ISSN 0001-4370, Oceanology, 2010, Vol. 50, No. 5, pp. 798–805. © Pleiades Publishing, Inc., 2010.
Original Russian Text © V.I. Burenkov, Yu.A. Goldin, M.D. Kravchishina, 2010, published in Okeanologiya, 2010, Vol. 50, No. 5, pp. 842–849.

MARINE GEOLOGY

The Distribution of the Suspended Matter Concentration in the Kara Sea in September 2007 based on Ship and Satellite Data

V. I. Burenkov, Yu. A. Goldin, and M. D. Kravchishina
Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow, Russia
E-mail: bur-07@yandex.ru, goldyuri@yandex.ru, kravchishina@ocean.ru
Received September 3, 2008; in final form, May 5, 2009

Abstract—The distribution of the suspended particulate matter concentration in the Kara Sea is analyzed based on ship and satellite data. The statistical relationships between the suspended matter concentration and the optical characteristics were revealed. Charts of the distribution of the suspended matter concentration in the Kara Sea were plotted, which confirmed that the application of optical methods for analyzing the spatial distribution of the suspended matter is effective. The most turbid waters were observed in the Ob Gulf, Yenisei Bay, the Baidaratskaya Gulf, and the adjacent regions. The smallest concentrations of suspended matter were observed in the central and western parts of the Kara Sea.

DOI: 10.1134/S0001437010050164

INTRODUCTION

The research of suspended matter of diverse origins with characteristic dimensions from 0.5 μm to 1 mm [15] is of interest to different branches of oceanology, specifically, when studying the processes of current sedimentation. Additionally, the transfer of substances sorbed on particles is of ecological importance. The main features of the suspended matter are formed as a result of the vital activity of marine organisms and the inflow of mineral substances. A number of studies are dedicated to the distribution of the suspended matter in the polar seas of Russia and, specifically, in the Kara Sea [1, 8, 14, 18, 19, 23, 24]. A review of the works on the distribution of the suspended matter in the polar seas of Russia based on optical methods is given in [16].

The optical methods provide efficient tools for studying the field of the suspended matter concentration. Earlier studies in the Laptev Sea (1991, the R/V *Yakov Smirnitskiy*), the Kara Sea (1993, cruise 49 of the R/V *Dmitriy Mendeleev*), the Barents Sea (1998, cruises 13 and 14 of the R/V *Akademik Sergey Vavilov*), and a number of missions in the White Sea have shown that the magnitude of the light attenuation coefficient of the seawater C is closely related to the concentration of the total suspended matter (TSM) and can be used for the sufficiently accurate express determination of its spatial distribution [8, 12, 16]. Correlation relations of the light attenuation coefficient at the wavelength of 530 nm and the suspended matter concentration in water samples collected concurrently with the optical measurements were obtained. Similar results are reported in [17] for the light attenuation coefficient at alternative wavelengths. In the present work, we analyze the data of similar research conducted during the 54th cruise of the R/V *Akademik Mstislav Keldysh* (September–October 2007) and generalize the results of concurrent measurements of the light attenuation coefficient and the concentration of suspended matter in the Arctic seas of Russia.

For some time, satellite data have been used to study the field of the suspended matter concentration. This approach is based on the feasibility of the retrieval of the magnitude of the backscattering coefficient of the suspended matter b_{bp} at 555 nm from the satellite data. For the first time, the relevant algorithm was developed in [7], where the magnitude of the b_{bp} was determined from the normalized water-leaving radiances measured with two spectral channels of the SeaWiFS color ocean scanner (510 and 555 nm). A correlation relationship was obtained linking the backscattering coefficient of the suspended matter and the concentration of the latter in the waters of the Barents Sea. Similar relationships were found for other seas of Russia and the Atlantic Ocean [11, 20]. Maps of the monthly distributions of the suspended matter concentration in the different seas of Russia have been created based on the satellite data for the last ten years [21, 22].

TECHNIQUES OF THE MEASUREMENTS AND THE DATA PROCESSING

We used a compact transmissometer (PUM) [3] for the vertical profiling of the light attenuation coefficient and the data of the MODIS-Aqua color ocean scanner for investigating the field of the suspended matter concentration. Such data are available approximately a day after the scanner's flight (in the case of the SeaWiFS, the time lag equals 14 days), which enables the express processing of the data and transmitting the latter, if necessary, to a research vessel for correcting its itinerary depending on the specific features of the distributions of the bio-optical parameters. Especially this approach was practiced during the 54th cruise of the R/V *Akademik Mstislav Keldysh* in the Kara Sea (September–October 2007). The procedures for the satellite data processing are described in [6]. The earlier algorithm [7] for the determination of the backscattering coefficient of the suspended matter using the spectral channels at 510 and 555 nm of the SeaWiFS scanner were modified to match the channels of the MODIS-Aqua scanner at 531 and 551 nm. Notice that the magnitude of the backscattering coefficient of the particles (the concentration of the chlorophyll and other similar parameters) found from the satellite data represents the value averaged over a certain layer. For the turbid waters of the Kara Sea, its thickness is close to 1 m, but, in more transparent waters, it can be as high as 10 m.

