3. Analysis of observed flow trends and cyclical fluctuations

Analysis of observations over inflows to Charvak and Andizhan reservoirs shows that linear trends are absent. This corresponds to findings that there are no considerable changes in precipitation observational series [4]. Papers [1-3, 5, etc.] show that annual total precipitation changes substantially in time; series of very dry or very humid periods may be separated out. For instance, the driest decade was during 1941-1950, while the most humid decades were during 1951-1960 and 1981-1990. Long-term precipitation fluctuations are mainly related to changes in general atmospheric circulation, while heavy abnormality in total precipitation is observed synchronously throughout a wide area.

Analysis of changes in mean values and variance of monthly precipitation over various 30-years intervals has shown that, due to climate changes, there is some increase in precipitation variability in Uzbekistan. However, simple conclusion regarding monthly and annual precipitation trends caused by climate change is impossible to draw [4].

Publication [5] considers standardized precipitation index (SPI) for particular seasons. The index was calculated by average monthly data from weather stations located in different areas within the republic.

$\mathrm{SPI} = [(p - \bar{p}) / \bar{p}] \times 100\%$, where p is observed precipitation; $\bar{p}$ is average precipitation. This index is widely used due to simple calculation and availability of relevant observations.

According to calculations, considerable SPI variance trends for particular seasons in Uzbekistan are not observed.

Figure 14 shows series of standardized spring precipitation index (March-May) computed for stations located in piedmont (Tashkent, Ferghana), Amudarya lower reaches (Urgench) and desert zone (Tamdy).

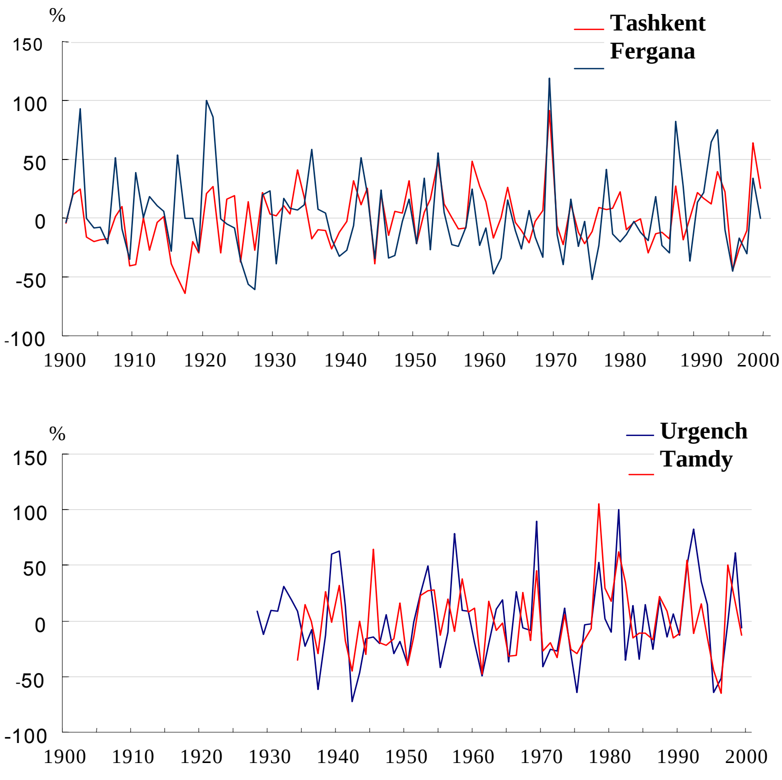

Fig. 14 | The change of standardized precipitation index by particular stations in Uzbekistan (spring months)

Figure 15 shows dynamics of average annual inflow to Charvak and Andizhan reservoirs (civil year). Here are observed high synchronism of run-off fluctuations and absence of significant long-term trends since precipitation makes primary contribution to the inflow.

