UDC 504.423+639.331.4 IRSTI 37.25.25; 37.25.03

ON THE POSSIBILITY OF USING REANALYSIS DATA TO ESTIMATE THE WATER TEMPERATURE OF THE CASPIAN SEA

A.Yeltay[1]*, D. Bekdair[2]

[1] RSE «Kazhydromet», Astana, Kazakhstan
[2] al-Farabi Kazakh National university, Almaty, Kazakhstan
E-mail: yeltay.aiz@gmail.com

Water temperature is one of the important hydrometeorological characteristics of large bodies of water, because of its influence on biological and chemical processes.
In this work, water temperature data from coastal observation points of Kazakhstan and remote sensing data of the Earth, such as satellite images, and reanalysis, were considered. In the long-term context, in the Kazakh sector of the Caspian Sea, the water temperature ranged from 10.8 ºC (Peshnoi) to 12.7 ºC (Kulaly Island). The effectiveness of the use of reanalysis data with the use of statistical criteria was evaluated. These quality criteria characterize the reliability of the results, and ERA5 realism data are effective and can be used for analysis, and research. All the databases under consideration showed that SST the average monthly minimum values are observed in January, and the maximum values are observed in the summer period. The change in water temperature over the years has a positive trend.

Key words: Caspian Sea, water temperature, reanalysis, dynamic

Accepted: 20.03.2023
DOI: 10.54668/2789-6323-2022-107-4-45-51

INTRODUCTION

The average global water temperature is rising (Climate change indicators, 2022).

The water temperature is one of the important characteristics of the state of the ecosystem of the Caspian Sea, where the Caspian seal and commercial fish species live, and influences physical, chemical, and other processes at sea (The Sea Project, 1996; Guseinov et. al, 2010).

An increase in the flow of rivers into the sea, as well as an increase in sea level, contribute to the establishment of a favorable temperature regime for biota (Guseinov et. al, 2010).

This work studies the water temperature or sea surface temperature (SST) of the Caspian Sea, the length of the coastline which is 5970 km, and an area of more than 386 thousand square kilometers, using Remote sensing data of the Earth, which allows observations to analyze the state of the entire sea.

The results of a number of authors have shown that for large bodies of water, the use of remote sensing data in research (space sniffing, reanalysis) gives fairly good results (Grankina et. al, 2019; Shevchenko et. al, 2022; Ivkina et.al, 2018; Myslenkov et. al, 2017).

In this regard, the study of changes in SST was carried out according to remote sensing data, since in the Kazakh sector under consideration, observations are carried out only at coastal stations.

The purpose of this work is to review the available databases on water temperature and assess the applicability of reanalysis data for analyzing changes in water temperature.

MATERIAL AND METHODS

The Caspian Sea is the world's largest inland body of water, located to the east of the Caucasus Mountains and to the west of the steppe of Central Asia (Caspian Sea, 2022). The average long-term values of SST in the Kazakh part of the Caspian Sea varied from 10.8 ºC (Peshnoi) to 12.7 ºC (Kulaly Island) based on the (CASPCOM, 2022) data of the marine stations: Peshnoi, Kulaly

Island, Fort Shevchenko, Aktau (Table 1). SST near the north and northeast parts of the sea is influenced by freshwater runoff from the Volga and Zhaiyk rivers.

Table 1

Water temperature specifications

Station	Control period	Long - term average, ºC	Maximum, ºC	Minimum, ºC
Peshnoi	1972…2020	10,8	35,6 (2000)	-1,7 (1993)
Kulaly Island	1961…2020	12,7	33,7 (1977)	-3,2 (2002)
Fort-Shevchenko	1961…2020	11,6	33,6 (2005)	-2,9 (1997)
Aktau	1977…2020	11,5	30,8 (1977)	-1,7 (1998)

In the distribution of SST within the year (Figure 1), the average monthly minimum values are observed in January, and the maximum values are observed in the summer period (Peshnoi, Kulaly Island, Fort-Shevchenko – July, Aktau – August). The lowest water temperature in winter was observed on the Kulaly Island (0.7 ºC), and the highest on Aktau (3.1 ºC). In the summer, the maximum temperature at the Kulaly Island station was 26.4 ºC.

