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Analysis of the sea surface temperature (SST) of the Caspian Sea from NOAA Satellites

Ismayil Zeynalov [*1], **Rena Akhmedova** [1], **Aybeniz Akhmedova** [1] **Almaz Rustamova** [1]

[1]*Institute of Geography, Caspian Sea Department, Baku, Azerbaijan*

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Abstract

The sea surface temperature (SST) of the Caspian Sea as a whole is determined by air temperature, depth, that is, heat reserve, wind characteristics (mixing) and advection. In different regions of this continental sea, in addition to the connection with air temperature common to all regions, their own factors dominate. For the Northern Caspian, this is primarily the influence of river runoff - warm continental runoff in spring and cool in autumn. In the Middle Caspian, deep-water rises near the eastern and western shores, reaching temperature contrasts of up to 15°C near the eastern shore. In the South Caspian, this is winter wind mixing and advection of waters from the Middle Caspian. In the daytime, in the spring-summer months, the heating of the sea manifests itself everywhere in the form of patches of warm water with temperature contrasts of more than 3°C - calm zones. In shallow water in the spring and autumn months, zones of heating and cooling are clearly visible, respectively, and the rate of heating and cooling is the higher, the shallower the depth of the sea, that is, the lower its heat reserve. The paper analyzes the available modern methods and means for determining the surface water temperature of the Caspian Sea. For their detection, data obtained by NOAA satellites and the AVHRR Pathfinder instrument (high-resolution radiometer) installed on them are used. And the main regularities in the atmosphere-sea system are revealed according to the average annual values of their changes over a long period of time.

1. Introduction

Information about the temporal variability of the surface temperature is required to study biological communities, ice regime, evaporation amount, heat balance, climate conditions of the adjacent sea area etc. The temperature change during the month, depending on season and meteorological conditions, in different areas of the sea goes in different ways. This work considers the temporal structures of the surface temperature. This makes it possible to compile maps of temperature fields both on the basis of individual contact measurements, and from satellite remote sensing data (Zeynalov and Makhmudova, 2021).

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The main systematized data of the ground hydrometeorological network stations and satellite supervision for the whole of globe can be received by using the server network of the USA National Ocean and Atmosphere Administration (NOAA). There is a separate entity of NOAA Satellites and Information with the body of the National Environmental Satellite, Data and Information Service (NESDIS). Within the framework of the NESDIS is functioning the Office of Satellite Data Processing and Distribution (OSDPD) for processing and distribution of satellite data which provides processing, systematization and supply to users in the USA and other countries data and information from the environmental satellites. The final goal of user`s maintenance is reaching by appropriate information production over the following three institutions: Satellite Service Division

* **Corresponding Author**

*(ismayil_zeynalov@outlook.com) ORCID ID 0000-0001-9391-583X
(rena.ahmedova.67@mail.ru) ORCID ID xxxx-xxxx-xxxx-xxxx
(aybenizahmedovageoph@gmail.com) ORCID ID xxxx-xxxx-xxxx-xxxx
(almaz rustamova 2@gmail.com) ORCID ID xxxx-xxxx-xxxx-xxxx

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(SSD); Information Processing Division (IPD): Direct Services Division (DSD).

There are number of other institutions for maintenance of the initial data for monitoring of the environment. For the considered purposes in the paper has been used the data from the IPD divisions of the Satellite Active Archive (SAA) through the Internet network. In the network is presented an opportunity of selection of such information which refers to Advanced Very High-Resolution Radiometer (AVHRR); Pathfinder – specialized software. Information production of the AVHRRPF (sometimes calls as PATMOS) with a free of access represents of the number of USA satellites NOAA-7-9 – and 14.

Within the framework of the PATMOS- A1 statistical characteristics have been calculated using the indicated above satellites for intensive outgoing radiation in all five channels of visible area of the spectrum, two channels as called "atmosphere transparency windows" for 10-12 micrometers and near infrared area for elimination of impact of atmospheric cloudless and cloudy conditions. Cloudy cover statistical characteristics have been calculated where condition describes by a huge of parameters.

