Conference Paper

Automation of Aerospace Observations of Manifestation of Oil and Gas in Marine Areas

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Abstract

The article deals with the tasks of creating aerospace data processing centers that monitor the impact of natural and man-made sources of oil and gas in marine areas. An important place among them is occupied by the task of automatical detecting and interpreting the properties of oil pollution of the water surface of marine areas. The article examines the methods and technologies that provide: localization of the object search area; real-time image acquisition using remote sensing systems; automatic interpretation of the manifestation of oil and gas in images of the research area; preparation of passports of oil pollution of the sea aquatories water surface.

Keywords: Earth remote sensing systems, aerospace monitoring, sources of oil and gas manifestations, sea aquatories, image interpretation.

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Received: 24 December 2019
Accepted: 9 January 2020
Published: 15 January 2020

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the BRDEM-2019 Conference Committee.

1. Introduction

The active involvement of marine areas in production activities throughout the twentieth century led to a significant increase in the anthropogenic impact on the natural components of the environment of the oceans. This trend continues in the beginning of the XXI century, which is connected, first of all, with the increase in the level of oil and gas production on the shelf, which by 2015 had reached 30% of the total recoverable hydrocarbons. According to estimates by the Ministry of Energy, about 260 billion tons of reference fuel, or 60% of the recoverable hydrocarbon resources in Russia, are concentrated in the Russian Arctic. In the Arctic zone of the Russian Federation 360 fields are discovered, 334 of which are located on land. In 2016, the Arctic produced 17% of Russian oil and about 80% of Russian gas.

Oil production, its transportation, processing and use in the Arctic is fraught with serious environmental risks. A special place among them is occupied by the tasks of identifying oil and gas manifestation in the marine areas. Their relevance is due to the duality of the object of research. In the tasks of searching for oil and gas deposits, oil and gas manifestation act as a geological indicator, and during construction and operation of production platforms, underwater pipeline systems, storage complexes and tanker transportation, they are a geoecological indicator of pollution of sea waters. An important place in this list is occupied by the oil spill response (OSR) system, which includes:

development of situational oil spill models;

development of methods of localization of sources of oil and gas spills;

determination of volumes of possible oil spills;

justification of the locations of the OSR resources, their nomenclature and quantity.

In this regard, the methods and technologies of monitoring observations that take into account the specifics of the projects being implemented and the nature of the emerging emergencies become relevant. At present, they are based on visual observations of water areas from aircraft and helicopters, which are carried out to determine the boundaries of oil spills on the surface of local areas of water areas in the current time. However, these methods have limitations at long-term observations of the state of the waters and control of oil leaks, as well as the need at cartographic documentation of oil spill areas. These tasks are relevant in the drilling of offshore exploration wells, the construction and operation of subsea pipelines, in the documentation of unauthorized discharge of water during the cleaning of tankers, as well as in the identification of oil and gas manifestations of natural sources. Expanding the spectrum of tasks to be solved involves the use of complex technical observation systems including [1, 6, 9, 10]:

earth remote sensing platforms (ERS) with optical, infrared and radar sensors;

aerial platforms with optical, infrared cameras, laser and radar sensors;

surface and underwater vehicles with video cameras, as well as those with side-scan sonars.

In this connection, methods and technologies for monitoring observations that take into account the specifics of the projects being implemented and the nature of emerging emergency situations become relevant. At present, they are based on visual observations of water areas from airplanes and helicopters, which are carried out to determine the boundaries of oil spills on the surface of water areas of current time. However, these methods have limitations for long-term observations of the state of water and control of oil leaks, as well as, if necessary, cartographic documentation of oil spill areas. These tasks are relevant in the drilling of offshore exploration wells, in the construction and operation of subsea pipelines, in documenting unauthorized water discharge during the cleaning of tankers, as well as in detecting oil and gas manifestations of natural sources.

There is a significant variability of target problems to be solved including:

forecast and search for offshore oil and gas fields;

development, arrangement and operation of offshore oil and gas fields;

design, construction and operation of underwater pipelines;

sea transportation, processing and sale of products from petroleum gas.

The purpose of the presented article is automation the processes of interpretation of the manifestation of oil and gas in images of the marine area water surface.

Achieving this goal involves (Figure 1):

construction of the geoinformation environment of the research area;

localization of the search area of the object based on the geoinformation environment;

obtaining images of the investigated area through remote sensing systems;

interpretation of images of objects in the research area;

preparation of passports of parameters of the observed object.