The water samples for the suspended matter were collected in the water thickness with the help of a Rosette hydrophysical complex. A plastic bucket was used to collect the surface water samples. The assessment of the concentration of the TSM, mg/l, involved filtering of water samples from 0.5 to 5 l in volume using preliminarily weighed nuclear filters (47 mm in diameter with a pore size of 0.45 μm) under a 0.4 vacuum atmosphere. Every sample was concurrently filtered through three nuclear filters. After the filtering, the filters were rinsed with a triple distillate and dried out at 50°C. The suspended matter concentration was found by the filters' weighting, which was accurate to within 0.1 mg. Altogether, 93 samples of suspended matter were obtained.

At every station, the water was sampled with regard to the preliminarily recorded vertical profiles of the light attenuation coefficient.

THE INTERDEPENDENCE BETWEEN THE OPTICAL CHARACTERISTICS AND THE SUSPENDED MATTER CONSENTRATION

As mentioned above, we estimated the concentration of the TSM from the measurements of the seawater's light attenuation coefficient C at 530 nm and the values of the suspended matter's backscattering coefficient b_{bp} retrieved from the satellite data. First, consider the interdependence of the attenuation coefficient and the concentration of the suspended matter.

To find the interdependence of the light attenuation coefficient and the suspended matter concentration, use was made of 49 pairs of concurrent measurements of the C and TSM. These data were combined with the results of the measurements performed in 1993 in the Kara Sea (cruise 49 of the R/V *Dmitriy Mendeleev* [5]). The testing confirmed the acceptable consistency of the data of the two expeditions. To compare the suspended matter concentration and the attenuation coefficient, we used data from depth levels where both quantities featured quasi-homogenous vertical distributions (in the case of high vertical gradients, errors inevitably arise due to the nonsynchronicity of the measurements and the difference in the accuracy of the depth determination).

A summary graph of the interrelation of the C and TSM is given in Fig. 1a. The regression equation has the form

$$\mathrm{TSM} = 0.834\,C - 0.06. \qquad (1)$$

The total number of data pairs is 156. The squared correlation coefficient is $r^2 = 0.93$, which points to the close relationship of the quantities in question.

This data set was combined with the result of the measurements in the Laptev Sea (cruise of the R/V *Yakov Smirnitskiy*) and the Barents Sea (1998, cruises 13 and 14 of the R/V *Akademik Sergey Vavilov*) and the total number of C and TSM paired measurements made up 285. The regression equation in this case has the form

$$\mathrm{TSM} = 0.837\ \mathrm{C} - 0.04. \qquad (2)$$

The squared correlation coefficient is $r^2 = 0.92$. The root-mean-square error in the determination of the concentration of the suspended matter is 30%. The summary graph of the interrelation of the C and TSM for this case is given in Fig. 1b. The insignificance of differences between (1) and (2) allowed us to use (2) as a common equation for all of the Arctic seas linking the values of the attenuation coefficient and the suspended matter concentration. In what follows, we shall use just this relationship. It should be noticed that the individual equations derived from the data of the different expeditions in the different seas exhibit certain discrepancies, but, as a rule, they are within the accuracy of the determinations of the attenuation coefficient and the suspended matter concentration.

The comparison of the vertical profiles of the light attenuation and the TSM concentration showed that they changed in a similar way at the majority of the stations. An example is given in Fig. 2. It should be noticed that such a good agreement does not always happen because of different factors. Among others, one can point to the transformation of the suspended matter composition with the depth and to errors of the suspended matter sampling and the assessment of the suspended particles' concentration.

As indicated above, the data of the MODIS-Aqua ocean color scanner were used for revealing the distribution of the suspended matter in the Kara Sea. It should be noticed that virtually permanent cloudiness is a specific circumstance of the satellite observations at high latitudes, which results in the low number of fragments of the satellite images suitable for data retrieval. The analytical treatment of the available data