Sea Surface Temperature datasets

Values of water temperature observed at coastal stations do not give a complete picture of their changes in the open water area; in this work, we assessed the possibility of using remote sensing data when studying water temperature.

The three different SST datasets were assessed in this study, like:

- Atlas of the World Ocean based on *observed data*. This is an archive of temperature, salinity, and hydrochemical indicators of water based on a database created from observations of coastal stations, ships, and floats. This paper analyzes data from the World Ocean Atlas from 1955 to 2017 (Boyer et. al, 2018; O'Carroll et. al, 2018; World Ocean Altas, 2022).

- *Satellites*. Surface water temperature data were analyzed from various satellite data provided by the NASA Ocean Biology Processing Group. The data are presented from 2002 to the present and are freely available.

- *Reanalysis* is dynamically smoothed and consistent data of a certain set of archival observations using a hydrodynamic model with a certain configuration. The Climate Data Warehouse (CDS) provides climate information on a global, continental, and regional scale. It contains various data such as satellite observations, field measurements, climate model projections, and seasonal forecasts (ERA5, 2022). The article focuses on the 1979…2021 ERA5 reanalysis data with the 0.25-degree resolution for the Caspian Sea (Anisimov et. al, 2015). The evaluation of the data was carried out according to the criteria of effectiveness, as:

- determination coefficient:

$$R^2 = \frac{[\Sigma(x_i-\bar{x})(y_i-\bar{y})]^2}{\Sigma(x_i-\bar{x})^2\Sigma(y_i-\bar{y})^2} \quad (1)$$

where, x – observed sea levels, y – sea levels according to remote sensing data.

- correlation coefficient:

$$r = \frac{\Sigma\Delta x * \Delta y}{\sqrt{\Sigma\Delta x^2 * \Sigma\Delta y^2}} \quad (2)$$

where, x are the observed sea level values, m, y - the sea level values according to remote sensing data, m, Δx and Δy are the detachments of the measured values from the average sea level value, m

- standard deviation:

$$\sigma = \sqrt{\frac{\Sigma(x_i-\overline{x})^2}{n}} \quad (3)$$

where, xi is the given value of the variable, x is the average value or norm, n is the number of values of the variable.

As a result of the analysis SST in the marine stations and reanalysis values for the observed years were similar, with high correlation coefficients (Peshnoi - 0.97, Kulaly Island - 0.95, Fort-Shevchenko - 0.96, Aktau - 0.91). The dynamic of SST was relatively synchronous in the observed and reanalysis data. The maximum difference was 2.7 ºC.

The results of comparing the two data show that, if necessary, the ERA5 reanalysis data can be used to analyze the change in the water temperature of the Caspian Sea (Figure 1).

