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CURRENT TRENDS OF TEMPERATURE VARIATIONS IN THE TERRITORY OF KAZAKHSTAN

Using linear and polynomial approximation methods and Fourier analysis, time series of temperature at stations of Kazakhstan were analyzed. It was demonstrated that in the last decade, to the south of the fiftieth latitude atmospheric temperatures increase had stopped, and to the north, temperature began to drop. Decrease did not begin at the same time and it manifests in different ways.

In recent years the problem of climate change has become one of the most pressing environmental problems discussed in the scientific world. In recent years, understanding of potential environmental and social impacts of global warming that have already been observed and is expected in future has markedly increased all over the world.

The problem of climate change on the territory of Kazakhstan has been explored by many researchers [1-3, etc.].

In [1] it was demonstrated that the warming, or rather, the process of climatic changes in temperature itself occurs in the territory of Kazakhstan not at the same time. Based on simultaneity of temperature changes the entire territory of Kazakhstan was divided into four zones, in each of which such change in temperature occurred in the last century in the same way (Fig. 1).

An explanation of the observed fact has also been given there. The temperature follows seminal changes in circulation. Since the territory of the Republic is vast, the prevalence of any type of circulation results in different consequences in remote areas of the territory. Thus, for example, the prevalence of C-type circulation according to [4] leads to a decrease in temperature below climatic in the Western Kazakhstan and above climatic in the Northern Kazakhstan. This is clearly demonstrated in [5].

There, in [1], it was also demonstrated for the first time that in the last decade of the past century temperature growth had stopped in the North-East of the country (Fig. 1, Pavlodar and Panfilov (Zharkent) stations). Therefore it was seen important to find out how temperature and precipitation have changed in the last 15-20 years. To do this, we used the time series of temperature and precipitation at the main (benchmark) stations for the period

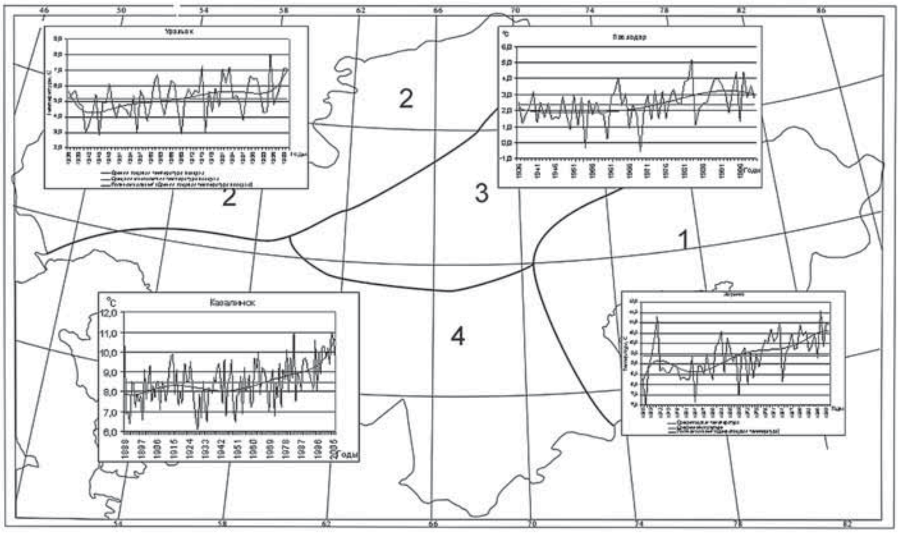

Fig.1. Results of territorial zoning of Kazakhstan based on the nature of temperature changes in the XXth century.

