

ISSN 1991-346X

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ  
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫНЫҢ

# Х А Б А Р Л А Р Ы

---

---

## ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК  
РЕСПУБЛИКИ КАЗАХСТАН

## NEWS

OF THE NATIONAL ACADEMY OF SCIENCES  
OF THE REPUBLIC OF KAZAKHSTAN

**ФИЗИКА-МАТЕМАТИКА  
СЕРИЯСЫ**



**СЕРИЯ**

**ФИЗИКО-МАТЕМАТИЧЕСКАЯ**



**PHYSICO-MATHEMATICAL  
SERIES**

**6 (304)**

**ҚАРАША – ЖЕЛТОҚСАН 2015 ж.  
НОЯБРЬ – ДЕКАБРЬ 2015 г.  
NOVEMBER – DECEMBER 2015**

1963 ЖЫЛДЫҢ ҚАҢТАР АЙЫНАН ШЫҒА БАСТАҒАН  
ИЗДАЕТСЯ С ЯНВАРЯ 1963 ГОДА  
PUBLISHED SINCE JANUARY 1963

ЖЫЛЫНА 6 РЕТ ШЫҒАДЫ  
ВЫХОДИТ 6 РАЗ В ГОД  
PUBLISHED 6 TIMES A YEAR

АЛМАТЫ, ҚР ҰҒА  
АЛМАТЫ, НАН РК  
ALMATY, NAS RK

Б а с р е д а к т о р

ҚР ҰҒА академигі,

**Мұтанов Г. М.**

Р е д а к ц и я а л қ а с ы:

физ.-мат. ғ. докторы, проф., ҚР ҰҒА академигі **Әшімов А.А.**; техн. ғ. докторы, проф., ҚР ҰҒА академигі **Байгүнчеков Ж.Ж.**; физ.-мат. ғ. докторы, проф., ҚР ҰҒА академигі **Жұмаділдаев А.С.**; физ.-мат. ғ. докторы, проф., ҚР ҰҒА академигі **Қалменов Т.Ш.**; физ.-мат. ғ. докторы, проф., ҚР ҰҒА академигі **Мұқашев Б.Н.**; физ.-мат. ғ. докторы, проф., ҚР ҰҒА академигі **Өтелбаев М.О.**; физ.-мат. ғ. докторы, проф., ҚР ҰҒА академигі **Тәкібаев Н.Ж.**; физ.-мат. ғ. докторы, проф., ҚР ҰҒА академигі **Харин С.Н.**; физ.-мат. ғ. докторы, проф., ҚР ҰҒА корр. мүшесі **Әбішев М.Е.**; физ.-мат. ғ. докторы, проф., ҚР ҰҒА корр. мүшесі **Жантаев Ж.Ш.**; физ.-мат. ғ. докторы, проф., ҚР ҰҒА корр. мүшесі **Қалимолдаев М.Н.**; физ.-мат. ғ. докторы, проф., ҚР ҰҒА корр. мүшесі **Косов В.Н.**; физ.-мат. ғ. докторы, проф., ҚР ҰҒА корр. мүшесі **Мұсабаев Т.А.**; физ.-мат. ғ. докторы, проф., ҚР ҰҒА корр. мүшесі **Ойнаров Р.**; физ.-мат. ғ. докторы, проф., ҚР ҰҒА корр. мүшесі **Рамазанов Т.С.** (бас редактордың орынбасары); физ.-мат. ғ. докторы, проф., ҚР ҰҒА корр. мүшесі **Темірбеков Н.М.**; физ.-мат. ғ. докторы, проф., ҚР ҰҒА корр. мүшесі **Өмірбаев У.У.**

Р е д а к ц и я к ең е с і:

Украинаның ҰҒА академигі **И.Н. Вишневский** (Украина); Украинаның ҰҒА академигі **А.М. Ковалев** (Украина); Беларусь Республикасының ҰҒА академигі **А.А. Михалевич** (Беларусь); Әзірбайжан ҰҒА академигі **А. Пашаев** (Әзірбайжан); Молдова Республикасының ҰҒА академигі **И. Тигиняну** (Молдова); мед. ғ. докторы, проф. **Иозеф Банас** (Польша)

Главный редактор

академик НАН РК

**Г. М. Мутанов**

Редакционная коллегия:

доктор физ.-мат. наук, проф., академик НАН РК **А.А. Ашимов**; доктор техн. наук, проф., академик НАН РК **Ж.Ж. Байгунчеков**; доктор физ.-мат. наук, проф., академик НАН РК **А.С. Джумадильдаев**; доктор физ.-мат. наук, проф., академик НАН РК **Т.Ш. Кальменов**; доктор физ.-мат. наук, проф., академик НАН РК **Б.Н. Мукашев**; доктор физ.-мат. наук, проф., академик НАН РК **М.О. Отелбаев**; доктор физ.-мат. наук, проф., академик НАН РК **Н.Ж. Такибаев**; доктор физ.-мат. наук, проф., академик НАН РК **С.Н. Харин**; доктор физ.-мат. наук, проф., чл.-корр. НАН РК **М.Е. Абишев**; доктор физ.-мат. наук, проф., чл.-корр. НАН РК **Ж.Ш. Жантаев**; доктор физ.-мат. наук, проф., чл.-корр. НАН РК **М.Н. Калимолдаев**; доктор физ.-мат. наук, проф., чл.-корр. НАН РК **В.Н. Косов**; доктор физ.-мат. наук, проф., чл.-корр. НАН РК **Т.А. Мусабаев**; доктор физ.-мат. наук, проф., чл.-корр. НАН РК **Р. Ойнаров**; доктор физ.-мат. наук, проф., чл.-корр. НАН РК **Т.С. Рамазанов** (заместитель главного редактора); доктор физ.-мат. наук, проф., чл.-корр. НАН РК **Н.М. Темирбеков**; доктор физ.-мат. наук, проф., чл.-корр. НАН РК **У.У. Умирбаев**