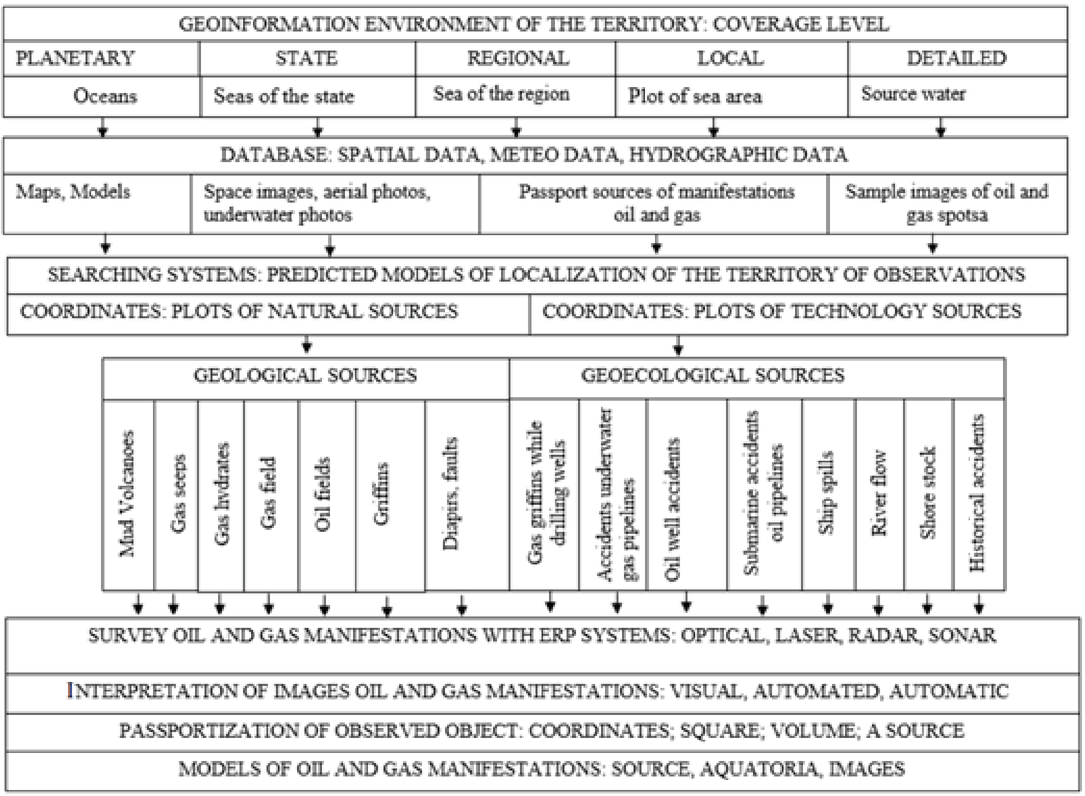


Figure 1: Technological scheme of remote monitoring observations of marine areas.

2. Methods and Equipment

2.1. Methods

The geoformation environment of the project plays the important role in the proposed interpretation of the manifestation of oil and gas in images of the research area. It consists of territorial and object-oriented models of the project.

Territorial models include topographic, meteorological, hydrological, hydro chemical and geophysical parameters of objects. It is developed in advance by creating a database that includes topographic, hydrological, geochemical, geophysical data, parameters of natural objects of the water area, cartographic models, and examples of images of observed objects.

Topographical parameters include digital topographic models of the sea bottom; digital elevation models; spatial coordinates of underwater geological and man-made objects.

Meteorological parameters contain characteristics of the direction and speed of wind flows, temperature, pressure and humidity of atmospheric air.

The hydrological parameters include temperature and salinity, speed and direction of currents at different horizons, main optical characteristics (integral transparency, spectral absorption and scattering).

Hydrochemical indicators are the concentration of dissolved oxygen; content of petroleum products, phosphorus, nitrogen and organic substances dissolved in seawater.

The geophysical parameters include: the level of seismic signals from earthquakes caused by natural and man-made factors, as well as indicators of formation pressure of rocks in the vicinity of boreholes.

Object-oriented models manifestation of oil and gas in images of the research area describe sources of spill formation, properties of their images. The image properties of the observed objects are directly related to the geological and geoecological sources of their origin [2, 4, 5].

