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ASSESSMENT OF THE IMPACT OF AIR TEMPERATURE DYNAMICS ON THE FORMATION AND CHANGE OF WATER RESOURCES IN THE KASHKADARYA BASIN UNDER CLIMATE CHANGE.

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Abstract: The Kashkadarya Basin is characterized by strong elevation gradients, with river runoff influenced by precipitation, snow accumulation, and melt processes in mountainous areas. Changes in air temperature may alter the timing and spatial distribution of snow cover and consequently affect seasonal water availability. This study examines long-term air-temperature variability and spatial snow-cover dynamics in the Kashkadarya Basin under changing climatic conditions. Historical observations from the Mingchukur (1951–2023) and Guzar (1928–2023) meteorological stations were analyzed using comparative, statistical, and trend-analysis methods. Annual mean, maximum, and minimum air temperatures were evaluated for both stations. In addition, MOD10A1 snow-cover data were processed in the Google Earth Engine (GEE) platform to compare the spatial distribution of snow cover in 2013 and 2025. The results indicate an overall increase in air temperature at both stations, with particularly notable warming in recent decades. The monthly analysis at Guzar also indicates higher temperatures during 1991–2023 than during the preceding periods. Snow cover was concentrated primarily in the eastern and high-mountainous parts of the basin and showed a strong relationship with elevation. The comparison of the 2013 and 2025 snow-cover maps suggests spatial differences in snow-cover distribution; however, quantitative analysis using consistent observation periods and spatial statistics is required to attribute these changes directly to climate change. The findings provide a basis for further assessment of climate-related changes in snow and water-resource conditions in the Kashkadarya Basin.

Keywords: Kashkadarya Basin; climate change; air temperature; snow cover; MOD10A1; Google Earth Engine; meteorological stations; temperature trends; remote sensing.



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Introduction. Today, as a result of the disruption of the ecological balance, a sharp imbalance is emerging between natural systems and the demographic needs of humanity. The negative impact of climate change on water resources is manifested at the global level, requiring urgent measures to effectively manage and rationally use water resources at the national and regional levels. The Kashkadarya basin is fed by rain, snow and glaciers [1], creating opportunities to analyze changes in river flow over time and related to air temperature, forecast future water resources and ensure ecological and economic sustainability in the river basin. Therefore, it is urgent to analyze the data of typical air temperatures from meteorological stations in the region (for the entire observation period) and to determine the impact of changes in snow cover on changes in river basin flow by comparing them with data from the Google Earth Engine (GEE) program [2].

In this study area, analyzing the low-water periods observed in rivers in certain years in direct connection with hydrometeorological conditions is considered one of the key scientific problems and remains relevant today. A.B.Burdykina, Y.N.Ivanov, K.S.Kabanova, G.V.Lopatin, O.P.Sheglova (1982) and other scientists were engaged in studying the formation processes and interannual variability of the flow of Central Asian rivers, including those of the Kashkadarya basin. In particular, the research conducted by O.P.Sheglova and representatives of her scientific school - A.R.Rasulov, S.R.Saidova, Z.S.Sirliboeva, H.K.Toshmetov, F.H.Hikmatov, D.P.Aytboev and others in the direction of analyzing the genesis of mountain river flows - made a significant contribution to the formation of the scientific foundations of this field. Since most of the scientific work carried out by these scientists has a history of about 20-30 years, this study differs from previous studies in that it is carried out on the basis of updated hydrometeorological data for the last decades on the example of the rivers of the Kashkadarya basin [3] and logically continues them. Through the analysis of scientific literature in the field, previously conducted studies and achieved results were summarized, which further strengthens the scientific basis of this work.

The insufficient analysis of the flow dynamics in the low and mid-mountain regions of the Kashkadarya basin rivers based on modern digital and remote sensing data and the lack of experience in analyzing interannual changes in glacier reserves and snow cover based on Google Earth Engine (GEE) platform and meteorological station data, pose problems related to the impact of hydrological processes on ecological and economic sustainability and future water resources management.