Редакционный совет:

академик НАН Украины **И.Н. Вишневский** (Украина); академик НАН Украины **А.М. Ковалев** (Украина); академик НАН Республики Беларусь **А.А. Михалевич** (Беларусь); академик НАН Азербайджанской Республики **А. Пашаев** (Азербайджан); академик НАН Республики Молдова **И. Тигиняну** (Молдова); д. мед. н., проф. **Иозеф Банас** (Польша)

«Известия НАН РК. Серия физико-математическая». ISSN 1991-346X

Собственник: РОО «Национальная академия наук Республики Казахстан» (г. Алматы)

Свидетельство о постановке на учет периодического печатного издания в Комитете информации и архивов Министерства культуры и информации Республики Казахстан №5543-Ж, выданное 01.06.2006 г.

Периодичность: 6 раз в год.

Тираж: 300 экземпляров.

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, ком. 219, 220, тел.: 272-13-19, 272-13-18,

[www.nauka-nanrk.kz](http://www.nauka-nanrk.kz) / [physics-mathematics.kz](http://physics-mathematics.kz)

---

© Национальная академия наук Республики Казахстан, 2015

Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75.

Editor in chief

**G. M. Mutanov,**  
academician of NAS RK

Editorial board:

**A.A. Ashimov**, dr. phys-math. sc., prof., academician of NAS RK; **Zh.Zh. Baigunchekov**, dr. eng. sc., prof., academician of NAS RK; **A.S. Dzhumadildayev**, dr. phys-math. sc., prof., academician of NAS RK; **T.S. Kalmenov**, dr. phys-math. sc., prof., academician of NAS RK; **B.N. Mukhashev**, dr. phys-math. sc., prof., academician of NAS RK; **M.O. Otelbayev**, dr. phys-math. sc., prof., academician of NAS RK; **N.Zh. Takibayev**, dr. phys-math. sc., prof., academician of NAS RK; **S.N. Kharin**, dr. phys-math. sc., prof., academician of NAS RK; **M.Ye. Abishev**, dr. phys-math. sc., prof., corr. member of NAS RK; **Zh.Sh. Zhantayev**, dr. phys-math. sc., prof., corr. member of NAS RK; **M.N. Kalimoldayev**, dr. phys-math. sc., prof., corr. member of NAS RK; **V.N. Kosov**, dr. phys-math. sc., prof., corr. member of NAS RK; **T.A. Mussabayev**, dr. phys-math. sc., prof., corr. member of NAS RK; **R. Oinarov**, dr. phys-math. sc., prof., corr. member of NAS RK; **T.S. Ramazanov**, dr. phys-math. sc., prof., corr. member of NAS RK (deputy editor); **N.M. Temirbekov**, dr. phys-math. sc., prof., corr. member of NAS RK; **U.U. Umirbayev**, dr. phys-math. sc., prof., corr. member of NAS RK

Editorial staff:

**I.N. Vishnievski**, NAS Ukraine academician (Ukraine); **A.M. Kovalev**, NAS Ukraine academician (Ukraine); **A.A. Mikhalevich**, NAS Belarus academician (Belarus); **A. Pashayev**, NAS Azerbaijan academician (Azerbaijan); **I. Tighineanu**, NAS Moldova academician (Moldova); **Joseph Banas**, prof. (Poland).

**News of the National Academy of Sciences of the Republic of Kazakhstan. Physical-mathematical series.**  
**ISSN 1991-346X**

Owner: RPA "National Academy of Sciences of the Republic of Kazakhstan" (Almaty)

The certificate of registration of a periodic printed publication in the Committee of information and archives of the Ministry of culture and information of the Republic of Kazakhstan N 5543-Ж, issued 01.06.2006

Periodicity: 6 times a year

Circulation: 300 copies

Editorial address: 28, Shevchenko str., of. 219, 220, Almaty, 050010, tel. 272-13-19, 272-13-18,

[www.nauka-nanrk.kz](http://www.nauka-nanrk.kz) / [physics-mathematics.kz](http://physics-mathematics.kz)

---

© National Academy of Sciences of the Republic of Kazakhstan, 2015

Address of printing house: ST "Aruna", 75, Muratbayev str, Almaty

**СОЛТҮСТІК ТЯНЬ-ШАНЬ АЙМАҒЫНЫҢ  
ЛИТОСФЕРАСЫН ГЕОДИНАМИКАЛЫҚ АУДАНДАСТЫРУ****А. В. Виляев, Д. М. Сұлтанова, Е. М. Акбергенов**

ЕЖШС «Ионосфера институты» АҚ «Ғарыштық зерттеулер мен технологиялар ұлттық орталығы»,  
Алматы, Қазақстан

**Тірек сөздер:** геодинамикалық аудандастыру, кластерлік талдау, солтүстік Тянь-Шань, геодинамика.

**Аннотация.** Геодинамиканың белсенді дамуы соңғы кездерде әртүрлі геодинамикалық карта және модельдер жасауының қажеттігін туғыздырады, сондай-ақ ақпараттарды өңдеу мен литосфералық процестер болжаудың жаңа әдістерін құрастыру. Геофизикалық қорғанындардың параметрлерінің талдау беруінен шыққан нәтижелердің жеткіліксіздігі, практикалық деректер жинағының қолдану қажеттілігін ынталандырады.