The list of geological sources of the manifestation of oil and gas includes mud volcanoes, gas seeps, gas hydrates, gas deposits, oil deposits, griffins, diapirs, tectonic faults.

Mud volcanoes (salsa) are geological formations that constantly or periodically eject mud masses and gases onto the earth's surface, often with water and oil. According to the composition of the products of the eruption, mud volcanoes have connections with oil and gas-oil field and can serve as indicators of the potential oil and gas potential of the territory.

Gas emissions (seep) are formed as a result of an intense flow of free gas from the bottom surface, localized by a kind of crater. Gas vultures constantly emit methane from the seabed into the water column and are gas bubbles that rise to the surface with a rising stream of seawater. The diameters on average are in the range from 10 to 40 m. The height of the torches is 100-200m (most of them do not reach the surface of the water and diffuse diffusely). Most often these are small gas jets that form a kind of gas clouds near the bottom. Most of the vultures are located in the transition zone between the continental shelf and the continental slope at a depth of 50 to 650 m.

Natural gas hydrates are an unstable mineral, the formation and decomposition of which depends on temperature, pressure, chemical composition of gas and water, properties of the porous medium, in which they are formed, and other factors. The gas component of gas hydrates is 95% represented by methane. For the formation of gas hydrates, low temperatures and high pressure are necessary. When the permafrost capacity decreases, methane hydrate decomposes and a gas reservoir is formed at a shallow depth, from which gas can burst to the surface.

The wide distribution of submarine volcanoes and gas hydrates in the bottom sediments of the seas and oceans creates a serious problem for the industrial development of the shelf and field exploitation. Dilution of the soil, the instability of gas hydrate deposits are the most difficult engineering task in the construction of oil platforms and laying of pipelines.

Methane emissions play an important role in ensuring the geoecological safety of the maritime transport routes. In particular, the Northern Sea Route passes through the emission zones, where large zones of underwater methane torches are located. Their sizes can reach a width of 1.300 meters or more [8]. The deep sources of methane migrating along rift faults are large oil and gas field of the sedimentary basins of the Arctic shelf.

Sources of geoecological manifestation of oil and gas are gas griffins during drilling, accidents of subsea gas pipelines and oil pipelines, accidents of oil wells, ship spills, river flow and historical accidents.

At present, oil is the most common substance causing pollution of sea areas. Every year, about 600,000 tons of oil enters the oceans during normal shipping, accidents and illegal discharges [3]. The volume of transportation of oil and oil products on tankers is estimated at 1.5 billion tons per year. It is known that 0.03% of oil and oil products transported by tankers is lost for various reasons. Spilled oil covers the surface of the sea, dissolves in the thickness of its water, sinks to the bottom and, as a rule, splashes onto the shore.

The result of space monitoring observations is the formation of a pollution passport, which should be the basis for taking management decisions on localizing and eliminating oil manifestations in the marine area. The composition of the passport should include:

- coordinates latitude and longitude (B, L) of the center point of the oil spill;
- shape of oil spills;
- structure of oil spills;
- color of oil stains in the sea;
- the composition of oil slick substances;
- area (dimensions) S (km^2) and volume V (m^3) of the oil spill;
- source of the manifestation of oil and gas.

2.2. Equipment

The approbation of the space monitoring technology was carried out within the framework of an integrated geoinformation environment implemented on an experimental sample of the AGIR-TM technology platform, developed on the Department of Geoecology of the «Gubkin University». It includes a search engine and technology modules that provide geolocation, inventory, interpretation, modeling and visualization.

The search system, which works on the basis of the database created, searches for oil and gas facilities by the name of the region and by coordinates on various substrates: on the globes, on the maps.

The geolocation module provides work with raster and vector data, and provides coordinate referencing and inventory of objects of interest. The result of this work are the coordinates (B, L) of the research object.

The interpretation module performs the recognition and vectorization of raster images in visual and automatic modes. The result of this work is the determination of the boundaries and area of oil manifestations S (km^2), their color characteristics and composition of components, the volume of oil spill V (m^3) and the source of formation.

The modeling module is designed to build object-oriented models (design, situational, monitoring) in statics and dynamics. The result of this work is the model of oil slick moving under various meteorological parameters and conditions of their formation.

The visualization module allows you to display models of oil and gas manifestations on visualization tools in statics and dynamics.