Materials and methods. According to its natural conditions, the Kashkadarya region is divided into two parts: the western part is a plain and the eastern part is a mountainous part. The vast area of the plain is occupied by the Karshi Desert (20-400 m above sea level). To the north of the Karshi Desert is the Jam Desert, which consists of a wavy plain and to the south it is adjacent to the Nishon Desert. Administratively and territorially, the Kashkadarya region borders on Bukhara [4] in the northwest, Samarkand and Navoi regions in the north and Surkhandarya region in the south and southeast. The climate of the Kashkadarya region differs from the central and northern natural

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geographical regions of Uzbekistan in that spring comes early, quickly turns into hot summer, winter is relatively short and the average annual January temperature in the plains and foothills is around +2°C. Summer is very dry, hot and long. In the plains, the long-term average air temperature in July is +28°C, +29°C and the absolute maximum temperature is +46°C, +47°C. In the mountains and in the valleys of the mountains, summer is slightly cooler.



Figure 1. Relief and hydrographic map of Kashkadarya region.

The main water source of the region is the Kashkadarya River, its tributaries, as well as the water brought by the Eski Anhor Canal, which receives water from the Zarafshan River and the Karshi Main Canal, which brings water to the desert zone and the Talimarjon reservoirs built on the canal. The study analyzed data on typical air temperatures from 2 meteorological stations for the entire observation period. It used methods of comparison, mathematical statistics and time trend analysis. The analyzed data were obtained from the pogodaiklimat.ru website. This database is the official website of the Russian Federation and receives available data from the Hydrometeorological Service Agency (Uzgidromet). While using the observation data, rows with incomplete data were removed. The location of the meteorological stations, their altitude above sea level, the duration of the observation years and their geographical coordinates are presented in Table 1.

Table 1

Information about weather stations

WMO code	Station name	Latitude	Longitude	Altitude, m	Observed period
38816	Mingchukur	38.65 N	66.93 E	2121	1951-2023
38612	Guzor	38.62 N	66.27 E	524	1928-2023

For the observation period, graphs and histograms of the average annual, maximum and minimum air temperatures were drawn based on the data of each weather station.

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Figure 2 below shows the graph of changes in air temperatures at the Mingchukur weather station. Observations at the Mingchukur weather station began in 1951. This weather station is distinguished by its location at the highest altitude (2121 m). Like other weather stations, the average annual air temperatures at Mingchukur also show an increasing trend (Figure 2). However, the trend of maximum and minimum air temperatures is unchanged, that is, there is no increase.

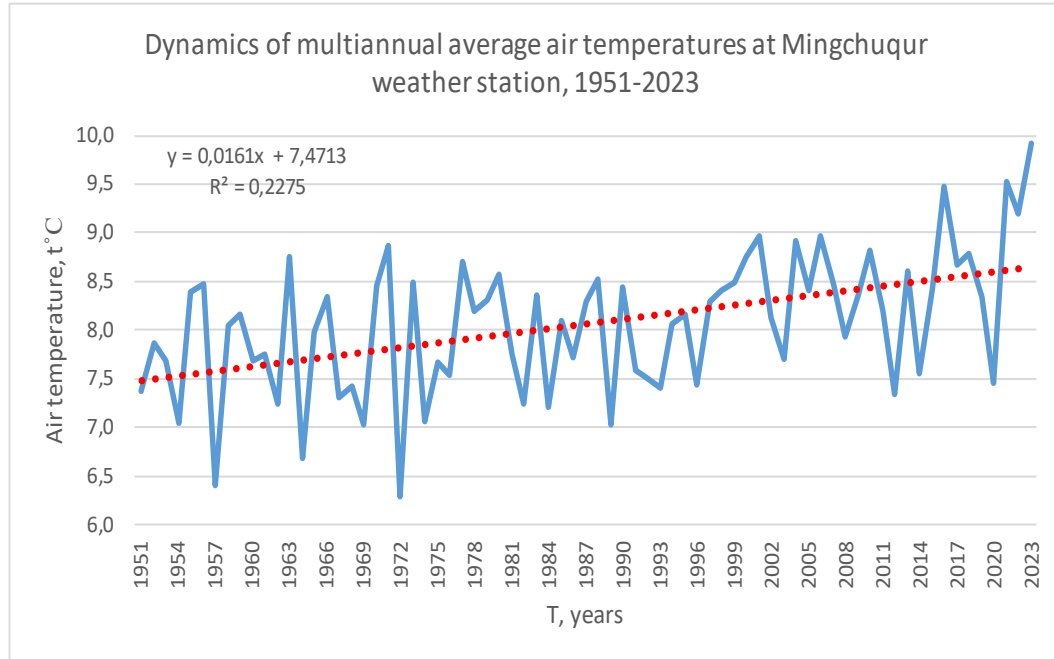


Figure 2. Dynamics of average air temperatures at the Mingchukur weather station, 1951-2023

