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INFLUENCE OF GLOBAL CLIMATE CHANGES ON HYDROLOGICAL REGIME OF RIVERS IN THE SOUTH WEST SIBERIA

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Abstract The research is aimed at studying the impact of climatic changes on the formation of surface runoff in the south West Siberia. To solve this problem, a statistical analysis of discharge data series on rivers in the area under study, and the simulation of the surface runoff in the model basins with the use of water balance equations were made. The dynamics of precipitation and air temperature during the warm period of the last two thousand years in the south of West Siberia was calculated, and the forecast for the next centuries was made. Using the results of statistical analysis of data series of average annual discharges for major rivers in the south of West Siberia the linear trends were calculated. The change in annual discharges for the last decades was estimated. The discharge forecast for the following 10 – 20 years was given, and the zones of its increase /decrease in the area under study were identified. Based on the water balance equation, the variable-based calculation of the runoff in the model basins for long-term annual average normal year and the years with scenario variations of temperature and precipitation was made.

Key words: observation, flow rate, average annual river flow, trend, forecast, climate change, river, West Siberia

AMS Mathematics Subject Classification: 86A05, 86-08

1 Introduction

Undoubtedly, the global increase of air temperature has an effect both on the World Ocean and the surface water. Over a period from 1976 to 2006 (30 years), the warming of the air temperature over Russia was $1.4°C$ ([7]). The interannual variation of the World Ocean level shows a pronounced upward trend of about 200 mm for past 180 years ([9]). A sinusoidal harmonic of the World Ocean level in reference to the trend line with the points of transition in 1882 and 1954, and the current positive sinusoidal branch is observed. The phase of the upward branch gives a steeper local linear trend for the period from 1954 to 2000 as compared to the general trend of increase of World sea level in 1860-2000.

The need to assess the water content due to climate change poses the following research objectives: 1) to identify the nature of variations in precipitation in West Siberia over the last 2000 years; 2) to reveal the existing trends in flow rate in the area under study over the past decades.

2 Objects of research

For each of the tasks within the south West Siberia (Fig. 1) the following objects of research were selected: For the reconstruction of precipitation in the south West Siberia - Lake Chany; To assess the change in the flow rate in the south West Siberia over the past decades - 69 hydrological stations on the rivers of the Ob-Irtysh basin with long series of observations of daily and monthly mean flow rate; To simulate the flow rate formation a typical bogged catchment of River Vasyugan (Maisk village) in the taiga zone and atypical for the territory of Great Vasyugan Mire, the catchment of River Kargat (Zdvinsk village) situated in the forest-steppe zone were selected.

Fig. 1 Location of objects under study: West Siberia, the Ob-Irtysh basin, Lake Chany, Great Vasyugan Mire, Glacier Maly Aktru (Gorny Altai)

3 Basin

Task 1. The basis for modeling precipitation in Lake Chany was formed by the long-term study of the reconstruction of fluctuations of its mirror for the last 2000 years with a 50-year time step, conducted by the Institute of Geology and Mineralogy SB RAS ([12]). The simulation is based on the equation of water balance for closed waters. The results of estimation of annual precipitation variation by the fluctuation of the Lake Chany table were compared with the ones obtained with sporo-pollen spectra ([6]). The calculation of the thermal regime and precipitation is based on the simulation model of glacier balance previously developed by the IWEP ([4]).

Task 2. The State Hydrological Institute was engaged in the study of water content variation due to climate warming. The complex statistical analysis was used to study the dynamics of the spring, summer-fall and winter flow of large, medium-size and small rivers of Russia as well as the intra-annual flow distribution ([9]). Currently, the foreign practice in hydrology has been also focused on the study of trends in water flow occurring due to the climate change. For instance, the trends of seasonal, average, minimal and maximal water flow were analyzed for natural river basins of Canada, the natural zones of which are similar to the ones in West Siberia ([1]; [2]; [3]; [8]; [10]; [11]).