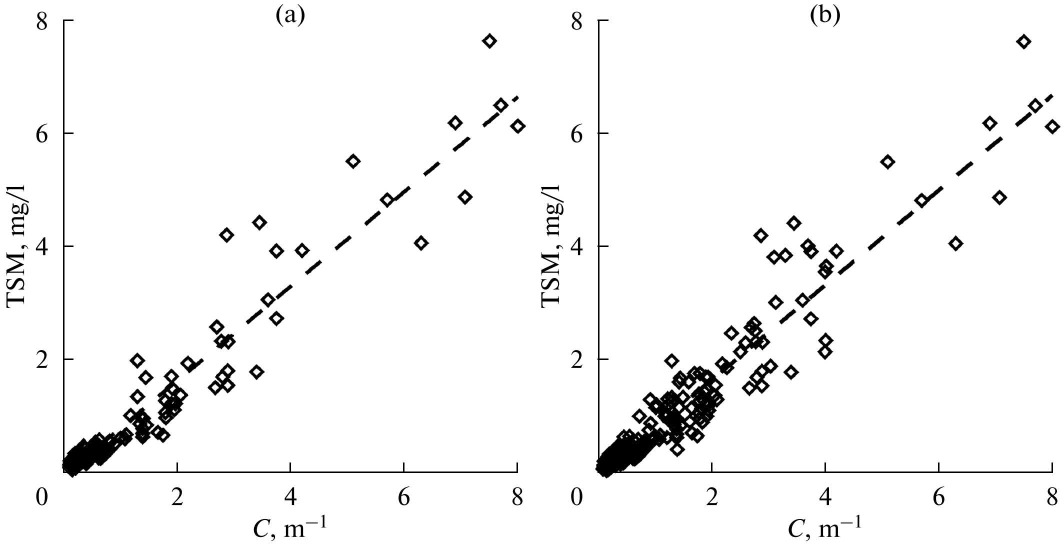

Fig. 1. The interdependence of the light attenuation coefficient *C* and the concentration of suspended particles TSM for the Kara Sea based on the evidence (a) from the concurrent measurements during the expeditions in 1993 and 2007 and based on (b) the data for the whole Arctic basin. For the details, see the text. The dashed lines depict the regression fitting. The equation parameters are given in the text.

indicates the poor chances to perform truly concurrent satellite observations and ship borne measurements in the Kara Sea. For this reason, we compared the magnitudes of the backscattering coefficient b_{bp} found for the satellite data and the estimates of the TSM concentration based on the satellite information over the whole period of the expedition in the Kara Sea. Being aware of some deficiency of this approach, consider the following circumstances. First, the analysis of the satellite data revealed the fairly stable distribution of the backscattering coefficient of the suspended matter over the period of the observations. Among others, this follows from the relative smallness of the changes in the b_{bp} values for several days at individual stations. Second, the distribution of the suspended matter concentration from the satellite data is qualitatively consistent with that from the ship borne measurements (in many cases, the term "quantitative consistency" is applicable too). Certainly, the data obtained should be considered as preliminary, but it is unlikely that more representative experimental material will be available in the foreseeable future (recall that obtaining satellite data for the waters of the Kara Sea is hampered by systematic cloudiness).

The joint examination of the satellite determinations of the backscattering coefficient of the suspended matter b_{bp} and the concentration of the TSM resulted in the following relationship:

$$\mathrm{TSM} = 450 b_{bp}^{0.98}. \quad (3)$$

This expression is based on 34 concurrent determinations of the b_{bp} and the TSM. The squared correlation coefficient is $r^2 = 0.87$.

THE DISTRIBUTION OF THE SUSPENDED MATTER CONCENTRATION IN THE KARA SEA FROM THE DATA OF THE SHIPBORNE AND SATELLITE MEASUREMENTS

The distribution of the suspended matter in the surface layer. Figure 3 demonstrates the spatial distribution of the suspended matter concentration in the surface layer plotted from the data of the MODIS-Aqua scanner for September 2007 and averaged over the period from September 1 to 26. As is evident from the distribution, in spite of the fairly long period of the averaging, the data are lacking in a number of aquatic areas of the Kara Sea; i.e., they were under permanent cloud cover during this period; such areas are marked with the white color in the satellite images.

As expected, the maximum concentrations of suspended matter occur in the Ob Gulf and Yenisei Bay thanks to the suspended particles supplied by the river runoff. The TSM estimates often exceed here 10 mg/l. It is worth noticing that the turbid waters from the Ob Gulf and Yenisei Bay are transported mainly eastwards by the Ob–Yenisei current.

The turbid waters occur in Baidaratskaya Gulf too. They travel as a narrow stripe northwards along the western shores of the Yamal peninsula. The excessive turbidity can be related here to the abrasion of the shores and the resuspension of the bottom sediments by the tidal currents. The particle concentration happens to be as high as 10 mg/l.

It is easy to see that frontal zones occur at the boundary of the Ob gulf and Yenisei Bay, where the suspended matter concentration sharply falls by an order of magnitude and more. At this boundary, the off-shore velocity of the flow of the river waters decelerates and the main amount of suspended particles sink down to the bottom (first of all, the largest particles of sand–silt dimensions). Beyond this boundary, the transformed river waters spread in the surface layer above the more weighty marine waters. The partly transformed riverine suspended matter penetrates into the open sea areas, which results in the relatively high concentration of suspended particles close to 0.5 mg/l. These lenses of desalinated waters at the sea surface are typical of the open Arctic ocean [4, 14]. It is quite probable that the distribution of the suspended matter concentration in the off-shore Arctic basin is subjected to the influence of events preceding the instants of the observations during an expedition. One of such events can be the propagation of river waters into the open sea as a result of floods.

The lowest suspended matter concentrations from 0.2 to 0.5 mg/l found from the satellite data occur in the west (near the Novaya Zemlya Islands) and north of the Kara Sea, where inflow of the river waters is weak and the biological productivity is low [9]. The research of the suspended matter conducted in September 1993 in the Kara Sea found the lowest particle concentration (less than 0.5 mg/l) in the west of the sea too [19, 24]. A domain of increased turbidity occurs west of the Yamal peninsula approximately in the center of the western Kara Sea. This domain roughly corresponds to the region of higher temperature on the SST satellite map (see Fig. 2 in [6]). Supposedly, the higher turbidity in this area is related to the phytoplankton development. In any case, high chlorophyll fluorescence occurs in this region [10]. Between the latter and the strip of turbid waters near the Yamal shores, more transparent waters reside. According to [10], the northbound Yamal current flows here.