Мақалда әдістеме кластерлік анализ арқылы Тянь-Шань аймағының геодинамикалық аудандастыру әдістемесі ұсынылады. Аймақтың кластерлі белдемділік статистикалық моделі алынды және геодинамика позициясынан алынған нәтижелерге талдау беру.

*Поступила 03.11.2015 г.*

**NEWS**

OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN

**PHYSICO-MATHEMATICAL SERIES**

ISSN 1991-346X

Volume 6, Number 304 (2015), 21 – 27

UDC 556.53

**STATISTICAL APPROACH TO ANALYSING STREAM DISCHARGE  
IN RESPONSE TO CLIMATE CHANGE AND GLACIER SHRINKAGE****Z. S. Zhantayev, A. A. Kaldybayev, A. Z. Bibossinov**

Institute of the Ionosphere, National Center for Space Research and Technology, Almaty, Kazakhstan.  
E-mail: azamat.kaldybayev@gmail.com

**Key words:** river runoff, climate change, glacier shrinkage, Karatal river basin, Mann-Kendall test.

**Abstract.** Based on runoff, air temperature, and precipitation data from 1960 to 2012, the effects of climate change and glacier shrinkage on water resources in the western part Zhetysu Alatau were investigated. The long-term trends of hydroclimatic variables were studied by using Mann-Kendall test. Analyzing weather station climatic data, we found a significant increase in temperature and quite stable trends for precipitation during study period. Positive trends in annual discharge were detected in almost all glacierized tributaries of Karatal river. This obvious upward trend in river runoff is likely connected with a general trend of increasing temperatures and intensive melting of glaciers in Tien-Shan.

**Introduction.** Water resources play the most important role in the sustainable development of society and economy in arid region, and they determine the evolution of ecological environment in the arid regions, including the two contrary processes of oasis formation and desertification.

Only a limited number of studies currently address the timing and evolution of expected glacier shrinkage and related changes in runoff [1]. Although glacier changes of Zhetysu Alatau (Eastern Tien Shan) in this region have been investigated [e.g. 2; 3;4], little is known about the whole variation characteristics of glaciers and glacier runoff in the KRB basin during recent decades.

In this paper, the long-term trends of the air temperature, precipitation and runoff time series are analyzed. To further understand the spatial distribution of the trends in the hydrometeorological variable, we divide the Karatal river into 5 sub-basins. The purposes of this study are to detect the trends of major hydroclimatic variables at annual and seasonal scales, and reveal association between climate change, glacier shrinkage and the variability of hydrological process response.

**Study area.** The Karatal river basin, which is the largest basin in Zhetysu Alatau, covers an area of 19,100 km<sup>2</sup>, with a catchment area of 5,300 km<sup>2</sup> [5]. The Karatal river originates on the north-western slopes of the Zhetysu Alatau central ridge. It is formed by the confluence of the Kora, Chizhin and Tekeli rivers [4], while further on the plain, it meets with its largest tributary, the Koksus river to form a united stream [6].

The mean annual air temperature is -5 -7 °C in the high-altitude zone of Zhetysu Alatau; January is the coldest month, with -13 -14 °C. The spatial distribution of precipitation is controlled by altitude and varies from 1,000 to 1,600 mm a<sup>-1</sup>, with maximum amounts occurring at elevations of 1,800-2,200 m a.s.l. [6].

**Hydro-meteorological data and trend analysing methods.** We acquired data from the Taldykorgan weather station, which was the closest weather station available to our study area. This station is situated in the foothills, and provided long-term temperature and precipitation records since 1960.

In order to determine and analyse the potential drivers of glacier changes and investigate the changes in river runoff over the past decades a trend analysis using the Mann-Kendall test [7] was carried out for the time series of air temperature, precipitation and runoff at selected climate and hydrological stations. For more detailed analyses the impact of dramatically decreasing glacier to the runoff variation, we used hydrological data from four stations for each glacierized sub-basin (Kora, Koksus, Koktal and Chizhin) and one station from non-glacierized catchment Tekeli (see Fig. 1).

