

IMPACT OF THE ZHAIYK RIVER ON CASPIAN SEA LEVEL

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The Caspian Sea is subject to multi-year, seasonal and short-period changes in level, especially due to the influence of anthropogenic and climatic factors. The conducted correlation and regression analysis of water level data of the river Zhaiyk river – Atyrau city and the Caspian Sea - Peshnoy Station showed a fairly high linear relationship ($r=0,93$, $R^2=0,87$) between the long-term average daily values of characteristics for 2006...2023. Rise in the Zhaiyk river - Atyrau city in the period of low water is directly reflected in the sea level rise at the sea Peshnoy Station, which was clearly seen in the current year. Thus, space images of Sentinel-2 L2A satellite for April-May 2024 recorded the inflow of river water into the Caspian Sea. The assessment of the relationship between the characteristics under consideration showed that high correlations are not the main factor in determining the impact of the Zhaiyk river flow of the sea, for its northeastern part, other factors of level change (storm winds, tidal events and others) should be considered in particular.

Keywords: level, correlation, regression, change, northeast section.

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INTRODUCTION

The coastal zones of seas and oceans are key to ecosystems and human activities, including for the 700 million people living in low-lying coastal and island regions below 10 meters above sea level (UN Chronicle, 2024; Sea Level Rise and Coastal Inundation, 2024). These areas are exposed to significant risks, including sea level fluctuations, storm surges and coastal erosion.

As the largest body of water in Kazakhstan, the Caspian Sea has a significant impact on the coastal regions of the country's west. The hydrometeorological regime of the Caspian Sea is influenced by a range of factors, including climate and human activity in the basin main rivers. The observed climatic changes in the sea area are characterised by an increase in mean annual and seasonal surface air temperatures, an increase in the frequency of extremely high daily temperatures, the duration of heat waves and changes in the precipitation regime. The rate of increase of average annual temperatures in the Caspian region ranges from 0,24 °C to 0,43 °C per 10 years, which confirms the high rate of climate change. The maximum warming is observed in the winter-spring period, which may negatively affect the hydrological regime of rivers such as the Zhaiyk, which is a key

source of water inflow to the Caspian Sea. During the conditionally natural period, the average annual flow was 327 m³/s, while in subsequent years this indicator decreased to 279 m³/s and 294 m³/s, respectively (Dolgikh, 2021). Until now, about 19 large reservoirs have been built, which regulate the flow of the main rivers of the Caspian Sea basin (Mitina, Malashenkov, 2013).

It's notable that Caspian Sea main sources of nutrition are the Volga, Terek, Zhaiyk (Ural), Kura and other rivers, as well as precipitation falling over the sea area (Caspian Sea, 2024). For the observed Kazakhstan part of the Caspian Sea, the Zhaiyk (Ural) is the main river flowing into it, which occur between April and June, and a decreasing trend in flow over recent decades.

The region has seen the number of days with temperatures above 30 °C increase by 1...8 days every 10 years, and days with minimum temperatures below 0 °C decrease by 2...5 days. Positive changes of annual precipitation are also observed at Peshnoy Station. (Ivkina et al., 2020; Davletgaliev, 2015). In recent years (2020 to 2023) an increase in rainfall has been recorded, especially in 2023 the rainfall totaled 214,6 mm. Before that it was: 2020...89,4 mm, 2021...77,1, 2022...166,2 mm. (Data from the website CliWare 2.1.02)

The northeastern part of the Caspian Sea is included in the state protected zone in the northern part of the Caspian Sea (Environmental Code of the Republic of Kazakhstan, 2021), which establishes a certain regime to preserve the ecological balance of the region.

The present study examines the impact of the Zhaiyk river (Ural) on the level of the Caspian Sea in its shallow northeastern part during the 2024 flood period.

MATERIALS AND METHODS

In this paper the dependence between the level of the Caspian Sea in its northeastern part near the Peshnoy Station and the water level on the Zhaiyk river– Atyrau city with the use of data from RSE «Kazhydromet» (Annual data on the regime and resources of surface waters of land...rivers Ural, 2023; Annual data on the regime of the Caspian Sea, 2022) based on correlation and regression analysis of data for the period 2006...2023.

