Detection a Natural Source of Oil in the South-Eastern Part of Black Sea During Monitoring of Oil Pollution With on European Maritime Safety Agency Satellite Service

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Abstract. The paper deals the presence of a natural source of oil, which is sometimes detected in the southeastern part of the Black Sea as part of the monitoring of oil pollution of the Black Sea using the EMSA (European Maritime Safety Agency) satellite service.

With the collaboration of EMSA CLEANSEANET System and MRCC (Maritime Rescue Coordination Center) of Maritime Agency of Georgia MRCC is regularly receiving data to region possible spills pollution.

The EMSA satellite service offers extensive surveillance of European waters for oil spills by using radar images acquired by Synthetic Aperture Radar (SAR) sensors on polar orbiting satellites. SAR sensors have the capability to detect oil slicks on the sea surface in darkness as well as daylight hours and to see through clouds.

The analysis CleanSeaNet Alert Report possible spills, it's safe to say that we are observing a natural expression of oil on the sea surface, which is formed by the migration of oil hydrocarbons in the sedimentary complex of the southeastern part of the Black Sea, seaward of the city of Poti (Georgia). Source identified based on the analysis of multi-temporal radar satellite imagery.

Keywords: Natural source of oil, CLEANSEANET System, Oil slicks, Black Sea.

1. Introduction

In 1955, the Azerbaijani scientist G.P. Tamrazyan predicted the eruptions of mud volcanoes for the next 4 years. An increase in activity was expected in August-September 1957, April-May, and October-November 1958. The forecast was brilliantly confirmed. And it was built on the basis of astronomical tables, from which the relative position of the Earth, Moon and Sun was selected. That is, the initiators of the activity of volcanoes are the tidal forces of the Moon and the Sun. Here, it turned out to be significant also when the tide comes: at apogee and apogelia or at perigee and perihelion. Statistics show that 60% of mud eruptions occur at times when full and new moons coincided with the moon's perigee. Eruptions begin, as a rule, in the evening, at about 6-8 hours local time [1].

This fact is also confirmed by that all natural source of oil, which is detect in the southeastern part of the Black Sea as part of the monitoring of oil pollution of the Black Sea using the EMSA satellite service eruptions begin in the evening, at the same time [2].

The total solar eclipse on July 31, 1981, in the zone of which the Caucasian mud volcanoes were located, confirmed the validity of such assumptions. It was at the moment of the full phase that gas bubbles and a large amount of water began to actively appear on the surface of the griffin. The activity of the volcanoes, as the instruments showed, manifested itself at this very moment, even many hills that had ceased their activity turned out to be broken from below by some incredible force [1].

For the occurrence of mud volcanism, powerful plastic strata, the presence of reservoir waters, the accumulation of continuously flowing gases, the existence of tectonic ruptures, and anomalously high reservoir pressure are required.

The analysis of radar images (RI) made it possible to establish a connection between the natural manifestations of oil observed on the sea surface and the processes of formation and migration of oil hydrocarbons in the sedimentary complex of the southeastern part of the Black Sea. Based on the analysis of spots detected on radar images of different times, obtained in the period from 1993 to 2011, the position of the source on the seabed was determined. The source is located at a point with coordinates 41° 58' 59" N 041° 07' 30"**E** at a depth of about 1050 m and works with a frequency of 0.3 - 5 hours. The first reliable observation of this griffin from space using space radar took place in December 1993 [3].

There are results of satellite observations, indicating natural emissions of oil in the Black Sea. According to their results, the Georgian sector of the Black Sea seeps out from 0.4 to 3 thousand tons of oil per year, and in the Turkish sector - up to 2 thousand tons per year [4], [5]. However, this work was carried out using space radar images without confirmation by "contact" research, as evidenced by a wide range of possible pollutant intake.

According to experts, the unloading of reservoir oils in the southeastern part of the Black Sea (See Fig.1.) only from this source, taking into account the constant flow, can provide an average supply of 1 to 8 tons per day or from 400 to 3000 tons of oil per year. The maximum possible estimates of the volume of natural oil emissions from the subsoil in this place according to space radar data can reach 7 thousand tons of oil per year [3].

