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Dynamic of Balkhash lake level under climate change conditions

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Abstract. The dynamics of the level of Lake Balkhash in conditions of climate change is considered. It is shown that the undisturbed runoff: the rise (decline) of the level occurs during the entire time that the annual amount of precipitation is above (below) the norm. The maximum (minimum) is observed at the moment when the parabola crosses the line of norm from the period of excess (shortage) of precipitation to deficiency (excess) of precipitation.

1. Introduction

Many studies have been devoted to studying the regime of Lake Balkhash [1-3 and others]. Among them, we note Kurdin R.D. [1], who has been working on this problem for many years, including the dependence of the level of lake precipitation in the basin. Kurdin R.D. noted that there is no significant correlation between the annual precipitation in the basin and the level of the Lake. At the same time, he discovered a two-year, as well as 10-12 and 17-22 year cyclicality in precipitation and runoff. In his opinion, the two-year cyclicality complicated the identification of 5-6-year cycles. Halperin R.I. in [2] studied the perennial fluctuations in the annual flow of rivers in various parts of the Ile-Balkhash basin from 1930 to 1980. The author found a significant variety of this characteristic for different parts of the flow formation. The integral curve of the annual flow of the river Ile characterizes the flow of most rivers in the Ile-Balkhash basin (IBB). The purpose of this study was to find a connection between precipitation in the zone of flow formation (Almaty station) and the level of the lake in its secular course.

2. Data sources and methods

The Ile-Balkhash basin is located in the southeast of Kazakhstan [6] and includes the territories of Almaty, the south-eastern part of Karaganda, the south-western part of East Kazakhstan and the eastern part of Zhambyl Oblast, as well as the north-western part of Xinjiang Province within the People's Republic of China. The IBB area within the Republic of Kazakhstan according to different sources varies from 304 thousand km^2 to 400 thousand km^2, whereas, according to our calculations, it reaches 440 thousand km^2 (figure 1).

The baseline data for the study were the series of mean monthly and annual air temperature and precipitation from 1970 to 2013 at 41 stations - by temperature, and at 29 stations - by precipitation, located on the territory of the Ile-Balkhash basin. To assess the influence of air temperature and precipitation on the level of Lake Balkhash, lake level data from 1879 to 2013 was used.

For data processing in our work, spectral and harmonic analysis, approximation methods of different degrees, and other generally accepted methods, which can be found in [4, 5] and other sources, are widely used.

Figure 1. The territory of the Ile-Balkhash basin (IBB).

The average precipitation amount entering the flow formation zone is 67 km^3/year, and in the drainless area (area of losses and runoff dispersion) is 49-km^3/year.

According to the data of [3] over the highlands of the Ile Alatau, the tendency of air temperature growth over the period 1937-2006 is 0.2 °C for every 10 years. The air temperature and the amount of precipitation in the high-mountainous zone of the Ile Alatau increased particularly during the cold period, and decreased in the spring months.

3. Results

Temperature. To study the trends in temperature and precipitation of the basin, we used observational data from 13 meteorological stations. At the same time, the observation period was different. For reference stations Almaty, Taldykurgan, Balkhash, Kuygan, the series of observations exceeded 70 years. In some cases, to assess, for example, the magnitude and sign of the temperature trend at the end of the twentieth century, shorter thirty-year periods were used. It was during this period, starting from the seventies, that the rise in climatic temperature was most pronounced. So, for Taldykurgan, centuries old (138 years) and harmonics of 38 and 23 years are allocated.

Precipitation. The distribution of precipitation over the basin area is not uniform (figure 2). According to hydrological conditions, the territory under consideration is divided into two conditional areas - mountain or runoff formation zone, and flat, or runoff loss and dispersion area. The amount of precipitation in the center of the basin is about 150 mm, and at its edges - 200-250 mm. The region of minimum precipitation is in the center of the Balkhash basin and repeats its shape. A number of authors note that over large water bodies, the amount of precipitation during the year decreases relative to dry land by about 15–25%, and above small ones - by 5–10% [7 and others]. A similar or somewhat greater decrease in precipitation occurs in our case (figure 2).

Rainfall increases to 400 mm, starting from the slopes of the low mountains. In mountain systems, they increase with height, and this number depends on the orientation of the slopes. The difference in annual precipitation on differently oriented slopes reaches 400-500 mm.

