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Original article

Spatial Features and Seasonal Variability of Suspended Matter Distribution in the Sea of Azov Based on Satellite Measurements

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Abstract
Purpose. The purpose of the work is to study spatial and seasonal variability of the total suspended matter concentration in the Sea of Azov over a long-term period using optical satellite data, and to assess its relationship with the intensity and duration of wind impact.
Methods and Results. An array of more than 3000 MODIS, Landsat-8 and Sentinel-2 satellite images for 2003–2024 was analyzed. The average suspended matter concentrations were mapped and the obtained fields were compared with the types of bottom sediments, bottom relief, and hydrometeorological conditions. It was established that during wind-wave roiling, significant optical inhomogeneities were recorded in the suspended matter field, conditioned, probably, by the different granulometric composition of bottom sediments, as well as by the features of bottom relief. It was shown that the maximum average long-term concentrations of suspended matter (up to 10 mg/L) were observed in the areas with fine-grained bottom sediments and complex bottom relief, namely in the coastal zone of the Yeysky Peninsula, by the Dolgaya Spit and Bank, and the Yelenina Bank. In the coastal areas of the Arabat Spit and Biryuchy Island Spit, and the Obitochnaya and Berdyansk Spits, the concentrations reached 5–6 mg/L. The analysis of hydrometeorological conditions showed that the impact of wind with a speed exceeding 10 m/s for 1–2 days or longer resulted in an increase in water turbidity practically throughout the whole region under study. The highest values of suspended matter concentration (more than 10 mg/L) were recorded at wind speeds exceeding 14 m/s and durations surpassing 5 days. As for seasonal dynamics, the maximum values were revealed in the winter period (7–9 mg/L in January), and the minimum ones were observed from June to September (0–1 mg/L).
Conclusions. The spatial distribution of suspended matter in the Sea of Azov is conditioned by lithodynamic factors (bottom sediment type and bottom topography) and the hydrometeorological conditions. The most intense wind-driven roiling takes place during the cold season, from October to April.

Keywords: Sea of Azov, suspended matter concentration, MODIS, roiling, satellite data, satellite images, satellite photographs, bottom sediments, wind mixing, Landsat, Sentinel-2

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Introduction

The Sea of Azov is the shallowest sea basin in the world: depths do not exceed 9 m over 54% of its area [1]. By its physical-geographical characteristics, the water body is an inland sea and belongs to the estuarine type [2]. The shores of the Sea of Azov are predominantly composed of quaternary loams and clays, which contributes to the intensive development of abrasion and abrasion-landslide processes; accumulative landforms consist of shell detritus and quartz sand [3]. Bottom sediments in more than three quarters of the water area are represented by clayey-silt deposits and are concentrated mainly on the Panov Accumulative Plain. Other types of bottom sediments include silts, mixed sediments, and sands [4].

The Sea of Azov is characterized by low water transparency and high values of total suspended matter (SM) concentration, represented mainly by fine-grained mineral and organogenic particles [4, 5]. The study of bottom sediment roiling and the spatial variability of SM concentration in the Sea of Azov is an important task due to the significant influence of this process on the marine ecosystem, in particular on phytobenthos, which strongly depends on water transparency [6]. Moreover, the input of SM into the water leads to significant changes in the optical characteristics of water, which must be taken into account when studying other processes in the marine environment, especially when using satellite measurements in the optical range.

Intense wind-wave mixing down to the bottom [5], causing roiling of bottom sediments, facilitates the active input of large amounts of SM into the water column. Another crucial factor that increases the SM concentration is abrasion. Studies [7–11] have shown that a significant part of the Sea of Azov coast is subject to intense erosion, resulting in the transport of suspended matter into the sea.

In addition to the factors described above, river runoff, which brings a large amount of terrigenous material [12, 13] and biogenic elements that promote phytoplankton blooms, particularly cyanobacteria, especially in the warm season [14, 15], thus increasing the concentration of organic SM [16], also affects SM concentration and the optical properties of the Sea of Azov waters. River runoff has a significant impact on water turbidity in Taganrog Bay. Taganrog Bay and Sivash Bay are the shallowest areas of the Sea of Azov; their waters are regularly mixed to the bottom, causing intense roiling of bottom sediments. In contrast, the inflow of Black Sea waters through the Kerch Strait reduces SM concentration in the southern part of the Sea of Azov [17].

The use of optical-range satellite data makes it possible to effectively study the characteristics of the aquatic environment in the surface layer of the World Ocean, in particular SM concentration. Studies [18–24] have shown that optical scanner data can be used to estimate the sources, spatial variability, and quantitative parameters of SM of various origins in the surface layer.

A number of studies based on *in situ*, model, and satellite measurements [25–31] have been devoted to investigating the concentration fields and dispersal mechanisms of SM, as well as determining its mineral and organic components in the Sea of Azov. However, previous studies were limited to individual areas of the water area or covered a limited observation period. In the present work, the entire available array of MODIS, Landsat-8, and Sentinel-2 satellite images has been analyzed, which allowed us to study the features of the spatial and seasonal distribution of total SM concentration over a long-term period using optical satellite data and to identify its relationship with the intensity and duration of wind impact.

Data

To study the SM distribution in the waters of the Sea of Azov, an array of daily optical satellite data from MODIS (Moderate Resolution Imaging Spectroradiometer) Aqua and MODIS Terra for 2003–2024, comprising more than 3000 images, was extracted from the Ocean Color portal (http://oceandata.sci.gsfc.nasa.gov/). The spatial resolution of the images is 1 km. The annual number of processed images varied from 161 to 356.

To map the average SM concentration and analyze its seasonal variability, a region covering the water area of the Sea of Azov, excluding the innermost part of Taganrog Bay, was selected (blue rectangle in Fig. 1). Statistical characteristics of the obtained SM concentration data series for the entire observation period are as follows: maximum 163.66; mean 5.15; median 2.12; standard deviation 8.85.

F i g. 1. Study area. The blue rectangle is the area for which statistical calculations of average and seasonal SM variability were performed. The red rectangle is the area for analyzing the dependence of SM concentration changes on storm events

Analysis of the dependence of SM concentration on storm events (at wind speeds of 8 m/s and higher) was carried out only for the central part of the water area (red rectangle in Fig. 1). The choice of this region is due to the need to reduce the influence of shallow waters on statistical calculations, since high SM concentrations are constantly observed in the coastal zone even under weak winds, creating noise in the statistical estimates.

SM concentration was calculated using a regional algorithm based on comparing the backscattering data of suspended matter obtained from the upwelling radiance brightness of the MODIS scanner with *in situ* measurements of SM concentration [32]. At the same time, the upwelling radiance brightness is affected not only by the quantity but also by the qualitative composition of SM. The absolute values of SM concentration substantially depend on the granulometric composition and type of bottom sediments. This algorithm [32] was used to obtain quantitative parameters that were used to analyze the seasonal and spatial variability of SM in the Sea of Azov. Verification of the obtained values against *in situ* data was not carried out in this work for the following reasons. First, satellite SM concentration data are averaged pixelwise with a spatial resolution of 1 km^2, which does not allow for a correct comparison with point *in situ* measurements. Comparison of absolute concentration values was performed only within the framework of this study. Second, *in situ* measurements were carried out sporadically at individual points, mainly under calm or low-wind conditions, and do not cover situations of strong waves, during which maximum SM concentrations are formed. Additionally, when analyzing situations, composite RGB (red-green-blue) MODIS images in pseudo-natural colors were selectively used.

