E3S Web of Conferences **371**, 01037 (2023) https://doi.org/10.1051/e3sconf/202337101037
AFE-2022

Long-term forecast of flow dynamics of Chirchik basin

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Abstract. Global climate change is undoubtedly one of the main threats to the world community among existing environmental problems. This problem has a particularly severe impact on water resources. Changes in hydrological processes or flows in river basins directly or indirectly affect the dynamics of changes in gross domestic product (GDP) in this region. Chirchik basin provides about 16% of GDP of the republic, and more than 70% of water resources are used for irrigation of crops [1-5]. For this reason, any factors affecting hydrological processes and flow dynamics in the river basin, especially climate change, immediately affect all aspects of life in the region, including the social level of society and economic stability. Assessing the impact of climate differences on river basin flow dynamics is important for ensuring sustainable agricultural productivity for river basins in the future, as well as reducing the ecological and environmental impacts of climate change. This situation calls for urgent and concerted action in several areas: technology, infrastructure, politics, economy, ecology and environmental protection. The article assessed the impact of changes in precipitation intensity on stream dynamics based on the Global Circulation Model (GCM) coordination scenarios, RCP4.5 and RCP8.5 for the years 2030, 2050 and 2070 using the delta approach method. The results of the study provided strong evidence for changes in stream dynamics in the Chirchik basin for the near and far future.

1 Introduction

In Central Asia, in agriculture, the critical implementation of the production trend, during sixty years, ensured that the Aral region occupied one third of all arid and semi-arid regions of the world, formed an ecosystem very sensitive to climatic changes, as a result of which changes in the dynamics of river flows, the productivity of agricultural crops and affected biomass [1-4].

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Today, global climate change is undoubtedly one of the main threats to the world community among existing environmental problems. This problem has a particularly severe impact on water resources. Changes in hydrological processes or flows in river basins directly or indirectly affect the dynamics of changes in gross domestic product (GDP) in this region. Chirchik basin provides about 16% of GDP of the republic, and more than 70% of water resources are used for irrigation of crops [1-5]. For this reason, any factors affecting hydrological processes and flow dynamics in the river basin, especially climate change, immediately affect all aspects of life in the region, including the social level of society and economic stability [5-7]. Operational and long-term management of water resources in the river basin due to climate change is directly related to changes in flow dynamics, exacerbating the existing problem.

Climate change, unprecedented disasters in the countries of Central Asia, Tien-Shan [8] and Pamir-Aloy [9] in the south, shrinking of the ice surface in the mountain ranges, and the Arol basin, which is important for the hydrological cycle in the region, to the desert, "Arol Kum". understanding of past and future changes in precipitation volume and intensity, risk assessment of water resource allocation and use, impacts of ecosystem change, agricultural productivity and food security, long-term management planning for today and the future requires urgent action [10-15].

Therefore, in the conditions of climate change, in terms of past and future trends of precipitation intensity, long-term forecasting of flow dynamics of the Chirchik basin is of scientific and practical importance [16-19]. In the article, using the delta approach method, in the future periods of 2030 (2020-2039), 2050 (2040-2069) and 2070 (2060-2099), global circulation model (GCM) coordination scenarios, RCP4.5 and RCP8.5 based on the impact of changes in precipitation intensity on flow dynamics was evaluated [20, 21].

2 Materials and methods

The Chirchik basin, the right tributary of the Syrdarya basin, is located in the north-east of Uzbekistan, between the western part of the Tien-Shan mountain range and the Syrdarya basin, at 41°10'00" north latitude and 69°45'00" east longitude (Fig. 1). Its length is 155 km, the total area of the basin is 14.9 thousand km^2, it is formed at the confluence of the Chotkal and Pskem rivers [15-21]. It has complex terrain, soil and climatic features. Water saturation is mixed, mainly depending on the snow cover. The average water flow is 221 m3/sec. Charvoq HPP is located in the upper stream.

