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Pollution of the Black Sea by Oil Products. Its Monitoring and Forecasting

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ABSTRACT

In the paper the current state of the Black Sea pollution by oil products is reviewed. The significant attention is paid to a satellite radar monitoring of the sea surface pollution. The paper contains also short description of the numerical models on simulation and forecasting of oil spill dispersion in the sea environment. Some result on simulation of oil pollution distribution in the Georgian water area based on advection-diffusion equation in conditions of real regional circulation is presented.

Key words: Black Sea, pollution by oil products, numerically modeling

1. Introduction

In recent decades an intensive pollution of many regions of the World Ocean with oil products and other highly toxic substances of anthropogenic origin takes place. In this regard a special place is held by inland water bodies which are particularly sensitive to anthropogenic loads due to their low water exchange with the World Ocean. Primarily, the aforementioned fact may be referred to the Black Sea, whose pollution level progresses significantly. It is well known that the Black Sea is one of the most contaminated basins of the World Ocean due to anthropogenic impact and hydrological features. The Black Sea is the inland sea most isolated from the World Ocean, it is only connected to the Mediterranean through the Turkish Straits and to the Sea of Azov – through the Kerch Strait. Specific features of the Black Sea make it very vulnerable to the anthropogenic loading leading to a significant increase in pollution level of the Black Sea with different pollutants. According to modern observations a pollution of the Black Sea by substances of anthropogenic origin is progressing [1-5]. Among the polluting substances oil and oil products are more dangerous and widespread components for the Black Sea environment as well as for the World Ocean [2, 4-6]. Besides that they can cause a serious damage to the marine living organisms, they can break a natural hydrological cycle and, consequently, cause anthropogenic climate changes. If on the big square of the ocean surface oil and oil products in a considerable quantity are poured, they will promote reduction of evaporation and simultaneously will decrease salt fluxes in the atmosphere because of decrease wind waves and splashes [7]. It is well known that salt particles play a role of the centers of condensation and consequently their deficiency will block processes of cloud's formation [8].

The degree of risk is especially great for shelf and coastal zones due to intensive human economic activity. In this respect Georgian coastal zone is not exception. Through the Black Sea passes the international transport corridor TRACECA (Transport Corridor Europe-Caucasus-Asia) and in the coming years shipping intensity is expected to increase. This fact creates a sufficient potential threat for the Black Sea and especially for the Georgian coastal zone.

At present, there is no such region in the World Ocean that would not be affected by the pollution of water with oil products. According to modern estimates, annually 1.7-8.8 million tons oil are released in the World Ocean.

Crude oil is a mixture of different fractions, whose main components are hydrocarbons (80-90%). In the marine environment, oil and oil products are in the form of oil films, dissolved and emulsified petroleum products, oil aggregates [3]. Significant concentrations of oil products in sea water are observed in the area of estuaries of large rivers - the Danube, Dnieper, Dniester and in the waters of the ports.

In conditions of growing anthropogenic loading on the sea ecosystems it is obvious that a reliable operational monitoring and forecast of pollution areas and concentrations in accidental situations is a very important problem. At present the modern satellite radar technologies provide to carry out monitoring of oil pollution of the sea surface with high space resolution [6].

The Black Sea crisis calls for a concerted international approach. Protection and environmental safety of marine ecosystems became an object of great attention in the 50s of the last century. The first international agreement was concluded in 1954 in London/United Kingdom on the prevention of oil pollution of the seas (1954 London Convention).This agreement imposed certain obligations on states to protect the marine environment.

Since 1990s the international cooperation between the Black Sea countries has entered into a new phase. On 30 November 1990 in London the International Convention on Oil Pollution Preparedness, Response and Co-operation (known as the OPRC Convention) was adopted. The Convention obliges its participating States including Georgia to ensure the readiness of the oil spills to be adequately reacted. In 1992 in Bucharest/Romania the six coastal countries (Bulgaria, Georgia, Romania, the Russian Federation, Turkey and Ukraine) signed and ratified the convention on the Protection of the Black Sea against Pollution. Since then, the commission on the Protection of the Black Sea against Pollution (the Black Sea Commission/BSC), acting on the mandate of the Black Sea countries, is responsible for the sustainable management of the Black Sea.

In this paper the current state of pollution of the Black Sea by oil products is reviewed. The significant attention is paid to a satellite monitoring of the sea surface oil pollution. The paper contains also short description of the numerical models on simulation and forecasting of oil spill dispersion in the sea environment. Some result of simulation of oil pollution distribution based on advection-diffusion equation in the Georgian water area in conditions of real regional circulation is presented.

2. The current state of the Black Sea oil pollution

In addition to the fact that covering the sea surface with oil spots significantly affects the characteristic parameters of sea-atmospheric interaction, oil pollution has a substantial impact on a number of hydrochemical and hydrobiological processes and consequently on the marine ecosystems. The consistency of oil can cause surface contamination and smothering of marine biota, and its chemical components can cause acute toxic effects and long-term accumulative impacts [9]. The environmental impact does not only depend on the size of the spill but also on the spread of the oil slick, the toxicity and persistence of the oil and the sensitivity of the environmental region affected.