Analysis of spatial features of SM distribution at higher resolution was performed using OLI (Operational Land Imager) data from Landsat-8 and Landsat-9 (30 m resolution) and MSI (Multispectral Instrument) data from Sentinel-2 (10 m resolution) for 2016–2022, obtained from the USGS website (https://earthexplorer.usgs.gov/) and the Copernicus Data Space Ecosystem (https://dataspace.copernicus.eu), respectively. Images with cloud cover not exceeding 30% of the study area were selected.

The analysis of the influence of wind conditions on water roiling was carried out using NCEP (National Centers for Environmental Prediction) High Resolution Global Forecast System wind field reanalysis data with a spatial resolution of 1 × 1° and a temporal resolution of 6 h. The data were provided by the Remote Sensing Department of Marine Hydrophysical Institute of the Russian Academy of Sciences (http://dvs.net.ru/).

Results and discussion

The Sea of Azov is regularly subjected to intense wind-wave action, under the influence of which the waters are characterized by increased turbidity, in some cases manifesting itself over the entire sea area [5]. Such situations can be observed in optical satellite images in pseudo-natural colors (RGB composites) (Fig. 2, *a*, *b*).

From the array of daily MODIS satellite images for 2003–2024, cases with increased water turbidity were selected. Comparison of the selected images with meteorological conditions showed that under the influence of wind from any direction with a speed exceeding 10 m/s, even for a relatively short duration (1–2 days), water turbidity increases almost throughout the entire study region. Fig. 2 presents a typical example of such an impact: from September 4 to 6, 2004, the intensification of wind over the sea from 5 m/s or less to 10–12 m/s (Fig. 2, *e*, *f*) caused a sharp increase in SM concentration in almost all areas of the sea from 0.5–1 mg/L to 3–10 mg/L (Fig. 2, *c*, *d*).

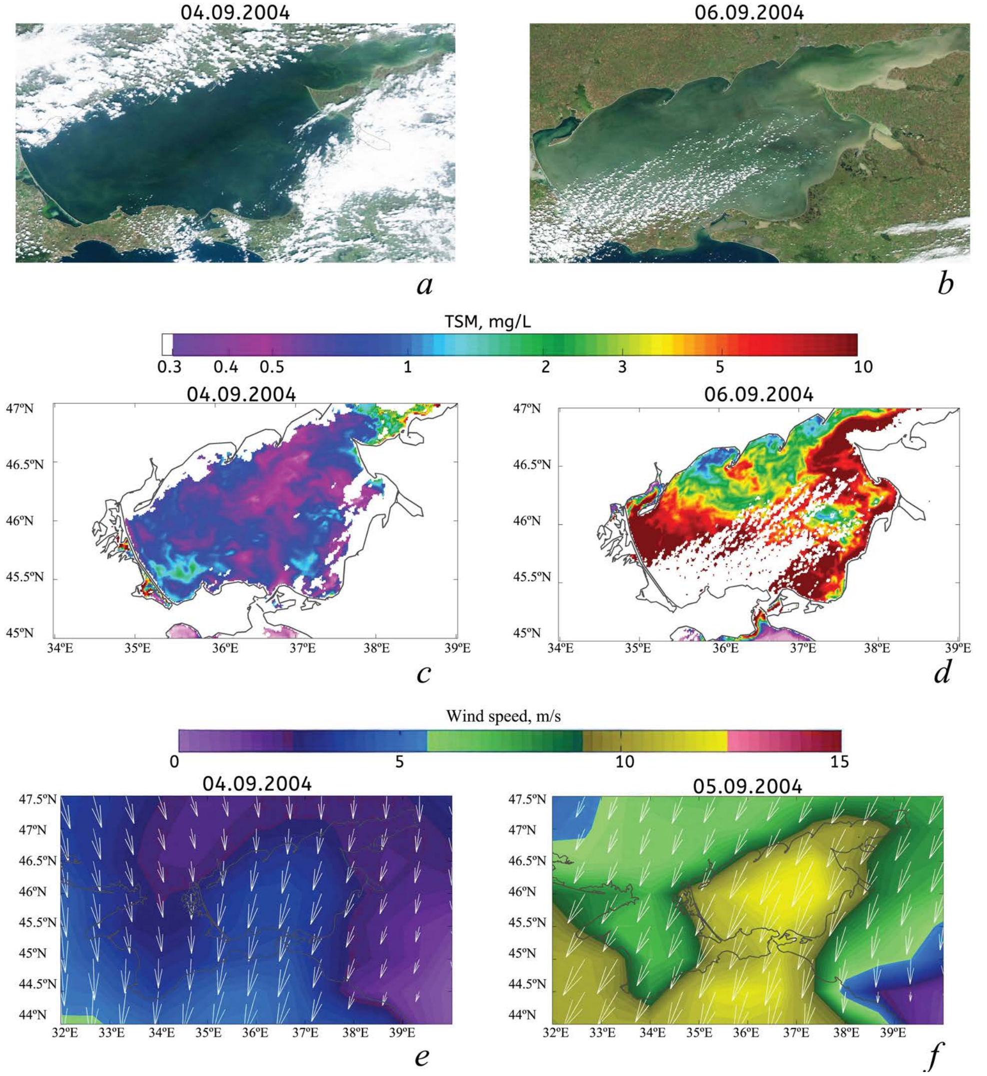
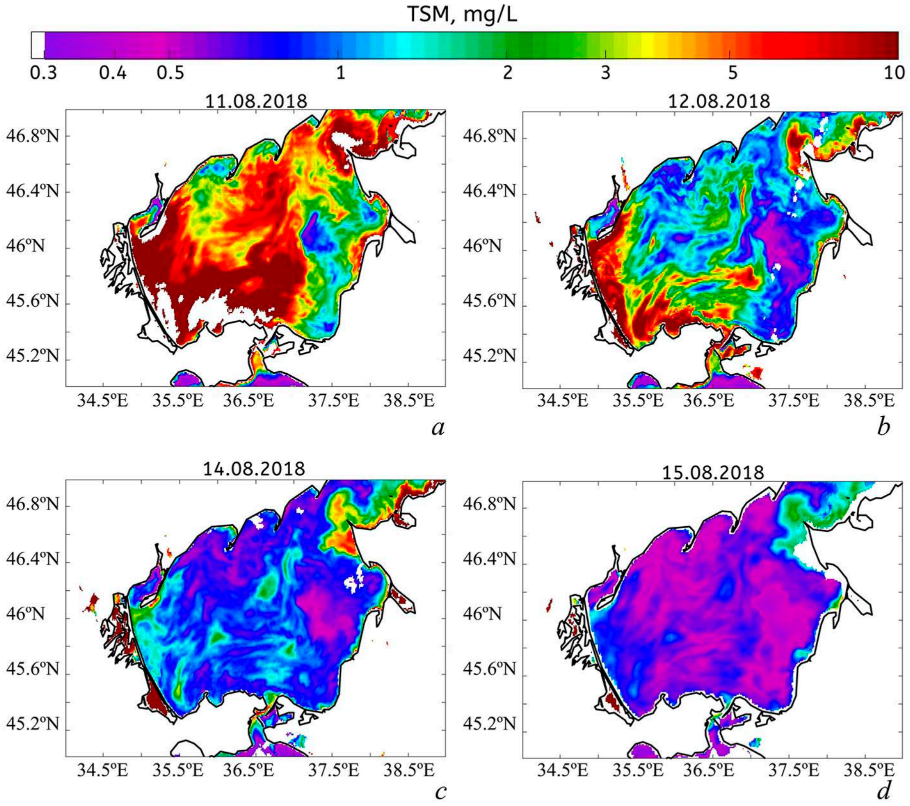


