Scenario of expected climate and change of surface drain in north Kazakhstan

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Abstract. Taking into account local peculiarities of the territory, scenarios of changes in temperature and precipitation for the future up to 2040 -2050 are built. On this basis, estimated probable change in runoff due to expected climate changes. The scenarios are based on physical laws, consisting in the presence of links between climatic fluctuations contained in time series of temperature and precipitation and climatic fluctuations in the indices of the general circulation of the atmosphere, identified on the basis of harmonic analysis. It is shown that one should expect stabilization of temperature in the region and even some decrease in it with a constant amount of precipitation. This will positively affect the surface runoff.

1. Introduction

Kazakhstan, located in the center of the continent, is equidistant from all the oceans, is experiencing a shortage of water resources almost throughout. Interannual variability of precipitation is great. In some years, the amount of precipitation can be twice or more than normal [1, 2].

North Kazakhstan plays a special role in ensuring food independence and security of the Republic (figure 1). This territory belongs to the zone of risky agriculture; here from five years only three crops are on average. Areas of irrigated agriculture located at the South of the country, mostly to satisfy local needs. Therefore, despite the problems, Northern Kazakhstan is the main agricultural region, where the main production of grain crops is concentrated.

The region under consideration includes five regions: North Kazakhstan (Petropavlovsk), Kokchetav (Kokchetav), Kustanay (Kustanay), Tselinograd (Astana) and Pavlodar (Pavlodar), however, the southern regions of Kustanay, Tselinograd and Pavlodar regions are no longer agricultural due to a marked decrease in precipitation and an increase in the temperature of the growing season.

The main rivers, part of the flow of which is formed in this territory and which are the most important sources of water in the region, are: Tobol, Ishim, Irtysh, Nura.

The aim of this study is to assess possible changes in runoff under climate change.

Figure 1. The Territory of Northern Kazakhstan.

2. Materials and methods

In this work, the official data of the hydrometeorological service of Kazakhstan [1, 2, 3] are used. These are the average monthly characteristics of temperature and precipitation at the stations of Northern Kazakhstan for the period of observations from the beginning of the twentieth century to the present time. In addition, we used some data on the study of the structure of agriculture in the region and the hydrological regime of rivers [1].

For the analysis, the initial series were approximated by a polynomial of the sixth degree, providing a significant smoothing of the series, at which, however, climate extremes remain. The disadvantage of this method of approximation is that we do not know how long the trend in the studied parameter will continue. Therefore, in addition to polynomial approximation, we widely use harmonic analysis of time series [3-5].

This gives us an opportunity, firstly, to check whether the polynomial trend at the end of the time series is confirmed by the corresponding course of the fundamental harmonics, and, secondly, to construct a scenario of changing the time series for 20-40 years ahead, as the sum of the continued fundamental harmonics for the future at each time point of the series [4, 5, 6].

Climatic variations in the region are a product of the General circulation of the atmosphere. To describe the General circulation, widely known Wagenheim indices were used for the first natural Synoptic region extending from the middle of the Atlantic to the Meridian of 100 °east longitude [7]. The whole territory of Kazakhstan is within this region. Quantitative characteristics of the intensity of the process Vangenheim typing do not contain.

3. Results

The authors of the method of dynamic climatology and the probabilistic-statistical method of climate forecast [8–13] introduce the concept of a group of analogs or a group of “nearest neighbors”. The closest neighbors are those whose temperature and precipitation regimes are close. Above, we showed that the temperature regime of the region differs little by territory, and the precipitation regime, despite their great variability, is also similar. Consequently, we can apply the notion of “closest neighbors” to our region.