In the 70-80s of the last century, researches conducted at the Novorossiysk Biological Station showed that oil pollution of the Novorossiysk Bay caused significant changes in the distribution of seaweed and animal species [3]. For example, water-plants Zostera and Cystoseira, which previously developed rapidly in the shallow parts of the sea, retreated to a depth of 3 m. Mussel, widely distributed earlier in the middle of the bay, now lives only in the open deep sections, where the waters are less polluted [3].

The main sources of oil pollution of the Black Sea are river runoff, direct discharges of domestic and industrial wastewaters, atmospheric deposition, port operations in the sea ports, accidental inflows and unauthorized spills from oil ships. At present the Black and Azov Seas are the marine region with the largest anthropogenic press in Europe [3]. Nowadays the Black Sea plays a role of corridor for oil transportation from the East to the West, and in the coming years this transportation is expected to increase. This fact creates a sufficient potential threat of even greater ecosystem pollution with oil products.

According to the data given in [2], the annual quantity of oil emissions into the Black sea for 2003 was 110000 tons. Particularly large anthropogenic load is experienced by the shallow north-western part of the Black Sea. A significant contribution to the level of oil pollution in the northwestern part of the sea is made by the Danube River. In one of the documents prepared by the Parliamentary Assembly of the Council of Europe [10], where the contribution of large rivers to the Black Sea pollution is quantified, it is mentioned that only the Danube annually carries out into the sea 50000 tons of oil products.

According to the data presented in [6], by 2007 about 170 million tons of oil and petroleum products passed through the Black Sea ports. According to statistics, from 0.1% to 0.5% transported oil is discharged to the ocean as a result of the discharge of washing and ballast water to the open sea. Considering this fact, the volume of oil products entering the Black Sea in the form of oil spots should be more than 150000 tons per year.

Among the major oil spills in the Black Sea in last decades, we can note an emergency spill near Novorossiysk on November 1999, when, due to damage to the terminal, 39 tons of oil spilled into the sea [2].

Fig.1. Oil patches on the Tuzla Spit on November 12, 2007 [11].

Large emergency spill occurred in the Kerch Strait as a result of a storm on 10 and 11 November 2007 [11]. The strong storm hit the Kerch Strait located between Ukraine in the West and Russia in the East, and linking the Sea of Azov with the Black Sea. Extremely severe conditions lasted 9 hours. Winds exceeding 30 m/sec produced the over 4 meter-high waves. A strong storm resulted in thirteen vessels being sunk and damaged. The incident caused loss of life, or property, and environmental harm. According to the data provided by the Ukrainian Ministry of Transport, the total amount of the immediate spillage was 1300 tonnes of heavy fuel oil, 2,3 tonnes of oil lubricants, 25 tonnes of marine diesel fuel oil and 5,5 tonnes of heating oil. Fig. 1 Illustrates pollution of the coast of Tuzla island by oil after emergency on November 12, 2007.

The Kerch accident became the most studied oil spill event in the world – numerous inspection trips on coast and at-sea and more than 60 complex cruises were organized.

Over the past 50 years in the Black Sea and especially in the Bosporus Strait, there have been many major oil spills than it was in the Kerch Strait. In October 1977 in Bosporus Strait as a result of damage to the Soviet tanker 20000 tons of oil spilled into the sea. In November 1979, as a result of the collision of the Romanian and Greek tankers 64000 tons of oil spilled into the sea. The largest in the past 20 years oil spill in the Black Sea occurred when the *Nassia* tanker and the *shipbroker* cargo vessel collided in the Bosporus Strait on 13 March 1994. *Shipbroker* got totally burnt. The major part of *Nassia's* cargo was spilled over into the sea and together with 20000 tons of burnt oil caused severe marine and air pollution on the Bosporus, and in the Black and Marmara Seas [11].

In the Marmara sea, nearly 450 different scale accidents were reported within the last 40 years. Several ship accidents happened during the past 20 years by the Black Sea coast of Bulgaria, Romania, Russia and Ukraine, however, they mostly brought small-scale oil spills or other kind of pollution [11].

On 24 December 2014 The pipeline near the city of Tuapse burst. According to Chernomor "Transneft" a subsidiary of Russia's main oil transport company "Transneft" the wall of the pipeline broke due to... a landslide. The company said in a statement, adding that the rupture caused 8.4 cubic meters to leak out into the Tuapse River, which empties into the Black Sea. Environmentalists warned however that the volume of the spill could be nearly 100 times greater than claimed by "Transneft". By estimation of World Wildlife Fund the surface area and characteristics of the spill indicated that there could be as much as 500 to 700 tons of oil in the Black Sea, which would be approximately 100 times as much as originally reported [12]. In Fig.2 oil leaks at the Tuapse River on December 14, 2014 are shown.

Fig. 2. Oil leaks at the Tuapse River in the Russian Black Sea coastal town of Tuapse, December 24, 2014. (Reuters photo).