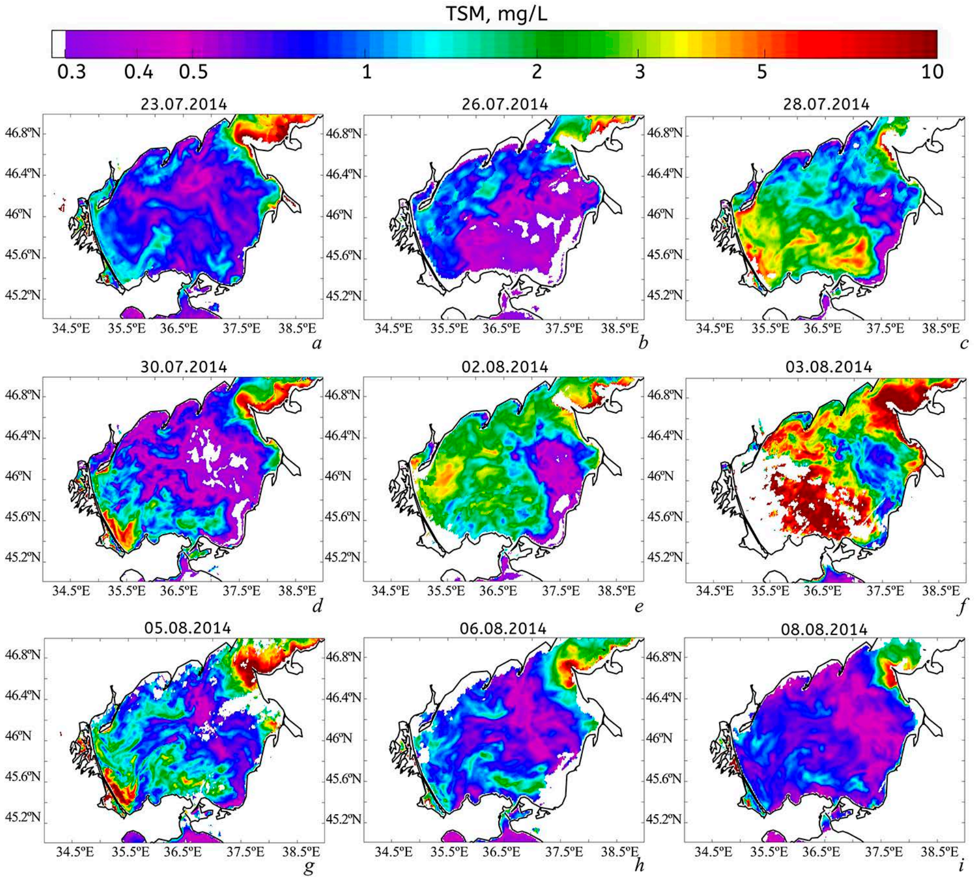
Fig. 2. Turbidity increase in the Sea of Azov from September 4 to September 6, 2004: *a*, *b* – RGB composite images from MODIS Aqua in pseudo-natural colors; *c*, *d* – MODIS Aqua data on SM concentration. Wind fields according to the NCEP wind reanalysis data on September 4 and 5, 2004 (*e*, *f*)

When wind speed decreased to 5 m/s or less, a decrease in water turbidity was observed. In most of the analyzed cases, the process of clearing in the central part of the water area under weak stable winds lasted on average 3–4 days. An example is the situation of August 11–15, 2018, when wind speed over the region decreased from 10–12 to 2–5 m/s (Fig. 3). In the image of August 11, SM concentration in the waters of almost the entire water area reached 5–10 mg/L (Fig. 3, *a*); in the following days it gradually decreased in the eastern part of the sea, and on August 15 it did not exceed 1.5 mg/L throughout almost the entire water area (Fig. 3, *b*–*d*).

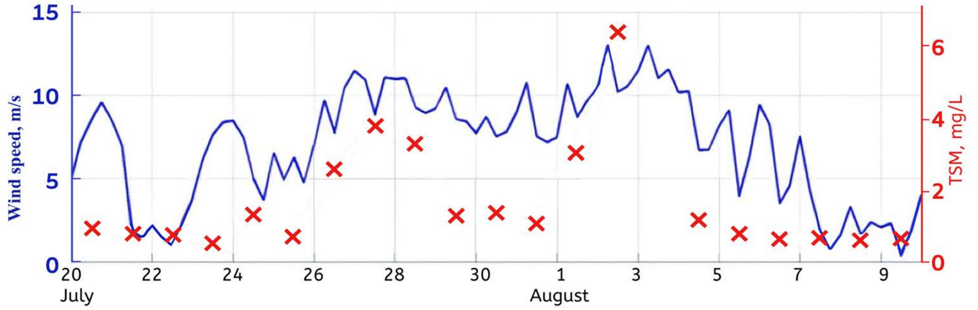


F i g. 3. Decrease in SM concentration in the Sea of Azov based on MODIS Aqua data on SM concentration: *a* – 11.08.2018; *b* – 12.08.2018; *c* – 14.08.2018; *d* – 15.08.2018

Consider as a typical example the roiling of suspended matter and its subsequent settling from July 23 to August 8, 2014 (Figs. 4, 5). Under the action of a northeast wind with a speed not exceeding 5 m/s on July 23, 2014, the waters of most of the water area contained a small amount of SM (up to 1.5 mg/L) (Figs. 4, *a*, 5), with the exception of Taganrog Bay, where active phytoplankton blooms are typical in summer [15, 33]. In the images of July 26, 2014 (Fig. 4, *b*), areas of turbid waters stand out in the northern and northwestern parts of the Sea of Azov, which is due to the increase in wind speed up to 7 m/s (Fig. 5). Then, on July 27–28, 2014, with a further increase in wind speed up to 12 m/s, low SM concentrations were observed only in a narrow strip of the sea along the eastern coast (Fig. 4, *c*). From July 28 to 30, the wind, characterized by a gradual decrease in speed, led to a reduction in SM concentration over most of the sea area (Fig. 4, *d*). The increase in wind speed from August 1 to 3 up to 13 m/s led to an increase in SM concentration up to 10 mg/L or more in certain areas (Fig. 4, *e*, *f*). The subsequent gradual weakening of the wind from August 4 to 10 to calm conditions resulted in the settling of SM in the Sea of Azov water area (Fig. 4, *g*–*i*; 5).