A narrow strip of enhanced turbidity is seen close to the Novaya Zemlya archipelago. Evidently, this is due to the supply of the melt water from the coastal land areas. The suspended particle concentration in the surface layer of the margins of the Novaya Zemlya Islands and their bays was as high as 1.3–2.3 mg/l, which is several times higher against the 0.4 mg/l typical of the surface waters of the Kara Sea in September–October of 2007. The particle concentration reached an extremely high level of 51.9 mg/l in the Ukromnya gulf of Blagopoluchiya Bay and was close to 9.8 mg/l in the melt waters of an ice massif. Judging from the satellite data, this material of ice origin yields no perceptible contribution to the suspended matter composition of the off-shore areas of the western Kara Sea.

The cold water domain on the SST map in Fig. 2 in [6] corresponds to the above strip of enhanced turbidity. This domain relates to a local upwelling in the northern coastal zone of the Novaya Zemlya Islands and, probably, to the uptake of melt waters from the land [10]. Near the northern tip of the Novaya Zemlya archipelago, the cold and turbid waters of the coastal upwelling deviate to the east thanks to the interaction of the eastern Novozemel'skoye current flowing alongshore to the northeast with the Barents sea waters penetrating from the north [10]. The fairly extended domain of cold and turbid waters to the east of the northern tip of the Novaya Zemlya archipelago is clearly distinguishable in the satellite distributions of the SST and TSM.

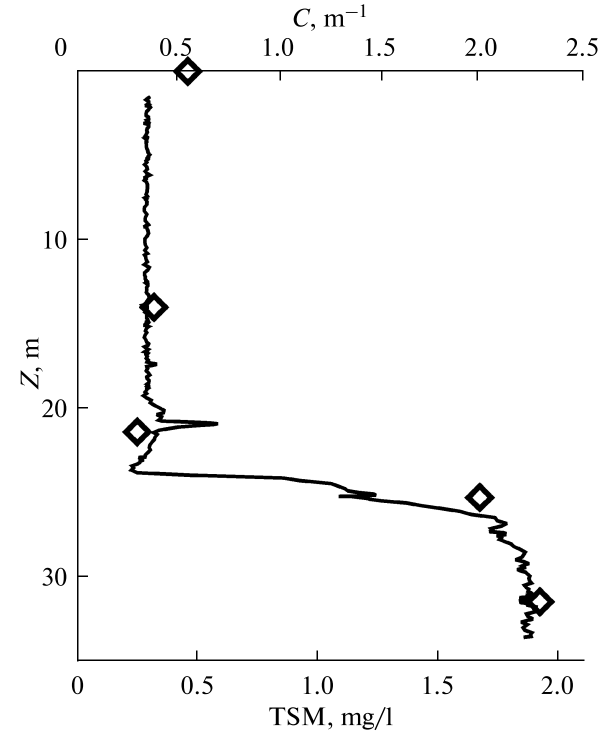

Fig. 2. An example of the quasi-synchronous measurements of the vertical distribution of the light attenuation coefficient C (solid) and the suspended matter concentration (diamonds) at station 4956.

The suspended matter distribution in the Yamal section. The shipboard research of the suspended matter distribution based on the optical measurements and water sampling were performed mainly in the Yamal (1) and Ob (2) sections (Fig. 3).

The first one, which was composed on the basis of the optical measurement data and using expression (2), is shown in Fig 4. The stations' positions and the depth levels of the water sampling are given in the same figure. Notice that the involvement of the optical data allowed us to plot the TSM distribution in greater detail.

The highest suspended matter concentration in the surface and bottom layers makes up 10 mg/l and occurs at station 4954, which is the closest to the shore. Apparently, the very turbid water is due to the bottom and shore abrasion induced by the tidal currents and due to the transport of turbid waters from the Baidaratskaya gulf. The suspended matter concentra-