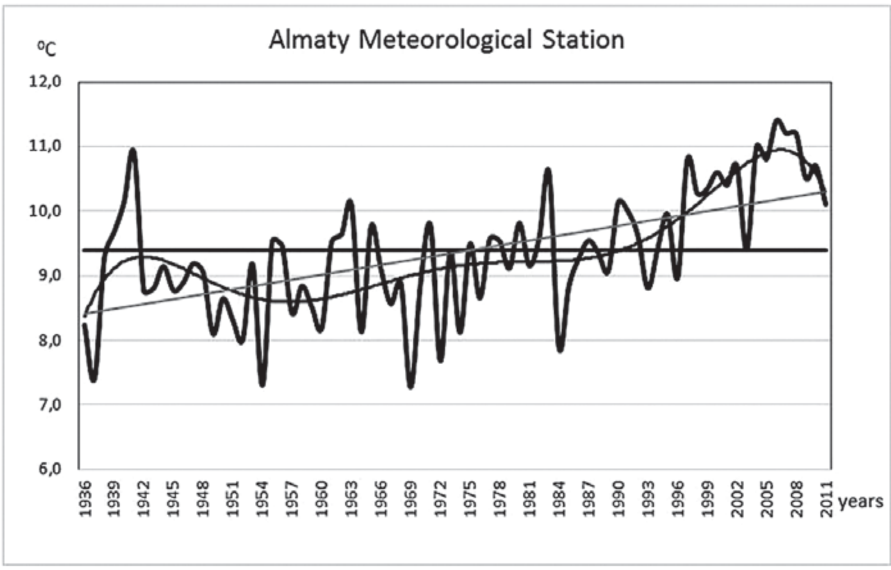

Fig 2. Time variation of air temperature at Almaty MS (°C)

Average annual air temperature
Norm
Polynomial trend
Linear trend

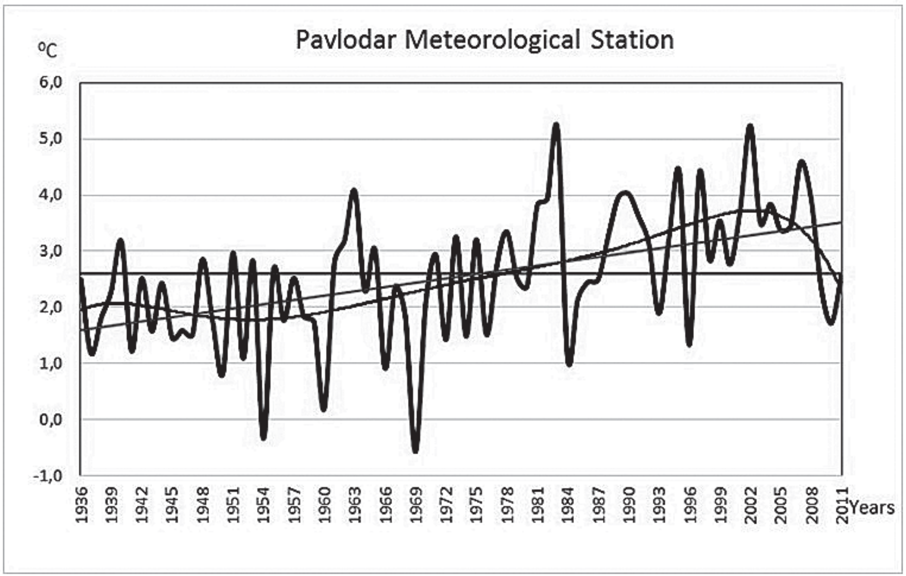

Fig.3. Time variation of air temperature at Pavlodar Meteorological Station (Indications according to Figure 2)