F i g. 4. SM concentration in the Sea of Azov based on the MODIS Aqua data: *a* – 23.07.2014, *b* – 26.07.2014, *c* – 28.07.2014, *d* – 30.07.2014, *e* – 02.08.2014, *f* – 03.08.2014, *g* – 05.08.2014, *h* – 06.08.2014 and *i* – 08.08.2014



F i g. 5. Wind speed in the Sea of Azov (excluding the apex of Taganrog Bay) based on the NCEP wind field reanalysis data, and SM concentration based on MODIS Aqua data for July 20 – August 10, 2014

In high-resolution Sentinel-2 images, under certain meteorological conditions, significant optical inhomogeneities are recorded in the suspended matter field. Fig. 6 shows the formation of a vortex dipole up to 15 km in diameter in the coastal zone near the Arabat Spit; smaller suspended matter inhomogeneities in the form of small eddies are observed at the periphery.

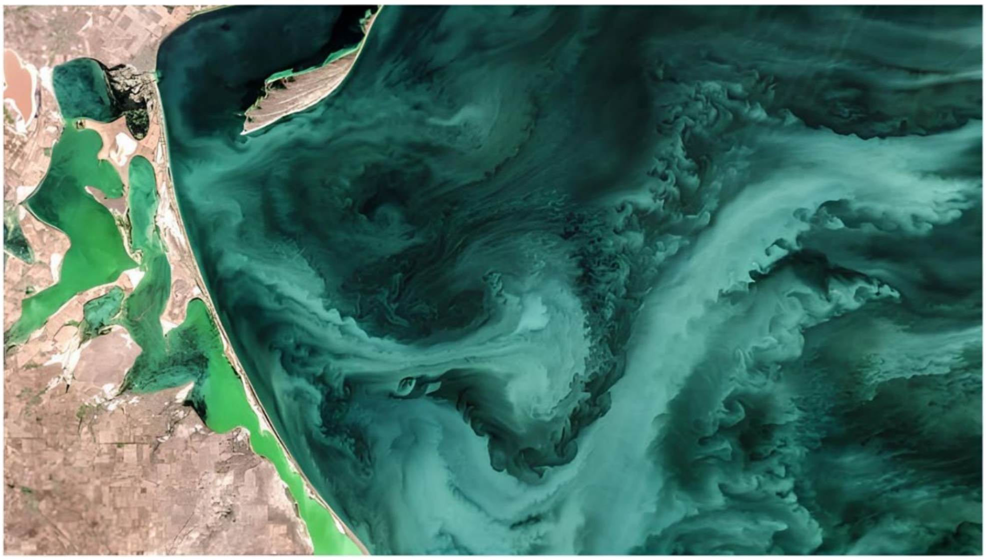
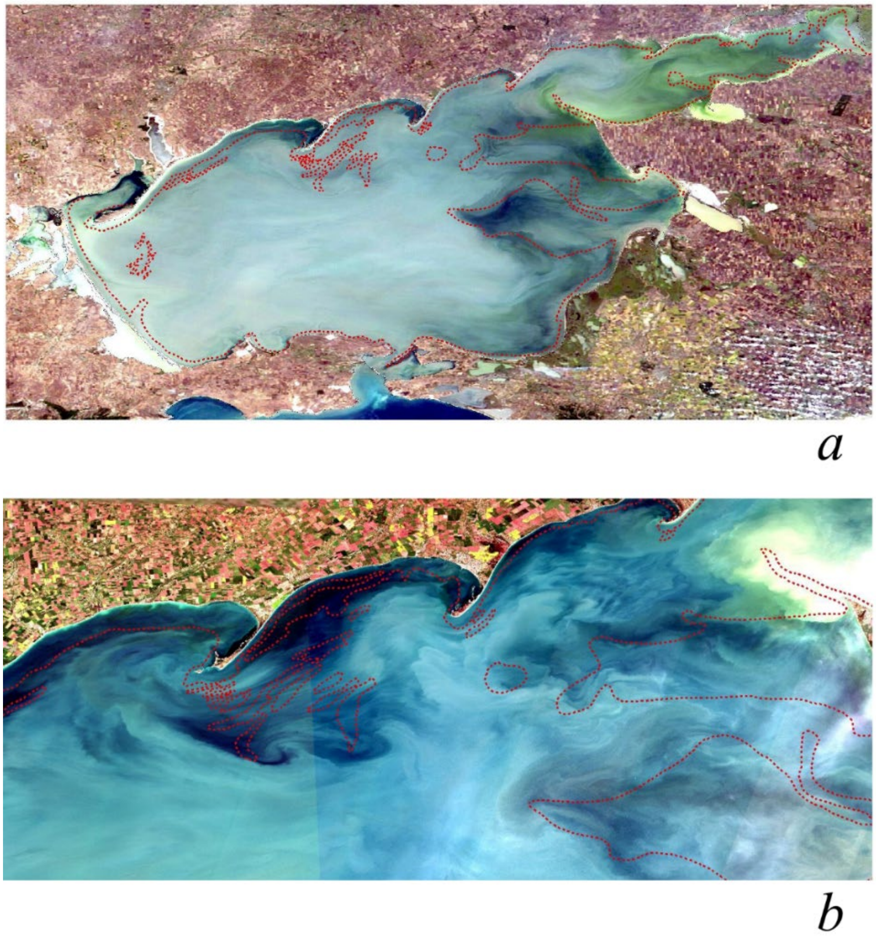


Fig. 6. Eddy structures in the western Sea of Azov along the Arabat Spit in the Sentinel-2 satellite image (RGB composite in pseudo-natural colors) dated 14 September 2021

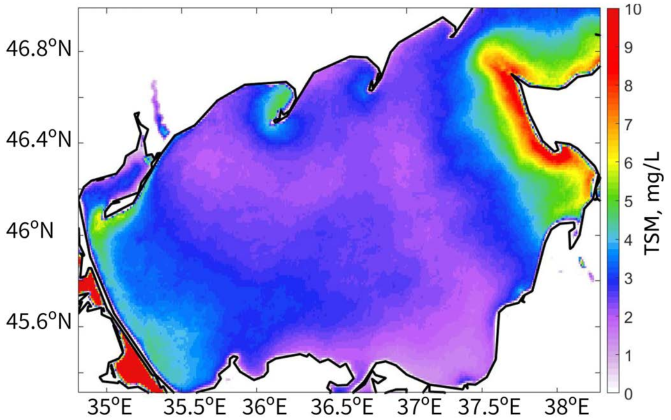
Changes in the upwelling radiance brightness in high-resolution satellite images serve as a good tracer of dynamic processes. However, SM concentration in shallow waters can be largely determined by the type of bottom sediments. Analysis of MODIS Aqua images showed that under wind-wave action, more transparent areas regularly appear in the same regions of the Sea of Azov, surrounded by more turbid water (Fig. 7). In particular, such a situation is observed in the eastern part of the water area in the region of the Achuevskaya, Zhelezinskaya, and Yelenina Banks; and to the southeast of the Obitochnaya Spit located on the northern shore of the sea. Their bottom topography is characterized by heterogeneity, with depths over the banks reaching up to 10 m. Comparison with the bottom sediment map of the Sea of Azov [4] revealed that most of the Sea of Azov bottom is covered by clayey silt-pelitic muds (fraction less than 0.1 mm), whereas sands (fraction 1–0.1 mm) are distributed along the coastline and only in the above-mentioned areas extend further seaward. Probably, differences in the granulometric composition of bottom sediments lead to their unequal roiling and settling, which is recorded in satellite images (Fig. 7).