Scenario temperature change. We construct the scenario for the future on the basis of a harmonic analysis of the time series of the temperature of the Shcherbakty station. For figure 2 presents the results of harmonic analysis of the time series of temperature at the Shcherbakty station under the assumption that the harmonics detected in the time series of temperature will remain, they have been extrapolated for the future until 2050. It can be expected that the temperature over the next 50 years due to the age-old harmonic will fall within its amplitude, about 2 °C by the end of the period. Against

the background of the decrease in climate temperature due to the decrease in the amplitude of the century harmonic, temperature fluctuations due to the second and third harmonics are possible, which, as in the analyzed time interval, will not exceed 0.8 °C. in the North-Eastern and Northern parts of the region, the temperature decrease will occur earlier than in the Central and southern parts. The climatic temperature difference across the territory will not exceed 2 °C.

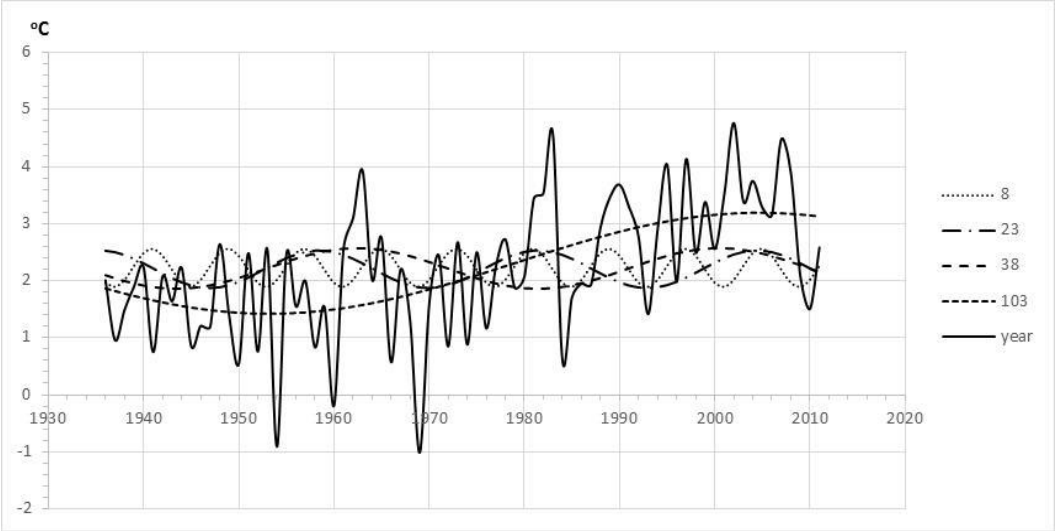

Figure 2. Shcherbakty Station. Results of harmonic analysis of temperature time series.

Scenario changes in precipitation. When building scenarios of precipitation dynamics for the future, we did not consider it possible to use only the results of the harmonic analysis of the time series of precipitation, by analogy with the construction of the temperature scenario. To build scenarios of precipitation dynamics for the future, we also used the link between the time series of precipitation and the components of the general circulation of the atmosphere (types of macro-processes). First of all, it should be noted the great similarity of approximation curves for precipitation series of all stations in all time series without exception, Brickner cycles of 39 to 58 years are easily distinguished. In this case, there is practically a connection of the type, the earlier the cycle began in the fifties – sixties of the last century, the longer they are. Climatic variations in precipitation are due to fluctuations in large-scale circulation. Maximum precipitation at the beginning of the XX century in Astana was due to the unusually high activity of processes of type W, and the first harmonic reached its maximum, and the harmonics of types C and E were poorly expressed. The presence of this maximum (figure 3) led to the appearance of an erroneous statement that against the background of global warming inside the continent it is natural to expect a decrease in the amount of precipitation [6].