The most serious pollutants of the marine environment in the Black Sea coast of Turkey are petroleum hydrocarbons. Water pollution by oil was the main cause of environmental degradation in the western part of the sea in 1970-1995 [13]. Oil fractions and crude oil fall into the marine environment as a result of emergency spills, leakage of petroleum products from transport vessels, urban and river run-offs and the discharge of contaminated water from tanker ballast tanks. Oil stains on the water ruined a lot of sea gulls and other species of birds. The ecological situation in this part of the sea has gradually improved, after the Turkish Coast Guard service has been prevented the discharge of ballast waters from the ships [13].

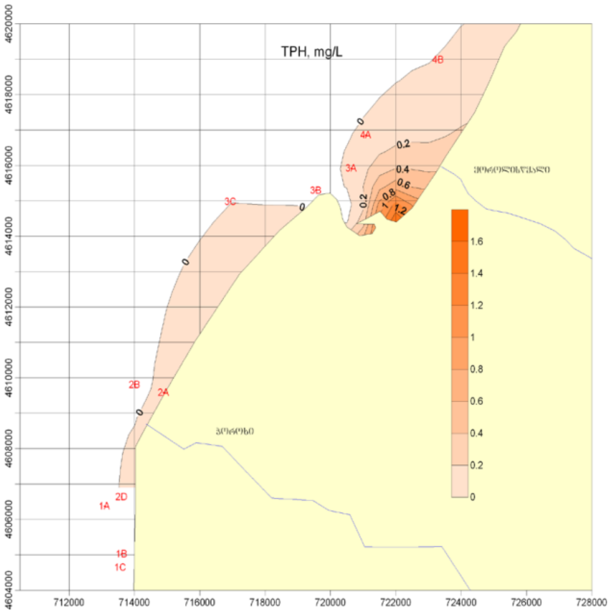

Fig. 3. Content of petroleum hydrocarbons in seawater at Gonio-Natanebi water area [14].

Studies carried out in Batumi-Gonio coastal zone (Georgian Sector of the Black Sea) in 2008-2009 [14] showed that the concentration of petroleum hydrocarbons were within 0,04-1,74 mg/l. Maximum value 1,74 mg/l was at the confluence of the Bartskhana river to the Black Sea. These studies also showed that major polluters of the Black Sea by oil products are rivers Bartskhana, Korolistskali, Supsa and Khobi. According to the data for 2009 concentration of oil hydrocarbons in Korolistskali 161 times higher than the permissible norm – 0.3 mg/l. In the internal water area of Batumi port was observed 0,52 mg/l. The map of distribution of petroleum hydrocarbons, created on the basis of measured data, is shown in Fig.3 [14].

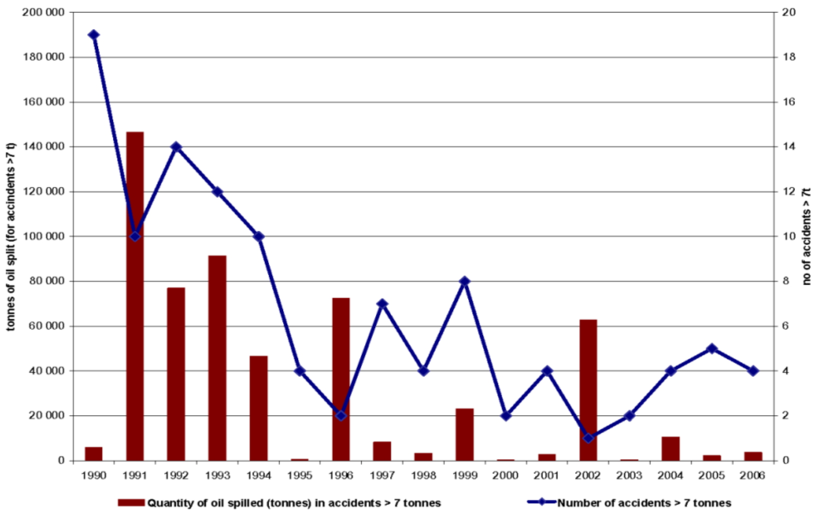

Fig. 4. Accidental oil tanker spills (above 7 tonnes per spill) in European seas during 1990-2006 [9].

It should be noted that according to European Environment Agency accidental oil tanker spills into the European Seas have decreased significantly during 1990-2006 [9]. Fig. 4 clearly illustrates this fact [9]. Despite the decreasing number of accidental oil spills in European waters (the Northeast Atlantic, Baltic, Mediterranean and Black Sea) major accidental oil tanker spills (i. e. those greater then 20000 tonnes) still occur at irregular intervals.

3. Satellite monitoring of oil pollution

In recent years the use of modern satellite remote sensing methods and satellite technologies in Earth Sciences has led to better understanding and study of the ongoing geophysical processes on our planet [4, 6, 15-23]. Over the last decades the development of remote sensing methods of sea surface from the Earth's artificial satellites has reached a completely new level. These methods made a revolutionary leap into the field of marine science and gave them completely new qualities. As the authors write in [15], now is impossible to imagine carrying out environmental monitoring without using information obtained with the help of remote diagnostic devices installed on various satellites specialized in remote sensing of the Earth. At present, remote sensing equipment makes it possible to carry out various regular observations of the ocean surface with high space resolution and high time frequency.