F i g. 7. Satellite images (RGB composites in pseudo-natural colors): *a* – MODIS Aqua on 11 September 2019; *b* – Sentinel-2 on 08 May 2022. The red dotted line denotes the boundaries of sand distribution (1–0.1 mm fraction) according to [4]

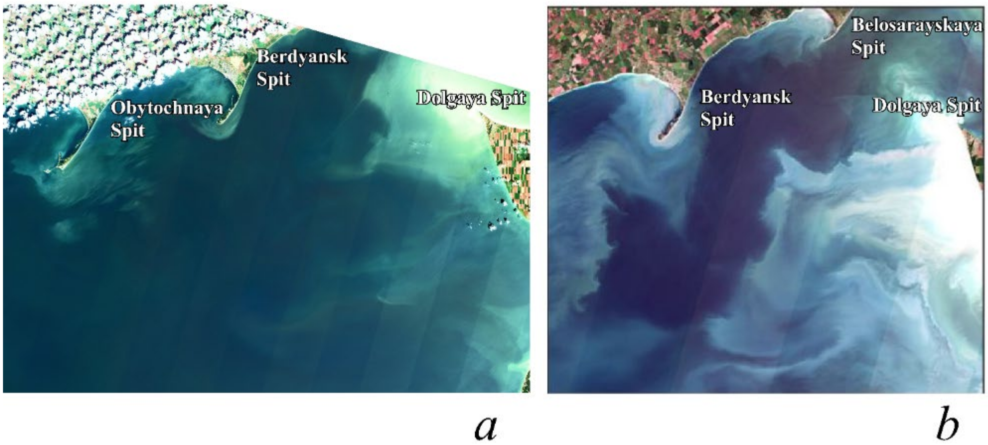
At the next stage of the work, based on the array of daily MODIS Aqua data for 2003–2024 (more than 3000 satellite images), a map of the average SM concentration in the Sea of Azov was constructed (Fig. 8).

For the central part of the Sea of Azov water area with depths exceeding 9–10 m, SM concentration values up to 3 mg/L are typical. Minimum SM concentrations are observed in the area adjacent to the Kerch Strait, which is associated with regular inflows of more transparent Black Sea waters having substantially lower SM and chlorophyll *a* concentrations compared to the Sea of Azov waters. The spatial-temporal variability and features of Black Sea inflows based on satellite data are described in [17], where it is shown that the areas of their most frequent distribution correspond to regions with minimum SM concentrations.



F i g. 8. Map of the average SM concentration in the Sea of Azov based on the MODIS Aqua data array for 2003–2024

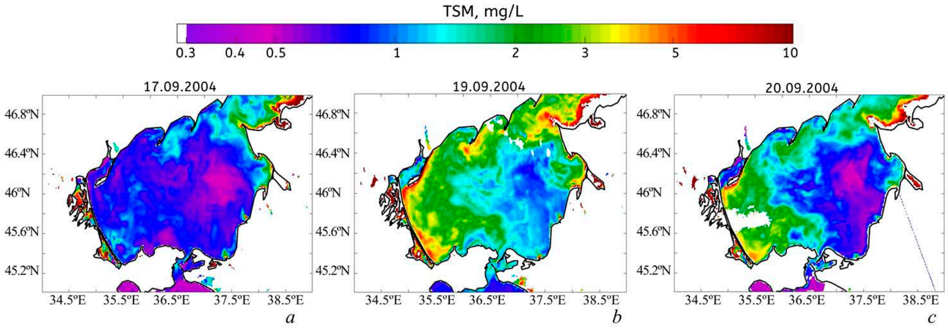
The highest SM concentrations are observed in Sivash Bay and in shallow waters with depths up to 6–8 m (Fig. 8), and in the coastal zone of the Yeysky Peninsula, Dolgaya Spit and Dolgaya Bank, and Yelenina Bank, where the values reach 10 mg/L (Figs. 8, 9). Accumulative landforms composed mainly of shell detritus and quartz sand [2] extend far into the sea and are most susceptible to active wind-wave action (waves and surges). The destruction of the shore and the underwater coastal slope in this area due to abrasion leads to a large input of terrigenous SM into the adjacent water area.



F i g. 9. Fragments of satellite images: *a* – Landsat-8 dated 24 June 2016; *b* – Sentinel-2 dated 27 April 2018

Elevated SM concentrations (5–6 mg/L) are also observed in the coastal areas of the Arabat Spit and Biryuchy Island Spit, and the Obitochnaya and Berdyansk Spits, which is also mainly associated with SM input resulting from abrasion. Comparison of MSI Sentinel-2 and OLI Landsat-8 and Landsat-9 satellite images with wind field data showed that an increase in turbidity in these areas occurs at wind speeds exceeding 5–8 m/s. At the same time, the surrounding waters of deeper areas may remain relatively clear (Fig. 9).

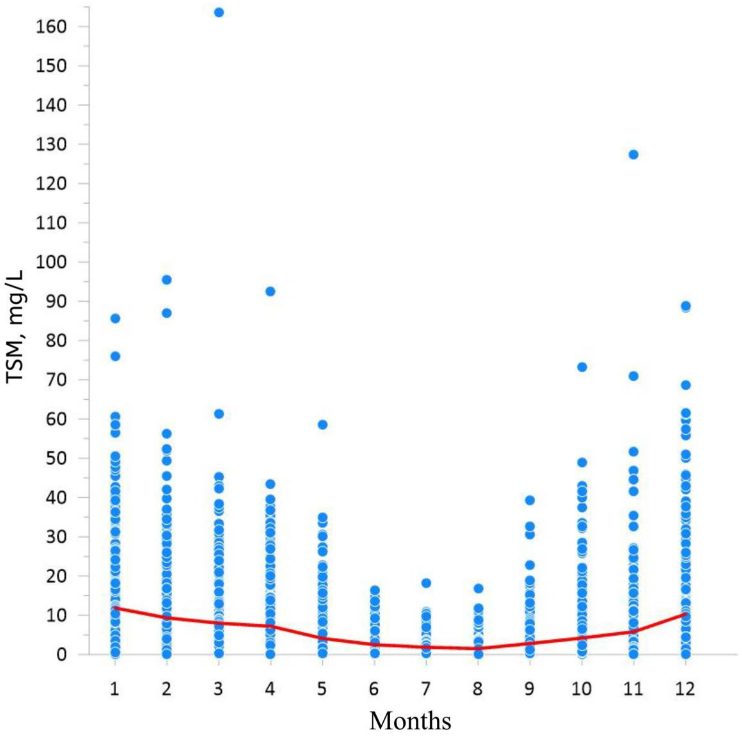
Fig. 10 shows a specific example when, under eastern and northeastern winds with speeds up to 7 m/s, areas with elevated SM values were localized in the region of the Obitochnaya, Berdyansk, Belosarayskaya, and Dolgaya Spits in MODIS Aqua images acquired on September 17, 2004. An increase in wind speed to 8–10 m/s on September 19–20, 2004 led to the expansion of more turbid water zones along the northern and western coasts of the Sea of Azov in the images. At the same time, in the central and eastern parts of the sea, SM concentration remained low.