The Pearson correlation coefficient is one of the main tools for assessing the linear relationship between river levels and sea levels. The correlation between the levels of the Zhaiyk river and the level of the Caspian Sea shows peculiarities depending on the season. Summer months are characterised by a lower correlation, which is explained by a decrease in river flow due to evaporation and lower precipitation.

Correlation analysis makes it possible to determine whether there is a relationship between the characteristics under consideration, as well as to identify the degree of association between them:

$$r_{xy} = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{(\sum(x_i - \bar{x})^2)(\sum(y_i - \bar{y})^2)}} \quad (1)$$

where, x_i is the value of the actual variable, \bar{x} - the mean or norm of the actual variable, y_i is the value of the variable being compared, (\bar{y}) – the mean or norm of the variable being compared;

Regression analysis was used to determine the nature of the relationship between the characteristics and to construct a regression relationship.

RESULTS AND DISCUSSION

Because of its shallowness, the north-eastern part of the sea is subject to frequent changes in sea level, both perennial and seasonal, as well as short-term changes under the influence of strong winds and tides.

During the period of systematic observations at the Peshnoy Station for 1929...2023, the sea level fluctuated around minus 27,67 m (BS – Baltic system), with a maximum of -26,04 m (BS) and a minimum of -28,86 m (BS) (Figure 1). The sea level data at Peshnoy Station were taken from the General Catalogue of the Caspian Sea Level available at the official site of CASPCOM (<http://www.caspcom.com/index.php?razd=sess&lang=1&sess=17&podsess=61>). Since 2006 the sea level at Peshnoy Station has been on a downward trend and by 2023 it has decreased by 1,67 m compared to 2006 to minus -28,72 m (BS).

Therefore, further calculations were made for the current period of sea level fall (2006...2023).

In turn, the intra-annual variation of sea level showed that over the multi-year period, the maximum is observed in May-June (39 % and 31 %, respectively) and the minimum in November-December (25 % and 19 %, respectively) (Fig. 2).