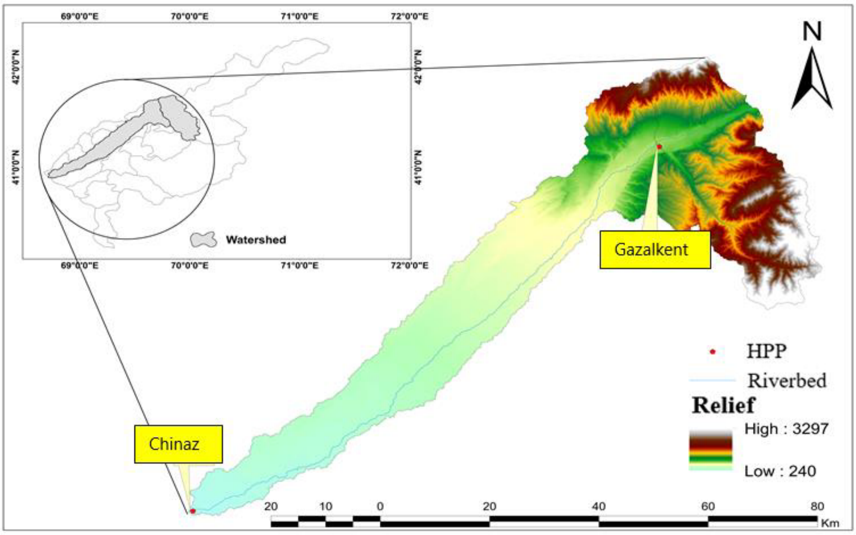


Fig. 1. Research area.

The climate is random, usually dry and arid, with a strong gradient of precipitation and temperature from the north to the south from the mountain ranges to the plains. Precipitation is uneven, in the northeast, and the intensity is high on the mountain slopes [9], mainly in winter and spring months. The minimum amount of precipitation is 250-300 mm in the south-western part of the basin, and reaches 550 mm in the north-east and in front of the mountain [10]. In the western part of the mountains, 1400-3000 mm of precipitation was observed under the influence of moist air masses. The average temperature in January ranges from -1.3 °C to -1.8 °C, in the summer months, the highest temperature rises to +47 °C in the plains [1]. Today, the effects of climate change are causing temperatures to rise above the limit.

There are several methods for transferring climate variability from GCM scenarios to hydrological models, the delta approach being the most common [14,15]. It is based on delta factors that describe the differences between past and future climates. This study analyzes delta factors for their dependence on time scale, intensity level, and return period [16]. Monitoring station and GCM data were used to calculate delta change scenarios [17]. Modeling river basin runoff changes using the delta method by calculating the difference between climate change PRCPs, in addition to the observed time series, monthly and annual averages, current and future PRCP closest GCM alignment scenarios, simulations using RCP4.5 and RCP8.5 dressed

In this study, coefficients of change are derived from simulations of the most important climate change variables for hydrology and precipitation, past, present, and future GCM coordination scenarios, RCP4.5 and RCP8.5.

The results of using equations [1] and [2] determine the output from GCM models, which can be expressed as follows for precipitation:

$$P_{Delta}(t) = P_{obs}(t)(P_{Future}/P_{control})$$

$$P'_{GCM,Future} = P_{GCM,Future}(P_{obs,reference}/P_{GCM,reference})$$

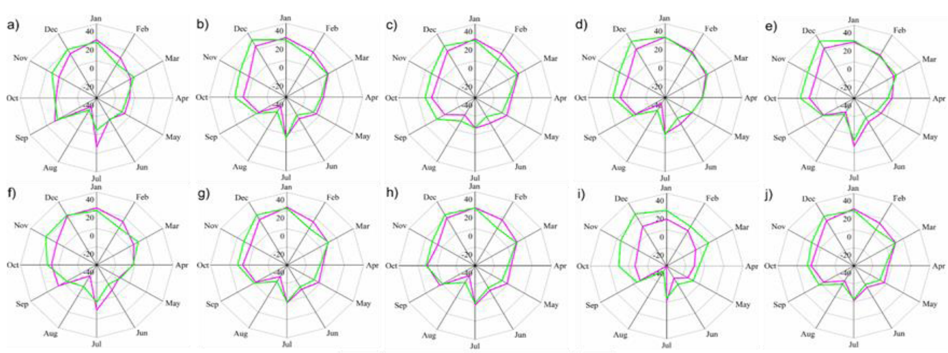
Where, P_{Delta} – future precipitation estimated by the delta method, (mm); P_{Future} - GCM average precipitation amount calculated on the basis of coordination scenarios, (mm); $P'_{GCM,Future}$ and $P_{GCM,Future}$ – Adjusted and unadjusted GCM for the future according to precipitation, (mm); P_{Obs} and P_{GCM} – benchmark – mean observed and GCM precipitation.