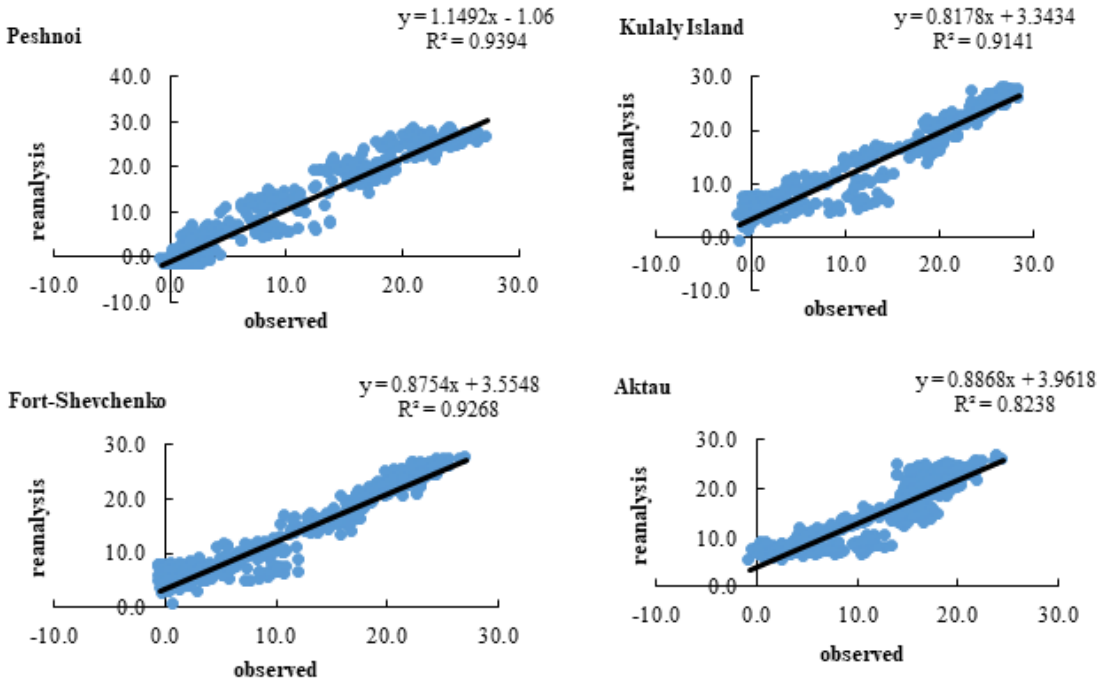

Fig. 1. 1979…2021 plots of the relationship between observed data and ERA5 reanalysis data.

Values of the coefficient of determination were from 0.82 (Aktau) to 0.94 (Peshnoi). The standard deviation was 2.9 ºC for Peshnoi, 3.2 ºC for Kulaly Island, 2.9 ºC for Fort-Shevchenko, and 3.8 ºC for Aktau.

These quality criteria characterize the reliability of the results, and ERA5 realism data are effective and can be used for analysis, and research.

RESEARCH RESULTS AND DISCUSSION

For the Caspian Sea, an analysis of changes in water temperature was carried out according to satellite and reanalysis data.

Data from 1995 to 2017 on maps compiled according to the World Ocean Atlas showed that the average ten-day statistical value of water temperature on the surface of the Caspian Sea was 18…24 ºC (Figure 2). The water temperature on the surface of the Caspian Sea in winter ranged from 4…12 ºC, in spring 10…22 ºC, in July-September 18…25 ºC, in October-December 5…16 ºC.

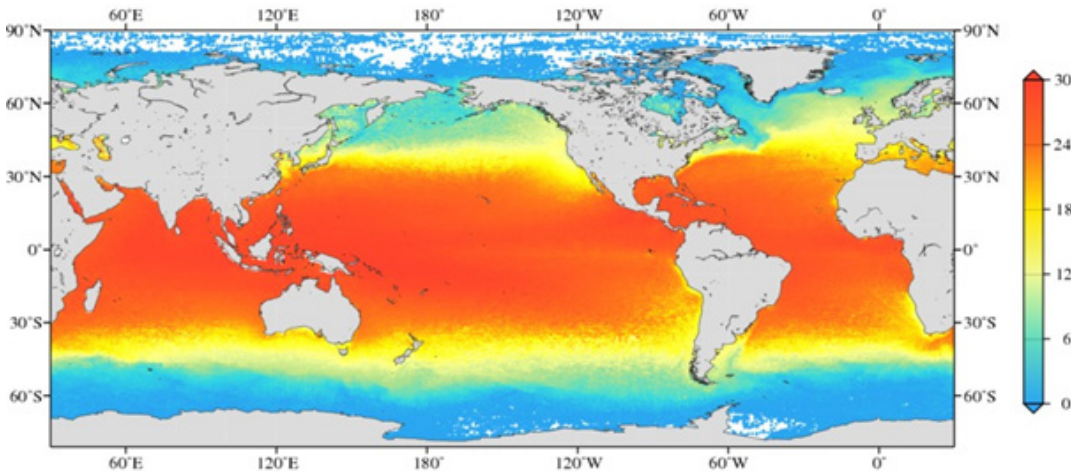

Fig. 2. Map of 1955…2017 average daily statistical value of water temperature.