4 Methods

Task 1.To assess changes in annual precipitation in the south of West Siberia, the results of paleolimnological reconstructions of water levels of Lake Chany (Novosibirsk oblast', Russia) were used ([5]).

The change in thermal regime (the magnitude of cooling) was defined with the use of a simulation model for calculating the ice balance components of the Maly Aktru glacier (the Altai, Russia) based on the climatic conditions (i.e. temperature of the warm period) dependence of the glacier tongue location. The values of a warming period were calculated by the extension of an ancient forest boundary compared to the modern one.

The assessment of cooling in the second half of the Holocene was based on determining the position of the moraine complexes and their radiocarbon dating. The evaluation of the warming period was made by the position of the upper forest boundary and by radiocarbon dating as well. The radiocarbon dating of organic debris (wood and peat) sampled in the moraine complexes and in lacustrine sediments located ahead of the moraines was performed using QUANTULUS 1220 in the laboratory of Cenozoic Geology and Paleoclimatology of the V.S. Sobolev Institute of Geology and Mineralogy, SB RAS. The results of dating were used to estimate the time of moraine complexes formation with regard to the time of the glaciers response to the cooling period and the time of the glacier's tongue advancement up to the moraine complex ([4]).

Task 2. For analytical presentation of scenario forecast based on linear trends, the approximate equality of flow rate, calculated from the series of observations $Q_0 (m^3/s)$, and the average value of series of the calculated linear trend $Q_0^T (m^3/s)$ was used.

5 Results and conclusion

Task 1. When modeling the water balance of Lake Chany, the variation of precipitation in the region over the past 2000 years was calculated. To determine the periodic dependence of series, the spectral analysis based on the Fourier one-dimensional transformation was used. The main frequencies contributing significantly to the periodic behavior of the whole series were identified. The curve calculated with the selected periods is shown in Fig.2.

The current upward positive sinusoidal branch on the graph of precipitation originated in the first half of the 20th century (1910), and the extremum of the function is forecasted by the year 2100. The existing trend will be observed up to the last quarter of the 21st century.

The study of glacier fluctuations in the alpine Altai allows the graphing of thermal variations in the warm season of the appropriate time period (Fig. 3). Similar to the precipitation series, the spectral analysis based on the Fourier one-dimensional transformation was used to reveal the main harmonics. On the graph, the average annual temperature fluctuation has a slightly larger oscillation than the one for precipitation, but the local situation within the last and the present century is also distinguished by a growing positive trend. The inflection point of the function of air temperature fluctuation fell on the early 20th century and, according to the forecast, a positive extremum is expected by the year 2170. Last year (2012) was within the quasi-linear upward trend; in the future, the temperature increase will take place with a decrease in the growth rate.

Rise of air temperature r and precipitation, taken as a whole, influences the formation of the surface runoff in the south West Siberia. The analysis of changes in water content of rivers involved the processing of data from hydrological gages with full observation period of at least 50 years. Using the different curves for each series, the calculation of representative period including the full cycles of water content was determined.