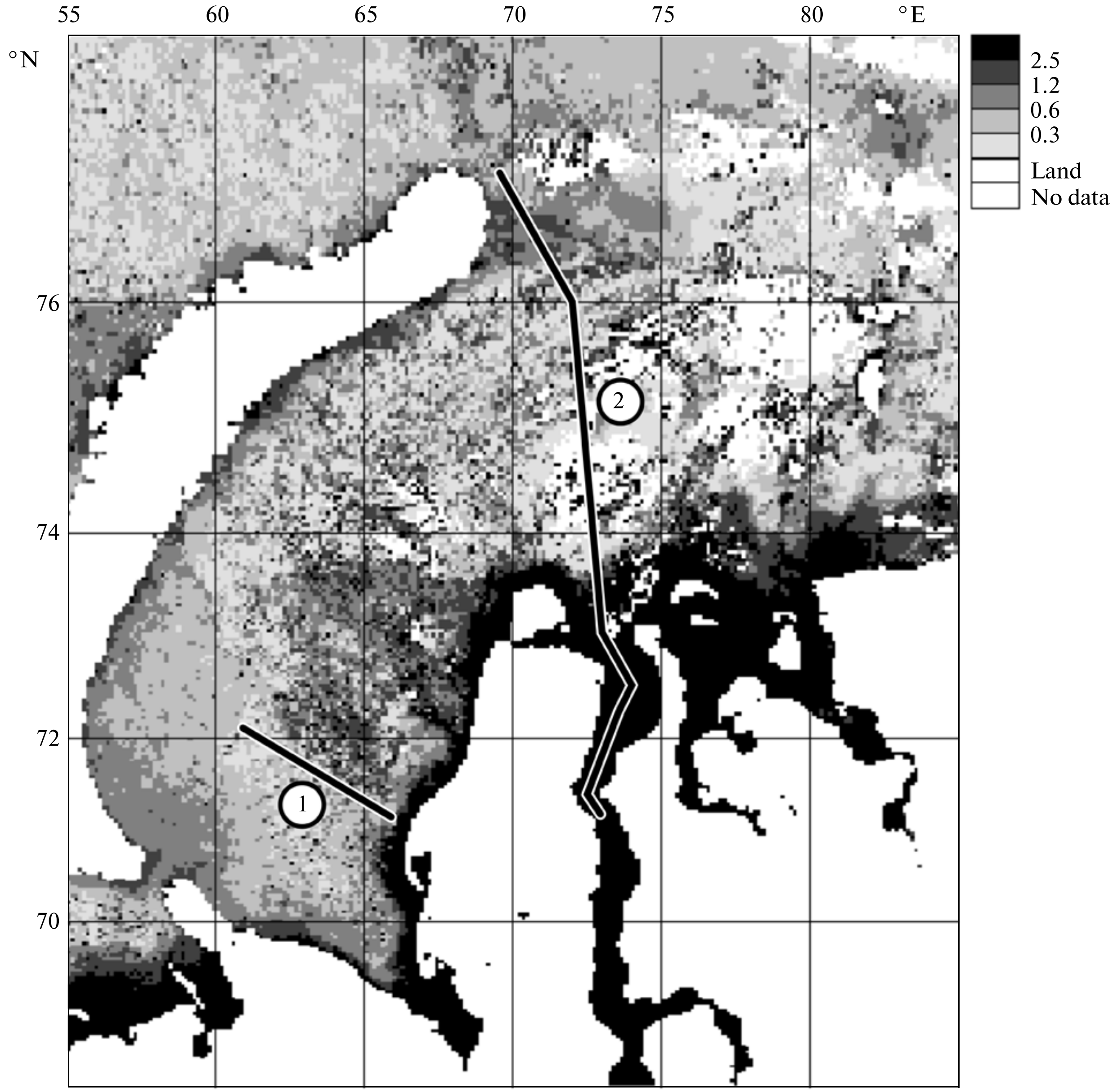

Fig. 3. The spatial distribution of the suspended matter concentration in the Kara Sea based on the evidence from the data of the MODIS-Aqua color scanner based on the algorithm developed for the present study. The data are averaged over the period of September 1–26, 2007. The lines depict the Yamal (1) and Ob (2) sections occupied during the expedition.

tion in the surface layer sharply falls off the shore and changes there in relatively narrow limits of 0.3–0.6 mg/l.

The phytoplankton development is the most likely factor causing the local increase up to 0.6 mg/l of the surface suspended matter concentration off shore at station 4960. The hydrological data indicate here a density jump at a depth of 10 m, and the surface chlorophyll was fairly high, making up up to 1.4 mg/m^3 [10]. The suspended matter concentration at this station rapidly decreased with the depth, being smaller than 0.2 mg/l below the depth level of 10 m. Hence, the phytoplankton hypothetically develops here mainly in the thin surface layer above the pycnocline. A similar phenomenon occurred earlier in the western Kara Sea in September of 1993 [19]. A suspended matter concentration below 0.5 mg/l is typical of the waters of the western Kara Sea, but higher concentrations from 0.6 to 1.7 mg/l were discovered in the surface 10 m thick layer at four stations. It turned out that this local increase in the turbidity was due to the diatoms blooming.

As a rule, the suspended matter concentration does not exceed 0.2 mg/l at depths greater than 20–30 m in the open Kara Sea.