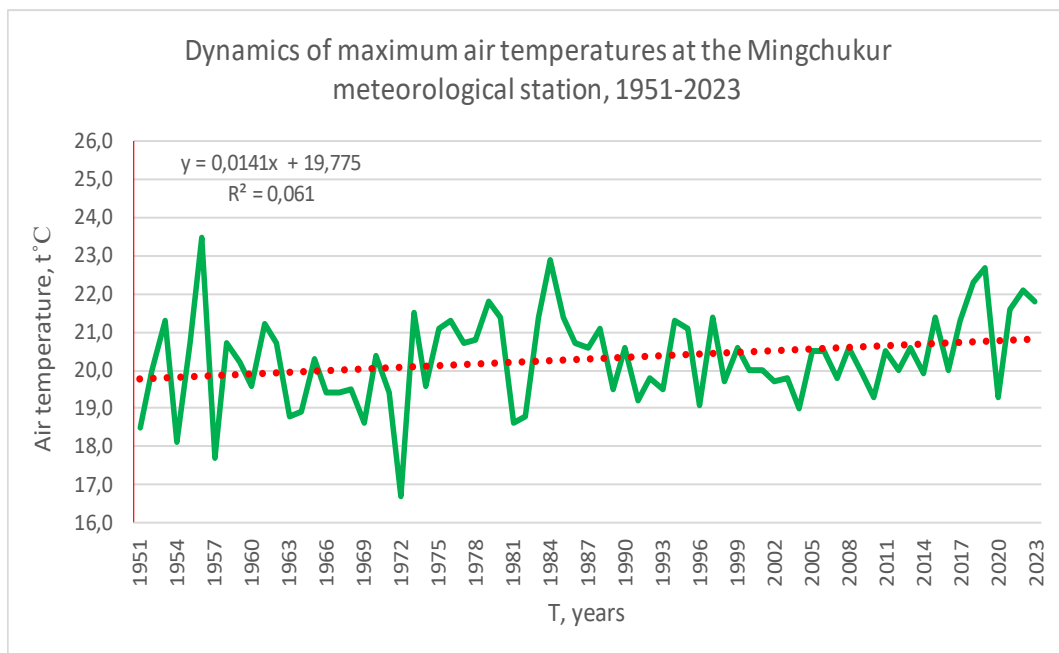


Figure 3. Dynamics of maximum air temperatures at the Mingchukur weather station, 1951-2023

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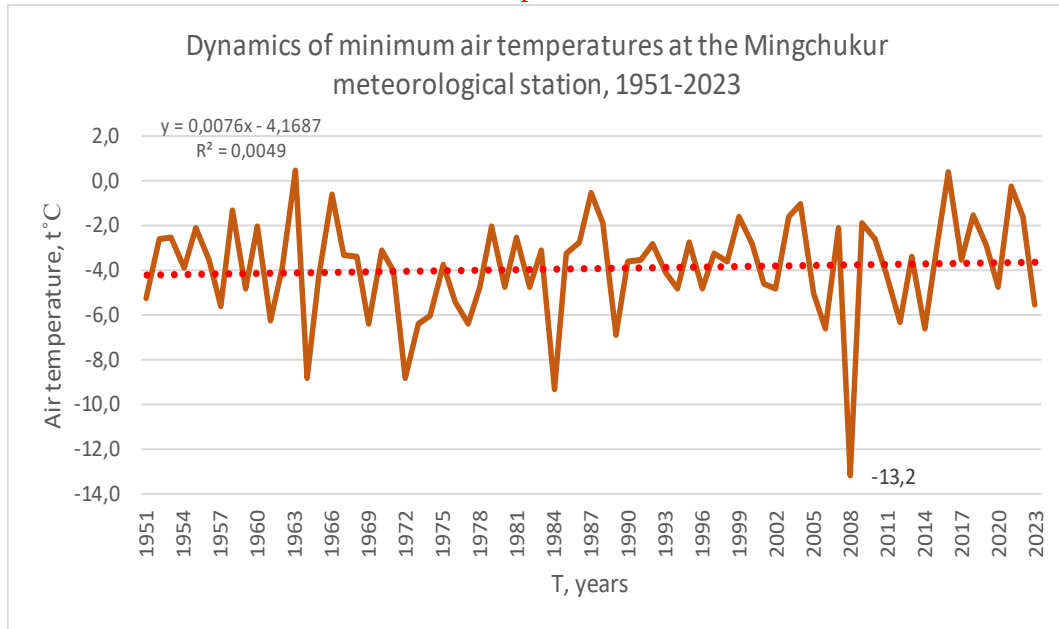