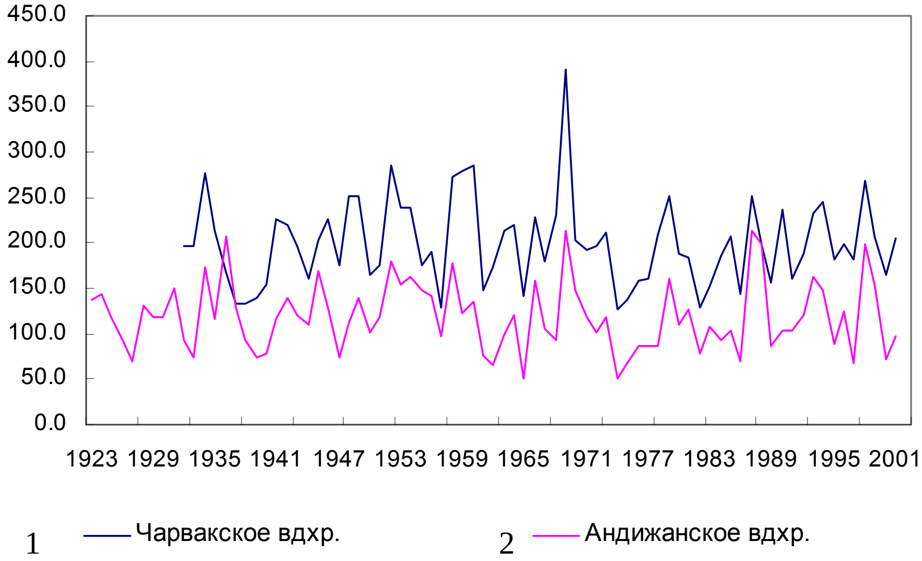

Fig. 15 | Changes in average annual inflow to Charvak (1) and Andizhan (2) reservoirs (civil year)

When we consider time variation of river run-off, where share of glacier feeding is higher, a steady tendency towards run-off increase may be noted. This completely corresponds to the finding that glacier contribution grows in conditions of observed climate warming in the region.

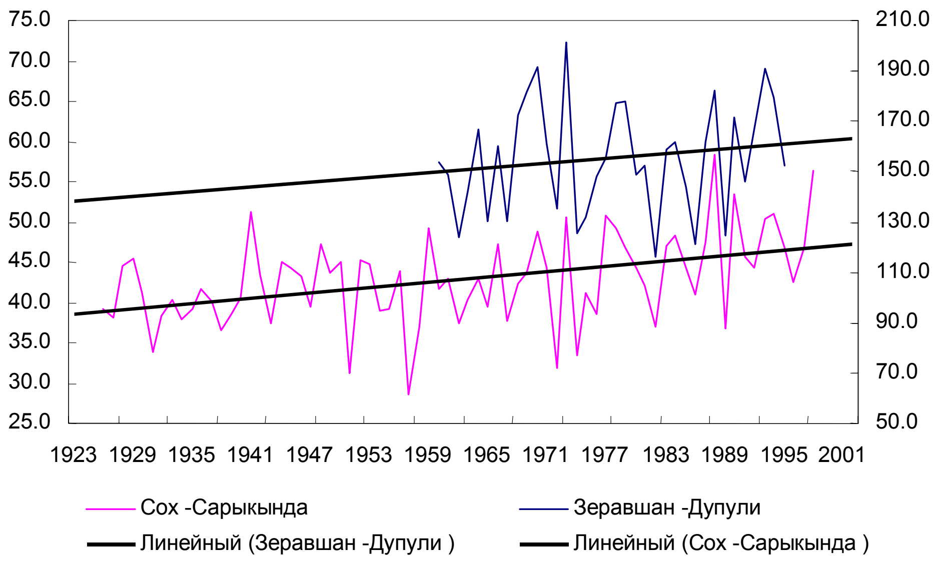

Fig. 16 | Changes in average annual run-off at stations Sokh-Sarykynda and Zerafshan-Dupuli (civil year)

Similar conclusion can be made when considering inflow to Nurek reservoir (Fig. 17). The data also indicate to slight increase in run-off due to rise of air temperature during last decade that may be considered as a consequence of human-induced regional climate change.