In addition, in the work under consideration, studies were carried out on satellite data (MODIS-Aqua, MODIS-Terra, VIIRS-SNPP), provided by the NASA Ocean Biology Processing Group database from 2002 to the present (NASA, 2022). With the help of these satellites, it is possible to track seasonal changes in water temperature in the Caspian Sea

Analysis of images from the MODIS-Aqua satellite in 2002-2021 showed that the water temperature in summer ranges from 24ºC to 30ºC, in autumn from 12 to 18ºC, in winter from 0ºC to 10ºC, in spring from 16ºC to 22ºC (Figure 3).

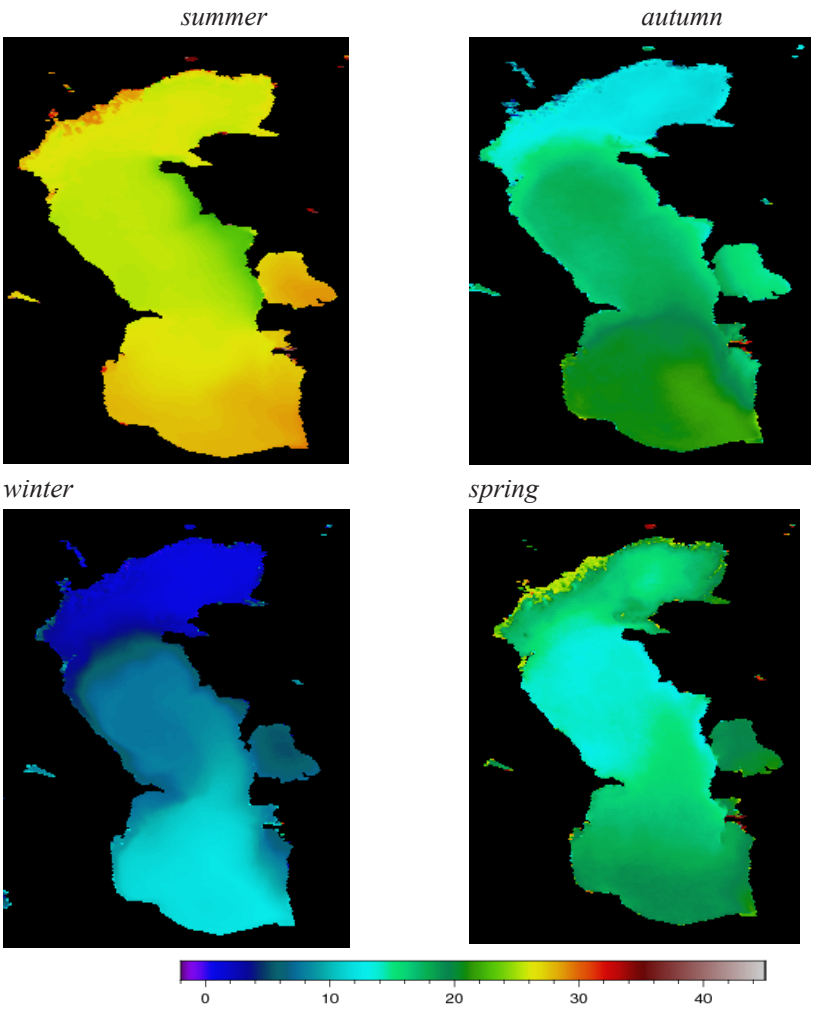

Fig. 3. Seasonal changes of the SST on the surface of the Caspian Sea in 2002...2021. According to the MODIS-Aqua satellite

According to the MODIS-Terra satellite, the water temperature in the Caspian Sea ranged from 23 to 27 ºC in summer, from 15 to 22 ºC in autumn, from 0 ºC to 9 ºC in winter, and from 14 ºC to 25 ºC in spring.

VIIRS-SNPP satellite shows that in 2002…2021 in summer, the water temperature ranged from 23-29ºC, in autumn - from 9ºC to 20ºC, in winter - from 1ºC to 11ºC, in spring - from 15 to 25ºC.