Figure 4. Dynamics of minimum air temperatures at the Mingchukur weather station, 1951-2023

Figures 3 and 4 above show the minimum and maximum air temperatures between 1951 and 2023. In both cases, the correlation coefficient is much smaller than 1. Thus, the trend is insignificant. The coldest temperature for the entire observation period was observed in 2008 (-13.2°C) and the warmest year was in 1956 (23.5°C).

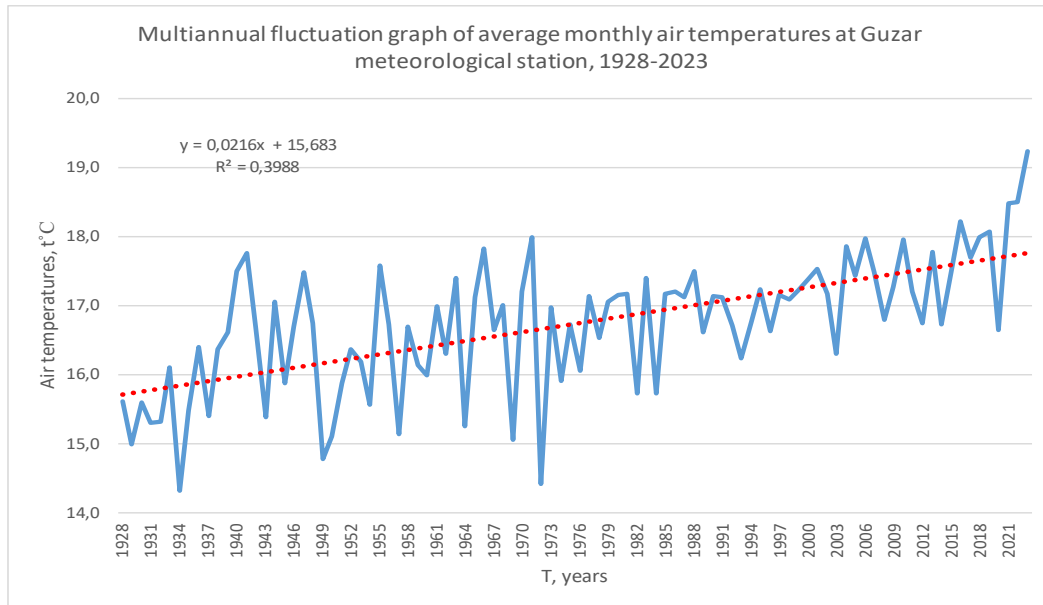


Figure 5. Dynamics of average multi-year air temperatures at the Guzar weather station, 1928-2023

During the observation period (1928-2023), the air temperature was below 15°C in 1934 and 1972. However, this situation has not been observed again. Since the 1990s, the annual average air temperature has been above 16 degrees. In recent years, the temperature has been rising above 18 degrees. The trend of air temperatures for the observation period shows an increase from 14.3°C to 19.2°C. Figure 6 below shows the dynamics of minimum

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air temperatures at the Guzar weather station. A 35-40-year periodicity (repeated oscillations) is clearly visible. This periodicity was not observed for the average and maximum air temperatures.