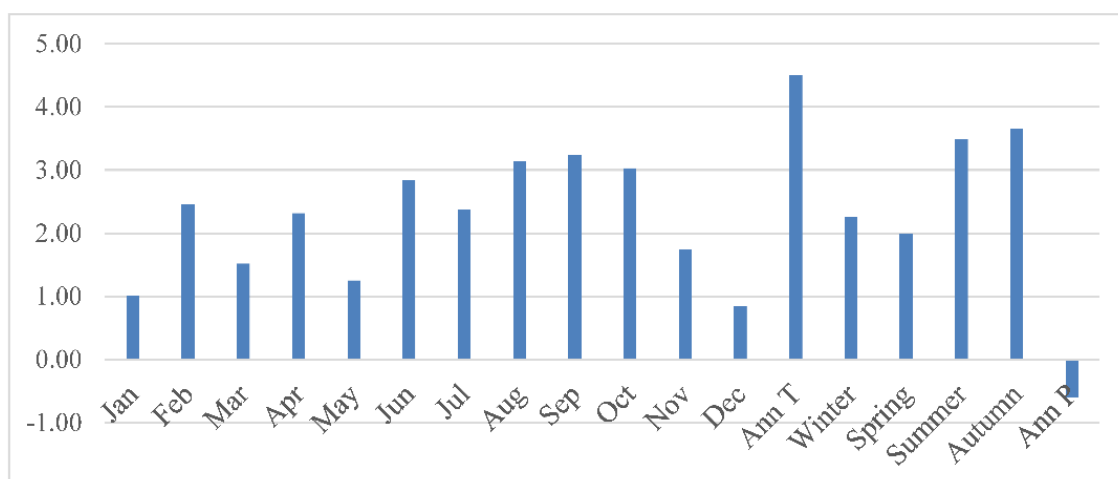


Figure 1 – Kendall test Z statistics for trends of monthly, annual and seasonal temperature and for annual precipitation of Taldykorgan station (Significant at  $P < 0.05$ ; critical value of  $Z < -1.96$  and  $> +1.96$  (two-sided))

The accumulative deviation test was applied to detect trends in air temperature at the Taldykorgan weather station. Test results showed that the temperature had step change point occurrence in 1977. Therefore, the data series was divided into two periods before and after 1977. Both periods included data series of more than 20 years, which is acceptable for the nonparametric Mann-Kendall test.

The rank-based nonparametric Mann-Kendall test is commonly used to assess the significance of monotonic trends in hydrometeorological time series (e.g., 8; 9; 10; 11; 12). In this test, the standard normal statistic  $Z$  is estimated and compared with the standard normal deviate  $Z_{\alpha/2}$ . The test statistic  $Z$  is not statistically significant if  $-Z_{\alpha/2} < Z < Z_{\alpha/2}$ . Correspondingly, this test shows a statistically significant trend if  $Z < -Z_{\alpha/2}$  or  $Z_{\alpha/2} < Z$  [9]. The confidence level fixed at  $\alpha = 0.05$  and critical  $z$  values for two-sided test are  $-1.96$  and  $+1.96$ . The standard normal statistic  $Z$  is estimated by the following formula as [8; 9].

$$Z_c = \begin{cases} \frac{S-1}{\sqrt{\text{Var}(S)}}, & S > 0 \\ 0, & S = 0 \\ \frac{S+1}{\sqrt{\text{Var}(S)}}, & S < 0 \end{cases} \quad (1)$$

Where

$$S = \sum_{i=1}^{n-1} \sum_{k=i+1}^n \text{sgn}(x_k - x_i) \quad (2)$$

$$\text{sgn}(\theta) = \begin{cases} 1, & \theta > 0 \\ 0, & \theta = 0 \\ -1, & \theta < 0 \end{cases} \quad (3)$$

$$\text{var}[S] = [n(n-1)(2n+5) - \sum_t t(t-1)(2t+5)]/18 \quad (4)$$

In which the  $x_k, x_j$  are the sequential data value,  $n$  is the length of the data set,  $t$  is the extent of any given tie. The magnitude of the trend is given as

$$\beta = \text{Median}\left(\frac{x_i - x_j}{i - j}\right), \forall j < i \quad (5)$$

In which  $1 < j < i < n$ . A positive value of  $\beta$  indicates an ‘upward trend’, and a negative value of  $\beta$  indicates a ‘downward trend’.

In addition, the relationship between hydrological and meteorological variables was explored by using Pearson’s correlation coefficient. The correlations calculated were tested for statistical validity at the 95% significance level.

**RESULTS. Changes in temperature and precipitation.** Annual mean temperature and total precipitation over the 47 year period of 1960–2007 were analyzed from the Taldykorgan weather station, situated close to the study area. The linear trend analysis of mean temperature indicated that the average rate of temperature increase was  $0.43 \text{ }^\circ\text{C} (10\text{a})^{-1}$ , while the summer (JJA) temperature rose  $0.28 \text{ }^\circ\text{C} (10\text{a})^{-1}$ . From 1960 to 2007, records at the same station displayed a slight decrease in annual precipitation. The results of Mann-Kendall test applied to annual and seasonal data series showed statistically significant trends during the period 1960–2007. Trend in Summer and Autumn seasons were higher than those in Winter and Spring. Monthly highest positive trend was for August, September and October months (Fig. 1).

**Trends of runoff.** Trends in monthly and annual runoff for the sub-basins of Karatal river were analysed. Discharge trend analysis was calculated for three periods: full-observed time and for periods before and after 1977 (step change year) for each hydrological station. Annual runoff of the almost all sub-basins showed increasing trend for annual, melting and frozen seasons for entire observed time (see Fig. 2 A). Increasing discharge trend was statistically significant in more glacierized catchments (Kora, Koku and Koktal). Trends of runoff for the melting season were similar to those in the annual cycle. However, runoff for the frozen season exhibited higher changes during entire observed time for all sub-basins, but the absolute changes remained small. Less glacierized (Chizhin) and non-glacierized sub-basins (Tekeli) show lower increasing trend in the melting season and annual time.

The discharge trend for the first period, before step change year (1977), showed slightly negative trend in annual and melting cycle. Positive trend was only for two stations, Chizhin and Tekeli. Neither positive nor negative trend were statistically significant during first period for annual and melting cycles. However, trend for cold months and frozen season was different. Discharge trend was increased in Koktal and decreased in Chizhin and both trends were statistically significant (Fig. 2 B).

