ABSTRACT
of the PhD Dissertation
in the specialty «6D061000 – Hydrology»
by **Aigerim Ardakovna Bolatova**

on the topic:
"Assessment and modeling of flow hydrograph of the Oba and Ulbi Rivers under climate change conditions"

Relevance of the research topic. The sustainable development of the country under climate change requires special attention to issues of water security and rational water resource management. The Irtysh River Basin plays a crucial role in ensuring economic growth and regional sustainability, while its tributaries are key sources of water resources. Under changing climatic conditions, there is an increasing need for scientific research aimed at assessing the runoff of the two main tributaries of the Irtysh River. These tributaries form a significant part of the basin's water balance, supplying water to key sectors such as industry, agriculture, and public water supply.
Effective assessment of runoff changes requires the use of modern hydrological models that account for a wide range of climatic factors and scenarios. Such models enable more accurate forecasts of water resource dynamics, including changes in snowpack water storage, which is the main source of runoff formation in the region. The use of these models allows not only an objective assessment of the current state of water resources but also the projection of possible future changes under climate change conditions.
The research results provide a scientific and methodological basis for optimizing the use of water resources in the Irtysh tributaries, meeting regional needs, and developing climate adaptation strategies. A modern, model-based approach to water resources management is an important step toward strengthening water security and ensuring sustainable development within the Irtysh River Basin.
The main tributaries of the Irtysh — the **Oba** and **Ulba Rivers** — have strategic importance for the region. They feed important reservoirs, including the Shulbinsk Reservoir, support irrigation of agricultural lands, provide water for settlements and enterprises, and are used for hydropower generation. Moreover, these water bodies play a crucial role in maintaining the ecological balance and sustainability of aquatic ecosystems in East Kazakhstan.
One of the less-studied scientific problems is the lack of data and models for assessing the hydrological impacts of climate change specifically for the Oba and Ulba Rivers. This includes changes in seasonal runoff distribution and the potential increase in the frequency and intensity of extreme hydrological events, such as floods or droughts. To address these issues, hydrological data analysis, climate scenario-based runoff modeling, and assessment of climate change impacts on the region's water management

system were conducted. Special attention was given to integrating climate, hydrological, and water-use data to assess future changes in water resources over the coming decades.

Thus, studying the hydrological regime changes of the Oba and Ulba Rivers under climate change is a vital step for assessing and managing Kazakhstan's water resources. Conducting such research helps not only to forecast water balance changes but also to develop effective climate adaptation measures that will ensure stable water supply and ecosystem resilience in the region.

The dissertation is devoted to studying the dynamics of the runoff of the Oba and Ulba Rivers under climate change conditions.

Object of the study: the Oba and Ulba Rivers.

Subject of the study: the dynamics of runoff changes under climate change conditions.

Research aim: to assess possible changes in the runoff of the Oba and Ulba Rivers and the inflow to the Shulbinsk Reservoir under projected 21st-century climate change scenarios.

Research objectives:

- Collection and statistical processing of hydrological data for the Oba and Ulba river basins.
- Calibration and adaptation of the **SWIM (Soil and Water Integrated Model)** hydrological model to simulate river runoff in the Oba and Ulba basins.
- Assessment of annual and snowmelt runoff changes of the Oba and Ulba Rivers in the 21st century using SWIM based on an ensemble of climate models.
- Evaluation of possible changes in inflow to the Shulbinsk Reservoir under 21st-century climate conditions.

Sources of data: archival and database materials of *RSE "Kazhydromet"* under the Ministry of Ecology and Natural Resources of the Republic of Kazakhstan, including minimum, maximum, and average air temperature, precipitation, wind, humidity, snow depth, and river discharge data. Climate projections were based on five Earth System Models (ESMs) from the CMIP5 ensemble used in the ISIMIP project: GFDL-ESM2M, HadGEM2-ES, IPSL-CM5A-LR, MIROC-ESM-CHEM, and NorESM1-M.

Methodological basis. The approaches used in the dissertation combine general scientific and specialized statistical methods with an integrated modeling methodology. Changes in periods with relatively stable long-term averages of hydrometeorological characteristics were analyzed using cumulative integral curves. The **SWIM** model and climate projections from CMIP5 were applied to assess the impact of climate change on the Oba and Ulba Rivers' runoff. Model performance was evaluated using statistical criteria such as the correlation coefficient, coefficient of determination, Nash–Sutcliffe Efficiency (NSE), Percent Bias (PBIAS), and Root Mean

Square Error (RMSE). Future runoff changes were estimated using an ensemble projection method based on ISIMIP CMIP5 data under RCP 4.5 and RCP 8.5 scenarios.

Scientific novelty:

- For the first time, projected runoff changes of the Oba and Ulba Rivers under 21st-century climate change have been assessed.
- The eco-hydrological model **SWIM** has been adapted and applied for the first time to simulate the hydrograph of the Oba and Ulba Rivers under climate change.
- Potential inflow changes to the Shulbinsk Reservoir were evaluated for the first time based on climate change scenarios.