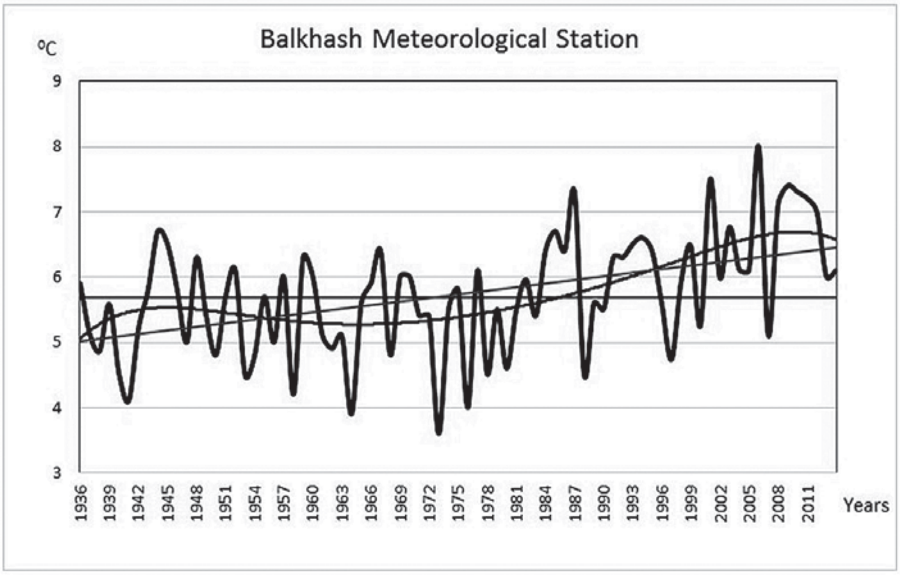

Fig.4 Time variation of air temperature at Balkhash Meteorological Station (Indications according to Figure 2)

through the year 2012. Time series were approximated by a straight line, a sixth degree polynomial, and were also subject to Fourier analysis (frequency analysis) to detect long-period harmonic curves and their plotting using the scenarios for the next decades.

Figure 1 and Figure 2-6 demonstrate approximation results of temperature time series at some stations as a straight line and a sixth degree polynomial.

You can see that the linear trend at all stations is positive, despite the addition of data to the time series for the last decades. This is understandable. Linear trend is a very conservative value, by its definition, [6,7]; only when temperature drops by an amount of warming which occurred, the trend will become zero, and after that a further drop of temperature will be negative. Because warming has lasted for more than half a century with different intensity, it will change its sign in half a century only, if fall of temperature indeed takes place. In the meantime, decrease in the trend will take place within a computation error; the accuracy of this decrease for the above reason will not be confirmed any time soon.

The advantage of polynomial approximation method is its high sensitivity to changes in dispersion and local mean along the time series [6,7, etc.]. As a result, based on polynomial approximation data, it is possible to determine cyclical fluctuations of varying duration in the time series in a rather reliable way. In our case, the way we used a polynomial approximation, identifies a Bruckner cycle and cycles that are close to it. In [1] it was based on these cycles identified in the temperature ranges, that territorial zoning of Kazakhstan had been performed.

The disadvantage of polynomial approximation method is also its advantage which is high sensitivity to local changes in the mean and variance. Fortunately, this disadvantage only appears on the ends of the time series [6,7, etc.]. We are of course interested in the end of series, i.e., reaction to changes of the end time. For example, Figure 1 shows that in Pavlodar in the late twentieth century, there had been a fall of temperature, recorded over a significant segment of time, and in Panfilov – over a short segment of time, that is, warming in Pavlodar is more reliable than that in Panfilov. In Uralsk, over a short time interval approximating line demonstrates significant warming. There has been a rise in temperature in Turkestan as well, but over a significant time interval. Consequently, the trend noted in Turkestan, is more reliable than that in Uralsk. Indeed, after the temperature time series lengthened by one and a half decades, approximating curve in Uralsk indicates fall of temperature (Fig. 4). At the same time, in Pavlodar, Panfilov (Zharkent) and Turkestan lengthening of temperature series did not result in changing the sign of the trend.

Thus, the situation is that for the purpose of timely decision-making on adaptation to climate change we must record the changes taking place as early as possible, and on the other hand, a linear interpolation method is not suitable for this, because it is very conservative. Polynomial interpolation method is unreliable because of its high sensitivity to changes in approximated values on the end of a time series and is overly sensitive to the inter-annual and other short-period fluctuations of the studied parameter, which is not a predictor of climate changes and requires a fairly long-term observation of the approximating line, to avoid errors in estimates.

Harmonics contained in the time series of the studied parameter, being temperature in this case, and identified using Fourier analysis are more trustworthy. This confidence is based on the following assumptions. Each harmonic discovered and identified in the original series is the result of impact of some factor that is known or is not fully known to us. The presence of harmonic indicates not only that there is such a factor, but also characterizes the intensity of effect (harmonic amplitude), and its frequency. There is every reason to expect that the influencing factor will continue in the future, and its effect will be the same as in previous years. The bases for these arguments (hypotheses) are the established facts of presence of diurnal and annual course harmonics in temperature series and simplicity of explanation thereof. As for harmonics with longer cycles, even though their source is not completely clear, the assumption that they are also affected by a specific source (or sources), which will continue in the future, also applies to them. Thus, harmonics have a certain physical interpretation and prognostic significance.