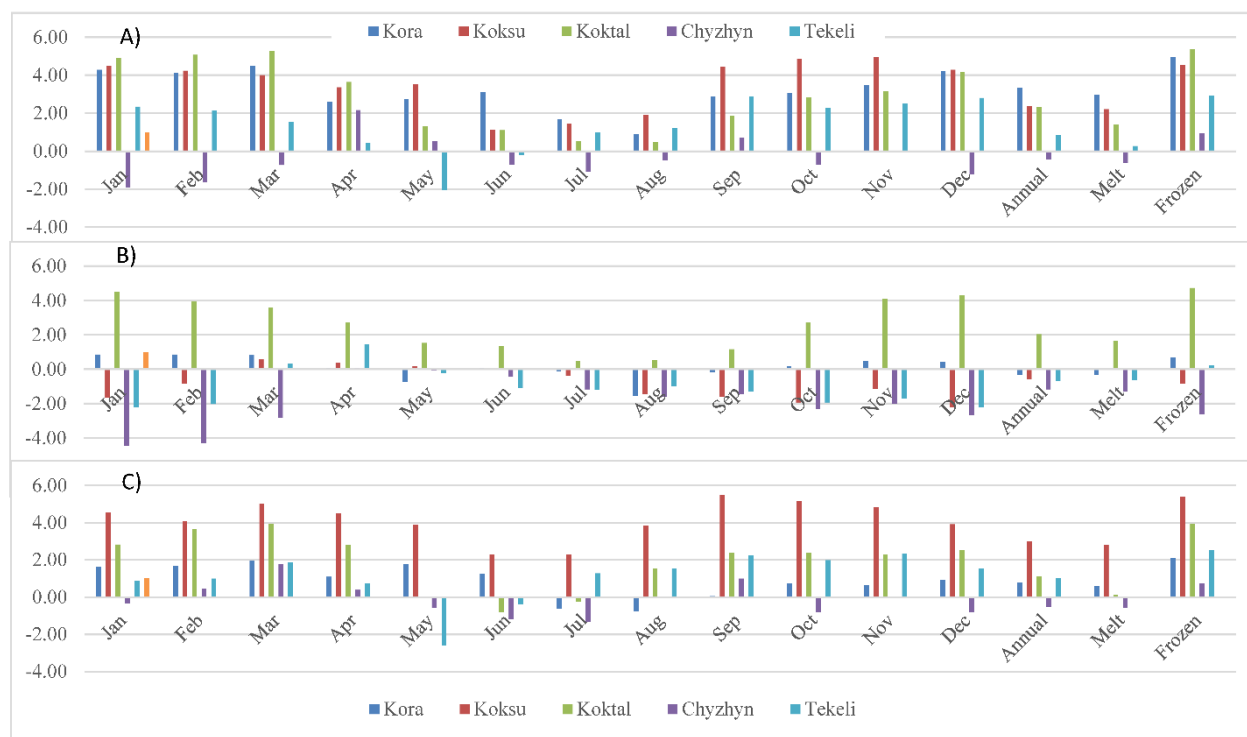


Figure 2 – Kendall test Z statistics for trends of monthly, annual and seasonal runoff for the Sub-basins of Karatal river. (A) for entire period, (B) and (C) for the periods before and after the 1977 (step change) year, respectively; (Significant at  $P < 0.05$ ; critical value of  $Z < -1.96$  and  $> +1.96$  (two-sided))

Runoff data for the second period (after 1977) indicated trends that are more positive. In the Koksus sub-basin, where the most glaciers were located ( $108.6 \text{ km}^2$  in 1956), trend analysis exhibited statistically significant increasing for melting, frozen and annual cycles. Three sub-basins, which were more glacierized, showed the slight increasing trend, while less glacierized had small decreasing trend during melting season (Fig.2 C).

Surprisingly, the runoff trend in the Kora sub-basin showed the decreasing trend for July, August and September months, in spite of relatively intensive glaciation (14%), and statistically significant increasing temperature in these months. Detailed analysis of year-to-year variation of runoff from this station showed the anomaly increasing discharge for the 1988-2000 period. Mean discharge for this months during 1988-2000 were two times higher than mean level during 1940-2014. This is the anomaly impact to the trend analysis for the second period. Thus, despite the fact that statistically significant positive trend during 1940-2014 for annual and melting season, trend for those was negative and positive during 1940-1977 and 1978-2014, respectively. This high runoff phenomenon during 1988-2000 might be technical mistakes during observation in the station or human factor impact. Neighbouring sub-basins showed the quite stable trend during this period.

**Discussion.** The Pearson’s correlation coefficient values (Table ) show that the runoff of the lower glacierized sub-basins, such as Tekeli, Chizhin and Koktal, has a strong and significant correlation with the precipitation. For the temperature, the correlations are much weaker and less significant, even for the comparatively the most glacierized Kora.

The Correlation Coefficients between the Annual Temperature Precipitation and the Runoff. Statistically significant trends are indicated in bold

	Kora	Koksus	Koktal	Chizhin	Tekeli
Temp.	-0.05	0.15	-0.17	-0.06	-0.15
Prec.	0.00	0.12	<b>0.27</b>	<b>0.33</b>	<b>0.47</b>
Significant at $P < 0.05$ .					