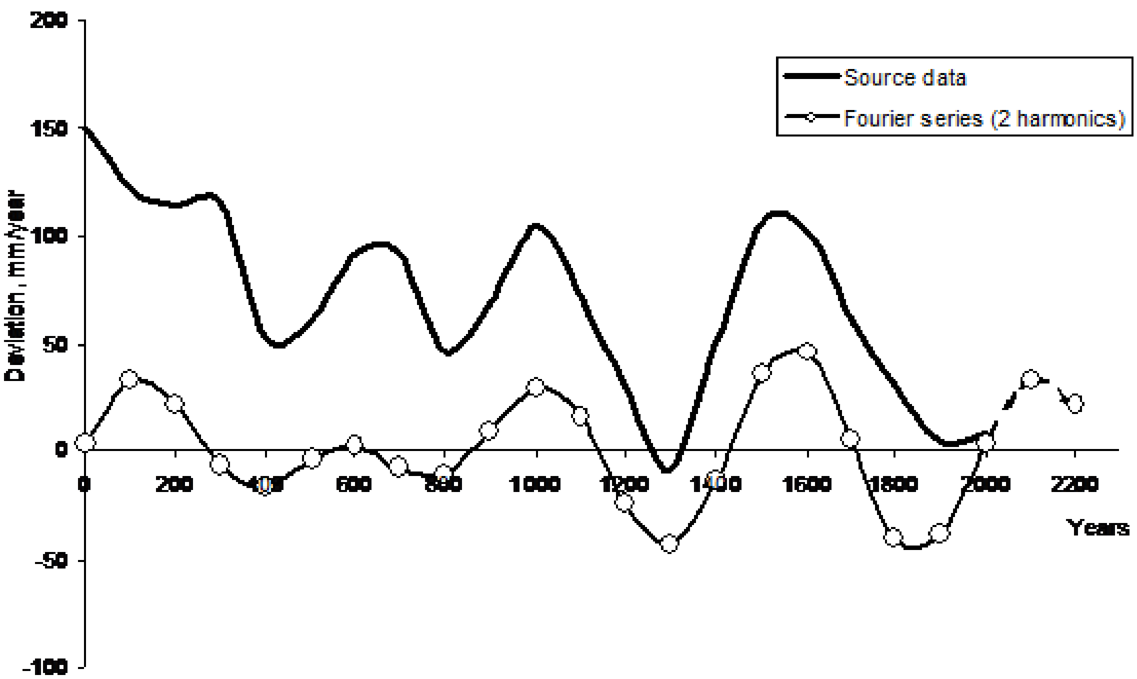

Fig. 2 Precipitation fluctuation in the southWest Siberia (mm/year) for the last two thousand years (based on the results of paleolimnological reconstructions of Lake Chany)