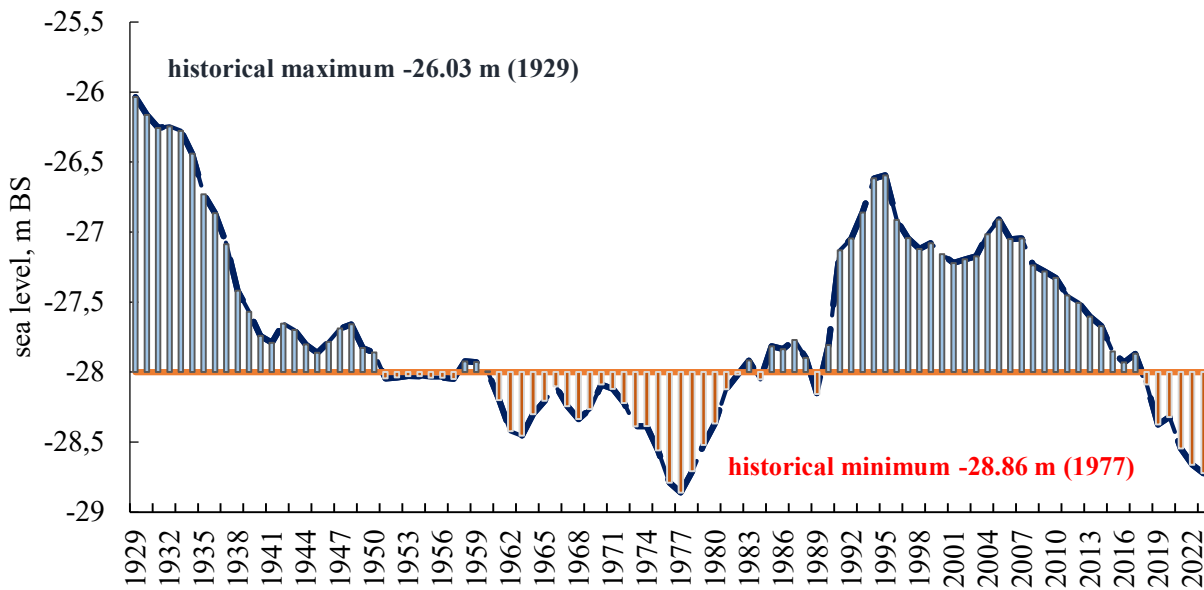


Fig. 1. Graph of changes in mean sea level at Peshnoy Station for 1929 to 2023

The location of the Peshnoy Station near the mouth of the Zhaiyk river (Ural) results in the fact that the hydrological characteristics of the sea in this area are affected by the river, which is noted by its influence on sea level, temperature regime and salinity values (Yeltay, Galayeva, 2020; Ivkina et al., 2020).

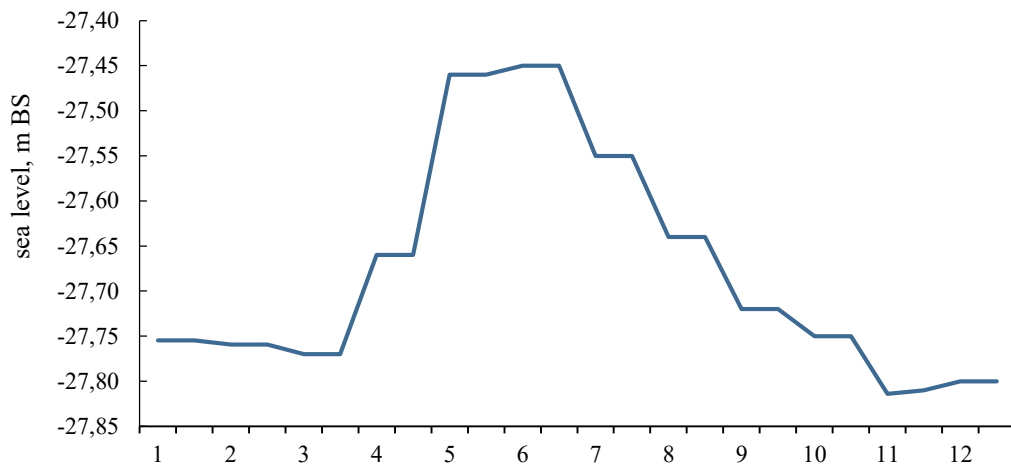


Fig. 2. Intra-annual variation of mean sea level at Peshnoy Station for the period 1929...2023

The correlation between the average daily values of the considered characteristics for April-June separately for each year showed that the closeness of the relationship between the data on average for the period 2006...2023 amounted to 0,54, in some years it ranged from 0,03 (2014) to 0,96 (2023). Looking at the correlation coefficients for individual months, they ranged from -0,11 to 0,92 in April, -0,55 to 0,79 in May, and 0,17 to 0,92 in June.

The conducted correlation analysis of average daily data for 2006...2023 showed that sea level variability near Peshnoy Station is not in direct dependence on the level of the Zhaiyk river

(Ural) near Atyrau city.

In this regard, for further assessment of the impact of river runoff on the sea, the data of multiyear (2006...2023) average daily values of the characteristics under consideration were applied. Analysis of long-term average water levels on the river and in the sea showed that the levels have a fairly high level of correlation, $r=0,93$. Regression analysis showed that the coefficient of determination is equal to 0,87 or 87 %, indicating that the data of water level in the river by 87 % explain the relationship between them and sea level data (Figure 3).