The absence of significant positive trends in summer season discharge can be explained by the low glacierized catchments (less than 15%) [13]. In addition, the evapotranspiration has negative effect on river runoff, but their role are limited [14]. Estimated changes in potential evaporation based on the empirical approach of [15, 16], which solely relies on temperature, suggest that evaporation changes are insignificant during the ablation season, mainly due to small changes in air temperature. However, due to increasing trend in spring and autumn months, trend showed statistically significant positive increasing for the melting and annual cycle in glacierized catchments. The effect on runoff changes was different in glacierized sub-basins of Karatal river. Relatively highest glacierized Kora (14% glaciation) showed highest positive trend, while smaller glacierized Koktal (5%) demonstrated smaller trend, with the statistically significant magnitude of 3.32 and 2.31, respectively. In the catchment with only 2% glaciation (Chizhin) trend was even negative with magnitude of -0.43. Apparently, the tipping point (peak water) for this catchment might be already passed [17, 18]. The tipping point is a phenomenon when runoff during warming climate will at first increase owing to higher temperatures and more meltwater, while this effect is gradually reduced when the glacier area begins to decline as a result of continued glacier mass loss [19-21]. Tekeli sub-basin without glacier showed slight increasing trend, but absolute water volume of rising trend was very small.

**Summary.** Based on runoff trend analysis, runoff in sub-catchments was controlled by temperature provoking the glacier melting stored for previous decades and centuries. River runoff demonstrated significant increasing trend during last half century at the expense of glaciers' melting intensification against a background of slight decreasing precipitation in the same time.

Even small glacierized areas (5% - 14% of total basin) had significant impact on the river runoff fluctuations in condition of global temperature increasing.

#### REFERENCES

- [1] Sorg A, Bolch T, Stoffel M, Solomina O, Beniston M (2012) Climate change impacts on glaciers and runoff in Tien Shan (Central Asia). *Nature Clim Change* 2:725-731
- [2] Cherkasov PA (2004) Calculation of the components of water-ice balance of inland glacier system, Almaty (in Russian)
- [3] Severskiy I.V., Vilesov E.N., Kokarev A.L., Shesterova I.N., Morozova V.I., Kogutenko L.V., Usmanova Z.S. (2012) Glaciological system of Balkhash-Alakol basin: state and current changes. *Probl Geogr Geoecol* 2:31-40 (in Russian)
- [4] Vilesov EN, Morozova VI, Severskiy IV (2013) Glaciation Dzhungar (Zhetysu) Alatau: past, present, future. Volkova, Almaty (in Russian)
- [5] Kudakov TK (2002) Modern ecological condition of Balkhash Lake basin. *Kaganat, Almaty* (in Russian)
- [6] Glacier Inventory of the USSR (1980) Central and Southern Kazakhstan, ed.II Balkhash basin, part 5. Karatal river basin (Leningrad: Hydrometeoizdat) (in Russian)
- [7] Kendall MG (1975) Rank Correlation Methods. Griffin, London
- [8] Hirsch RM, Slack JR (1984) A nonparametric trend test for seasonal data with serial dependence. *Water Resources Research* 20(6):727-732
- [9] Gan TY (1998) Hydroclimatic trends and possible climatic warming in the Canadian Prairies. *Water Resour Res* 34(11):3009-3015
- [10] Xu ZX, Liu ZF, Fu GB, Chen YN, Huang JX (2010) Trends of major hydroclimatic variables in the Tarim River basin during the past 50 years. *J Arid Environ* 74:256-267
- [11] Wang H, Chen Y, Li W, Deng H (2013) Runoff Responses to Climate Change in Arid Region of Northwestern China During 1960–2010. *Chin GeograSci* 23(3):286–300
- [12] Yao Z, Liu Z, Huang H, Liu G, Wu S (2014) Statistical estimation of the impacts of glaciers and climate change on river runoff in the headwaters of the Yangtze River. *Quater Intern* 336: 89-97
- [13] Kaldybayev A, Yaning Chen Y, EvgeniyVilesov E (2016) Glacier change in the Karatal river basin, Zhetysu (Dzhungar) Alatau, Kazakhstan. *Annals of Glaciology* 57(71). doi:10.3189/2016AoG71A005
- [14] Kriegel D, Mayer C, Hagg W, Vorogushyn S, Duethmann D, Gafurov A, Farinotti D (2013) Changes in glacierisation, climate and runoff in the second half of the 20th century in the Naryn basin, Central Asia. *Glob Planet Change* 110(A):51-61
- [15] Thornthwaite CW (1948) An approach toward a rational classification of climate. *Geogr Review* 38(1):55–94
- [16] Chen JY, Ohmura A (1990) On the Influence of Alpine Glaciers on Runoff. *IAHS Publ.* 193 (Symposium at Lausanne 1990- Hydrology in Mountainous Regions. I-Hydrological Measurements; the Water Cycle), 117–125
- [17] Birsan M, Molnar P, Burlando P, Pfaundler M (2005) Streamflow trends in Switzerland, *J Hydrol* 314:312–329
- [18] Rango A, Martinec J, Roberts R (2007) Relative importance of glacier contributions to streamflow in a changing climate. In: *Proceedings of the Second IASTED International Conference, August 20-22, 2007. Water ResourManag, Honolulu, Hawaii, USA, pp 203-207*
- [19] Ye BS, Ding YJ, Liu FJ, Liu C.H (2003) Responses of various-sized alpine glaciers and runoff to climatic change. *J Glaciol* 49(164):1-7

[20] Huss M (2011) Present and future contribution of glacier storage change to runoff from macroscale drainage basins in Europe. *Water Resour Res* doi:10.1029/2010WR010299

[21] Sorg A, Huss M, Rohrer M, Stoffel M (2014) The days of plenty might soon be over in glacierized Central Asian catchments. *Environ Res Lett*. doi:10.1088/1748-9326/9/10/104018