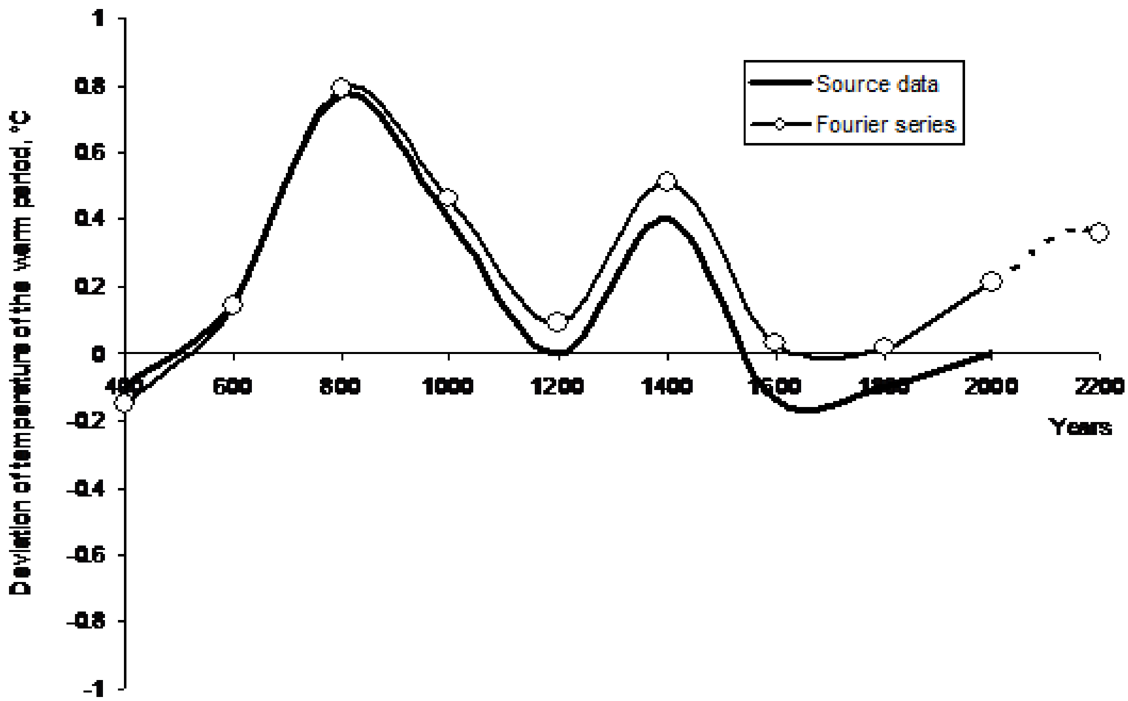

Fig. 3 Deviation of temperature of the warm period from the mean (°C) in the south West Siberia for the last two thousand years (based on the glacier fluctuations in the alpine Altai)

When making a hydrological forecast the term "scenario", i.e. a plausible and often simplified description of events in the future, based on the consistent set of assumptions about driving forces and key relationships, was used. The basic requirement in scenario forecast is the maintenance of the current long-term trend in the annual flow in the rivers under consideration. This condition is acceptable for a 10 – 20 year forecast, as the surface runoff is mostly subject to precipitation fluctuation, which currently shows a quasi-linear upward trend.

Task 2. Based on the results of the forecast, the following zones of flow change are identified in the area under study (Fig. 4):

Zone 1 (–). By the year 2030, the decrease of flow in rivers Anui (–2.2 % / 10 years), Katun (6.2 % /10 years), Biya (0.54 % /10 years) will lead to a decrease in the discharges of Ob River at the Fominskoye water gage by 3.1% as compared to 2010.

Zone 2 (+). By the year 2030, the increased discharges of the left tributaries of the Ob, in particular, river Aley (0.40% / 10 years) and river Charysh (0.85% / 10 years) leads to the increased discharges in Ob River by 1.1% (Barnaul water gage) and 1.2% (Kamen-on-Ob water gage) as opposed to 2010.

Zone 3 (–). Right-bank tributaries of River Ob with decreasing discharges (rivers Chumysh, Berd, Tom, Chulym) produce the decrease in discharge of Ob River at Kolpashevo water gage by 3.1% as against 2010.

Zone 4 (+). Right-bank tributaries of Ob River, rivers Ket' and Tym, show the increasing discharges. By the year 2030, the relative increase will make up 0.5% and 1.3%, respectively.

Zone 5 (–). The left tributary of Ob River, river Kasmala, and the rivers of the Ob-Irtysh interfluve (rivers Kulunda, Burla, and Kargat) will show the discharge decrease by 5.2%, 3.15, 0.85, and 3.9%, respectively, for 10 years.

Zone 6 (+). Within the Great Vasyugan Mire a steady increase in the discharges takes place. This area demonstrates the maximum relative change of the discharge by the year 2030: river Om – 11.5% (south-west), and river Parabel' – 11.0% (east).

Zone 7 (–). Right tributaries of the Irtysh, Rivers Shish and Tui, will reduce water content at a rate from –0.9 to – 3.1% for 10 years.

Zone 8 (+). The right tributary of river Irtysh – river Demyanka (its catchment area is a forested territory (50%) and wetlands (30%)) has a 5.4% increase discharge every 10 years.

Zone 9 (+). Running through the Russian territory river Ishim – the left tributary of river Irtysh, increases its water content by 6 –7% every 10 years due to its forest–covered and wetland basin. From the Russian-Kazakhstan border up to Omsk and Tyumen regions, forests cover 62% and bogs – 8% of the total basin area of 27 000 km2. The river site from the Tyumen region up to the river's mouth near village Orekhovo (the catchment area is of 20 000 km2) is forested by 45% and waterlogged by 30%.

Zone 10 (–). According to the forecast, left-bank tributaries of river Irtysh in the forest-steppe and steppe zones of river Miass (waterlogged by 5% or less), river Tobol (waterlogged in selected sites by 7 – 16%) and adjacent river Vagai running in the taiga zone will reduce their discharge.