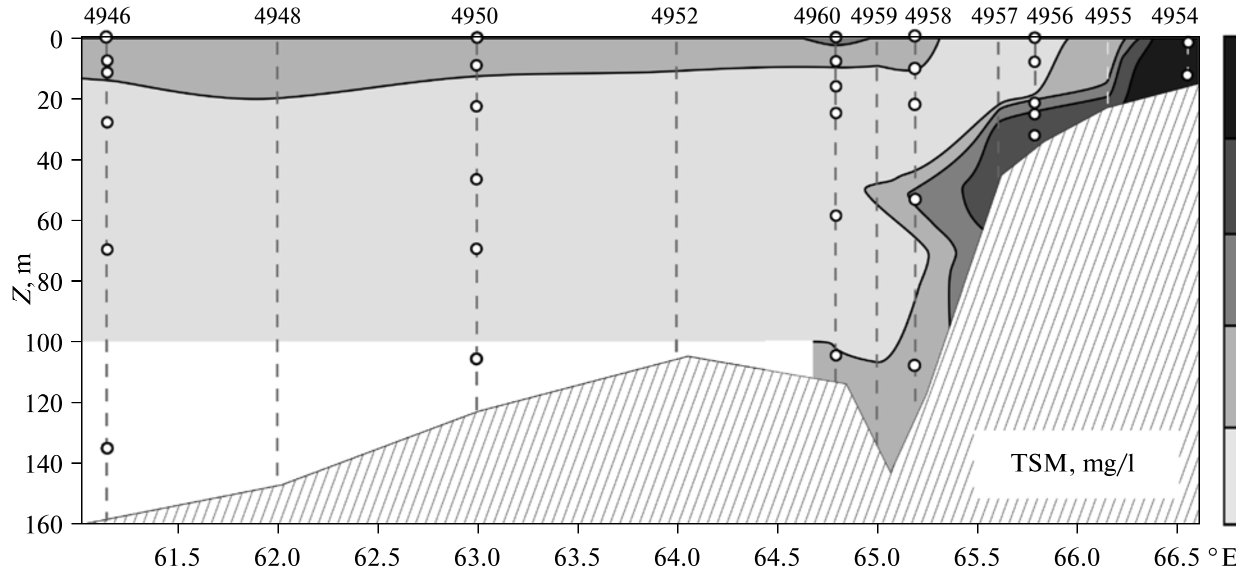

Fig. 4. The distribution of the suspended matter concentration in the Yamal section. The concentration scale (right) is given in mg/l. The circles mark the depth levels of the water sampling for the suspended matter at the different stations.

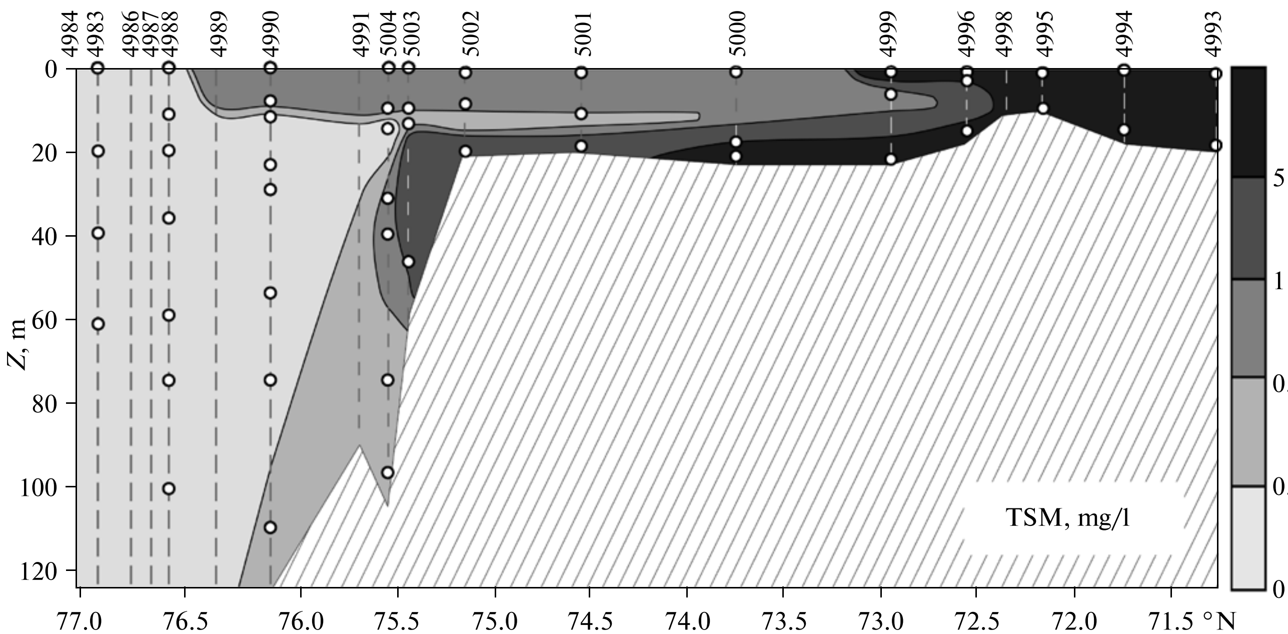

Fig. 5. The distribution of the suspended matter concentration in the Ob section (from the Ob River to the St. Anna trench). The concentration scale (right) is given in mg/l. The circles mark the depth levels of the water sampling for the suspended matter at the different stations.

A strong nepheloid layer develops in the near-bottom thickness in the east of the section, where the suspended matter concentration becomes as high as 16 mg/l at the most shallow station (station 4954). This nepheloid layer is observable to the point of station 4960; the suspended matter concentration substantially decreases when moving off shore.

The suspended matter distribution in the Ob section. Figure 5 shows the spatial distribution of the TSM based on the optical measurements data and the recalculation using (2).

In the section from the river Ob to the St. Anna trench, the suspended matter concentration regularly decreased northwards by an order of magnitude and more with the distance from the Ob estuary. As a rule, the suspended matter concentration at the surface depth levels of the Ob estuary exceeded 7 mg/l, but it reached 80 mg/l near the bottom thanks to the tidal resuspension of the bottom sediments.