#### ЛИТЕРАТУРА

[1] Sorg A, Bolch T, Stoffel M, Solomina O, Beniston M (2012) Climate change impacts on glaciers and runoff in Tien Shan (Central Asia). *Nature Clim Change* 2:725-731

[2] Черкасов ПА (2004) Расчет составляющих водно-ледового баланса внутриконтинентальной ледниковой системы. Алматы

[3] Кокарев АЛ, Шестерова ИН, Морозова ВИ, Когутенко ЛВ, Усманова ЗС (2012) Ледниковые системы Балкаш-Алакольского бассейна: состояние, современные изменения. *Вопросы географии и геоэкологии* 2:31-40

[4] Северский ИВ, Вилесов ЕН, Морозова ВИ. (2006) Оледенение Джунгарского (Жетысу) Алатау: прошлое, настоящее, будущее. Алматы: КазНУ, 2013, 244 с

[5] Кудеков ТК, Современное экологическое состояние бассейна озера Балхаш. Алматы, 2006, 388с

[6] Каталог ледников СССР (1980) Центральный и Южный Казахстан, выпуск ШБалхашский бассейн, часть 5. Бассейн реки Каратал. Ленинград: Гидрометеозидат

[7] Kendall MG (1975) *Rank Correlation Methods*. Griffin, London

[8] Hirsch RM, Slack JR (1984) A nonparametric trend test for seasonal data with serial dependence. *Water Resources Research* 20(6):727-732

[9] Gan TY (1998) Hydroclimatic trends and possible climatic warming in the Canadian Prairies. *Water Resour Res* 34(11):3009-3015

[10] Xu ZX, Liu ZF, Fu GB, Chen YN, Huang JX (2010) Trends of major hydroclimatic variables in the Tarim River basin during the past 50 years. *J Arid Environ* 74:256-267

[11] Wang H, Chen Y, Li W, Deng H (2013) Runoff Responses to Climate Change in Arid Region of Northwestern China During 1960–2010. *Chin GeograSci* 23(3):286–300

[12] Yao Z, Liu Z, Huang H, Liu G, Wu S (2014) Statistical estimation of the impacts of glaciers and climate change on river runoff in the headwaters of the Yangtze River. *Quater Intern* 336: 89-97

[13] Kaldybayev A, Yaning Chen Y, Evgeniy Vilesov E (2016) Glacier change in the Karatal river basin, Zhetysu (Dzhungar) Alatau, Kazakhstan. *Annals of Glaciology* 57(71). doi:10.3189/2016AoG71A005

[14] Kriegel D, Mayer C, Hagg W, Vorogushyn S, Duethmann D, Gafurov A, Farinotti D (2013) Changes in glacierisation, climate and runoff in the second half of the 20th century in the Naryn basin, Central Asia. *Glob Planet Change* 110(A):51-61

[15] Thornthwaite CW (1948) An approach toward a rational classification of climate. *Geogr Review* 38(1):55–94

[16] Chen JY, Ohmura A (1990) On the Influence of Alpine Glaciers on Runoff. *IAHS Publ.* 193 (Symposium at Lausanne 1990- Hydrology in Mountainous Regions. I-Hydrological Measurements; the Water Cycle), 117–125

[17] Birsan M, Molnar P, Burlando P, Pfaundler M (2005) Streamflow trends in Switzerland, *J Hydrol* 314:312–329

[18] Rango A, Martinec J, Roberts R (2007) Relative importance of glacier contributions to streamflow in a changing climate. In: *Proceedings of the Second IASTED International Conference, August 20-22, 2007. Water Resour Manag, Honolulu, Hawaii, USA*, pp 203-207

[19] Ye BS, Ding YJ, Liu FJ, Liu C.H (2003) Responses of various-sized alpine glaciers and runoff to climatic change. *J Glaciol* 49(164):1-7

[20] Huss M (2011) Present and future contribution of glacier storage change to runoff from macroscale drainage basins in Europe. *Water Resour Res* doi:10.1029/2010WR010299

[21] Sorg A, Huss M, Rohrer M, Stoffel M (2014) The days of plenty might soon be over in glacierized Central Asian catchments. *Environ Res Lett*. doi:10.1088/1748-9326/9/10/104018

#### КЛИМАТТЫҢ ӨЗГЕРУІ МЕН МҰЗДЫҚТЫҢ ҚЫСҚАРУЫНЫҢ ӨЗЕН СУЫНА ӘСЕРІН СТАТИСТИКАЛЫҚ ӘДІС АРҚЫЛЫ ТАЛДАУ

Ж. Ш. Жантаев, А. А. Қалдыбаев, А. Ж. Бибосінов

«Ионосфера институты» ЕЖШС «Ғарыштық зерттеулер мен технологиялар ұлттық орталығы» АҚ,  
Алматы, Қазақстан

**Тірек сөздер:** өзен суы, климаттың өзгеруі, мұздықтардың қысқаруы, Қаратал өзенінің бассейні, Манн-Кендалл тесті.

**Аннотация.** 1960–2012 жылдар аралығындағы өзен суы, ауа температурасы мен жауын-шашын мәліметтеріне негізделі отырып Жетісу Алатауының батысындағы су ресурстарына климаттың өзгеруі мен мұздықтардың қысқаруының әсері зерттелді. Гидроклиматтың ұзақ уақыттық ауытқуының тренді Манн-Кендалл тесті арқылы қарастырылды. Климаттық мәліметтерді талдай отырып, зерттеліп отырған уақыт аралығында температураның едәуір жоғарылауы мен жауын-шашынның тұрақтылығы байқалды. Жылдық өзен суының көбеюі Қаратал өзенінің барлық мұзды салаларында анықталды. Өзен суының артуы температураның жалпы жылынуымен және мұздықтардың белсенді қысқаруымен байланысты.