Zone 11 (+). Tributaries of the left-bank Irtysh from the taiga zone will increase their water content (tributaries of river Tobol are rivers Iset', Sos'va, Tura, and river Konda – a tributary of river Irtysh).

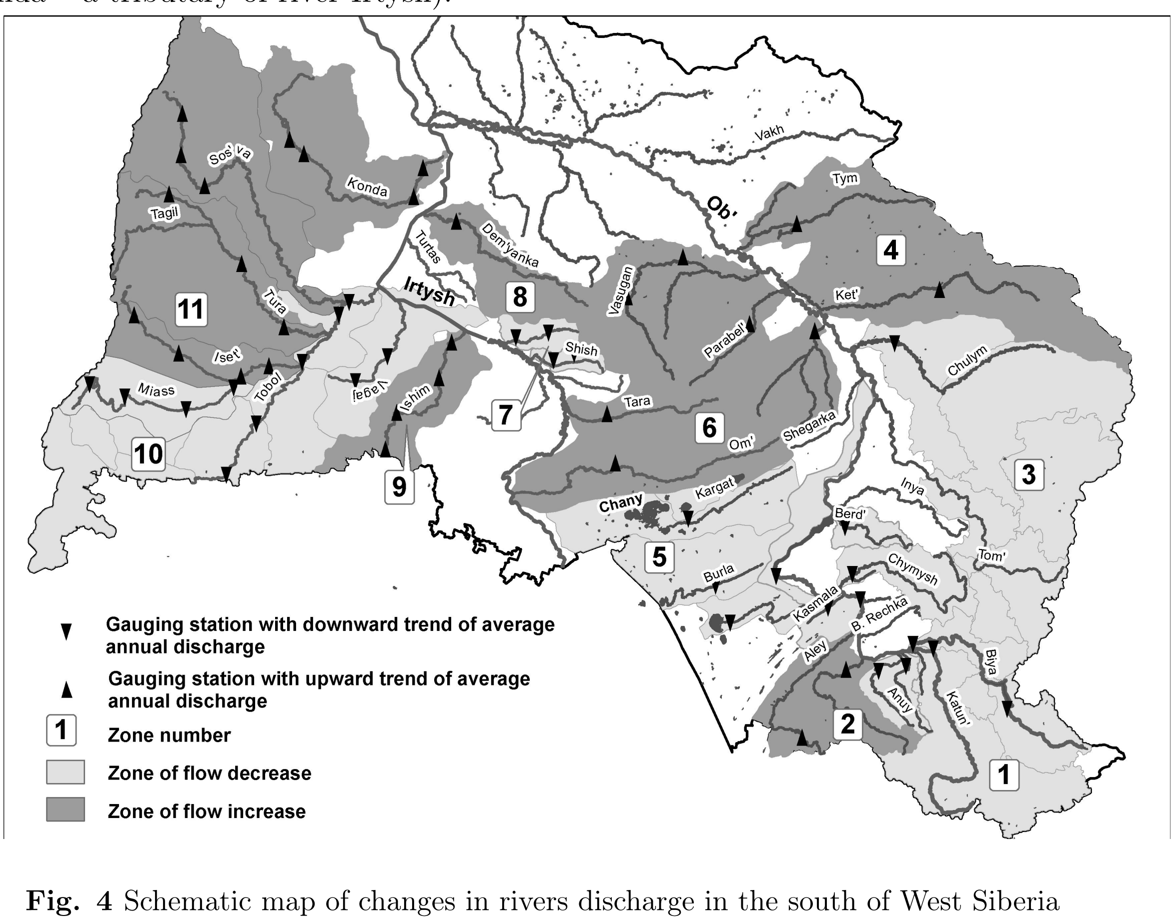

Fig. 4 Schematic map of changes in rivers discharge in the south of West Siberia

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