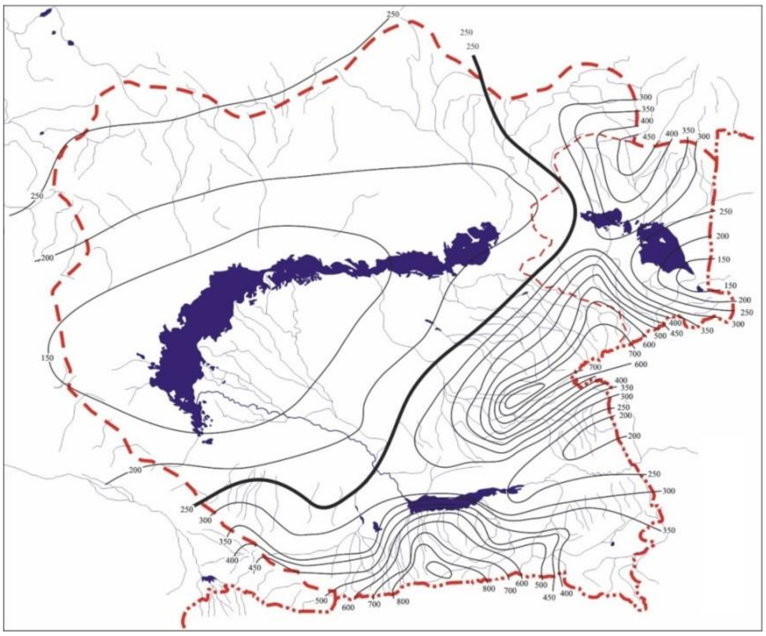


Figure 2. Distribution of annual precipitation in IBB (mm) within the territory of Kazakhstan.

The main patterns of precipitation distribution are determined primarily by the activity of synoptic processes. However, relief, all kinds of elevations, plays a large role. At the same time, for elevations, their average height above the adjacent plain is a very important factor. For slopes of high mountains and ranges, the dependencies are more complicated. The maximum precipitation occurs at altitudes of 1500–2500 m; it is clearly visible both for the Ileisk and Zhetysu Alatau.

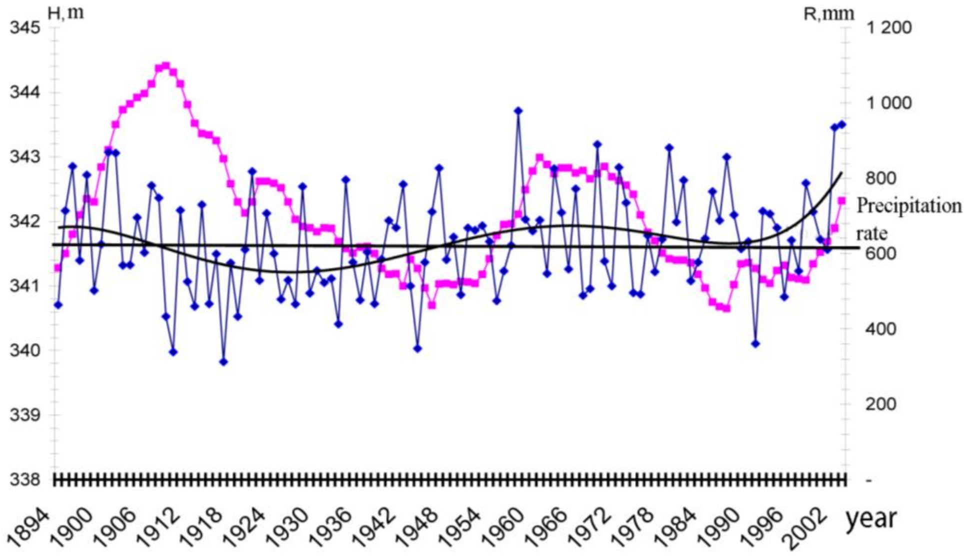
In order to concretize the desired connection, a time-plotted schedule of annual precipitation was constructed according to the data of the Almaty Model and the dynamics of the Lake level. A parabola approximated the time series of precipitation in Almaty for more than a century. The graph in accordance with the “norm” of precipitation for Almaty is also applied (figure 3).