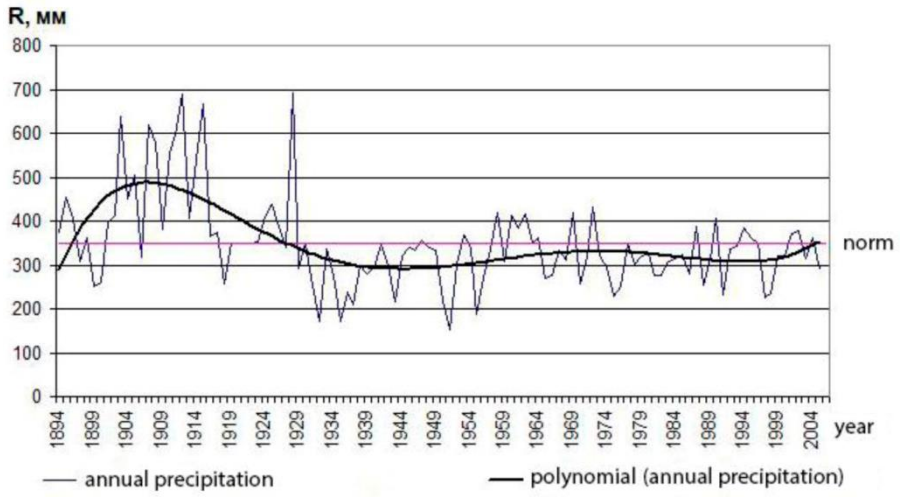

Figure 3. Astana. Time series of precipitation.

On the basis of the expected changes in the General circulation of the most likely course of precipitation with small climatic fluctuations with highs at present and in the thirties of the 21st century and with a minimum of about 2020-25 years, the amplitude of the oscillations ±20 mm from the norm.

4. Discussion

It is impossible to analyze climate change in a particular region without comparing the results with processes in the Northern hemisphere, with global processes. A large number of climate models have made it possible to successfully implement a number of climate forecasts, mainly regional ones. However, their inadequate consideration of regional climate changes and other problems [4, 13, 14 and others] force to study significant physical factors and their role in climate dynamics. Thus, the authors [14, 15] showed that climatic changes in the Northern hemisphere is the result of "meandering" waves in the General circulation of the atmosphere, and in [16, 17] shows the necessity of taking into account the polar-Arctic relations, etc. To the similar conclusions reached by the authors of [15] and [16] indicated the role and amplification of planetary waves in climate change, i.e. the role of the circulation. This is confirmed by our studies described above and contained in [4].

The role of the Pacific surface temperature dynamics on the weather-forming processes of the Northern hemisphere is known [11-18 etc.]. In [18] its role in climate change was studied. Half-century cycles are well traced in the time series of temperature and precipitation. We revealed similar cycles as a result of harmonic analysis in the series of precipitation on our territory [3, 4, 8].

5. Summary

Over the next 50 years, the temperature in Northern Kazakhstan will decrease within the amplitude of the secular harmonic, about 2°C by the end of the period. Against the background of a decrease in climatic temperature due to decreases in the amplitude of the secular harmonics, temperature fluctuations are possible due to the second and third harmonics, which, as in the analyzed time interval, will not exceed 0.8°C. Lowering the temperature, which we expect, although small, will help to reduce evaporation, which will have a positive impact on agriculture, as the amount of precipitation in the region will not change significantly.

Harmonics in the rows of precipitation vary little over the territory, and this makes it possible to use the “nearest neighbors” method when building a scenario for the future. In relation to precipitation, when building a forecast for the future, it is more expedient to use the links between climatic changes in precipitation and fluctuations in the indices of the general circulation of the

atmosphere. In Northern Kazakhstan, precipitation is most likely to occur with small climatic fluctuations, with the maxima presently and in the thirties of the 21st century and with a minimum around 2020-25, the amplitude of oscillation ± 20 mm from the norm.

Thus, although temperatures in the region are expected to decrease in the coming decades, contributing to a decrease in evaporation, and precipitation is expected near the norm, the flow of local rivers is likely to change slightly, but in some seasons its fluctuations can significantly change both in the greater and in the smaller side, which suggests the need to continue research and determine the range of adaptation measures for the future.

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