During the period under review (1979…2021), the average long-term SST from ERA5 data was 11,3 ºC in the Peshnoi, 13,7 ºC in Kulaly Island, 13,9 ºC in Fort-Shevchenko, and 14,1 ºC in Aktau. According to the reanalysis data, the maximum SST values were in summer (Peshnoi, Kulaly Island – 25,1 ºC, Fort-Shevchenko – 24,6 ºC, Aktau – 22,3 ºC), and the minimum in winter (Peshnoi -minus 0,5 ºC, Kulaly Island – 5 ºC, Fort-Shevchenko – 5,8 ºC, Aktau – 7,8 ºC).

In the intra-annual distribution, the analysis of reanalysis data showed identical results to the observed data, so SST within the year,

the average monthly minimum values are observed in January, and the maximum values are observed in the summer period (Peshnoi (26,4 ºC), Kulaly Island (26,4 ºC), Fort-Shevchenko (26,0 ºC) – July, Aktau (23,5 ºC) – August).

The dynamics of changes in SST showed a tendency to increase its value (Figure 4). The maximum of the average annual values of SST was in Peshnoi 12,8 ºC (2010), in Kulaly Island and Fort Shevchenko 14,8 ºC (2010) and 15,6 ºC in Aktau (2007).

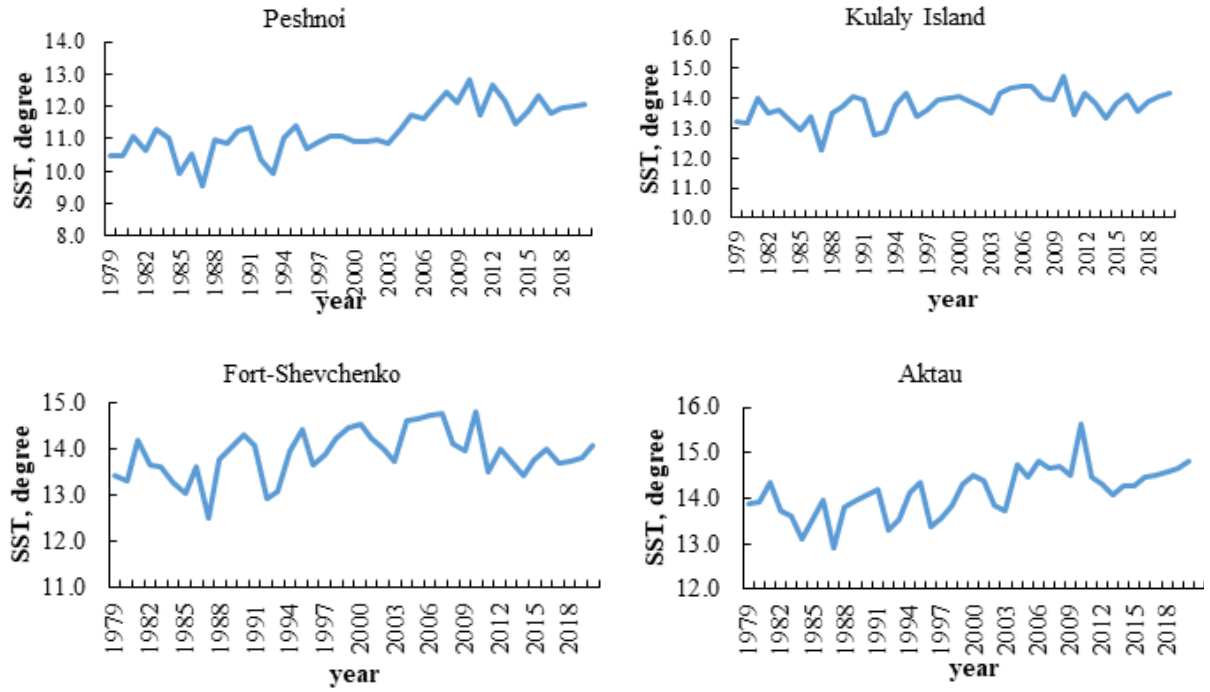

Fig.4. Graphs of the dynamics of the SST from ERA5 data.

CONCLUSION

An analysis of changes in water temperature during the year according to the data of the state control network (sea stations and stations: Peshnoi, Kulaly Island, Fort-Shevchenko, Aktau) showed that the water temperature in the northeastern part of the Kazakh part of the Caspian Sea is lower than in the middle part.