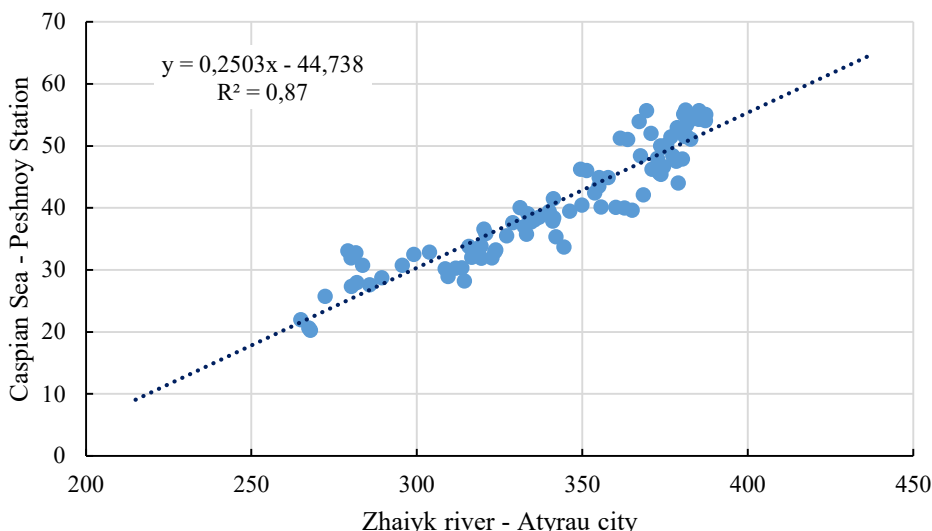


Fig. 3. Graph of relationship between the water level of the Zhaiyk river - Atyrau city and the Caspian Sea near Peshnoy Station

Figure 4 shows a graph of the course of multiyear average values of water levels and for individual years, which shows that the daily course of levels is generally similar. Thus, increase of the level on the Zhaiyk river near Atyrau city during flood period directly reflected on sea level

changes near Peshnoy Station. This highlights the significant impact of river runoff on water exchange and sea level changes in the north-eastern Caspian Sea. It is essential to consider this when assessing the water balance and forecasting hydrological processes in the region.