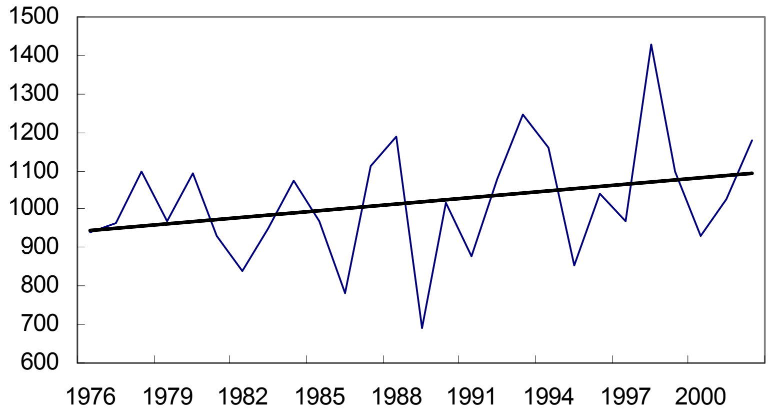

Fig.17 | Changes in inflow to Nurek reservoir during warm period

As known, any human influence exerted on climate is laid on background "noise" of natural climate variability related to atmospheric circulations changes and fluctuations caused both by internal fluctuations and external impact such as changes in solar activity, Earth rotation parameters, volcanic eruptions, etc.

Diagnosis and analysis of current climate changes in Central Asia enabled series of cyclic fluctuations in temporal temperature series to be identified. 22-years quasi-cyclicity was identified in changes of average annual temperature and average temperature during cold and warm half year against the background of warming tendency that is cyclicity, which is similar to such called Cheil cycle of geomagnetic activity, related to magnetic polarity of sun spots. Given cyclicity describes 24, 19, and 12% dispersions of basic series, respectively (see section 1.1).

Changes in precipitation regime are connected with regional circulation change. Publication [3] studied long-term fluctuations of annual precipitation averaged for plane and mountain areas and for particular weather stations, as well as their trends. Cyclicity or periodicity was identified through autocorrelation functions. Periodicity of 30-35 years and 2-3, 4-5, and 6-7 year cycles were found out. This completely corresponds to research results in [2]. Precipitation and run-off series are characterized by cyclicities similar to period of fluctuations in solar activity and various circulation indices, fluctuations having a period of 4-6 years and quasi-biennial cyclicity [1-3]. Low-frequency fluctuations (35-40 years) in precipitation and run-off series may be connected with the change of circulation periods [7].

In this context, we have conducted analysis of run-off series using a model of cyclical components [6], which consecutively singles out complex trends that are the sum of linear trend and one or two harmonics. Significance of identified trends may be assessed through correlation coefficients and values of described dispersion. Extrapolation of identified trends allows us to estimate potential run-off changes for short-term.

Table 21 | Parameters of trends identified in temporal series of run-off with prevalent rain-snow contribution

Periods	Described dispersion, %	Correlation coefficient	Series length
Inflow to Andizhan reservoir			
37	3.7	0.21	70
9	13.1	0.37	70
Inflow to Charvak reservoir			
38	6.3	0.25	70
9	21.2	0.46	70
Sokh-Sarykynda			
37	19.1	0.43	67
10	21.1	0.44	67