Because the Black Sea ecosystem is experiencing increased anthropogenic impact, which is importantly associated with oil contamination, therefore it is very important and urgent to implement an operational satellite radar monitoring system that will effectively identify the areas of spillage and sources. With this purpose the modern satellite radiolocation has great importance, which is very effective tool to identify oil pollution zones and sources in basin scale operatively [4, 6, 17, 18]. The satellite technology has such advantages as high resolution, simultaneous monitoring over the large territory at any weather conditions, etc. High spatial resolution of modern space borne radars with synthesized aperture (SAR) installed on the satellites *ERS-2* and *Envisat* of the European Space

Agency allow us to accurately detect film contaminations of even a relatively small size and evaluate their parameters.

Spilled oil on the sea surface forms an oil spot, which leads to damping of the gravitational-capillary component of surface waves and forms areas of smoothing, called slicks. They are displayed in a dark tone on the radar images. However, there are a number of natural factors limiting the applicability of space radar to solve the problem of identifying oil spills. At a weak wind of 1-2 m/s oil films do not differ on a background of a dark sea surface. In a strong wind they disappear from the surface due to intense wave mixing. The wind speed between 3 m/s and 8 m/s is ideal for detecting oil contamination [6]. In this case, slicks look dark on the background of light agitated surface of the sea.

Slick on the sea surface can be formed not only because of oil pollution, but the cause of slicks can be various organic compounds. Sources of organic matter in the ocean are animals and plants, as well as natural sources of crude oil [24]. Biogenic substances form on the surface of the sea films in several monomolecular layers 10^{-7}-10^{-6} cm thick, accumulating in areas of high biological activity. Biogenic films are the result of the life activity of marine organisms and plants, mainly phyto and zooplankton, as well as bacteria. They are formed in the sea as a result of complex biochemical reactions in the process of vital activity and decomposition of marine organisms, and can not be considered as sea pollution. Organic films remain in the sea at weak winds for a long time and begin to break down when the wind speed exceeds 6-7 m/s. After the termination of the strong wind, organic substances are again carried to the surface and form slicks. Not only oil and oil products form anthropogenic films on the sea surface, but also various technical and household oils, fatty acids and alcohols, synthetic surfactants contained in domestic, industrial and sewage. Spilled into the sea, oil forms films of varying thickness, since oil and its products are complex mixtures. Due to its physico-chemical properties, oil can exist in the ocean for a long time in the form of films, in emulsified form or in the form of aggregates. With a strong wind, the stain is destroyed and an oil emulsion appears in the layer of wind mixing. Unlike organic matters, oil never spreads to monomolecular layers, and its films have a large thickness.

Among numerous papers devoted to satellite radar monitoring of the sea surface pollution it should be noted [15], where results obtained in the course of multiyear satellite monitoring of oil pollution in the Baltic, Caspian and Black seas are summarized. An integrated approach to detection and spreading forecast of oil pollution is based on joint analysis of various data of satellite remote sensing of the sea surface. As a result of the analysis of various data of satellite remote sensing of the sea surface areas worst affected by oil pollution were revealed. The greatest part of anthropogical pollution of the surface in the Baltic and Black Seas detected during monitoring activities is accidental spills and deliberate discharges of liquid oil products along the main ship routes. For three years 2009-2011 of satellite observations more than 600 cases of pollution of the Black Sea surface by oil products as a result of ship discharges have been revealed in the Sea water area.

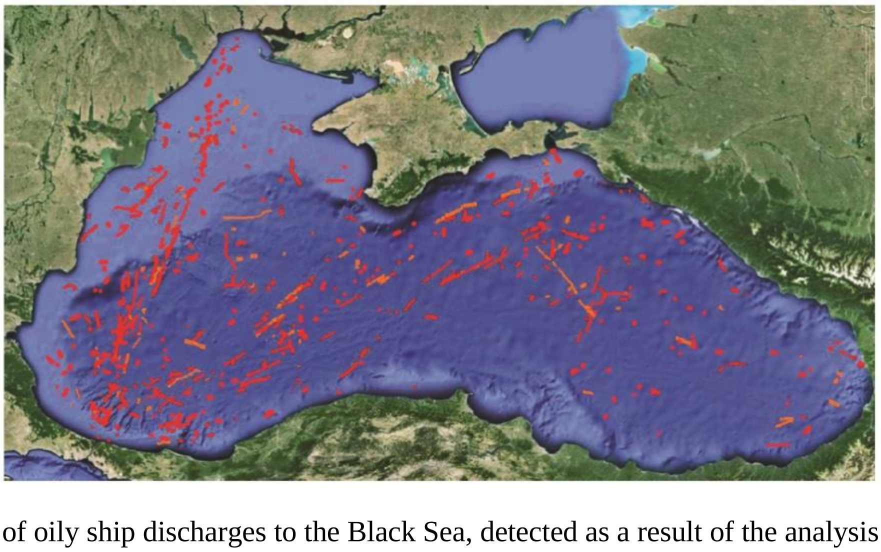

Fig.5. Map of oily ship discharges to the Black Sea, detected as a result of the analysis of satellite radar data in 2009-2011 [15].