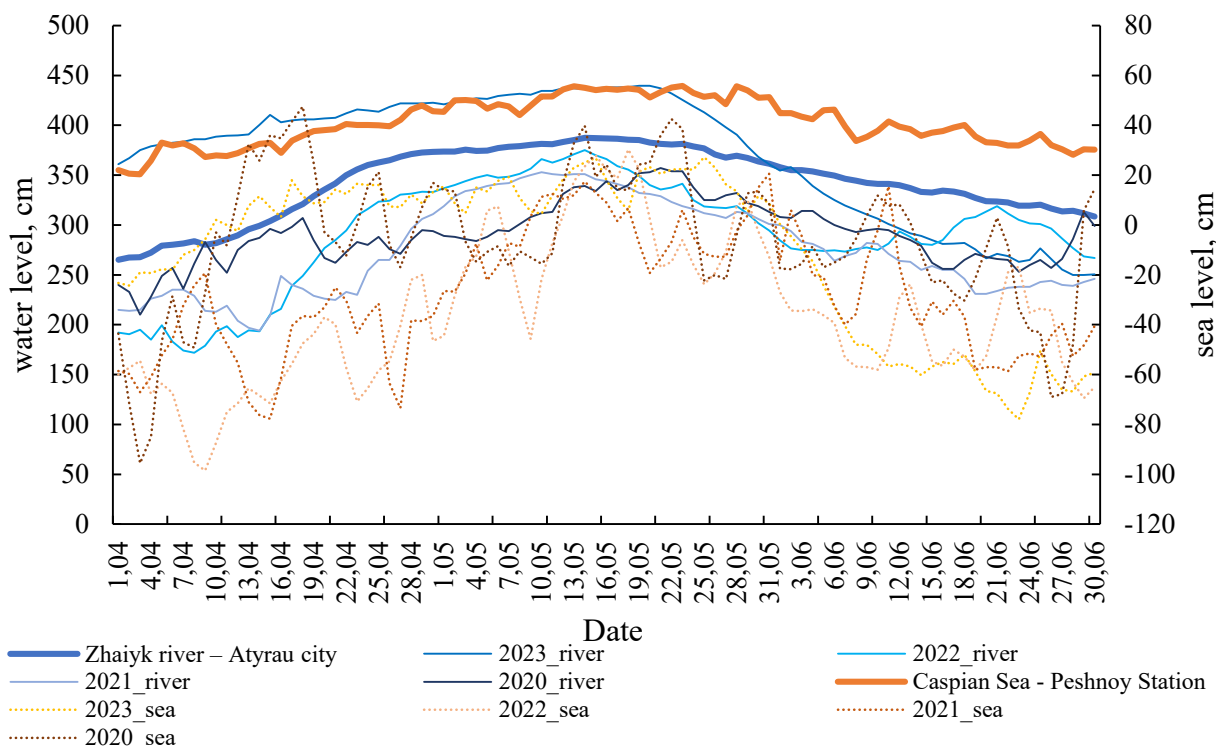


Fig. 4. Graph of level progress on the Zhaiyk river – Atyrau city and Caspian Sea - Peshnoy Station

In the current year, between 11 April and 10 May, a gradual increase in sea level was observed in the Peshnoy Station data, reaching a maximum of 125 cm (from -28,72 m (BS) to

-27,47 m (BS)). From 11 May to 27 June, there was no further increase in sea level, with the level in the Peshnoy area averaging around -27,29 m (BS) (or 71 cm). However, despite the observed sea

level rise in Peshnoy by 1.25 m, no significant sea level change was noted at other sea stations along the Kazakhstan coastline during this period. Sentinel-2 L2A satellite space images

for April-May 2024 (Figure 5) show the spread of river water on the northeastern part of the Caspian Sea (Copernicus browser, 2024).

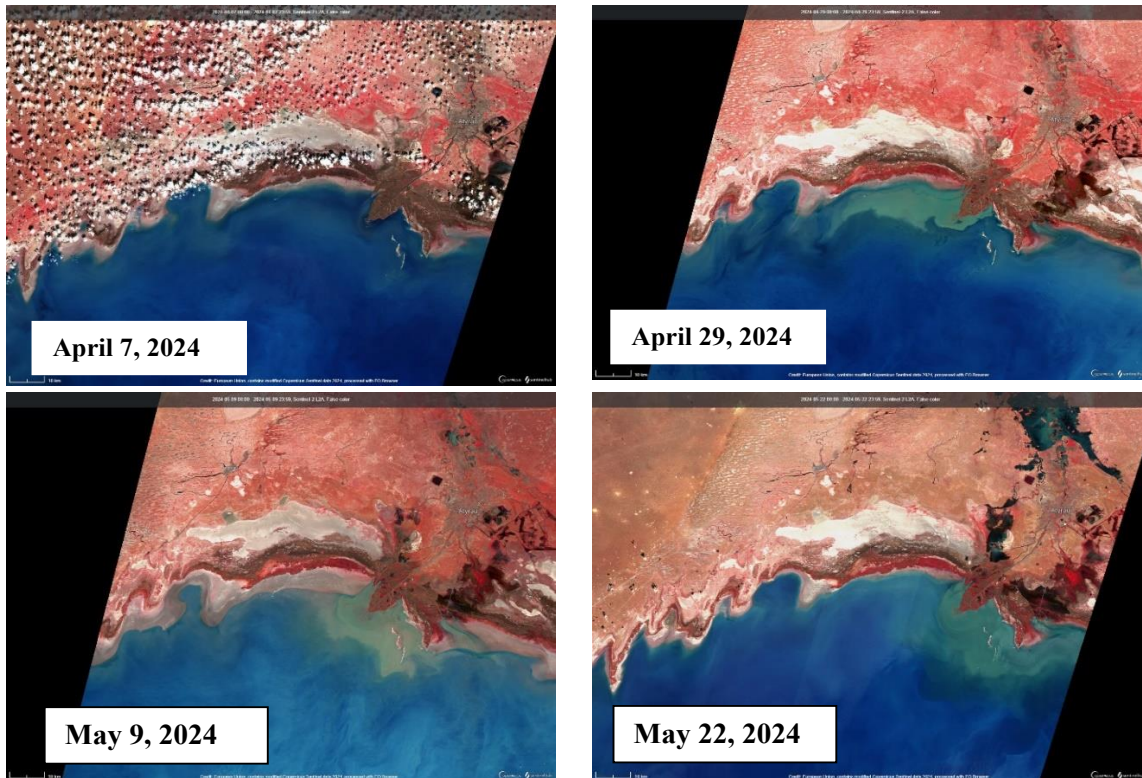


Fig. 5. Space images of the Caspian Sea water areas in April-May 2024 (Copernicus browser; 2024)