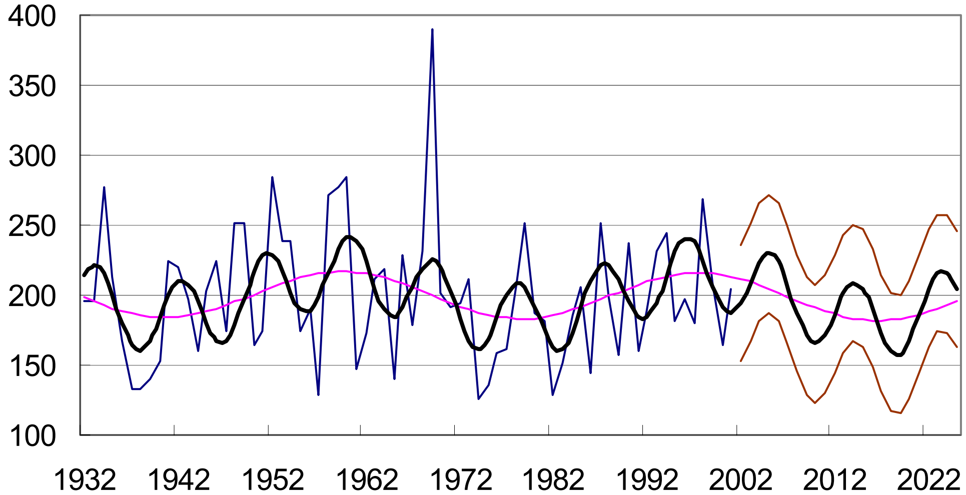

Fig.18 | Changes in inflow to Charvak reservoir and identified trends

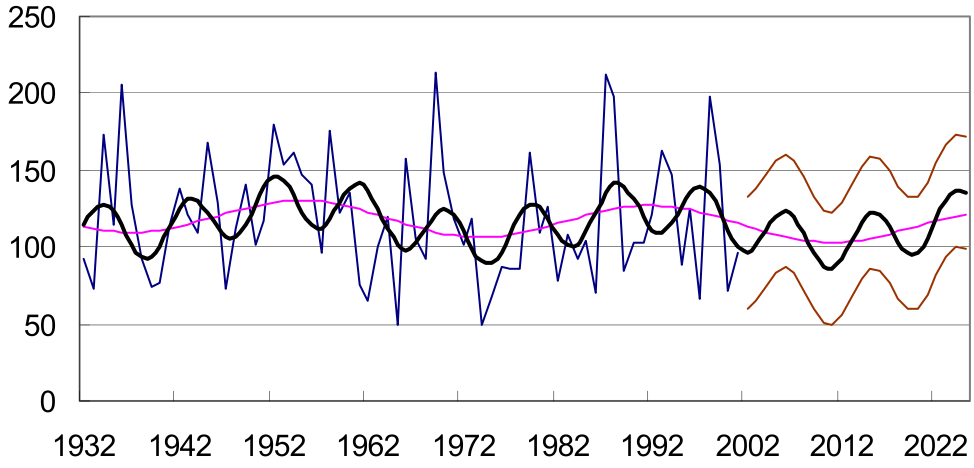

Fig. 19 | Changes in inflow to Andizhan reservoir and identified trends

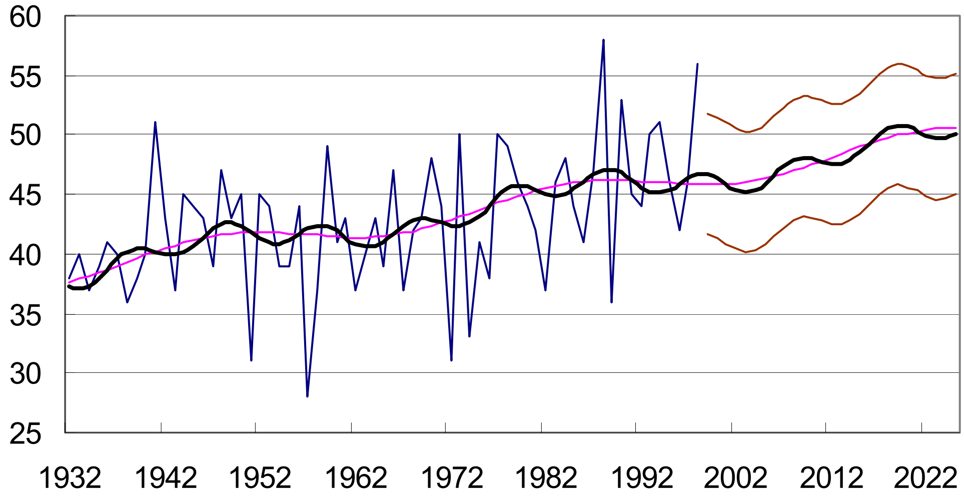

Fig. 20 | Changes in run-off at station Sokh-Sarykynda and identified trends

Table 21 gives parameters of identified complex trends, while the trends themselves are shown in Fig.18-20. Selected cycle of 37-38 years can be compared with the change of circulation periods, while cycle of 9-10 years is compared with the period of solar activity fluctuation, which at present is close to 10 years. Linear trend is clearly seen on Figure 20.

However, it should be taken into account that extrapolation of linear positive trends observed in temporal series of run-off, with prevalent glacier contribution, will give real diagnosis until compensation opportunities of glaciers are exhausted.

Analysis of temporal series of run-off, with prevalent glacier contribution, has shown fluctuations of 22-23 years that appear in temporal temperature series and a fluctuation over a period of 5 years (Table 22). Identified complex trend made it possible to describe essential part of dispersion (to 36, 5% for temporal series of inflow to Nurek reservoir during warm period of a year).