In Fig.5 a generalized map of oil pollution of the Black Sea water area, obtained on the basis of deciphering satellite radar data for 2009-2011, is presented. This Figure shows the cumulative map of oil-containing spills revealed from satellite radar data in the aquatic area of the Black Sea for three years. Year-by-year numbers of oil spills detected are 286, 253, and 247 correspondingly. All these pollution events are caused by spillages of oil-containing waters from moving ships. As expected, spillages are concentrated along the main shipping routes such as Istanbul-Novorossiysk, Istanbul-Odessa and Istanbul-Tuapse. Besides these routes, a large amount of spills is observed near the major ports of Bulgaria, Turkey, Romania and Ukraine as well as near oil loading terminals [16].

In Fig. 6 satellite radar images obtained from satellite ERS-1 and ERS-2 on 12 and 13 May 1996 for some water area of the Caspian Sea are presented where by dark color oil stains on the sea surface are clearly visible [6]. Often vessels produce multiple discharges of polluted waters in motion. Fig. 7 shows an example of such a phenomenon and illustrates the trace of the oil spill along the trajectory of the ship fixed from the satellite in the Japanese Sea on the radar image of the ERS-1 satellite.

(a) (b)

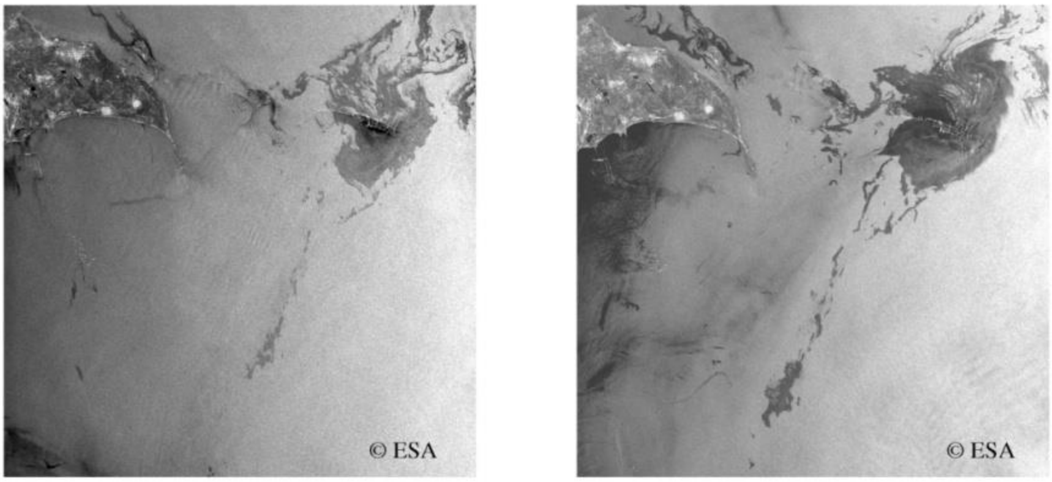

Fig. 6. Satellite radar imageries of oil slicks on the Caspian Sea surface received from satellites -ERS-1 on May 12 (a) and ERS-2 on May 13 (b), 1996 [6].

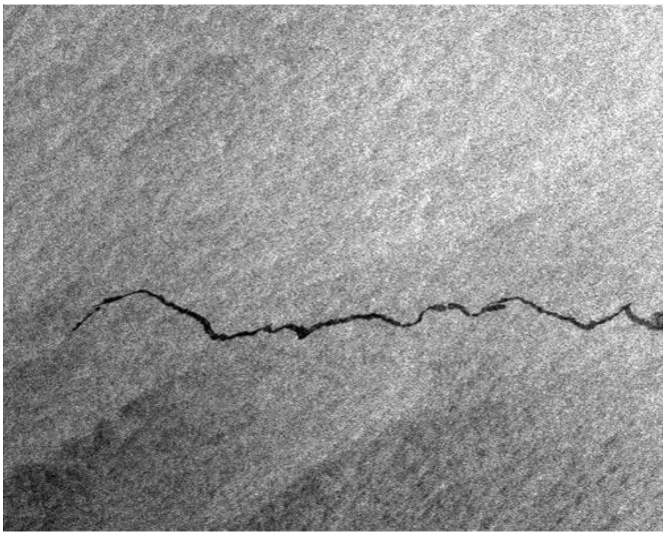

Fig.7.Trace of an oil spill along the trajectory of a ship in the Japanese Sea on a radar image received from a satellite (20.05.1994, 14:20 UTC) [25]

In [15, 21] it is noted that illegal discharges of ballast water containing oil products are so common for the Black Sea that in aggregate they cause much greater damage to the ecosystem of the Black Sea than individual catastrophic oil spills.

In [15, 16] the results of a long-term satellite monitoring of the Black Sea revealing sea surface pollution by oil as well as manifestations of biogenic and anthropogenic surface films are presented. It turns out that in case of the Black Sea, the detection of oil spills caused by ship discharges is more complicated as compared with other seas due to intensive phytoplankton bloom and to natural hydrocarbons seeps that can be detected in various areas of the Black Sea.