In April-May of the current year, the relationship between the water level on the river and Peshnoy Station have a very high correlation coefficient ($r=0,99$), according to regression

analysis, the data of the Zhaiyk river – Atyrau city on 97 % explain the relationship between them and sea level data (Figure 6).

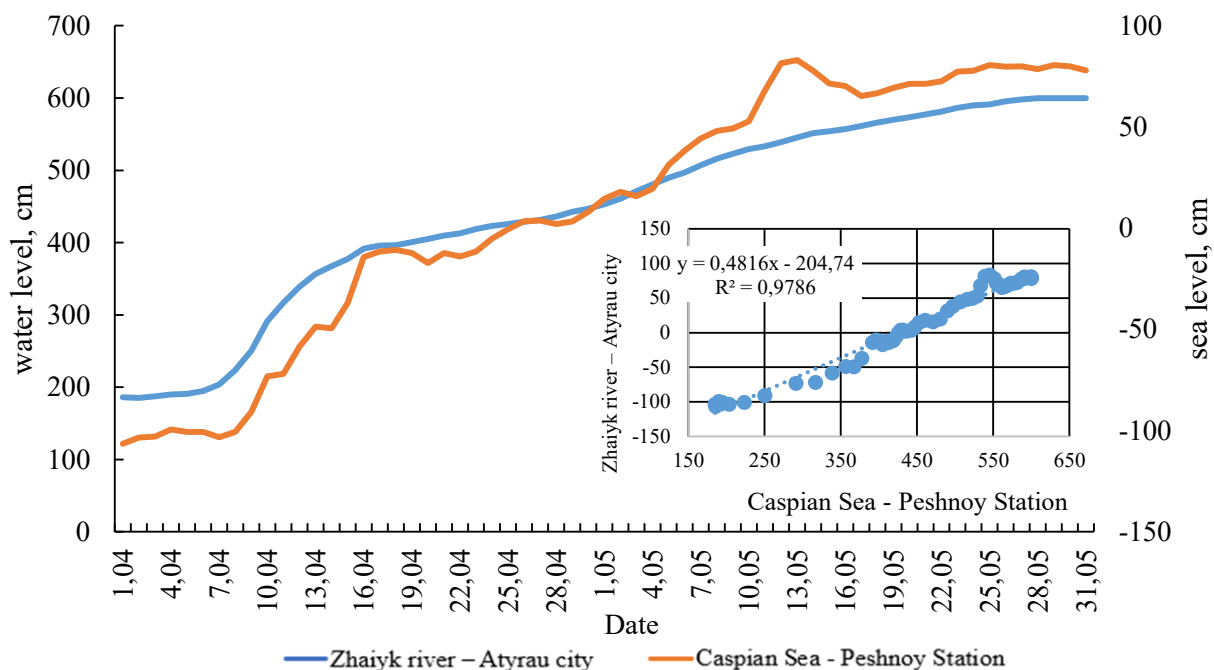


Fig. 6. Graph of level progress on the Zhaiyk river – Atyrau city and Caspian Sea - Peshnoy Station for April-May 2024

CONCLUSION

In conclusion, it should be noted that sea level changes in the Caspian Sea are the result of a complex interaction of natural and anthropogenic factors. Observations carried out during the 2024 flood period showed that the increase in water level in the Zhaiyk river caused a localized increase in sea level in the vicinity of the Peshnoy Station settlement.