Various databases are used in the study of water temperature, for example, archives, maps, Atlases, and space images.

Using the Atlas of the World Ocean, an analysis of the average ten-day statistical values of sea surface water temperature for the period from 1995 to 2017 was carried out. Over the years, the surface water temperature of the Caspian Sea has been in the range of 18...24 ºC.

In general, the results of the data applicability assessment showed good coefficient values, as well as observation and reanalysis data, which are in good agreement with each other. The dynamic course of water temperature was relatively synchronous in the observed years and reanalysis data.

The maximum difference showed 2,7 ºC. The results of the study are consistent with a number of works on the temperature regime of the Caspian Sea (Ivkina et al., 2018; Electronic Atlas of the Caspian Sea, 2015).

REFERENCES

1. Caspian Sea [Electronic resources]. - https://www.britannica.com/place/Caspian-Sea.
2. CASPCOM [Electronic resources]. - http://www.caspcom.com/index.php?lang=1&proj=5.
3. O'Carroll AG, Armstrong EM, Beggs HM, Bouali M, Casey KS, Corlett GK, Dash P, Donlon CJ, Gentemann CL, Høyer JL, Ignatov A, Kabobah K, Kachi M, Kurihara Y, Karagali I, Maturi E, Merchant CJ, Marullo S, Minnett PJ, Pennybacker M, Ramakrishnan B, Ramsankaran R, Santoleri R, Sunder S, Saux Picart S, Vázquez-Cuervo J and Wimmer W. Observational Needs of Sea Surface Temperature. Frontiers in Marine Science 6:420. doi: 10.3389/fmars.2019.00420
4. Boyer Tim P, Garcia Hernan E, Locarnini Ricardo A, Zweng Melissa M, Mishonov

Alexey V, Reagan James R, Weathers Katharine A, Baranova Olga K, Seidov Dan, Smolyar Igor V. World Ocean Atlas 2018. NOAA National Centers for Environmental Information. Dataset URL: https://www.ncei.noaa.gov/archive/accession/NCEI-WOA18, date: 05.04.2022.
5. World Ocean Atlas [Electronic resources]. – NCEI. - https://www.ncei.noaa.gov/products/world-ocean-atlas.
6. ERA5 monthly averaged data on single level from 1979 to present [Electronic resources]. – Sea surface tempereature. https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels-monthly-means?tab=overview
7. Anisimov A.E., Iarovaia D.A, Barabanov V.S. Reanalysis of Atmospheric Circulation for the Black Sea-Caspian Region. Physical Oceanography, [Electronic resources] (4), pp. 13-25. doi:10.22449/1572-160X-2015-4-13-25
8. NASA's ocean color web. [Electronic resources]. – EARTH DATA. - https://oceancolor.gsfc.nasa.gov.
9. Unified state information system on the situation in the world ocean [Electronic resources] http://hmc.meteorf.ru/sea/casp/sst/sst_casp.html.
10. Climate Change Indicators: Sea surface temperature [Electronic resources] https://www.epa.gov/climate-indicators/climate-change-indicators-sea-surface-temperature#:~:text=From%201901%20through%202020%2C%20temperature,1880%20(see%20Figure%201
11. Huseynov K.M., Gasanova A.Sh. Characteristics of environmental factors of the water area of the middle part of the Caspian Sea in conditions of transgression of the sea // Izvestiya DGPU. Natural and exact sciences. 2010. №3. URL: https://cyberleninka.ru/article/n/harakteristika-sredovyh-faktorov-ak
12. Grankina T.B., Ibraev R.A., Mogilnikov P.A. Verification of ERA-Interim reanalysis data in the Azov-Black Sea basin // Marine Hydrophysical Journal. 2019. №3 (207). URL: https://cyberleninka.ru/article/n/verifikatsiya-dannyh-reanaliza-era-interim-v-azovo-chernomorskom-basseynevatorii-sredney-chasti-kaspiyskogo-morya-v-usloviyah-transgressii-morya.
13. Shevchenko G.V., Lozhkin D.M. Seasonal variations in the surface temperature of the sea of Okhotsk and surrounding regions from satellite data. Journal of Oceanological Research, 50 (1), 25–37, https://doi.org/10.29006/1564-2291.JOR-2022.50(1).3.
14. Ivkina N.I., Kaipov I.V., Bekmukhamedov B. E. et al. Estimation of temperature changes in the surface water layer of the Caspian Sea based on remote sensing data // Astrakhan Bulletin of Environmental Education. – 2018. – № 4(46). – С. 12-21. – EDN XVFHZZ.
15. Myslenkov S.A., Krechik V., Soloviev D. Water temperature analysis in the coastal zone of the Baltic Sea based on thermistor chain observations and satellite data // Proceedings of Hydrometcentre of Russia.
16. Electronic Atlas of the Caspian Sea [Electronic resources] http://www.geogr.msu.ru/casp/