In the course of practical approbation of the approach outlined, the performance of the interpretation module in evaluating oil manifestations on the water surface of the sea aquatories was tested. It should be noted that in modern methods of monitoring observations the solution of this task is carried out on the basis of remote sensing radar systems. These systems make it possible to successfully solve the problem of detecting oil manifestations and determining their boundaries (areas). However, they have limitations in determining the color characteristics oil manifestations, which makes it impossible to determine their composition. The solution of this task is provided by images obtained by multispectral space remote sensing [11--13].

In the course of experimental approbation, studies of images of oil and gas shows obtained by a color aerial camera from an aircraft and the Landsat-8 multispectral camera (SC) were conducted.

Classical methods for solving interpretation problems are based on the use of direct and indirect features. Direct signs are: the shape, the size of the structure and the color of objects. Indirect signs set the properties and type of the object based on dependencies with direct signs observed in the pictures. The existing guidelines on visual observations of oil spills provide recommendations for determining the main signs of the spots [16, 17] (Figure 2).

An important place in the interpretation of oil spill images is given to the composition of hydrocarbon oil manifestations. Hydrocarbons are complex compounds of various chemical substances with different physical and chemical properties that determine their behavior and time of existence on the water surface.

In case of spills, different three types of hydrocarbons: light refined products; heavy refined products and crude oil.

Light processing products have silver-gray color shades. They are formed by light fractions of oil and are contained in gasoline, kerosene, diesel fuel, household fuel oil, which have high fluidity and evaporation.

Heavy oil products are black in color. They have a high viscosity.

These include fuel oil, fuel for ship engines, discharged bilge water.

Crude oil can vary in color from brown to black. Its characteristics differ greatly depending on the composition, especially on the proportions of light and heavy fractions. After being in the sea for some time, crude oil loses light fractions due to weathering.

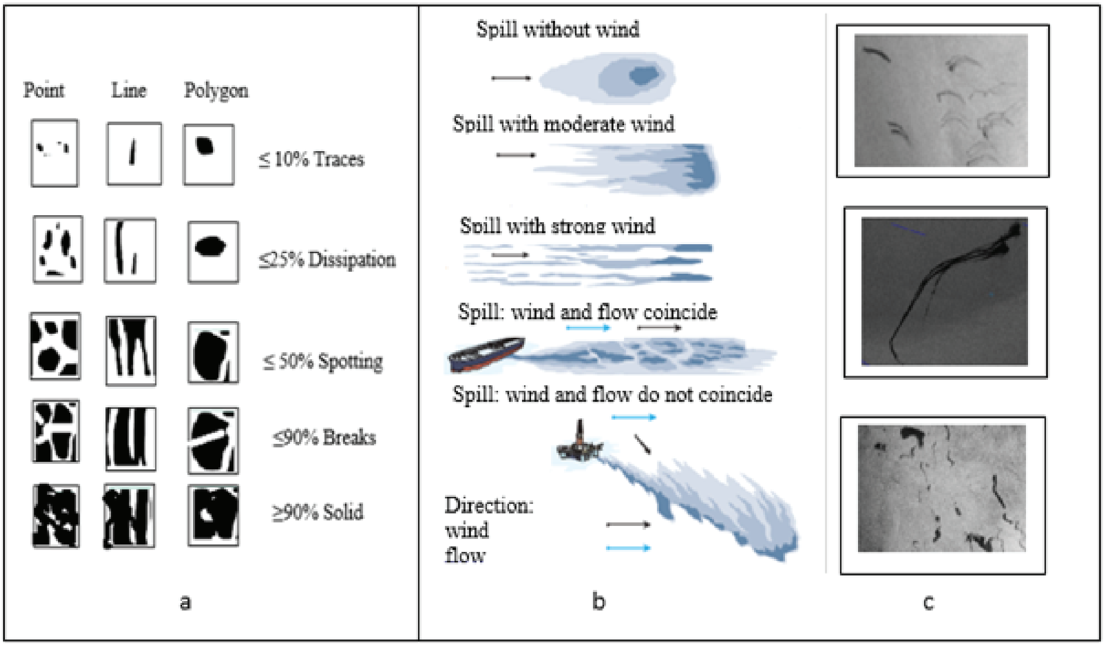


Figure 2: Geometric signs of oil and gas appearances: the structure and shape of spots: the structure of oil spills (a) [16]; spill form models (b) [17]; form examples manifestation of oil pollution in image (c).