Based on the PATMOS – A2 version statistical characteristics of the atmospheric aerosol optical thickness above oceans as well as values of the absorbed solar (short wavelength) radiation and thermal (long wavelength) radiation have been calculated which define radiation balance on the top of an atmosphere. In the climate and climate change investigations usually use a monthly average value of appropriate characteristics.

Below presents some of data analysis results off the PATMOS- A2 information production for the term of 1982-2000 in two allocated areas of Near - Caspian region (from 38^0 up to 42^0 north longitude from 44^0 to 52^0 east latitude; and from 34^0 up to 50^0 north longitude, from 44^0 up to 56^0 east latitude) incorporation with data of a ground measuring network based on characteristics, as monthly average values of air temperature, atmospheric pressure and average speed of a wind at the surface level. The first of selected areas approximately covers the territory of Azerbaijan and second - wider area of territory of Russia, Azerbaijan, Georgia, Iran, Turkmenistan, and Kazakhstan. The specified data of a ground network are accessible through the Internet network and other information center of the USA national climate data center (NCDC).

It can be considered some of examples of interpretation to be received information production for the purposes of investigation of climate variability of selected two foregoing mention Near Caspian region for the last 20 years (Sefer et al. 2009).

2. Method

The paper analyzes the changes in the values of sea surface temperature (SST) for individual sections of the Caspian Sea, taking into account various manifestations of an anthropogenic nature. The surface temperature of the waters of the Caspian Sea as a whole is determined by air temperature, heat storage, wind characteristics (mixing) and advection. In different regions of this continental sea, in addition to the connection with air temperature common to all regions, some of their own factors also dominate.

For the Northern Caspian, this is primarily the influence of river runoff - warm continental runoff in spring and cool in autumn. In the middle of the Caspian Sea, the rise of deep waters near the eastern and western shores reaches temperature contrasts of up to 15^0C near the eastern shore. In the South Caspian, this is winter wind mixing and advection of waters from the Middle Caspian. In the daytime in the spring-summer months, the heating of the sea manifests itself everywhere in the form of patches of warm water with temperature contrasts of more than 3^0C - a calm zone. In shallow water in the spring and autumn months, zones of heating and cooling are clearly visible, respectively, and the rate of heating and cooling is the higher, the shallower the depth of the sea, that is, the lower its heat reserve. 19 The work carried out by the author confirmed the correctness of the proposed methodological approach and the basic assumptions for organizing experimental satellite monitoring of sea surface temperature fields: - the use of an algorithm for taking into account the distorting influence of the atmosphere makes it possible to reduce both geographical due to shallow water and meteorological due to taking into account the distorting influence of aerosol formations, limitations in interpretation of satellite spectrum-zonal information; - the choice of satellite NOAA as a satellite platform for operational background monitoring of the sea surface and TERRA, ESA as platforms for episodic surveys under existing conditions is the only possible one in case of extreme situations (Mekhtiyev M.G., 2022). Both geographical due to shallow water, and meteorological due to taking into account the distorting influence of aerosol formations, limitations in deciphering satellite spectral-zonal information; - the choice of satellite NOAA as a satellite platform for operational background monitoring of the sea surface and TERRA, ESA as platforms for episodic surveys under existing conditions is the only possible one in case of extreme situations (Mekhtiyev, 2022). both geographical due to shallow water, and meteorological due to taking into account the distorting influence of aerosol formations, limitations in deciphering satellite spectral-zonal information; - the choice of satellite NOAA as a satellite platform for operational background monitoring of the sea surface and TERRA, ESA as platforms for episodic surveys under existing conditions is the only possible one in case of extreme situations (Mekhtiyev, 2022).