In this research we do not use spectral analysis. The advantage of Fourier analysis versus spectral analysis is that the detected harmonic is synchronized with the analyzed time series based on time, while spectral analysis only establishes the existence of a harmonic [7,8, etc.]. Therefore we will perform Fourier analysis of temperature series for some stations. We are going to use a modification of Fourier analysis, improved by A.V. Babkin, allowing not only identify but also add up the most significant ones in view of the trend [9, etc.].

Fig.7-10 demonstrates the results of Fourier analysis of temperature time series for some of the most prominent stations.

In Pavlodar, there are age-old harmonic (93 years), and 38 and 23 years-old harmonics. 38 and 23 years-old harmonics are summarized with the age-old (Fig. 7). It can be seen that 93+38 harmonics and 93+23 38 harmonics are in a phase of recession and the drop in temperature will continue for a long time, for a few decades.

Not at all of the stations the age-old harmonic is so well identified as in Pavlodar, but age-long or longer harmonics are present everywhere; we see harmonics of two hundred years or more as a situation, where the length of series and its structure are such that an age-old harmonic is distorted in favor of its best position through its extension.

In Uralsk, there are 38 and 23 years old harmonics present, which were separately added up with 203 years old harmonic. Decrease in amplitudes of 38 and 23 years old harmonics had just started. In the past century, it was not there yet (Fig. 8). It is evident that the two harmonics are in the process of amplitude decrease and in the coming years, temperature fall will continue.

In Kyzyl-Orda, Shymkent, Turkestan and Balkhash (Fig. 9), Panfilov (Zharkent) (Fig. 10) temperature drop has not started yet, but temperature rise had stopped.

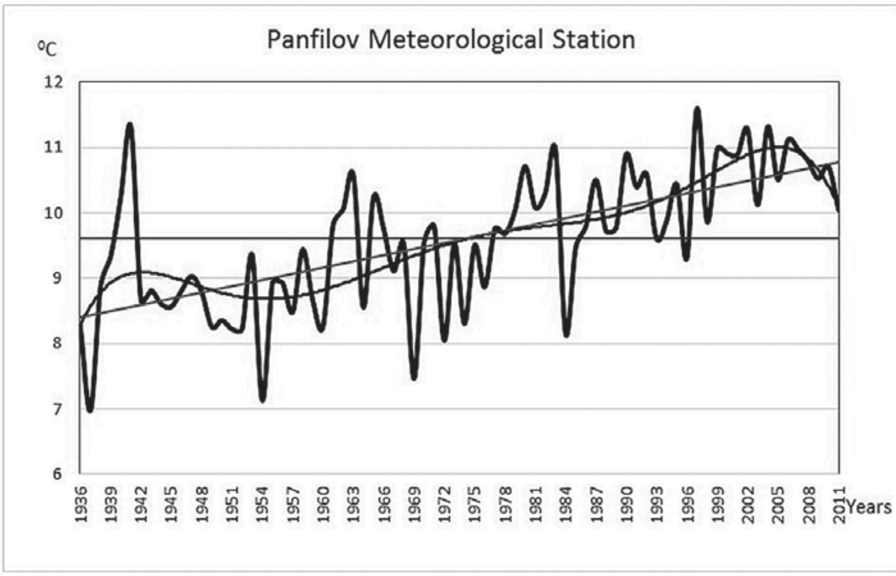

Fig.5 Time variation of air temperature at Panfilov (Zharkent) Meteorological Station (Indications according to Figure 2)