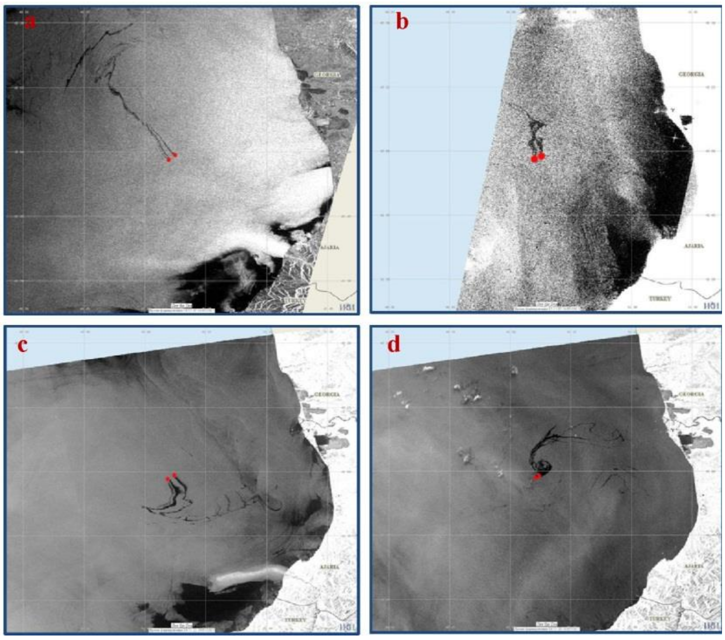

Fig. 8. Surface slicks in the continental slope area offshore Georgia as seen in satellite radar imagery on 27.10.2010 at 07:32 UTC (a), 17.09.2011 at 07:21 UTC (b), 08.11.2014 at 15:10 UTC (c), and on 15.10.2014 at 15:10 UTC (d) [15, 16].

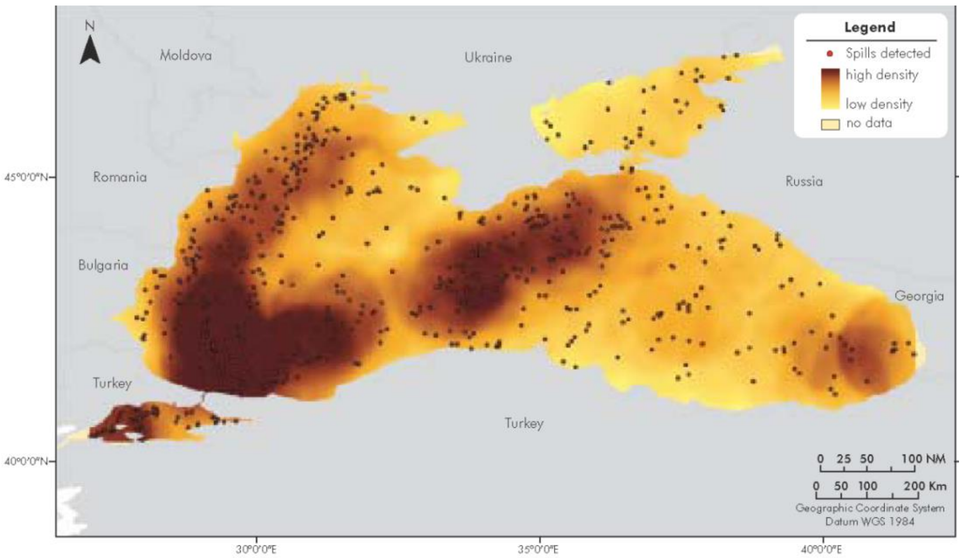

Fig. 9. Map of detected oil spills and oil spill density in the Black Sea during 2000-2002 [26]

With the purpose of illustrating Fig. 8 gives some examples of patterns of oil pollution detected in SAR (synthetic aperture radar) images taken over the continental slope area offshore Georgia.

Surface slicks in Georgian water area are caused by natural hydrocarbon seepages from the sea bottom. Certain types of surface pollution detected in sea surface radar imagery (Fig.8) are caused by natural hydrocarbon seeps at the Black Sea bottom. Researches carried out in the Georgian continental slope are showed that four cold methane seeps are located on the sea floor in this area. The presence of oil traces in bottom sediments is a distinguishing feature typical of these seeps [15, 16].

In Fig. 9 detected oil spills and oil spill density in the Back Sea during years 2000 to 2002 are shown. From this Figure is visible that the most pollution areas are south-western and central part of the sea basin. Oil polluting area is also in the Georgian sector, but with less intensity [26].

At present, the system of operational satellite monitoring is working successfully in the different regions of the World Ocean – in the Russian sector of the Black Sea, in the south-eastern part of the Baltic Sea, in the north part of the Caspian Sea, etc.

4. Forecasting methods of oil pollution

The development of oil pollution forecasting methods is one of the urgent problems of contemporary applied oceanology [2, 6, 11]. A reliable operational forecast of distribution and concentration areas of pollutants in case of accidental oil spills will allow to optimize the effectiveness of performing measures in order to bring down to the minimum the possible negative consequences caused by oil pollution.

The spread of oil spills in the sea is a very complex process, depending on a large number of factors that determine both the state of the environment and the properties of petroleum hydrocarbons. The forecast of oil spill transport in the sea environment requires first of all forecast of sea circulation processes.