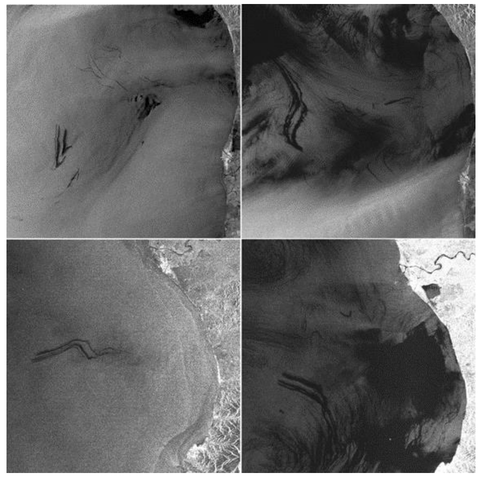


Figure 1. Oil slicks, the south-eastern waters of the Black Sea

Detailed bathymetric data showed that there is a positive landform at this location at the bottom - which, obviously, is the source of these oil outbursts. This is also confirmed by the data of independent geophysical studies carried out by IFM-GEOMAR (Kiel, Germany). In addition, the RI in this area revealed a number of smaller spots confined to secondary structures, which indicates the presence of a number of other natural sources of oil. They are also of interest and require further research.

Based on an analysis of the spots found on radar images in the southeastern Black Sea, oil slicks are shown in red, drifting in different directions from the ascent site under the influence of wind and currents (See Fig.2.).

The local elevation of the seabed located at a depth of about 1050 m is an underwater source of oil. The use of radar surveys at different times can significantly increase the likelihood of detecting natural sources of oil at sea (See Fig.3.).

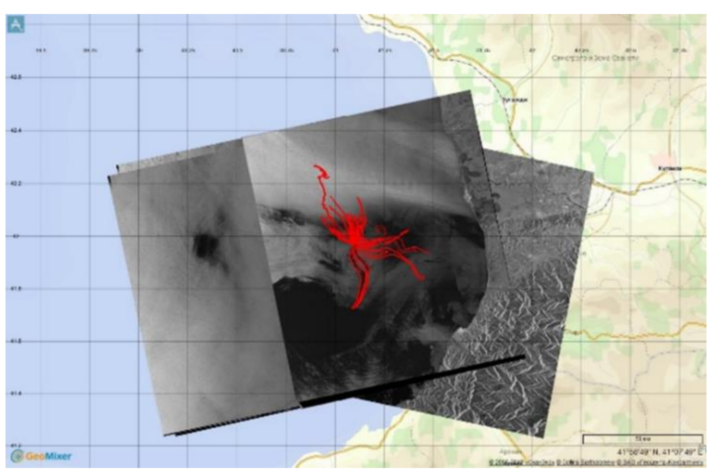


Figure 2. Analysis of spots detected on radar images in the southeastern Black Sea

For the analysis and study of natural oil shows detected by radar survey, a geoformation technique was used. This method proved to be very successful and many natural sources of oil in different seas were discovered with its help [6].

This natural oil infiltration is one of the characteristic features of this part of the Black Sea. Estimates of oil emissions can be obtained by measuring the areas of spots on radar images and based on simple physical considerations that relate the thickness of the oil film to its color, which varies from rainbow at the ascent point to silvery gray at the periphery of the oil slick [6].

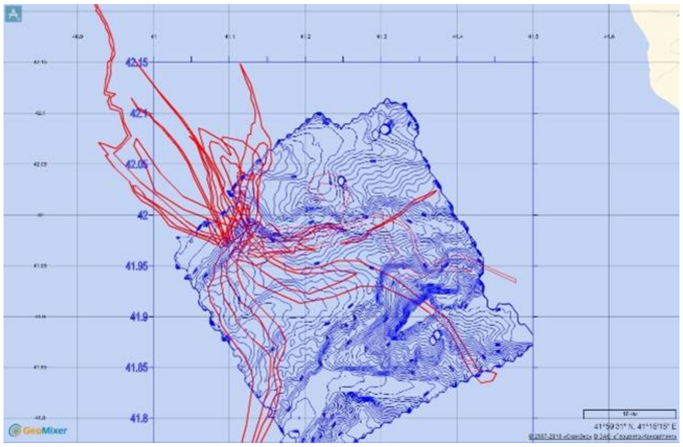


Figure 3. The local elevation of the seabed located at a depth of about 1050 m

2. Monitoring of oil pollution using European Maritime Safety Agency satellite service

CleanSeaNet is the European satellite-based oil spill monitoring and vessel detection service. It analyses images, mainly from synthetic aperture radar (SAR) but also from optical missions, to:

- Detect possible oil on the sea surface, including illegal discharges of mineral oil;
- Identify potential polluters, and
- Monitor the spread of oil during maritime emergencies.