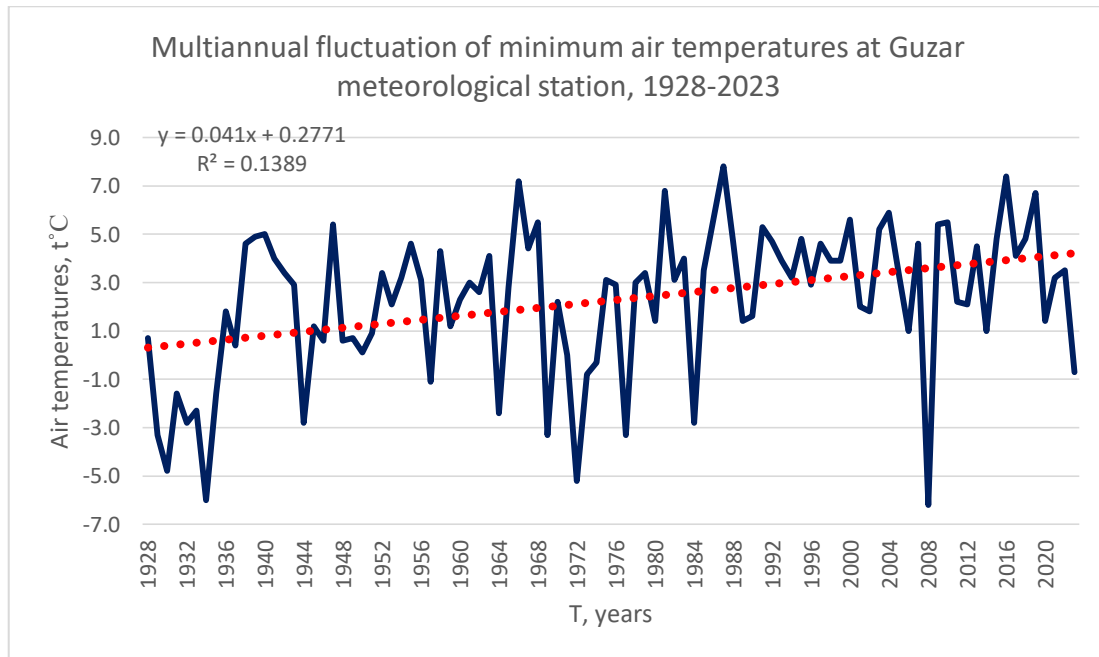


Figure 6. Dynamics of minimum air temperatures at the Guzar weather station, 1928-2023

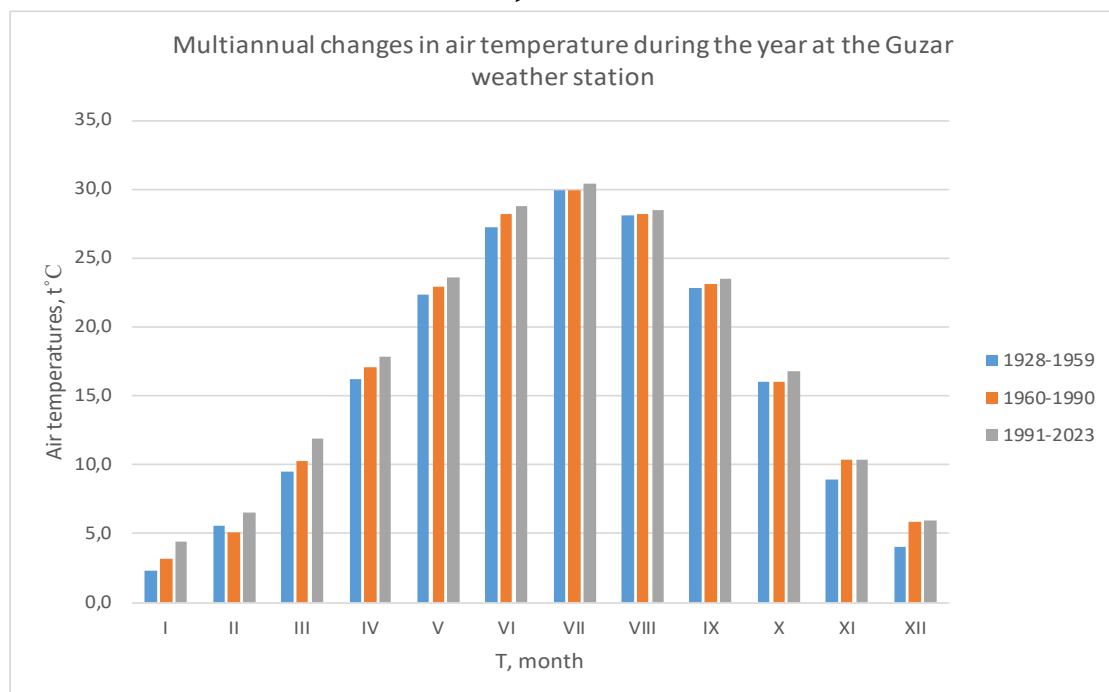


Figure 7. Histogram of monthly distribution of average air temperatures at the Guzar weather station, 1928-2023

Analysis of monthly changes in air temperatures at the Guzar weather station [5] showed that in the 1991-2023 period, temperatures increased in all months of the year compared to the other two periods (1928-1960 and 1961-1990). This increase was

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especially noticeable in January, February, March, as well as in October, November and December.