Key findings submitted for defense:

1. Analysis of hydrometeorological data series in the Oba (Shemonaiha) and Ulba (Ulba Perevalochnaia) basins revealed an increase in mean annual air temperature since the 1990s, a slight decrease in precipitation since 1995, and a decrease in river discharge due to climate change.
2. The study confirmed the applicability of the **SWIM** model for simulating the runoff hydrograph of the Oba and Ulba Rivers for the 1961–2020 observation period, enabling scenario-based runoff modeling under projected climate conditions.
3. Modeling under global warming scenarios (RCP 4.5 and RCP 8.5) indicated a slight increase in runoff in the Oba River Basin and a shift of the runoff peak from May to April (one month earlier) in both basins.

Description of the main research results

For the analysis, hydrometeorological data were obtained from meteorological stations Shemonaikha (1936–2020), Ust-Kamenogorsk (1930–2020), and Leninogorsk (1935–2020) from the beginning of their operation until 2020, as well as from hydrological gauging stations on the Oba River – Shemonaikha village, and the Ulbi River – Ulbi Perevalochnaya village for the period 1931–2020. Based on the data of cumulative integral curves, a noticeable increase in the mean annual air temperature has been observed since the early 1970s. The long-term average of the mean annual air temperature since the 1970s increased by 0.82°C at the Leninogorsk station, 0.89°C at the Ust-Kamenogorsk station, and 1.58°C at the Shemonaikha station.

The total annual precipitation values show a slight decrease since the late 1970s and early 1980s—by approximately 5% at Leninogorsk and 8% at Ust-Kamenogorsk. As further analysis revealed, this has also affected the river flow characteristics. The annual runoff of the Oba River (Shemonaikha) decreased by about 12%, and that of the Ulbi River (Ulbi Perevalochnaya) decreased by about 10%. These results were obtained by calculating the characteristics of the annual river runoff for periods with relatively stable long-term mean annual discharges under conditions of climate-induced changes in the components of the water and heat balance.

It should be noted that a recent tendency of increasing annual precipitation and average annual water discharge in the studied tributaries of the Irtysh River, observed since the early 2010s, may become stable over time and lead to a future increase in precipitation and runoff across the basin.

The author assessed climate change in the Oba and Ulbi river basins based on the outputs of Global Climate Models (GCMs). Graphs of long-term mean monthly dynamics of precipitation and temperature were constructed for the baseline period (1981–2010), mid-century (2041–2070), and end-century (2071–2099) under RCP4.5 and RCP8.5 climate change scenarios for both studied basins.

According to the GCM results, the amount of precipitation in both catchments is expected to increase by 8–12% under both scenarios by the middle of the century compared to the baseline period. The projected temperature rise under the RCP8.5 scenario may exceed 3.5°C in both basins.

After calibrating the SWIM model and analyzing the input climatic data from the GCMs, river runoff modeling for the Oba and Ulbi rivers was carried out under the medium (RCP4.5) and high (RCP8.5) emission scenarios to assess the impact of projected climate change on water resources availability in the studied basins.

According to the obtained results, an overall increase in mean annual runoff within the range of 6–8% can be expected for the Oba River, and smaller changes, not exceeding 5%, for the Ulbi River. Seasonal shifts were identified under both climate scenarios: the spring peak is projected to occur in April in the future instead of May in the baseline period. The forecasted seasonal shift is mainly associated with temperature rise, which could lead to earlier snowmelt.

Scientific and practical significance. The research provides long-term runoff change assessments for the Oba and Ulbi Rivers, essential for water management planning under climate change. The results can support sustainable water management strategies, optimize water withdrawals, and regulate reservoir operations.

The study forms a scientific basis for developing adaptation measures, optimizing reservoir management regimes, and improving flood risk management. The findings can inform normative and strategic documents in the field of water management. Although focused on specific river basins, the approaches and conclusions can be applied to other regions of Kazakhstan with similar hydrological conditions.

Author's contribution. All analyzed results were obtained by the author personally and include:

1. Collection and analysis of initial data;
2. Collection, processing, and analysis of climate change scenarios;
3. Adaptation and calibration of the SWIM hydrological model;
4. Execution of hydrological simulations.

Research approbation. The main results were presented at:

- The *5th International Workshop on Meteorological Science and Technology in Central Asia*, Nanjing, China, 14–16 October 2019;

- The *7th International Workshop on Meteorological Science and Technology in Central Asia*, 15–17 November 2022 (online).

  Six papers have been published based on the dissertation results, including one in a peer-reviewed national journal, one in an international indexed journal, two in journals recommended by the Committee for Quality Assurance in Education and Science (KZ), and two in international conference proceedings.

  Structure of the dissertation. The dissertation is presented on 120 pages and consists of definitions, notations and abbreviations, an introduction, five chapters, a conclusion, and a list of 81 references. It includes 20 tables, 29 figures, 5 formulas, and 6 appendices.