Analyses of the relationship between water level data in the Zhaiyk river and sea level at Peshnoy Station settlement revealed a significant straight-line relationship with a high correlation coefficient based on multi-year averages ($r=0,93$). However, despite the detected correlation, the results of the regression analysis do not allow reliable forecasting of future sea level changes. This is due to the fact that in the area under consideration the sea level is subject to short-term and periodic fluctuations caused by wind and other local factors.

In the current year, the change of water level on the Zhaiyk River in the first decade of April by 131 cm and its further increase during the flood period resulted in sea level rise in the area of Peshnoy station by 125 cm (from 11 April to 10 May). It is also worth noting that rainfall during this period was 0,4 mm in April and 27,7 mm in May.

Sea level rise during the flood period may exacerbate the impact of surge events, which may lead to increased wave heights and other negative impacts on coastal areas. Thus, for a more accurate risk assessment and the development of effective measures to protect coastal zones, it is necessary to conduct continuous monitoring and comprehensive analysis of sea level in the area where the Zhaiyk river flows into the Caspian Sea, taking into account both natural fluctuations and the impact of anthropogenic factors.

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ЖАЙЫҚ ӨЗЕНІНІҢ КАСПИЙ ТЕҢІЗІ ДЕҢГЕЙІНЕ ӘСЕРІ

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Каспий теңізі деңгейінің ұзақ мерзімді, маусымдық және қысқа мерзімді өзгерістерге ұшырауы, әсіресе антропогендік және климаттық факторларға байланысты болады. 2006...2023 жылдарға арналған сипаттамаларға сәйкес Жайық өзені – Атырау қаласы мен Каспий теңізі – Пешной станциясы су деңгейі деректерінің корреляциялық және регрессиялық талдауы көпжылдық орташа тәуліктік мәндер арасында айтарлықтай жоғары сызықтық байланысты ($r=0,93$, $R^2=0,87$) көрсетті. Су тасқыны кезеңінде Жайық өзені – Атырау қаласы суының көтерілуі биылғы жылы Пешной теңіздік станциясындағы теңіз деңгейінің көтерілуінен айқын көрініс тапты. Осылайша, 2024 жылдың сәуір-мамыр айларына арналған Sentinel-2 L2A спутнигінің ғарыштық суреттері өзен суының Каспий теңізіне құйылуын тіркеді. Қарастырылып отырған сипаттамалар арасындағы байланысты бағалау Жайық өзені ағынының теңізге әсерін анықтауда жоғары корреляцияның негізгі фактор болып табылмайтынын көрсетті. Каспий теңізінің солтүстік-шығыс бөлігі үшін теңіз деңгейінің өзгеруіне басқа факторлардың әсерін (дауыл желдері, толқындық құбылыстар және т.б.) ерекше ескеру қажет.

Түйін сөздер: деңгей, корреляция, регрессия, өзгерістер, солтүстік-шығыс бөлігі.

ВЛИЯНИЕ РЕКИ ЖАЙЫК НА УРОВЕНЬ КАСПИЙСКОГО МОРЯ

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Каспийское море подвержено многолетним, сезонным и коротко- периодическим изменениям уровня, в особенности из за влияния антропогенных и климатических факторов. Проведенный корреляционный и регрессионный анализ данных уровня воды реки Жайык – г. Атырау и Каспийское море – станция Пешной показал достаточно высокую прямолинейную связь ($r=0,93$, $R^2=0,87$) между многолетними средними суточными значениями характеристик за 2006...2023 гг. Повышение на реке Жайык – г. Атырау в период половоля непосредственно отражается на повышений уровня моря у морской станции Пешной, что отчетливо было видно в текущем году. Так космические снимки спутника Sentinel-2 L2A за апрель-май 2024 года зафиксировали поступление речной воды в Каспийское море. Проведенная оценка связи между рассматриваемыми характеристиками показала, что высокие корреляционные связи не являются основным фактором определения влияния стока реки Жайык на море, для северо-восточной его части в особенности должны рассматриваться другие факторы изменения уровня (штормовые ветра, приливные явления и другие).

Ключевые слова: уровень, корреляция, регрессия, изменения, северо-восточная часть.

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