The mechanism of distribution and transformation of oil spilled in the marine environment is described in sufficient detail in [2, 27-29]. In addition to advective transfer and turbulent diffusion, in the first days after the spillage oil concentrations are also affected by evaporation, emulsification, and dissolution processes. A sufficient number of works is dedicated to the modeling of oil patch transfer in the Black Sea and in other seas (e. g. [2, 30- 41]). We will mention some of them. In [2] an integrated model of the Black Sea water circulation and oil patch drift on the basis of the random walking particles approach, which allows tracking the motion of single particles (sum total of them makes an oil slick). Circulation parameters were derived from DiaCAST model [42] adapted for the Black Sea. The model from [2] was also used for the Caspian Sea [31-33], but the fields of currents and turbulence were reproduced by means of POM model [43] adapted for the Caspian Sea.

As advanced model of oil pollution drift [34], which is an additional module to the operational model of ocean circulation, was developed at Danish Meteorological Institute. Turbulent motion is described by Monte Carlo method. This model is used for the North and Baltic Seas and allows forecasting not only the oil slick spread on the sea surface, but also the amount of oil immersed in the lower layers.

3D oil pollution model MOTHY [35-37] connected to the model of ocean circulation was developed by French meteorological service *Meteo-France*. MOTHY model is used for the Aegean Sea, the Mediterranean Sea and for other regions of the World Ocean. The adaptation of this model to the Bourgas bay [38] was performed by Bulgarian national meteorological service. Nowadays MOTHY is a component of a system of operational marine forecasts in Bulgaria and it can be used in case of emergencies.

In [39] a system of the weather, wind-induced waves and sea current simulation, in which the model of oil slick drift is included, was developed. MMS model [44] is used for operational weather forecasting in the Black Sea region, for the simulation of wave-induced waves – *WAVEWATCH*III [45], and the Black Sea hydrodynamics is calculated by means of POM model [43]. The simulation system is implemented for the north-western shelf of the Black Sea and for estuaries of the Dnieper and the Bug.

In [41] a 3D numerical model for transport and fate of oil spills in seas based on the particle approach is presented. The amount of oil released at sea is distributed among a large number of particles tracked individually. Horizontal and vertical diffusion are taken into account using a random walk technique. The model takes into account: advection, surface spreading, evaporation, dissolution, emulsification, turbulent diffusion, the interaction of the oil particles with the shoreline, sedimentation and the temporal variations of oil viscosity and surface tension. The model has been applied to simulate the oil spill accident in the bohai Sea.

In [46-48] the process of oil propagation all over the Black Sea spilled on the sea surface in large quantity was simulated on the basis of a 2D advection-diffusion equation for non-conservative impurity. The components of the sea current velocity corresponded to the annual mean climatic conditions and were calculated by the nonlinear barotropic sea dynamics model [49]. Numerical experiments performed at different location of pollution sources showed that the Rim Current having cyclonic character predetermines the principal features of the oil pollution distribution; on expiration of a certain time (about 1,5-2 months) after emission, the process of distribution of oil concentrations practically does not depend on the location of the oil pollution source, pollution is distributed over the whole water area of the Black Sea and tendency to alignment of concentrations is noticed.

At present the model [46-48] is adapted for the easternmost part of the Black Sea and included in the easternmost Black Sea regional forecasting system as a separate module [50-54]. This regional system is a subsystem of the basin-scale nowcasting/forecasting system. The current field used in the oil spill transport model is calculated from the regional model of the Black Sea dynamics, which is a core of the regional forecasting system. The forecasting system permits to forecast oil pollution zones and oil concentrations for 3 days with spatial resolution 1 km in the Georgian Black Sea coastal zone. Numerical experiments performed for the cases of various locations of a hypothetic pollution source occurring under actual circulation modes, showed a significant role of dynamic processes in formation of some features of spatial-temporal pollution distribution.