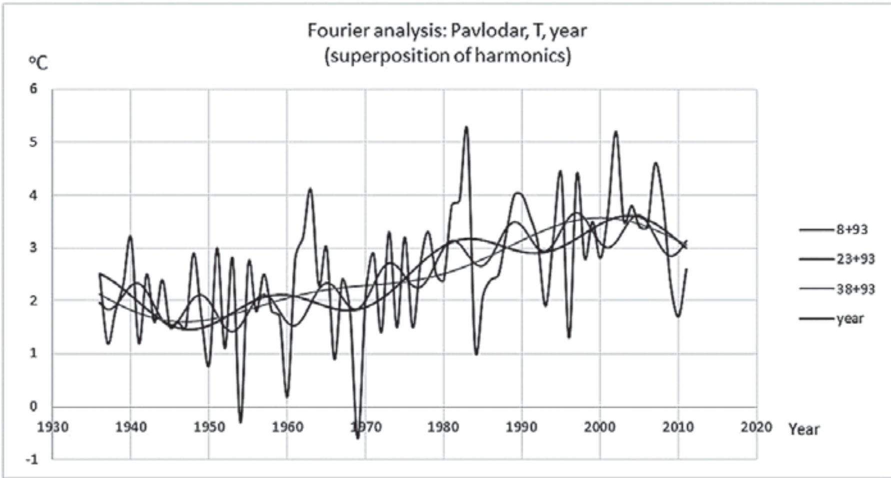

Fig.6 Fourier analysis of temperature time-series at Pavlodar MS.

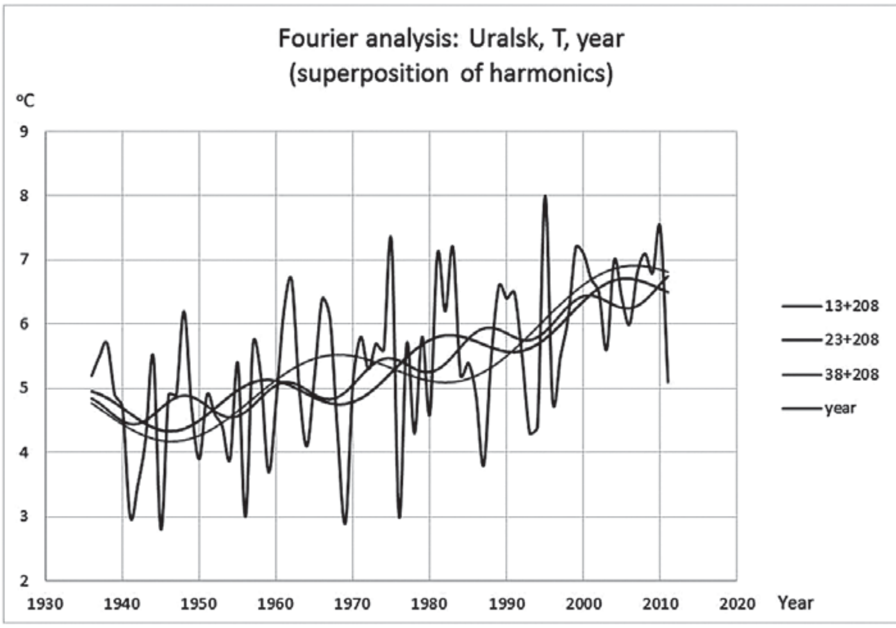

Fig.7 Fourier analysis of temperature time-series at Uralsk MS.

tained by us now on the analysis of current trends of temperature change indicates that such changes take place in good agreement with regional characteristics noted in [1] and Buckner cycles stages in them.

Kazakhstan.

In general, throughout the area, the most noticeable drop in temperature takes place in the North-East of the Republic (Pavlodar, Semipalatinsk, Astana, etc.). The temperature drop is also observable in the North-West of the Republic (Uralsk, etc.). To the south of the fiftieth latitude the cooling has hardly started, but raise in temperature had stopped.

From [5,10,11, etc.], and others we know that macro-processes to the north and to the south of the fiftieth latitude differ significantly. As stated above, they differ over the western and the northern regions of the Republic.

Therefore, climatic changes of temperature throughout the territory of Kazakhstan are due to changes in planetary circulation.

Despite the above-mentioned lack of polynomial approximation, it must be admitted that this method in [1] has helped to identify Bruckner cycles in the temperature time series, and based on that to implement territorial zoning of the Republic. This was made possible because polynomial approximation method, with the exclusion of the series end, essentially performs the addition of the most significant harmonics, including trend.