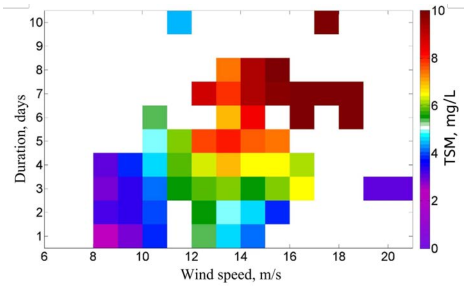
F i g. 10. SM concentration in the Sea of Azov based on MODIS Aqua data: *a* – 17 September 2004; *b* – 19 August 2004; *c* – 20 September 2004

The seasonal variability of SM concentration in the Sea of Azov, obtained by averaging all MODIS Aqua images over the entire study area for 2003–2024, is shown in Fig. 11. The highest SM concentration values are characteristic of the winter period (7–9 mg/L), with a maximum in January; the waters are most transparent from June to September (0–1 mg/L).

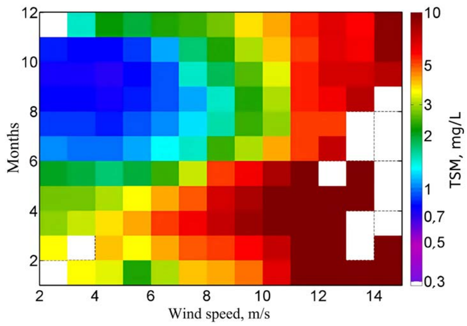
The intensity of wind-driven roiling is influenced not only by wind speed but also by other parameters such as storm duration, which determines the length of turbulent energy impact on bottom sediments, as well as stratification, which dampens turbulence in the upper layer. For a quantitative assessment of the dependence of SM concentration on wind characteristics, storm events with an average daily wind speed exceeding 8 m/s were identified. For each event, the mean and maximum wind speeds, storm duration, as well as the mean and maximum SM concentrations during the storm were determined. It was revealed that intense SM formation occurs at wind speeds exceeding 10 m/s (Fig. 12). At the same wind speed, SM concentration can vary greatly depending on storm duration: the highest values (more than 10 mg/L) were recorded during intense storms with speeds exceeding 14 m/s and durations exceeding 5 days, whereas under short-term (1–2 days) wind impact of the same intensity, SM concentration did not exceed 5 mg/L.



F i g. 11. Seasonal variation (red line) and values (blue dots) of SM concentration in the Sea of Azov for 2003–2024 based on MODIS Aqua images

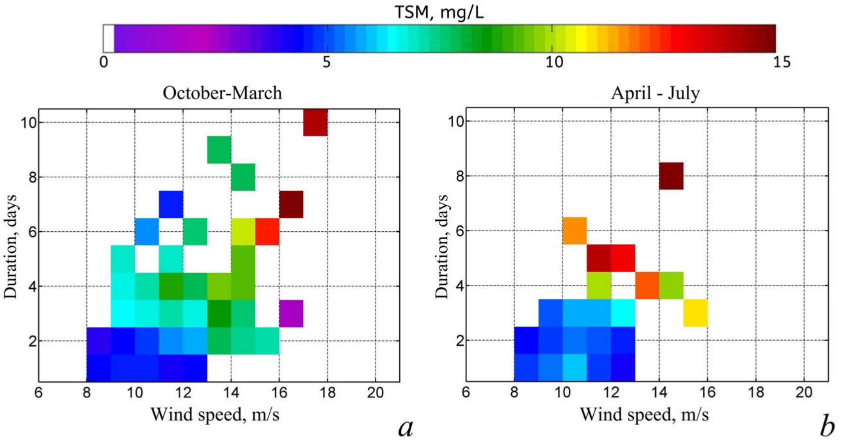


F i g. 12. SM concentration in the central Sea of Azov (based on MODIS Aqua satellite images) depending on the average daily wind speed exceeding 8 m/s (NCEP reanalysis data) for 2003–2017



F i g. 13. SM concentration in the central Sea of Azov (based on MODIS Aqua satellite images) depending on wind speed (NCEP reanalysis data) and the month of the year for 2003–2017

This dependence also has a pronounced seasonal course (Fig. 13). In winter and spring, an increase in SM concentration up to 4 mg/L is observed already at wind speeds of 5 m/s, whereas in summer and early autumn, an increase is recorded only at wind speeds exceeding 9 m/s. One of the reasons for this distribution of SM concentration in the warm season may be significant water heating and the formation of a thermocline closer to the bottom. As a result, for currents to reach the bottom, more intense wind action is required to destroy the thermal stratification during the warming period. The dissipation of turbulent energy due to the high stratification of the water column leads to a weakening of the bottom sediment roiling process.



F i g. 14. SM concentration in the central Sea of Azov (based on MODIS Aqua satellite images) depending on the average daily speed of storm events exceeding 8 m/s (NCEP reanalysis data) for 2003–2017: *a* – from October to March, and *b* – from April to July

In addition, high SM concentrations in the winter period may be observed as a result of longer storm impacts. Fig. 14, *a* shows that in the cold season (October – March), storm events with an average wind speed exceeding 8 m/s and a duration exceeding 6 days are recorded much more often than in the warm season from April to July (Fig. 14, *b*). At the same time, SM concentrations exceeding 5 mg/L in the central part of the water area are observed at wind speeds of 9 m/s and a duration of 3 days. In the warm season, SM concentration much more rarely exceeds 5 mg/L during storms lasting less than 3 days. It should be noted that in the summer period and early autumn, intense phytoplankton blooms occur in the Sea of Azov [15, 16]; therefore, the increase in SM concentration during this period may be associated with biological processes. In this regard, August and September were excluded from the analysis (Fig. 14).

Conclusion

Based on the array of MODIS, Landsat-8, and Sentinel-2 satellite data, an analysis of the spatial and seasonal distribution features of total SM concentration in the Sea of Azov water area (excluding the innermost part of Taganrog Bay) for 2003–2024 has been carried out.