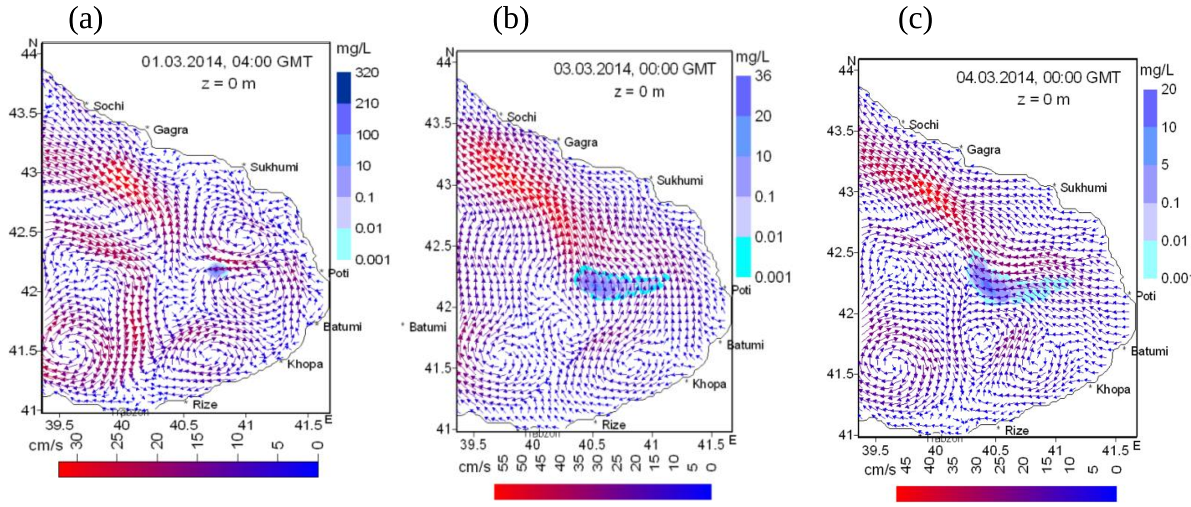

Fig.10. The surface current and simulated oil spill transport at different time moments (after start of oil spillage): (a) - 4 h, (b) - 48 h, (c) - 72 h. (The forecasting period: 00:00 GMT, 1-4 March, 2014), [53].

Fig. 10. illustrates forecasted regional circulation in the easternmost part of the Black Sea and drifting of oil slick in case when 50 t oil was abnormally spilled during 2h on distance about 65 km from Poti shoreline. The forecasting period was 00:00 GMT, 1-4 March 2014. From Figure it is well that in the eastern part of the considered area the triplet structure consisting of two anticyclonic vortexes and middle cyclonic vortex is formed on 1-2 March 2014. During the forecasting interval the current is substantially transformed – the triplet structure gradually breaks up and the current directed to the north-west is formed, but there are also some vortexes with relatively small sizes. Such circulating reorganization is essentially reflected on moving of the oil spill. In the course of migration the oil slick deforms and concentrations gradually decrease that is caused by diffusion expansion and other nonhydrodynamic factors.

5. Conclusions

Currently, the Black Sea is the marine region with the greatest press in Europe and its pollution with various anthropogenic substances is progressing. The main polluters of the Black Sea are oil and oil products. In addition to river and coastal runoff, which gives chronic pollution of the marine environment, the transportation of oil and oil products by the sea and the operation of oil terminals is a major potential threat to the sea ecosystem. Conducted studies and assessments show that for the Black Sea a frequent release of ballast and wash waters from tankers are serious source of pollution by oil products. It is expected that in the near future the transport role of the Black Sea will be increased which creates a serious potential threat to the marine ecosystem.

The development and functioning of the high resolutions operational satellite radar monitoring systems for the World Ocean including the Black and other regional seas is very actual and important problem of the modern operational oceanography. Performed observations have demonstrated a clear necessity of implementing operational satellite monitoring of water area pollution, which are able to determine the source of pollution, conduct quantitative assessment of its scale and predict its drift parameters. In [15] it is hoped that the appearance on the satellites of new highly sensitive sensors and the development of techniques for processing the satellite data will contribute to a more reliable identification of oil slicks and the determination of their thickness.

A real time prediction of oil spill transport and fate is very important for clean-up operations and to estimate its impact on the marine environment. A lot of publications are devoted to the modeling of oil spill transport in the Black Sea and in other seas. Some of them are used in a operational mode for some regions of the world ocean. The oil spill transport model based on a solution of the 2D advection-diffusion equation is a component of the easternmost Black Sea regional forecasting system [50-54], which enables to forecast for 3 days the main 3D dynamic fields – the current, temperature and salinity with 1 km resolution in the Georgian sector of the Black Sea and surrounding water area, but at accidental oil spills the forecasting system provides also to forecast oil pollution zones and concentrations.

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შავი ზღვის ნავთობპროდუქტებით დაჭუჭყიანების შესახებ. მისი მონიტორინგი და პროგნოზი

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რეზიუმე

სტატიაში მიმოხილულია ნავთობპროდუქტებით შავი ზღვის დაჭუჭყიანების თანამედროვე მდგომარეობა. მნიშვნელოვანი ყურადღება ეთმობა ზღვის ზედაპირის ნავთობით დაჭუჭყიანების თანამგზავრულ მონიტორინგს. სტატია შეიცავს აგრეთვე ზღვის გარემოში ნავთობის ლაქის გავრცელების მოდელირებისა და პროგნოზის რიცხვითი მოდელების მოკლე აღწერას. წარმოდგენილია რეალური რეგიონული ცირკულაციის პირობებში შავი ზღვის საქართველოს აკვატორიაში ნავთობით დაჭუჭყიანების გავრცელების მოდელირების ზოგიერთი შედეგი, რომელიც მიღებულია ადვექცია-დიფუზიის განტოლების საფუძველზე.

О загрязнении нефтепродуктами Черного моря. Его мониторинг и прогноз

А. Кордзадзе , Д. Деметрашвили

Резюме

В статье обозревается современное состояние загрязнения Черного моря нефтепродуктами. Значительное внимание уделяется спутниковому мониторингу нефтяного загрязнения поверхности моря. Статья содержит также краткое описание численных моделей распространения и прогноза нефтяного загрязнения в морской среде. Представлены некоторые результаты моделирования распространения нефтяного загрязнения на основе уравнения переноса-диффузии в грузинской акватории Черного моря при реальной региональной циркуляции.