Table 1: Coding system of color of oil pollution under the Bonn Agreement (2004).

Code	The color of the oil slick	Composition	Fortitude / evaporation	Thickness of the slick, µm	Volume m^3 / km^2
1	Silver gray	Oil slick, light fractions, gasoline, diesel fuel, kerosene	Low persistence, evaporation in a few hours	0,05-0,3	0,05-0,3
2	Rainbow	Oil slick, light and medium crude oil	Low persistence, evaporation 40% in 24 hours.	0,3-5,0	0,3-5
3	Bluish	Light and medium fractions, fuel oil	Medium persistence, evaporation 10% for 24 hours	5,0-50	5-50
4	Metal	Crude and fuel oil	High persistence, low speed evaporation	50-200	50- 200
5	Brown	Water-oil emulsions, heavy fractions of crude oil		200	200

Indirect signs of image interpretation linking the color characteristics of oil and film thickness, based on the Bonn Agreement on the coding of an oil spill, are presented in Table 2.

3. Results

Using the considered feature descriptions, algorithms for automatic analysis and classification of oil spills were developed. As an example, we examine aeroimages of spills displaying an accident: on the platform (Figure 3); on ship 1 (Figure 4); on ship 2 (Figure 5).

In the course of interpretation, the colors of the encoding were shown with conditional colors that are well displayed on the monitor screen. The results of classification of oil spills are shown in Table 3.

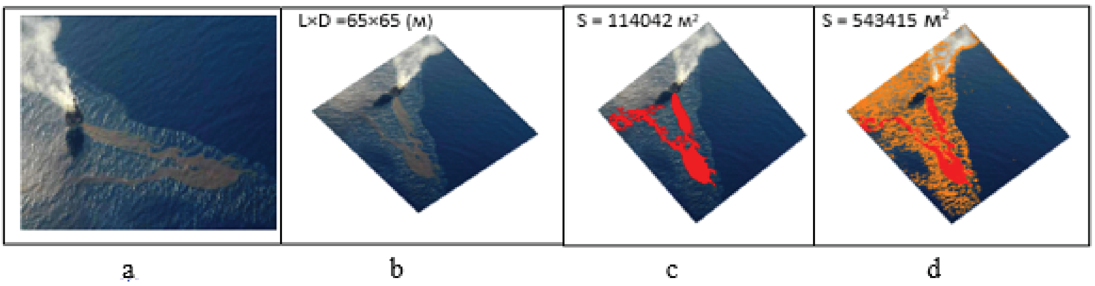


Figure 3: Interpretation of an accidental spill on an oil platform: Original image (a); Orthoimage (b); Code 4: brown (c); Code 3: Blue (d).