Passing northwards, a frontal zone develops in the waters of salinity of 10–15 psu (close to station 4999) featuring a sharp drop of the suspended matter concentration. There, the interaction of the riverine and marine waters leads to the precipitation of an increased amount of relatively large-grain material along with the pelitic substance thanks to the change in sign of the clay minerals. Concurrently, the coagulation of colloids and the flocculation of dissolve iron and dissolved organic matter occur [13]. North of this zone (north of station 4999), the activity of brackish water and marine organisms gains increasing significance. This zone occupies the Ob shallows and the internal shelf. The sediment concentration varies from 0.4 to 0.6 mg/l in the near-surface layers. A nepheloid layer with a suspended matter concentration as high as 20 mg/l occurs near the bottom in the shelf part of the section.

The suspended matter concentration varies in the range of 0.2–0.3 mg/l near the surface and virtually in the entire water thickness at the external shelf when approaching the St. Anna trench. The fine particles of modified riverine sediments arrive here in negligible amounts.

CONCLUSIONS

The comparison of the satellite information and the ship borne determinations of the concentration of suspended particles in the water samples and using submersible optical instrumentation provided support for the efficiency of the application of the optical techniques for research in field of the concentration of suspended matter. The interrelations of the particle concentration and the optical properties were established based on concurrent measurements. The satellite map obtained is consistent with the data of the direct determinations at least at a qualitative level, but the quantitative consistency mostly took place too. The analysis performed allowed us to reveal the basic patterns of the distribution of the suspended matter in the Kara Sea's waters. The most turbid waters occur in the Ob gulf, Yenisei Bay, the Baidaratskaya gulf, and the adjacent regions. The lowest suspended matter concentrations were found in the central and western Kara Sea. A narrow strip of turbid waters is observable close to the western margin of the Yamal peninsula. The strip is due to the resuspension of the bottom sediments by the tidal motions and, probably, due to the water transport from the Baidaratskaya gulf. The waters from the Ob gulf and Yenisei Bay, whose enhanced turbidity is attributable to the river runoff, propagate mainly eastwards. The eastern coastal zone of the Novaya Zemlya Islands features a narrow strip of higher suspended matter concentration related to the supply of extra suspended particles with the runoff of the melt water from the land.

ACKNOWLEDGMENTS

The imagery of the MODIS-Aqua color ocean scanner used in the present study was obtained from the DAAC GSFC NASA data center.

The authors are grateful to the head of the expedition, V.M. Flint, for his support and interest in the study; to V.A. Artem'ev, A.V. Grigor'ev, and O.V. Prokhorenko for help with the measurements and data processing; to E.G. Morozov, V.V. Kremenetskiy, and A.N. Demidova for help with the water sampling; and to I.A. Nemirovskaya for help at all the stages of the study.

This work was supported by the Presidium of the Russian Academy of Sciences (project 4.4 of program 17), by the Department of Earth Sciences of the Russian Academy of Sciences (project Nanoparticles), by the Grant of the President of the Russian Federation (grant nos. NSh-361.2008.5 and MK-1747.2008.5), and by the Russian Foundation for Basic Research (project nos. 08-05-00094 and 10-05-00098).

REFERENCES

1. N. A. Aibulatov, V. A. Matyushenko, V. P. Shevchenko, et al., "New Data on the Transverse Structure of Lateral Fluxes of Particulate Matter in the Peripheral Areas of the Barents Sea," Geoekologiya, No. 4, 526–540 (1999).
2. V. A. Artem'ev, V. I. Burenkov, A. V. Grigor'ev, et al., *The Pechora Sea: Systemic Studies*, Chl. 3: *Optics* (MORE, Moscow, 2003), pp. 247–262 [in Russian].
3. V. A. Artem'ev, V. R. Taskaev, V. I. Burenkov, and A. V. Grigor'ev, "Universal Compact Gauge of Vertical Distribution of Light Attenuation Index," in *Multidisciplinary Studies of the World Ocean: The Meridian Project (Atlantic Ocean)* (Nauka, Moscow, 2008), pp. 165–172 [in Russian].
4. V. I. Burenkov and A. P. Vasil'kov, "The Effect of Continental Run-Off on the Spatial Distribution of Hydrological Characteristics of Waters of the Kara Sea," Okeanologiya **34** (5), 652–661 (1994).
5. V. I. Burenkov, Yu. A. Gol'din, B. A. Gureev, and A. I. Sud'bin, "The Main Ideas on the Distribution of Optical Characteristics of the Kara Sea," Okeanologiya **35** (3), 376–387 (1995).
6. V. I. Burenkov, Yu. A. Gol'din, V. A. Artem'ev and S. V. Sheberstov, "Optical Characteristics of Waters of the Kara Sea Based on Onboard and Satellite Observational Data," Okeanologiya **50** (5), 716–729 (2010).
7. V. I. Burenkov, S. V. Ershova, O. V. Kopelevich, et al., "An Estimate of the Distribution of Suspended Matter in the Barents Sea Waters on the Basis of the SeaWiFS Satellite Ocean Color Scanner," Okeanologiya **41** (5), 653–659 (2001) [Oceanology **41** (5), 622–628 (2001)].
8. V. I. Burenkov, V. M. Kuptsov, V. V. Sivkov, and V. P. Shevchenko, "Spatial Distribution and Size Composition of Suspended Matter in the Laptev Sea in August–September 1991," Okeanologiya **37** (6), 920–927 (1997) [Oceanology **37** (6), 831–837 (1997)].
9. V. I. Vedernikov, A. B. Demidov, and A. I. Sud'bin, "Primary Production and Chlorophyll in the Kara Sea

in September 1993," Okeanologiya, No. 5, 693–703 (1994).