---

**СТАТИСТИЧЕСКИЙ ПОДХОД К АНАЛИЗУ РЕЧНЫХ СТОКОВ  
В ОТВЕТ НА ИЗМЕНЕНИЕ КЛИМАТА И СОКРАЩЕНИЕ ЛЕДНИКОВ****Ж. Ш. Жантаев, А. А. Калдыбаев, А. Ж. Бибосинов**ДТОО «Институт ионосферы» АО «Национальный центр космических исследований и технологий»,  
Алматы, Казахстан**Ключевые слова:** речной сток, изменение климата, сокращение ледников, бассейн реки Каратал, Манн-Кендалл тест.**Аннотация.** Основываясь на данных речного стока, температуры воздуха и осадков с 1960 по 2012 год, были исследованы последствия изменения климата и сокращение ледников на водные ресурсы в западной части Жетысуского Алатау. Долгосрочные тренды гидроклиматических колебаний были изучены с помощью теста Манна-Кендалла. Анализируя климатические данные, мы обнаружили значительное повышение температуры и достаточно стабильных тенденций осадков в период исследования. Положительные тренды в годовом стоке были обнаружены почти во всех оледененных притоках реки Каратал. Повышение речного стока, скорее всего, связано с общей тенденцией повышения температуры и интенсивного таяния ледников Тянь-Шаня.*Поступила 03.11.2015 г.***NEWS****OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN  
PHYSICO-MATHEMATICAL SERIES**

ISSN 1991-346X

Volume 6, Number 304 (2015), 27 – 33

**GIS ANALYSIS OF MODERN GEODYNAMIC PROCESSES  
ON THE TERRITORY OF ALMATY****Zh. Sh. Zhantayev, A. Zh. Bibossynov, A. A. Kaldybayev,  
B. E. Junisbekova, S. M. Nurakynov**"Institute of Ionosphere", JSC "National Center of Space Research and Technology", Almaty, Kazakhstan.  
E-mail: nurakynov@gmail.com**Key words:** Geographic information system, remote sensing, synthetic aperture radar, displacement of Earth surface, cluster analysis.**Abstract.** The paper shows the efficiency of GIS and remote sensing data to identify and analyze modern geodynamics. For the territory of Almaty new data about the modern deformations of crust are received. On the territory of Almaty, we identified tectonic faults, which are the boundaries of crustal blocks and can move even during small earthquakes. Today, the problem of tectonic faults and their zones of influence on the territory of city become very important due to intensive development of the city with high-rise buildings. They are located irregularly within the territory of city, and such kind of distribution of buildings can make different strain on the ground, what can increase the possible seismic hazard. GIS analysis of modern geodynamic processes of the Earth's surface, buildings and structures are the crucial and important topic on the background of the rapid growing urban infrastructure.

**Publication Ethics and Publication Malpractice  
in the journals of the National Academy of Sciences of the Republic of Kazakhstan**

For information on Ethics in publishing and Ethical guidelines for journal publication see <http://www.elsevier.com/publishingethics> and <http://www.elsevier.com/journal-authors/ethics>.

Submission of an article to the National Academy of Sciences of the Republic of Kazakhstan implies that the described work has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see <http://www.elsevier.com/postingpolicy>), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. In particular, translations into English of papers already published in another language are not accepted.

No other forms of scientific misconduct are allowed, such as plagiarism, falsification, fraudulent data, incorrect interpretation of other works, incorrect citations, etc. The National Academy of Sciences of the Republic of Kazakhstan follows the Code of Conduct of the Committee on Publication Ethics (COPE), and follows the COPE Flowcharts for Resolving Cases of Suspected Misconduct ([http://publicationethics.org/files/u2/New\\_Code.pdf](http://publicationethics.org/files/u2/New_Code.pdf)). To verify originality, your article may be checked by the Cross Check originality detection service <http://www.elsevier.com/editors/plagdetect>.

The authors are obliged to participate in peer review process and be ready to provide corrections, clarifications, retractions and apologies when needed. All authors of a paper should have significantly contributed to the research.

The reviewers should provide objective judgments and should point out relevant published works which are not yet cited. Reviewed articles should be treated confidentially. The reviewers will be chosen in such a way that there is no conflict of interests with respect to the research, the authors and/or the research funders.

The editors have complete responsibility and authority to reject or accept a paper, and they will only accept a paper when reasonably certain. They will preserve anonymity of reviewers and promote publication of corrections, clarifications, retractions and apologies when needed. The acceptance of a paper automatically implies the copyright transfer to the National Academy of Sciences of the Republic of Kazakhstan.

The Editorial Board of the National Academy of Sciences of the Republic of Kazakhstan will monitor and safeguard publishing ethics.

Правила оформления статьи для публикации в журнале смотреть на сайте:

[www:nauka-nanrk.kz](http://www.nauka-nanrk.kz)

<http://www.physics-mathematics.kz>

Редактор *М. С. Ахметова*  
Верстка на компьютере *Д. Н. Калкабековой*

Подписано в печать 10.11.2015.  
Формат 60x881/8. Бумага офсетная. Печать – ризограф.  
10,2 п.л. Тираж 300. Заказ 6.