The change in temperature during the month, depending on the time of year and meteorological conditions, occurs differently in different areas of the sea. In this paper, the time structures of the surface temperature are considered. Knowledge of such a structure makes it possible to construct maps of the temperature field both on the basis of individual contact and satellite remote measurements (Mekhtiyev, 2022).

For the selected research region, Figure 1 shows the values of the water surface temperature for the selected 14 years of continuous observations (from January 2001 to December 2015). The left side of Fig. 1 shows the corresponding average annual values (averaged over 12

months) for each year of the observations under consideration. One can see a fairly smooth course of monthly averages for the selected region with maxima in 2002, 2005, 2013. The average annual values of the corresponding values vary approximately from 14.2^{0}C to 15.8^{0}C. The presence of such smooth curves for monthly averages reflects the time course of the temperature of the "earth's surface-atmosphere" system over a given region. Much more complex is the behavior of the average annual values of the studied quantities for each year out of the selected 14 years of observations. One can note an almost systematic deviation in the average annual values of the water surface temperature for the selected region. For example, according to the curve in Fig. 1 in 2002, these values were 15^{0}C and 15.06^{0}C for the selected "square" of the territory of Azerbaijan and the entire Caspian region, respectively; in 2001 - 14.5^{0}C and 15.2^{0}C; in 2004 - 15.3^{0}C and 13.4^{0}C in 2014 (the minimum values for the entire observation period under consideration); in 2008 - 15.4^{0}C and 15.9^{0}C (maximum values for the entire period under review). The curve in Fig. 1 does not show such significant discrepancies for the corresponding value, nevertheless demonstrating a clear similarity in the extreme events of 2003, 2010, 2015, and other years of observations. These discrepancies can probably be explained by the more complex nature of the impact of climate systems on the final values of the quantity under study. Other characteristic explanations for these discrepancies are also possible. From the analysis of the data, it can be seen that 2007 and 2013 are extreme in terms of the variability of the average annual temperature observed from satellites.

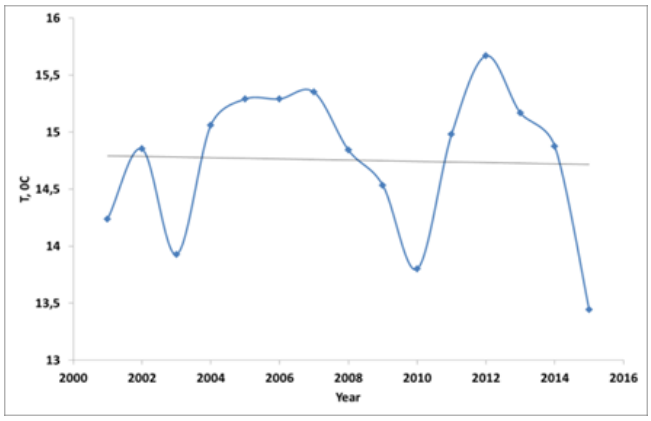

Figure 1. Data of water surface temperatures in the Caspian Sea from satellites of the NOAA series with a resolution of 50 km