Analysis of MODIS Aqua images showed that under wind-wave action, optical inhomogeneities are recorded in the SM concentration field, which often manifest as zones with low SM content: in the eastern part of the water area in the region of the Achuyevskaya, Zhelezinskaya, and Yelenina Banks, and to the southeast of the Obitochnaya Spit on the northern coast of the sea. The bottom sediments of these areas are predominantly composed of sands (fraction 1–0.1 mm), whereas the rest of the sea is characterized by silt-pelitic sediments (fraction less than 0.1 mm). Due to significant differences in the granulometric composition of bottom sediments, their roiling and settling occur differently, which is recorded in satellite images.

The central part of the Sea of Azov water area with depths exceeding 9–10 m is characterized by low SM concentration values. Elevated SM concentration values are observed in shallow waters with depths up to 6–8 m, which is associated with suspended matter input resulting from abrasion. The maximum SM concentrations are recorded in the coastal zone of the Yeysky Peninsula, Dolgaya Spit and Dolgaya Bank, Yelenina Bank (up to 10 mg/L), the Arabat Spit and Biryuchy Island Spit, and the Obitochnaya and Berdyansk Spits (5–6 mg/L).

Analysis of the influence of storm situations showed that a sharp increase in SM concentration in the Sea of Azov water area occurs when wind speed increases above 10 m/s, and within 1–2 days after the start of wind action, water turbidity increases almost throughout the entire study region. The highest SM concentration values (more than 10 mg/L) were recorded at wind speeds exceeding 14 m/s and durations exceeding 5 days. When wind speed decreased to values of 5 m/s or less, the clearing of the central part of the water area lasted on average 3–4 days.

In the seasonal course of average SM concentration, the highest values (7–9 mg/L) are observed in the winter period with a maximum in January, and the lowest (0–1 mg/L) are observed from June to September. A study of the seasonal distribution of SM concentration during storm situations showed that in winter and spring, an increase in SM concentration up to 4 mg/L is observed even at wind speeds of 5 m/s. In the summer months, an increase in SM concentration above 2 mg/L occurs only at wind speeds exceeding 9 m/s. The weakening of bottom sediment roiling in summer is associated both with a general decrease in wind activity and with an increase in the stratification of the water column, which hinders the penetration of wind-wave energy to the bottom.

REFERENCES

1. Matishov, G.G., 2006. Geomorphologic Peculiarities of the Azov Sea Shelf. *Vestnik Yuzhnogo Nauchnogo Tsentra RAN,* 2(1), pp. 44-48. https://doi.org/10.23885/1813-4289-2006-2-1-44-48 (in Russian).

2. Matishov, G.G., Kovaleva, G.V. and Pol’shin, V.V., 2009. New Data on the Sedimentation Rate in the Sea of Azov in the Late Holocene. *Doklady Earth Sciences,* 429(1), pp. 1369-1372. https://doi.org/10.1134/S1028334X09080285

3. Tsygankova, A.E., Bespalova, L.A., Ivlieva, O.V. and Magaeva, A.A., 2020. Using a Dynamic Approach for Zoning the Coast of the Sea of Azov. *Ecology. Economy. Informatics. System Analysis and Mathematical Modeling of Ecological and Economic Systems,* 1(5), pp. 207-213. https://doi.org/10.23885/2500-395X-2020-1-5-207-213 (in Russian).

4. Matishov, G.G., 2007. Seismic Profiling and Mapping of the Azov Sea Recent Bottom Sediments. *Vestnik Yuzhnogo Nauchnogo Tsentra,* 3(3), pp. 32-40 (in Russian).

5. Sorokina, VV. and Kulygin V.V., 2013. Long-Term Variability of the Water Transparency (Secchi Depth) in the Sea of Azov. *Oceanology,* 53(3), pp. 287-293. https://doi.org/10.1134/S0001437013030107

6. Gromov, V.V., 2012. Aquatic and Coastal Vegetation of the Northern and Western Coast of the Azov Sea. *Journal of Siberian Federal University. Biology,* 2(5), pp. 121-137. https://doi.org/10.17516/1997-1389-0140 (in Russian).

7. Kosyan, R.D. and Krylenko, V.V., 2007. Comprehensive Characteristics of the Current State of the Shores of the Sea of Azov. In: V. V. Denisov, A. D. Chinarina, N. V. Lebedeva and S. V. Kreneva, eds., 2007. *Ecosystem Studies of the Azov, Black, and Caspian Seas and Their Coasts*. Apatity: Publishing House of the Kola Science Center of the Russian Academy of Sciences. Vol. 9, pp. 50-67 (in Russian).

8. Kushnir, V.M., 2008. Estimation of the Weighed Sediments Characteristics from Optical Scanners Data. *Ecological Safety of Coastal and Shelf Zones and Comprehensive Use of Shelf Resources*, 16, pp. 224-235 (in Russian).

9. Matishov, G.G., Bespalova, L.A., Ivlieva, O.V., Tsygankova, A.E. and Kropyanko, L.V., 2016. The Sea of Azov: Recent Abrasion Processes and Problems of Coastal Protection. *Doklady Earth Sciences*, 471(2), pp. 1269-1272. https://doi.org/10.1134/S1028334X16120059

10. Skripka, G.I., Kosolapov, A.E., Bespalova, L.A. and Ivlieva, O.V., 2017. Monitoring Hazardous Exogenous Processes in the Coastal Zone of the Sea of Azov Using Remote Sensing Data and GIS Technologies. In: IWP RAS, 2017. *Water Resources: New Challenges and Solutions: Collection of Scientific Works Dedicated to the Year of Ecology in Russia and the 50th Anniversary of the Institute of Water Problems, Russian Academy of Sciences*. Novocherkassk: OOO Lik, pp. 531-536 (in Russian).

11. Ermolov, A.A., Ignatov, E.I., Kizyakov, A.I. and Ilyushin, D.G., 2019. Abrasion Shores of the Azov and Black Seas. *Ecology Economy Informatics. Geoinformation Technologies and Space Monitoring*, (4), pp. 142-146. https://doi.org/10.23885/2500-123X-2019-2-4-142-146 (in Russian).

12. Sorokina, V.V. and Berdnikov, S.V., 2008. Mathematical Modeling of the Terrigenous Sedimentation in the Sea of Azov. *Oceanology*, 48(3), pp. 418-427. https://doi.org/10.1134/S0001437008030144

13. Vasilenko, N.V., Kubryakov, A.A. and Stanichny, S.V., 2024. Characteristics of the Kuban River Plume according to Satellite Data. *Izvestiya, Atmospheric and Oceanic Physics*, 60(12), pp. 1522-1535. https://doi.org/10.1134/S0001433825700197

14. Luzhnyak, O.L., 2011. Phytoplankton Development of the Taganrog Gulf at Spring-Summer Period Consequence Exclusively Warm-Winter 2006/2007. *Bulletin of Higher Educational Institutions. North Caucasus Region. Natural Sciences*, (1), pp. 67-71 (in Russian).