3 Results and discussion

Changes in precipitation intensity: Global or regional climate change has undoubtedly taken the first place among the main environmental problems of the world community today. The effects of climate change, primarily due to global warming, are extensive and complex, and will greatly affect existing water resources and the hydrological cycle, resulting in unexpected ecological and environmental problems. In order to develop measures to prevent and eliminate problems that may arise, the results of this study evaluated how changes in the intensity of precipitation for different periods (2030, 2050, 2070) will affect the water level dynamics of the Chirchik Basin in the future, under the conditions of climate change.

Preliminary data on changes in precipitation intensity and frequency for selected GCM models in different future periods were determined, with all observation stations showing almost identical average monthly changes for the RCP4.5 and RCP8.5 scenarios (Fig. 2). In all models, the main changes in precipitation were observed in the winter and autumn months, and in general, this trend was found to be stronger for the RCP4.5 scenario at all stations except the Tuyabuguz observation station (Figure 2i). Despite the decrease in summer precipitation, precipitation activity was observed for July at all observation stations in both scenarios. In March, according to the RCP4.5 scenario, at the Bekobod (Fig. 2a) and Tuyabuguz (Fig. 2i) stations, precipitation decreases are observed, at other monitoring stations, Chatqol (Fig. 2b), Chimgan (Fig. 2c), Aygaing (Fig. 2d -Fig.), Pskem (Fig. 2e), Kyzylcha (Fig. 2f), So'goq (Fig. 2g), Tashkent (Fig. 2h) and Yangiyol (Fig. 2j), the decrease begins in April. In the winter season, despite the increase in precipitation intensity, for February, under the RCP8.5 scenario, a significant decrease in average monthly precipitation was observed at almost all stations, with a large share of the decrease occurring at the Bekobod station.

No significant differences were found between GCM models and observational data when river flow reliability was evaluated using monthly mean data.



RCP4.5 RCP8.5

Fig. 2. Monthly changes in precipitation intensity generated in future periods compared to GCM coordination scenarios: (a) Bekabad; (b) Chotkol; (c) Chimion; (d) Oigaing; (e) Pskem; (f) Kizilcha; (g) Sukok; (h) Tashkent; (i) Tuyabuguz; (j) Yangiyul

Also in the basin, for the periods of 2030-2050 and 2070, on the basis of observation and GCM data, the dynamics of the annual change of the water level in the river flow with the ratio of precipitation intensity was analyzed. Figures 5 and 6 show the future annual water level changes based on precipitation trends. It can be said that the changes in the water level of the Chirchik basin, the results of the monthly and annual analysis repeat the same, unfortunately, in these cases, the decrease in the water level of the Chinoz hydropost is repeated, and this situation means that climate change affects several areas: technology, infrastructure, politics, economy, ecology and requires urgent and concerted action to protect the environment (Fig. 3).

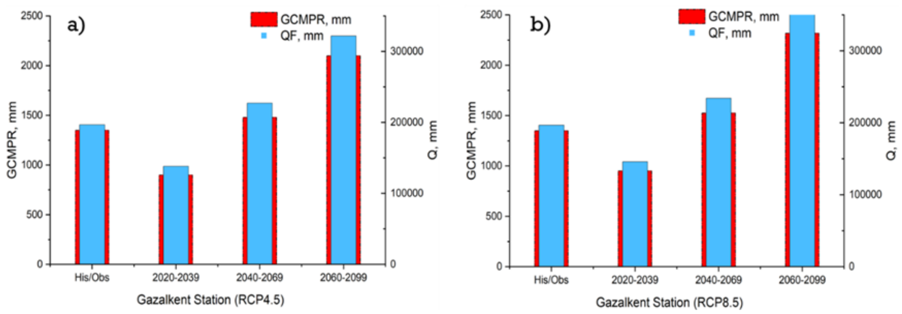


Fig. 3. The ratio of water flow to precipitation in 2030, 2050 and 2070 at all stations in the Chirchik basin (Ghazalkent hydropost).