To study the dynamics of snow cover in the Kashkadarya river basins, geoinformation technologies for the period 2013-2025 were downloaded using the Google Earth Engine (GEE) platform using MOD10A1 Snow2013 and MOD10A1 Snow2025 [6] for months with low or no cloud cover.



Figure 8. Snow cover thickness for 2013 obtained via Google Earth Engine platform.

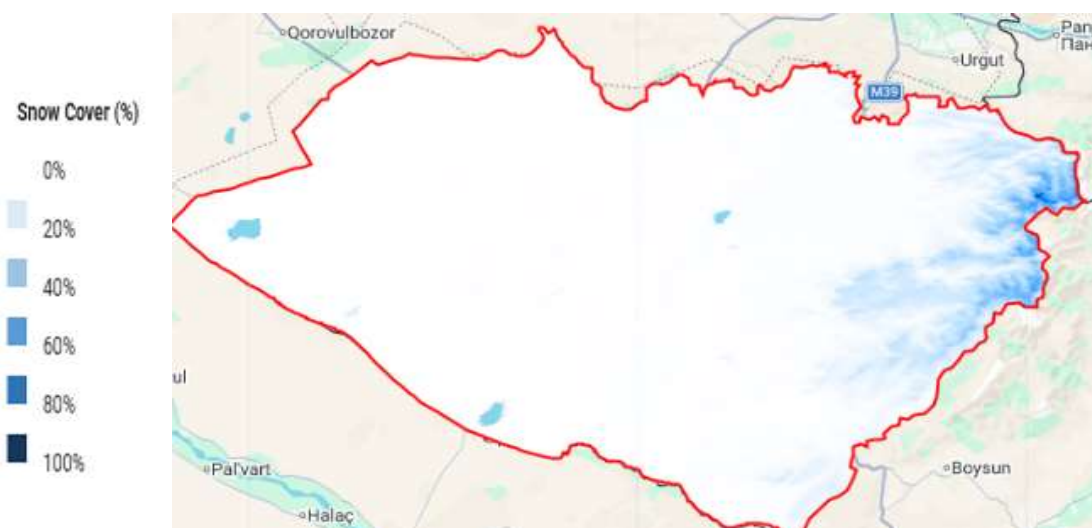


Figure 9. Snow cover thickness for 2015 obtained via Google Earth Engine platform.

Results and conclusions

As can be seen from the graphs, the trend of air temperatures is increasing. In all graphs The analysis of long-term meteorological observations indicates an overall warming tendency in the Kashkadarya Basin. At the Mingchukur station, mean annual air temperature shows an increasing trend during 1951–2023, whereas the trends in maximum and minimum temperatures are comparatively weak based on the fitted linear relationships. At the Guzar station, the long-term record for 1928–2023 also indicates an increase in

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mean annual air temperature, with substantially higher temperatures observed during the most recent decades.

The monthly analysis at Guzar indicates that mean air temperatures during 1991–2023 were higher than during the earlier observation periods, particularly in winter and the transitional seasons. This pattern indicates a shift toward warmer conditions in recent decades. The minimum-temperature series also exhibits multi-decadal fluctuations; however, the apparent 35–40-year periodicity should be confirmed using formal time-series or spectral analysis before being interpreted as a statistically established cycle.

The MOD10A1-based analysis shows that snow cover is concentrated mainly in the eastern and high-mountainous parts of the Kashkadarya Basin, consistent with the basin's elevation gradient. The comparison of the 2013 and 2025 maps indicates differences in the spatial distribution of snow cover. Nevertheless, these differences should be interpreted cautiously because direct attribution to climate change requires consistent observation dates or periods, quantitative snow-cover statistics, and consideration of meteorological conditions during the selected dates.

Overall, the observed warming tendency and changes in snow-cover distribution have potential implications for the seasonal availability of water resources in the Kashkadarya Basin. However, the present study does not directly quantify changes in river discharge or establish a statistical relationship between air temperature and runoff. Future research should integrate long-term precipitation, river-discharge, glacier, and snow-cover datasets and apply robust trend and correlation methods to quantify the effects of climate change on basin water resources.

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