in the elevated regions of the Altai mountain range.

The annual distribution of the total evaporation occurs throughout the summer period, usually in June or July, which are the warmest months in the whole territory. During the winter period of the year as a whole, for example, in the southern regions of the territory, Z values are less than 10-12% of annual amounts.
Calculating runoff and evapotranspiration of unexplored catchments by different methods, it is of particular importance to control the accuracy of the results. In this regard, to determine the applicability of the method based on the equation of connection of thermal and water balances, it is necessary to compare the calculated values with the measured values [15-17]. Such calculations were performed for several rivers located in the South of Western Siberia, whereas the incoming components of thermal power and water resources were taken for the center of gravity of the watershed, taking into account the data of meteorological stations located in the watershed of these rivers, and in case of their absence in the field of distribution of these characteristics.

The analysis of the ratio of calculated (climatic) and measured (hydrological) runoff (figure 2) showed that the compared values are well correlated (R²=0.85) and have close connections, and this statement is true for both small and medium river basins.

![Figure 2. Comparison chart of calculated runoff values with measured values for small and medium rivers in the South of Western Siberia.](image)

This comparison also shows that in the area of small runoff values there are deviations of the compared values; hence, it is necessary to take into account the influence of the watershed on the runoff. Local morphological features of the watersheds also contribute to the divergence of the studied values, which, in turn, affects the nature of moisture in these areas. Therefore, it is necessary to consider such parameters as the height of the watershed, the geographic latitude, the values of the lowest moisture capacity, available resources, heat and moisture, described by the variables of temperature and precipitation, the humidity of the air, conditions of formation and peculiarities of snow cover distribution) [9]. In this regard, climatic and physical-geographical features of the territory play an important role in the research process, as well as the analysis of the correspondence of the results with the peculiarities of the specific physical and geographical situation in the region. Determination of the quantitative values of heat and moisture resources requires considering the local conditions for the formation of these elements.

An important characteristic of hydrological and climatic calculations is the parameter of the coupling equation n, which shows the conditions for the formation of runoff from the watershed. The
values of this parameter vary from one (lower theoretical limit) to three and four for the plains of arid regions [3, 4, 7]. In other words, the values of the parameter n are determined by the ratio of total evaporation and humidification under optimal conditions [5]. Figure 3 shows theoretical curves and empirical values of relative values of total evaporation δz and wetting δh of river basins in Western Siberia. The graph indicates that the calculated values of total evaporation and moisture were obtained at the parameters n from 2.5 to 3.0, which corresponds to the flat nature of the study area, and confirms that the possible values of this parameter for the river basins in Western Siberia and adjacent territories are in the range from 2.0 to 3.0.

![Diagram](image.png)

**Figure 3.** Theoretical curves and empirical values of relative values of total evaporation δz and wetting δh of river basins in Western Siberia.

Application of the method allows the CGD to assess the conditions of natural moisture and heat provision on the investigated territory in various available heat and moisture intervals.

The comprehensive study of the laws of moisture and heat circulation is of particular importance in the conditions of weak hydrometric study of the South of Western Siberia, as it complements the existing information base of the region obtained at the same methodological information level about the incoming and outgoing components of a single and continuous process of heat and moisture exchange.

4. **Conclusion**

Application of the method of hydrological and climatic calculations with the use of modern data on atmospheric precipitation in conjunction with the thermal power characteristics of the study area have allowed us to obtain regional dependences of water balance elements and determine the features of the spatial and temporal distribution of the natural moisture indicator in the territories of the study region.

The results have confirmed that the size and territorial distribution of the values of natural moisture and heat resources depend on both the latitude and the height of the watershed. In turn, the spatial-temporal distribution and transformation of moisture and heat resources affect the territorial distribution features of annual runoff value.

The terrain has a significant impact on the formation of surface runoff. The height of the terrain determines both the degree of moisture and the slopes of the watershed surface, as well as the intensity of surface runoff. Recognition of these features in the equation of water and heat balance is necessary and associated with the introduction of different values of the parameter n, depending on the local conditions of flow formation.
Analysis of the ratio of calculated and measured annual runoff has shown that the differences between the compared values in various reliability degrees depend on the size of the watershed. In this regard, the use of the water balance method for the calculation of runoff in conditions of insufficient moisture of river basins should always be appropriately justified.

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