The average annual change in the water level of the Chirchik River occurs in both hydroposts, according to the RCP4.5 and RCP8.5 scenarios. The decrease in the level at the Chinoz hydropost compared to the Gazalkent hydropost is due to the use of water resources between the two observation posts. The main annual growth is observed for the period of 2070 (Fig. 4).

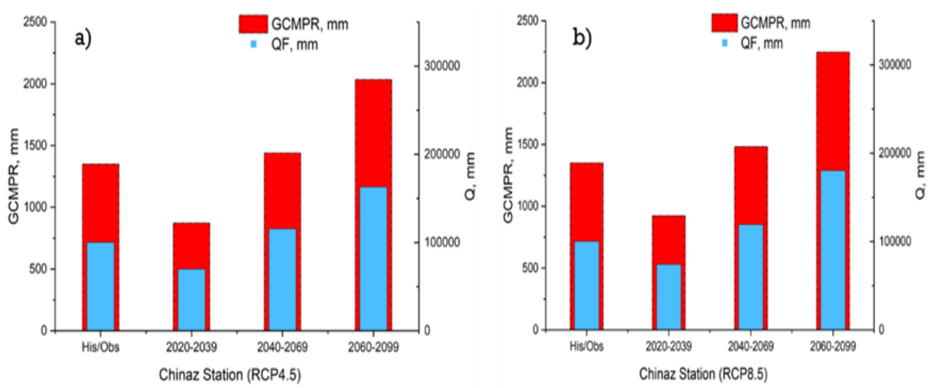


Fig. 4. The ratio of water flow to precipitation in 2030, 2050 and 2070 at all stations in the Chirchik basin (Chinoz Hydropost).

The results of the analysis mean that the increase of the water level in the basin does not determine the availability of water resources in the future, in this case, it is necessary to simulate the changes in the level dynamics, taking into account the important factors affecting the climate change, such as evapotranspiration and temperature, which are characteristic of the analysis of the changes in the water level. Also, based on the results of the above analysis, when predicting the changes in water level dynamics in water resources use and river basins for the future, taking into account all the characteristics of the basin, using specific hydrological models such as SWAT, MIKE SHE, in addition, GCM coordinating all (RCP1 .9, RCP2.6, RCP3.4, RCP4.5, RCP6, RCP7, RCP8.5) scenarios, using 21 models, taking into account the characteristics of temperature, total evaporation and human activity, conducting research on the changes in water level dichemistry, provides an opportunity for operational management of water resources in the basin, sustainable agricultural productivity and food security.

This study will serve as useful information for ensuring sustainable agricultural productivity and food security in the Chirchik basin in response to climate change, ecological and environmental protection, developing a mechanism for operational management of water resources in improving the social level of society, and achieving economic stability.

4 Conclusions

River basins play an important role in many areas such as changes in water level dynamics, human activities, economy, politics, industry, agricultural sustainability and food security, ecology and environmental protection. For this reason, in the conditions of climate change, predicting possible changes in river basins, water level dynamics, basins, including the Chirchik River, productivity of agricultural crops, food safety, ecology and environmental protection, improvement of the social level of society, operational use of water resources is of particular interest in the development and adoption of management measures.

Research work, determining the impact of climate change on the dynamics and flow of Chirchik River water level changes, changes in precipitation intensity, GCM coordination scenarios, CMIP5 archive based on RCP4.5 and RCP8.5, using 5 models, three different periods 2030 (2020-2039), analyzed for 2050-y (2040-2069) and 2070-y (2060-2099). Climate models were simulated in combination with the delta approach, which is a practical and appropriate method for the development of long-term measures for operational management of water resources, assessing changes in time and space. The use of climate models and related scenarios is essential for predicting the effects of climate change, to address future uncertainties, and for research that allows rapid decision-making in water resources management.

River basins, and taking into account all parameters of the climate, additional research is required to assess the uncertainties in the climate models in the study area. In addition, as a rule, the study of regional models of climate change strengthens the accuracy in predicting changes in water level dynamics.

Although this research is typical, in response to climate change in the Chirchik Basin, ensuring sustainable agricultural productivity and food security, protecting ecology and environment, improving water resources management, improving the social level of society, developing a mechanism for operational management of water resources and economic serves as useful information in achieving sustainability.

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