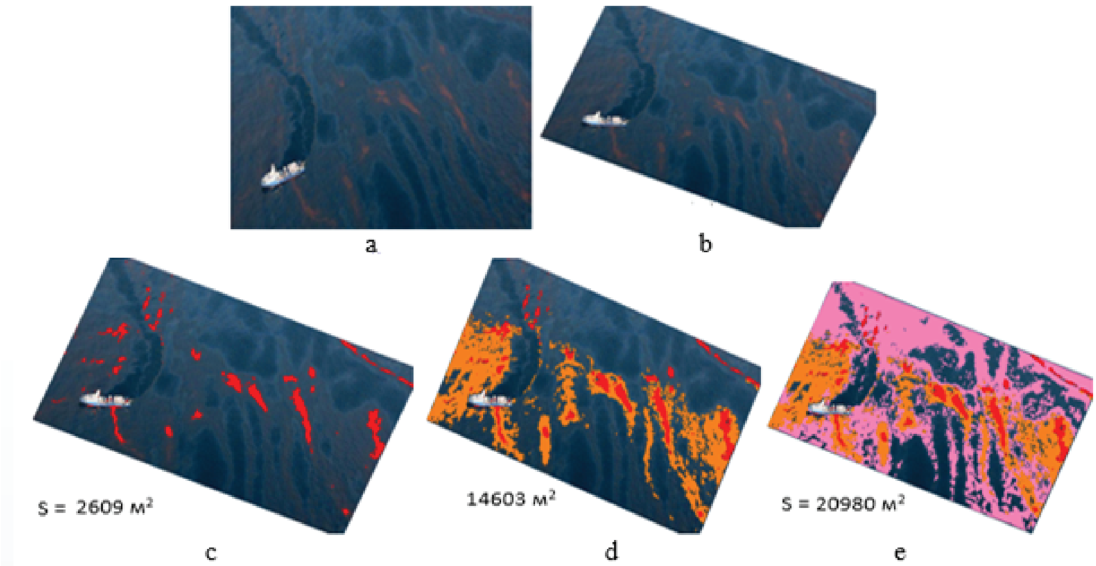


Figure 4: Interpretation of an accidental spill on a ship 1: Original image (a); Orthoimage (b); Code 5: orange (c); Code 4: brown (d); Code 3: blue (e).

The results of the classification of oil pollutions in a color image obtained by means of RGB channels Landsat-8 (Figure 6), caused by oil manifestation on sea oil platforms, allowed us to identify the following areas:

Silver-metallic color: S = 2088022 m^2; V = 10.5 m^3

Figure 5: Interpretation of an accidental spill on a ship 2: Orthoimage (a); (Code 4: brown, Code 5: orange) (b).

Table 2: Certification of oil spill.

A source spill	The form	Structure	Code: color	Composition	Area S(м^2)	Volume V(м^3)
1 oil platform: Размеры: 65×65 (м)	Polygon	Breaks 80%	3: blue 4: brown	Average fractions crude oil Raw oil, heavy fractions	543415 114042	543,42 114,04
2 Ship 1: 45 × 10 (m)	Line Polygonal	Breaks 80%	2: rainbow 3: blue 4: brown	Light fractions Average fractions Heavy Fractions	20980 14603 2609	20,98 14,60 2,61
3 Ship 2: 45 × 10 (m)	Polygon	Solid, 95%	4: brown 5: orange	Heavy Fractions Heavy Fractions	36 547 10965	36,55 10,96

Brown: S = 2687408 m^2; V = 134.4 m3 - 357.5 m^3

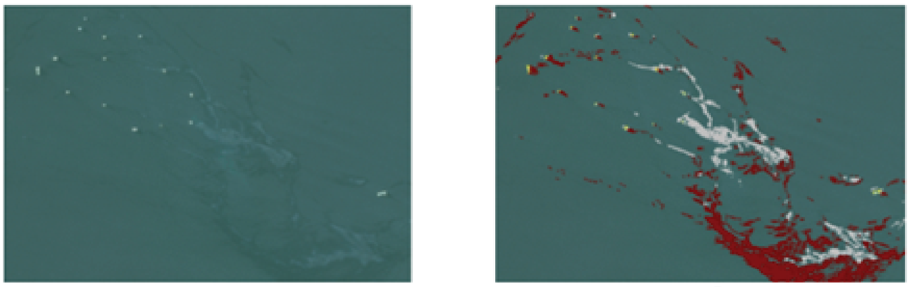


Figure 6: Classification of oil pollution of sea oil platforms: the original image (a); graded image (b).

The second method of the interpretation considers the possibility of classifying the oil thermal displays by multizonal images obtained of the spectral channels of the Landsat-8 satellite (Table 4 [14]). To optimize image classification in various spectral channels, methods have been used to isolate areas of oil contamination of indices for water bodies (Table 5 [15], Table 6).

TABLE 3: Landsat-8 bands information.

Wavelength (μm)	Band
Band 1: 0.43 - 0.45	Coastal aerosol
Band 2: 0.45 - 0.51	Blue
Band 3: 0.53 - 0.59	Green
Band 4: 0.64 - 0.67	Red
Band 5: 0.85 - 0.88	Near IR
Band 6: 1.57 - 1.65	SWIR 1
Band 7: 2.11 - 2.29	SWIR 2 (MIR)
Band 8: 0.50 - 0.68	Panchromatic
Band 9: 1.36 - 1.38	Cirrus
Band 10: 10.60 - 11.19	Thermal Infrared (TIRS) 1
Band 11: 11.50 - 12.51	Thermal Infrared (TIRS) 2

TABLE 4: Spectral indices of water bodies.