The advantage of A.V. Babkin's method has the advantage over polynomial approximation method only on the end of the time series, and also that, unlike polynomial approximation method, it comprises physical interpretation. Comparison of the results obtained by us now on the analysis of current trends of temperature change indicates that such changes take place in good agreement with regional characteristics noted in [1] and Buckner cycles stages in them.

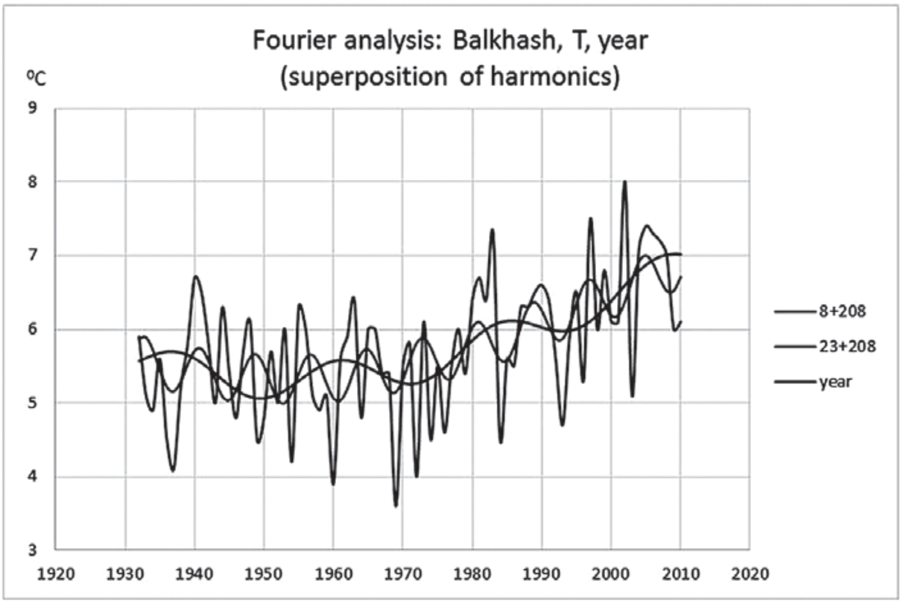

Fig.8 Fourier analysis of temperature time-series at Balkhash MS.

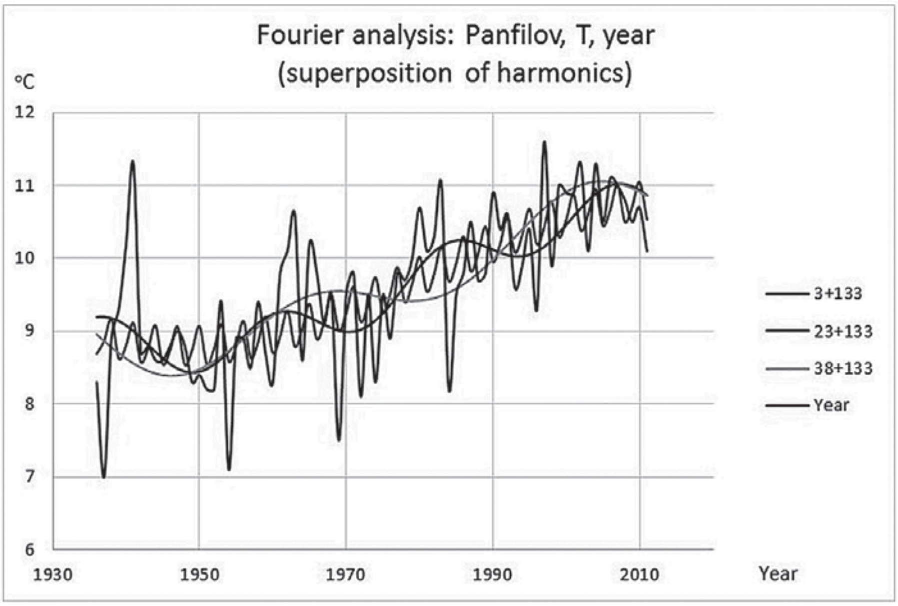

Fig.9 Fourier analysis of temperature time-series at Panfilov (Zharkent) MS.

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