Table 22 | Parameters of trends identified in temporal series of run-off with prevalent rain-snow contribution

Period	Described dispersion, %	Correlation coefficient	Series length
Zerafshan-Dupuli			
23	14.2	0.35	36
5	29.4	0.50	36
Inflow to Nurek reservoir (April-September)			
22	14.3	0.35	27
5	36.5	0.60	27

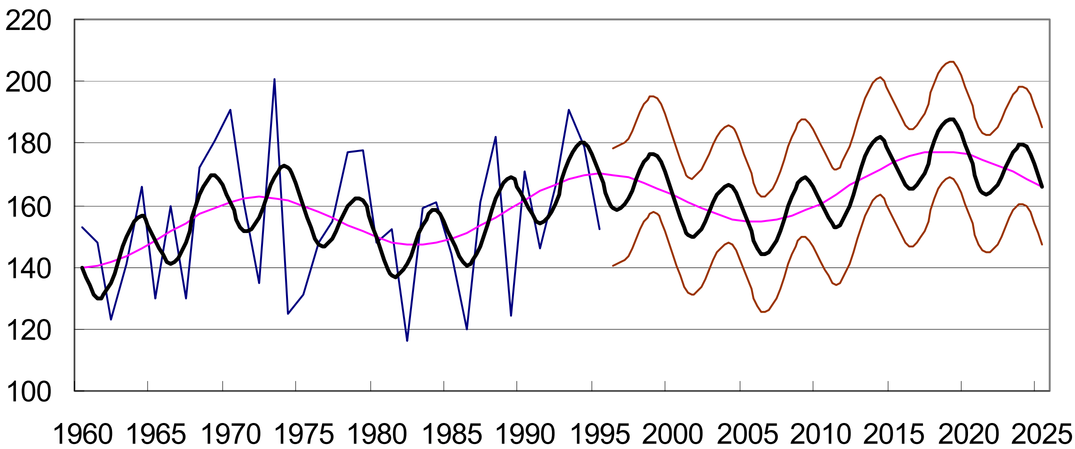

Fig. 21 | Changes in run-off at station Zerafshan-Dupuli and identified trends

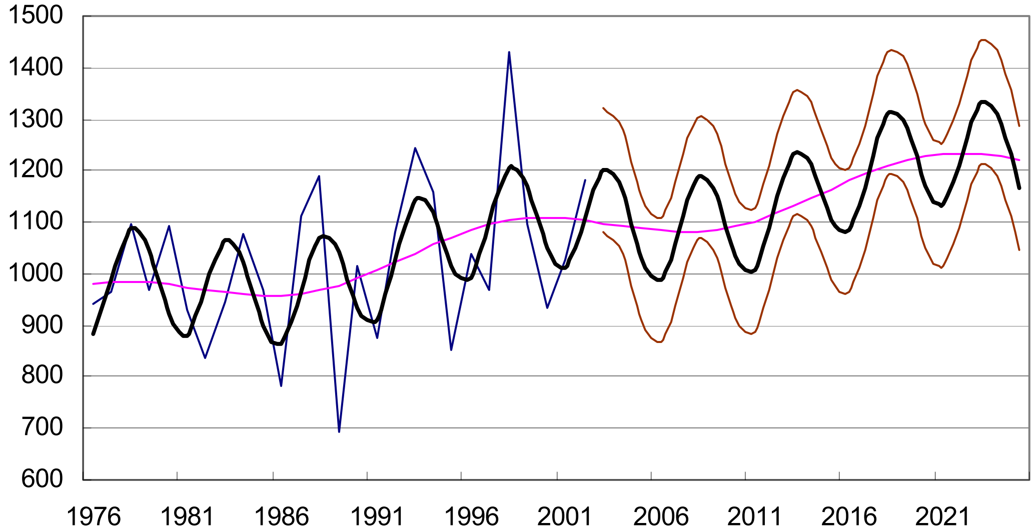

Fig. 22 | Changes in inflow to Nurek reservoir during warm period and identified trends

Figures 18-22 also show possible variations of given series, both positive and negative standard deviation of residual series after removal of trends.

However, taking into account that all natural run-off fluctuations have quazi-cyclical structure, identified harmonic series are impossible to use for forecasts. At the same time, identified run-off fluctuations indicate to increase of flow variation in particular periods.

Based on conducted trend analysis, the following can be concluded:

- considerable changes are not found out for rivers with essential snow contribution. Identified quazi-periodicities are explained by changes in precipitation regime;

- rivers with essential glacier contribution are characterized by slight increase in run-off, which is connected with warming of climate in the region.

It should be noted that extrapolation of linear positive trends observed in temporal series of run-off, with prevalent glacier contribution, will give real diagnosis until compensation opportunities of glaciers are exhausted.