10. A. G. Zatsepin, "Hydrophysical Characteristic of the Kara Sea," in *Report on Work in Cruise 54 of R/V "Akademik Mstislav Keldysh*," Vol. 2: *Team Leader Reports* (IO RAN, Moscow, 2008), pp. 2–10 [in Russian].
11. O. V. Kopelevich, V. I. Burenkov, and S. V. Sheberstov, "Development and Use of Regional Algorithms for Calculation of Bio-Optical Characteristics of Russian Seas Based on Satellite Color Scanners," in *Modern Problems of Remote Probing of the Earth from Space,* (OOO Azbuka, Moscow, 2006), issue 3, Vol. II pp. 99–105 [in Russian].
12. O. V. Kopelevich, V. I. Burenkov, Yu. A. Gol'din, and G. S. Karabashev, "Optical Methods in Oceanology and Sea Geology," in *New Methods in Oceanology,* Ed. by M. E. Vinogradov and S. S. Lappo (Nauka, Moscow, 2004), Vol. 1 [in Russian].
13. A. P. Lisitsyn, "Marginal Filters of and Biofilters of the World Ocean," in *Oceanology at the Start of the XXI Century*, Ed. by A. L. Vereshchaka (Nauka, Moscow, 2008) [in Russian].
14. A. P. Lisitsyn, "Marginal Filter of Oceans," Okeanologiya **34** (5), 735–747 (1994).
15. A. P. Lisitsyn, *Osadkoobrazovanie v okeanakh* (Nauka, Moscow, 1974) [in Russian].
16. A. P. Lisitsyn, V. P. Shevchenko, and V. I. Burenkov, "Hydrooptics and Particulate Matter in Arctic Seas," Opt. Atmos. Okeana, No. 1, 61–71 (2000).
17. V. A. Matyushenko, I. K. Popov, and I. L. Misyuchenko, "Spatial Distribution of the Attenuation Index in Waters of the Kara Sea," Dokl. Akad. Nauk **2** (3), 403–406 (1995).
18. V. S. Medvedev and E. M. Potekhina, "Quantitative Distribution and Dynamics of Particulate Matter in the Southwestern Part of the Kara Sea," in *Modern Process of Sedimentogenesis on Shelfs of the World Ocean* (Nauka, Moscow, 1990), pp. 110–120 [in Russian].
19. V. P. Shevchenko, O. V. Severina, N. G. Maiorova, and G. V. Ivanov, "Quantitative Distribution and Composition of Particulate Matter in Estuaries of Ob and Yenisei Rivers," Vestn. Mosk. Univ., Ser. 4., No. 3, 81–86 (1996).
20. V. I. Burenkov, A. A. Klyuvitkin, and S. V. Sheberstov, "Suspended Matter Concentration in Surface Layers of the Atlantic Ocean Derived from Data of Ocean Color Scanner MODIS," in *Proceedings of IV International Conference: Current Problems in Optics of Natural Waters (ONW' 2007), Nizhny Novgorod, September 11–15, 2007* (Nizhny Novgorod, 2007), pp. 154–156.
21. O. V. Kopelevich, V. I. Burenkov, S. V. Sheberstov, et al., "Continuation of Long-Term Series of Data in the Bio-Optical Characteristics of the Russian Seas from Satellite Ocean Color Data," *Proceedings of IV International Conference: Current Problems in Optics of Natural Waters (ONW' 2007), Nizhny Novgorod, September 11–15, 2007* (Nizhny Novgorod, 2007), pp. 75–78.
22. O. V. Kopelevich, V. I. Burenkov, S. V. Vazyulya, et al., "Bio-Optical Characteristics of the Seas of Russia from Data of the SeaWiFS Satellite Ocean Color Scanner," CD-ROM. M. SIO RAS (2007).
23. V. N. Lukashin, S. V. Ljutsarev, A. D. Krasnyuk, et al., "Suspended Particulate Matter in the Ob and Yenisei Estuaries," Ber. Polarforsch **300**, 155–178 (1999).
24. V. P. Shevchenko, A. P. Lisitzin, G. I. Ivanov, et al., "Quantitative Distribution of Suspension and Suspended Organic Carbon in the Kara and Barents Seas," in *Natural Conditions of the Kara and Barents Seas. Proceedings of the Russian–Norwegian Workshop-95* (Norsk Polarinstitutt, Oslo, 1997), pp. 431–435.