Table 1. Average monthly values of SST for the Caspian Sea

Year	January	February	March	April	May	June	July	August	September	October	November	December
2001	7.87	4.03	6.99	9.47	16.17	18.20	24.91	24.91	21.15	15.55	12.71	8.90
2002	7.52	6.28	7.91	10.22	15.55	15.55	25.82	26.38	22.69	18.37	13.21	8.73
2003	6.86	5.58	5.11	7.11	14.80	16.70	24.24	26.30	21.64	17.50	12.40	8.87
2004	7.90	7.59	8.62	10.13	15.59	19.43	25.36	26.35	22.14	15.73	13.52	8.38
2005	7.43	5.30	6.09	10.21	16.91	20.08	26.03	26.01	24.13	17.44	13.45	10.41
2006	6.97	5.74	7.03	10.39	15.54	23.94	25.79	26.49	23.22	17.74	12.57	8.08
2007	7.36	6.33	6.99	8.96	16.12	22.62	26.17	26.74	23.93	17.34	12.82	8.82
2008	5.38	5.87	6.28	10.85	15.95	19.65	25.25	26.24	21.93	17.40	13.60	9.71
2009	6.06	5.41	6.89	8.89	15.33	20.16	25.55	24.54	22.08	17.84	12.48	9.17
2010	8.02	4.96	5.89	9.72	15.76	7.26	26.74	23.00	22.42	16.89	13.19	11.75
2011	8.22	6.54	5.66	9.26	16.43	23.56	26.04	26.27	22.12	16.39	11.37	7.90
2012	6.31	5.71	5.66	10.96	17.68	24.14	26.45	24.61	22.76	19.21	14.30	10.24
2013	7.00	5.95	7.15	10.85	16.33	22.55	26.26	25.85	21.75	16.28	13.35	8.69
2014	7.45	5.32	6.38	9.98	16.91	22.03	25.94	26.29	22.13	16.31	11.28	8.48
2015	6.96	5.46	6.65	9.67	16.09	22.28	7.71	24.95	24.41	16.49	12.12	8.51
Total	7.15	5.74	6.62	9.78	16.08	19.88	24.55	25.66	22.57	17.10	12.82	9.11

Which characterize the thermal features of the Caspian Sea observed from satellites for some model representations. The fact is that during a separate day it is possible to receive information on the same territory from several orbits of NOAA satellites. The corresponding territories can be covered during separate revolutions by clouds or be free from it. When presenting the final information product in the form of average monthly values, some of the corresponding scenes are inevitably "burdened" by the presence of cloud cover, while the other part may not contain clouds. It can be seen that the average annual values of the water surface temperature with a cloudless sky for individual years differ little from the similar curves in Fig. 1. The maximum of these deviations is again noticeable for the territory of Azerbaijan (absolute value is about 14.9^{0}C) followed by a fairly even course of the corresponding values of about 14.9^{0}C for the rest of the observation years. Even more unexpected is the appearance of the maximum of these deviations for the entire Caspian region (its absolute value reaches 15.8^{0}C) with a subsequent fairly smooth course near 15^{0}C for the rest of the observation years. It is possible that these incomprehensible things are related to the small amount of sample data in the territory under consideration. The data are similar to the data in Fig. 1, but characterize the values of the absorbed solar radiation flux by the "earth's surface-atmosphere" system. Again, one can note a fairly monotonous course of the annual values illustrated in Figure 1 at the top of the values for the selected region with maxima in 2007-2013 (about 15.3 - 15,5^{0}C) in 2003-2015 year.

These data characterize the thermal features of the Caspian Sea observed from satellites for some model representations. The fact is that during a separate day it is possible to receive information on the same territory from several orbits of NOAA satellites (in reality, up to four orbits from two simultaneously functioning

satellites). The corresponding territories can be covered during separate revolutions by clouds or be free from it. When presenting the final information product in the form of average monthly values, some of the corresponding scenes are inevitably "burdened" by the presence of cloud cover, and the other part does not contain clouds (Mekhtiyev, 2022). The analysis of the available archives of satellite observation data of the Caspian Sea showed the characteristic features of the interannual values of the corresponding value for 14 years of observations (2001 - 2015). The results obtained showed statistical patterns in the behavior of the studied quantity, but also introduced uncertainties into some results of the interpretation of the available data. These are the first results of such studies of the total set of parameters characterizing the state and variability of the biosphere and climate of the selected region. The basis for further research in this direction should be the study of the criteria for the statistical significance of the results obtained (Ismailov, 2023).

3. Conclusion

In the work, an analysis was carried out on the basis of the available SST values of the Caspian Sea in order to develop a further methodology for collecting and analyzing satellite data.

The data obtained from the NOAA series satellites improve the ability to consider the re-analysis of the average annual values of the characteristics of the water surface temperature intensities.

These studies further consider the atmosphere-sea system, which is necessary in solving the problems associated with the environmental problems of the Caspian Sea.

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