In figure 3 perennial cycles are easily detected, not only during lake level, but also during precipitation. These cycles are offset in relation to each other by a quarter of the full period, consisting of one rise and one fall of the level. Accordingly, the relationship between the perennial precipitation fluctuations and the lake level in the temporary section of undisturbed runoff is as follows:

1) in the course of precipitation, two full long-period (half a century) cycles take place: from 1907 to 1948 (the period is below the multiyear average) and from 1948 to 1988 (the period is higher than the multiyear average);

2) the extremum in the lake level comes exactly at the time of the parabola transition, approximating the amount of precipitation through the norm.

During the transition from the period of excess precipitation to the norm and below the norm, we observe the maximum of the lake level, and during the transition from the period of lack of precipitation to the norm to the norm - the minimum of the level (figure 3). The pattern is violated after 1970 in connection with the filling of the Kapchagai reservoir; the maximum level would have been observed in 1986-1987, and was observed until 1972. A decrease in precipitation below the normal by 50 mm (less than 10% of the norm) in the period from 1910 to 1946 led to a decrease in the lake level by 3.7 m. In general, with a climatic increase in temperature from the norm in the Lake basin (Balkhash station) by 1° C the lake level decreases by 0.16 + -0.025 m.



- ● - - level of lake Balkash (H, m); - ♦- ♦ - the amount of precipitation per year at the MS Almaty; ——— - trend line

Figure 3. A course of annual precipitation at the MS of Almaty and the level of the Lake Balkhash.

4. Discussion

It was interesting to compare our data and the forecast of climate change in Kazakhstan with the data of other authors. According to the IPCC over the past 100 years (1901-2000), the global surface temperature of the northern hemisphere has increased by 0.6 ± 0.2 °C [8]. At the same time, warming was not uniform: it was noted in two periods - from 1910 to 1945. And from 1976 to 2000, and in the interval 1946-1975. there was a slight cooling. The same periods of warming and cooling are noted in other papers [3, 9, 10]. The authors [11] explain this by the peculiarities of circulation in the oceans. The warming in the twentieth century was the greatest in the last 1000 years, and the 1990s were the warmest, with 1998 having the highest surface air temperature [3]. The site http://www.cru.uea.ac.uk/ presents the results of the analysis of the time series of the average global temperature obtained in the European Center for Medium-Range Forecasts. It can be seen that in the second half of the twentieth century, a positive temperature trend was observed everywhere. Having added the last two years, the authors somewhat lifted the end of the approximating curve, which, however, did not change the fact that there was a slowdown in the temperature rise process (hiatus). About the termination of the growth of global air temperature is reported in our [12] and a number of other works.

In [9], the authors cite the temporal variation of the temperature of the surface of the Pacific Ocean during the past century to the present (the EL-NINO phenomenon). As is well known, this phenomenon affects precipitation over a large part of the Northern Hemisphere [9, 13]. It is noteworthy, therefore, that the cycles in the temperature field of the Pacific Ocean correspond to the cycles in the series of precipitation of our region.

It was shown in [14], that the impact of climate change on the processes in the Aral Sea basin is significant. Reservoirs of the arid zone are sensitive to the slightest climatic fluctuations in temperature and precipitation.

In [15, 16], the authors also studied the dependence of runoff on climate (the rivers of Britain and the Yangtze River). The balance between precipitation and temperature on the one hand and surface runoff on the other, being quite stable over a time span from one year to several, is very sensitive to climatic changes, i.e. changes in the time period up to 10 years. The results obtained confirm that the sensitivity of water systems to climate change is high even outside the arid zone. There are other works devoted to this problem, but with similar results. The results obtained by the authors of [14–16] are consistent with ours.

5. Conclusion

The correlation between the air temperature in the area of loss of flow and the level of the lake is significant and is minus 0.65. In general, with a climatic increase in temperature from the norm in the lake basin (Balkhash station), the lake level drops by 1 °C by 0.16 ± 0.025 m. At the same time, precipitation in the area of loss of runoff does not affect the amount of runoff due to its insignificance. The time course of precipitation at the meteorological station of Almaty, approximated by a parabola, against the background of the norm, is in best agreement with the long-period fluctuations of the lake level with undisturbed runoff: the rise (decline) of the level occurs during the entire time that the annual precipitation is above (below) the norm. The maximum (minimum) is observed at the moment when the parabola crosses the line of norm from the period of excess (shortage) of precipitation to deficiency (excess) of precipitation.

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