О ВОЗМОЖНОСТИ ПРИМЕНЕНИЯ ДАННЫХ РЕАНАЛИЗА ДЛЯ ОЦЕНКИ ТЕМПЕРАТУРЫ ВОДЫ КАСПИЙСКОГО МОРЯ

А.Г. Елтай[1]*, Д. Бекдаир[2]

[1] РГП «Казгидромет», Астана, Казахстан
[2] КазНУ имени аль-Фараби, Алматы, Казахстан
E-mail: yeltay.aiz@gmail.com

Температура воды является одной из важных гидрометеорологических характеристик крупных водоемов из-за ее влияния на биологические и химические процессы. В этой работе были рассмотрены данные о температуре воды с прибрежных наблюдательных пунктов Казахстана и данные дистанционного зондирования Земли, такие как спутниковые снимки и реанализ.

В многолетнем разрезе в казахстанском секторе Каспийского моря температура воды колебалась от 10,8 °С (Пешной) до 12,7 ° С (Кулалы остров). Была оценена эффективность использования данных реанализа с использованием статистических критериев. Эти критерии качества характеризуют надежность результатов, а данные ERA5 эффективны и могут быть использованы для анализа и исследований. Все рассматриваемые базы данных показали, что среднемесячные минимальные значения температуры воды наблюдаются в январе, а максимальные значения наблюдаются в летний период. Изменение температуры воды имеет положительную тенденцию.

Ключевые слова: Каспийское море, температура воды, реанализ, динамика.

КАСПИЙ ТЕҢІЗІ СУЫНЫҢ ТЕМПЕРАТУРАСЫН БАҒАЛАУ ҮШІН РЕАНАЛИЗ ДЕРЕКТЕРІН ҚОЛДАНУ МҮМКІНДІГІ ТУРАЛЫ

А.Ғ. Елтай[1]*, Д. Бекдаир[2]

[1] «Қазгидромет» РМК, Астана, Қазақстан
[2] әл-Фараби атындағы ҚазақҰУ, Алматы, Қазақстан
E-mail: yeltay.aiz@gmail.com

Судың температурасы биологиялық және химиялық процестерге әсер етуіне байланысты ірі су объектілерінің маңызды гидрометеорологиялық сипаттамаларының бірі болып табылады. Бұл жұмыста Қазақстанның жағалаудағы бақылау пункттерінен судың температурасы туралы деректер және спутниктік суреттер мен реанализ сияқты Жерді қашықтықтан зондтау деректері қаралды. Көпжылдық бөліністе Каспий теңізінің қазақстандық секторында судың температурасы 10,8 °С-тан (Пешной) 12,7 ° С-қа (Құлалы арал) дейін ауытқиды. Статистикалық критерийлерді қолдана отырып, реанализ деректерін пайдалану тиімділігі бағаланды. Бұл сапа критерийлері нәтижелердің сенімділігін сипаттайды және ERA 5 деректері тиімді және талдау мен зерттеу үшін пайдаланылуы мүмкін. Қарастырылып отырған барлық мәліметтер базасы су температурасының орташа айлық минималды мәндері қаңтарда, ал максималды мәндер жаз мезгілінде байқалатынын көрсетті. Су температурасының өзгеруі оң үрдіске ие.

Түйін сөздер: Каспий теңізі, су температурасы, реанализ, динамика.