Normalized Difference Water Index (NDWI)

$$NDWI_1 = \frac{NIR-SWIR}{NIR+SWIR} \quad (1)$$

$$NDWI_2 = \frac{\text{Green}-NIR}{\text{Green}+NIR} \quad (2)$$

Modified normalized difference water index (MNDWI)

$$MNDWI_2 = \frac{\text{Green}-SWIR}{\text{Green}+SWIR} \quad (3)$$

Automated water extraction index (AWEI)

$$AWEI_{nsh} = 4 \cdot (\text{Green} - SWIR1) - (0.25 \cdot NIR + 2.75 \cdot SWIR2) \quad (4)$$

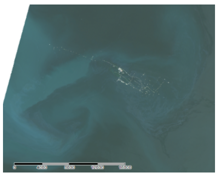
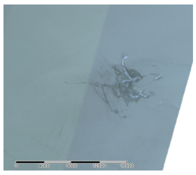
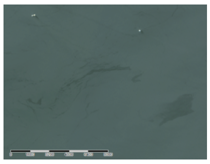
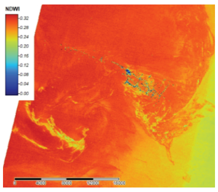
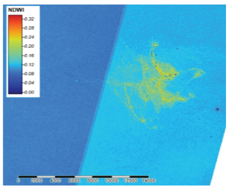
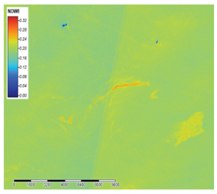
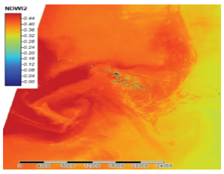
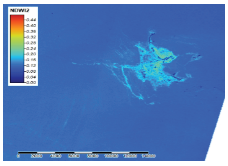
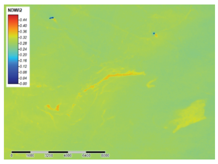
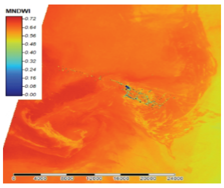
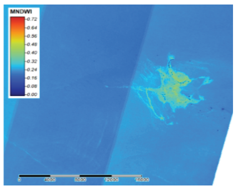
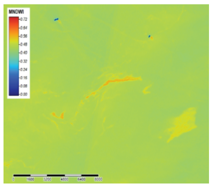
$$AWEI_{sh} = \text{Blue} + 0.23 \cdot \text{Green} - 1.5 \cdot (NIR + SWIR1) - 0.25 \cdot SWIR2 \quad (5)$$

4. Discussion

The results of experiments conducted with automatic extraction of oil and gas manifestations using spectral indicators of reservoirs (Table 6) showed the effectiveness of the $NDWI_1$ index. It provides a classification based on a comparison of the near (NearIR) and short (SWIR1) infrared channels. Good classification results are also provided by using images obtained from the $NDWI_2$ and $MNDWI_2$ indices. In this case, a comparison of the ``green'' (Green) channel with the near (NearIR) and short (SWIR1) infrared channels is used, respectively.

The results obtained in the course of experimental approbation of the methods of automatic interpretation and certification of oil spill parameters in the framework of the technology of aerospace monitoring observations showed their performance.

Table 5: The selection of oil images on the basis of spectral indices.

spectral index	1 site	2 site	3 site
the original image			
$NDWI$			
$NDWI$			
$MNDWI$			

Successfully classified areas of oil outlets in color aerial photographs are caused by pollution from the oil platform and spills from ships.

When using multizonal images obtained in the spectral channels of the Landsat-8 satellite, an increase in the efficiency of classification of areas of oil pollution is achieved by using the spectral index NDWI1 operating in the near (NearIR) and short (SWIR1) infrared channels.

Along with this, it should be noted that for successful application of this approach in the tasks of eliminating emerging oil spills, it is necessary to further develop a software package for modeling forecasting the state of marine spills under changing meteorological and hydrological conditions. This will allow one to control the dynamics of changes in the characteristics of the oil spill during their stay on the water surface and to increase the efficiency of placing booms to minimize their spread.

5. Conclusions

In the course of the work, methods were developed and tested aimed at automating the recognition of aerospace images of oil and gas projections of marine areas in the AGIR-TM geographic information system.

Experimental studies have provided practical testing methods:

building the geoinformation environment of the study area;

localization of the search area of the object based on the geoinformation environment;

imaging of the study area using remote sensing systems;

automatic interpretation of images of oil and gas manifestations of the water surface based on color separation and the use of spectral indices;

creating passports of parameters of oil spill sites.

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