15. Vasilenko, N.V., Medvedeva, A.V., Aleskerova, A.A., Kubryakov, A.A. and Stanichny, S.V., 2021. Features of Cyanobacteria Blooms in the Central Part of the Sea of Azov from Satellite Data. *Sovremennye Problemy Distantsionnogo Zondirovaniia Zemli iz Kosmosa*, 18(5), pp. 166-180. https://doi.org/10.21046/2070-7401-2021-18-5-166-180 (in Russian).

16. Saprygin, V.V., Berdnikov, S.V., Kulygin, V.V., Dashkevich, L.V. and Mestetskiy, L.M., 2018. Spatial Distribution and Seasonal Dynamics of the Chlorophyll a Concentration in the Sea of Azov Based on MERIS Images. *Oceanology*, 58(5), pp. 689-699. https://doi.org/10.1134/S0001437018050132

17. Vasilenko, N.V., Aleskerova, A.A., Kubryakov, A.A., Mizyuk, A.I. and Stanichny, S.V., 2023. Propagation of the Black Sea Waters in the Sea of Azov Based on the Satellite Data and the NEMO Model. *Physical Oceanography*, 30(4), pp. 484-507.

18. Miller, R.L. and McKee, B.A., 2004. Using MODIS Terra 250 m Imagery to Map Concentrations of Total Suspended Matter in Coastal Waters. *Remote Sensing of Environment*, 93(1–2), pp. 259-266. https://doi.org/10.1016/j.rse.2004.07.012

19. Zhang, M., Tang, J., Dong, Q., Song, Q. and Ding, J., 2010. Retrieval of Total Suspended Matter Concentration in the Yellow and East China Seas from MODIS Imagery. *Remote Sensing of Environment*, 114(2), pp. 392-403. https://doi.org/10.1016/j.rse.2009.09.016

20. Burenkov, V.I., Goldin, Yu.A. and Kravchishina, M.D., 2010. The Distribution of the Suspended Matter Concentration in the Kara Sea in September 2007 Based on Ship and Satellite Data. *Oceanology*, 50(5), pp. 798-805. https://doi.org/10.1134/S0001437010050164

21. Loisel, H., Mangin, A., Vantrepotte, V., Dessailly, D., Ngoc Dinh, D., Garnesson, P., Ouillon, S., Lefebvre, J.-P., Mériaux, X. [et al.], 2014. Variability of Suspended Particulate Matter Concentration in Coastal Waters under the Mekong's Influence from Ocean Color (MERIS) Remote Sensing over the Last Decade. *Remote Sensing of Environment*, 150, pp. 218-230. https://doi.org/10.1016/j.rse.2014.05.006

22. Nechad, B., Ruddick, K., Schroeder, T., Oubelkheir, K., Blondeau-Patissier, D., Cherukuru, N., Brando, V., Dekker, A., Clementson, L. [et al.], 2015. CoastColour Round Robin Data Sets: A Database to Evaluate the Performance of Algorithms for the Retrieval of Water Quality Parameters in Coastal Waters. *Earth System Science Data*, 7(2), pp. 319-348. https://doi.org/10.5194/essd-7-319-2015

23. Kopelevich, O.V., Vazyulya, S.V., Sheberstov, S.V. and Bukanova, T.V., 2016. Suspended Matter in the Surface Layer of the Southeastern Baltic from Satellite Data. *Oceanology*, 56(1), pp. 46-54. https://doi.org/10.1134/S0001437016010069

24. Lisitzin, A.P., Klyuvitkin, A.A., Burenkov, V.I., Kravchishina, M.D., Politova, N.V., Novigatsky, A.N., Shevchenko, V.P. and Klyuvitkina, T.S., 2016. Distribution and Composition of Suspended Particulate Matter in the Atlantic Ocean: Direct Measurements and Satellite Data. *Doklady Earth Sciences*, 466(1), pp. 78-81. https://doi.org/10.1134/S1028334X16010116

25. Kushnir, V.M., 2009. Characteristics of the Azov Sea Near Surface Layer Derived from the Optical Scanners of the MODIS System. *Issledovanie Zemli iz kosmosa*, (3), pp. 35-46 (in Russian).

26. Kushnir, V.M. and Berdnikov, S.V., 2010. Weighed Substance and Chlorophyll_a in the Sea of Azov According to Contact Measurements and Space Surveys. *Ecological Safety of Coastal and Shelf Zones and Comprehensive Use of Shelf Resources*, 22, pp. 103-115 (in Russian).

27. Kushnir, V.M., Povazhny, V.V. and Berdnikov, S.V., 2014. Mineral and Organic Components of Suspension Derived from Space Surveys and Direct Measurements in the Azov Sea and the Kerch Strait. *Morskoy Gidrofizicheskiy Zhurnal*, (2), pp. 22-31(in Russian).

28. Matishov, G.G., Shulga, T.Ya., Khartiyev, S.M. and Ioshpa, A.R., 2018. Studies of Particulate Matter Distribution by Aqua Modis Data and Simulation Results. *Doklady Earth Sciences*, 481(1), pp. 967-971. https://doi.org/10.1134/S1028334X18070267

29. Kochergin, V.S., Kochergin, S.V. and Stanichny, S.V., 2020. Variational Assimilation of Satellite Data on Surface Concentration of Suspended Matter in the Azov Sea. *Sovremennye Problemy Distantsionnogo Zondirovaniya Zemli iz Kosmosa*, 17(2), pp. 40-48. https://doi.org/10.21046/2070-7401-2020-17-2-40-48 (in Russian).

30. Churilova, T.Ya., Efimova, T.V., Moiseeva, N.A. and Skorokhod, E.Yu., 2022. Spectral Light Absorption Coefficient of Particles and Colored Dissolved Organic Matter in the Sea of Azov. *Fundamental and Applied Hydrophysics*, 15(3), pp. 73-83. https://doi.org/10.48612/fpg/ex1p-9vtp-phu8 (in Russian).

31. Shul'ga, T.Ya. and Suslin, V.V., 2018. Investigation of the Evolution of the Suspended Solids in the Sea of Azov Based on the Assimilation of Satellite Data in a Hydrodynamic Model. *Fundamentalnaya i Prikladnaya Gidrofizika*, 11(3), pp. 73-80. https://doi.org/10.7868/S2073667318030097 (in Russian).

32. Kremenchutskiy, D.A., Kubryakov, A.A., Zav'yalov, P.O., Konovalov, B.V., Stanichniy, S.V. and Aleskerova, A.A., 2014. Determination of the Suspended Matter Concentration in the Black Sea Using to the Satellite MODIS Data. *Ecological Safety of Coastal and Shelf Zones and Comprehensive Use of Shelf Resources*, 29, pp. 5-9 (in Russian).

33. Lishaev, P.N., Aleskerova, A.A., Kubryakov, A.A., Vasilenko, N.V. and Stanichny, S.V., 2022. Spatiotemporal Variability of Cyanobacteria Blooms from Their MODIS-Based Automatic Identification. *Izvestiya, Atmospheric and Oceanic Physics*, 58(9), pp. 981-992. https://doi.org/10.1134/S0001433822090134

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