The service was developed and is operated by EMSA, and is available to all EU member states, European Free Trade Association/European Economic Area member states, candidate countries and European Neighborhoods Policy participating countries [7].

The EMSA CleanSeaNet system has been operating in Europe since April 2007. On March 10, 2015, an agreement was signed between the European Maritime Safety Agency and the Georgian Maritime Transport Agency.

Data from these satellites is processed into images and analyzed for oil spill, vessel detection and meteorological variables. The information retrieved includes among others: spill location, spill area and length, confidence level of the detection and supporting information on the potential source of the spill (i.e. detection of vessels and oil and gas installations). Optical satellite images can also be acquired upon request, depending on the situation and user's needs [8].

The EMSA CleanSeaNet system provides the following Service Chain:

- Architecture includes - Satellites, Service providers and CleanSeaNet Data Centre;

Figure 4. EMSA CleanSeaNet system - Architecture

- Near Real Time service – satellite images are acquired in segments up to 1400 km long. 30 min are for a 400 km long image;

Figure 5. EMSA CleanSeaNet system - Near Real Time service

- Planning the satellite scenes;

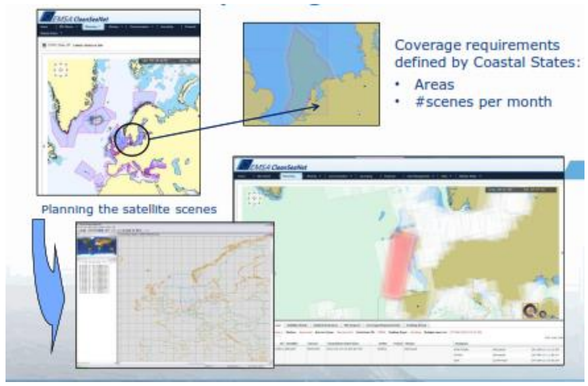
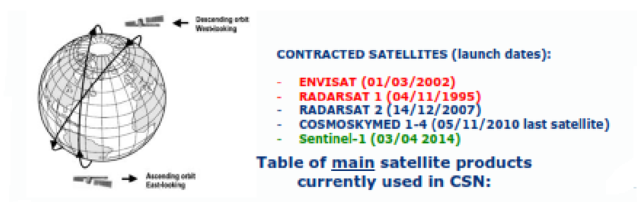


Figure 6. EMSA CleanSeaNet system - Planning

➢ Acquisition and Processing. Acquisition is normally done by direct real-time downlink when the satellite passes through the Ground Station Mask. The main aim of the processing is to make the raw radar data into a usable image with adequate resolution, by applying heavy digital processing and a number of corrections. The final format is called Level1b or Native1;



SATELLITE	PRODUCT IDENTIFICATION	Description	Resolution (Range x Azimuth, meters)	Spacing (Pixel x Line, meters)	Area Coverage (Range x Azimuth, km)
RADARSAT-2	RS2_SNA	ScanSAR Narrow	50 x 50	25 x 25	300 x 300
RADARSAT-2	RS2_SCW	ScanSAR Wide	100 x 100	50 x 50	500 x 500
COSMOSKYMED	CSK-HR	ScanSAR HUGE	100 x 100	50 x 50	200 x 200
COSMOSKYMED	CSK-HR	ScanSAR Wide	30 x 30	15 x 15	100 x 100

Figure 7. EMSA CleanSeaNet system - Acquisition and Processing

➢ RadarSat 2 (RS-2) usage in CSN. RadarSat 2 is a Canadian polar-orbiting C-Band SAR satellite, originally launched by the Canadian Space Agency, operated in a Public-Private Partnership by a Canadian Company, MacDonaldDettwiler (MDA). Orbits (North Pole – North Pole) have a duration of approx. 100 minutes. 24 days orbit cycle. Network and Coverage Ground stations RS-2 [9].

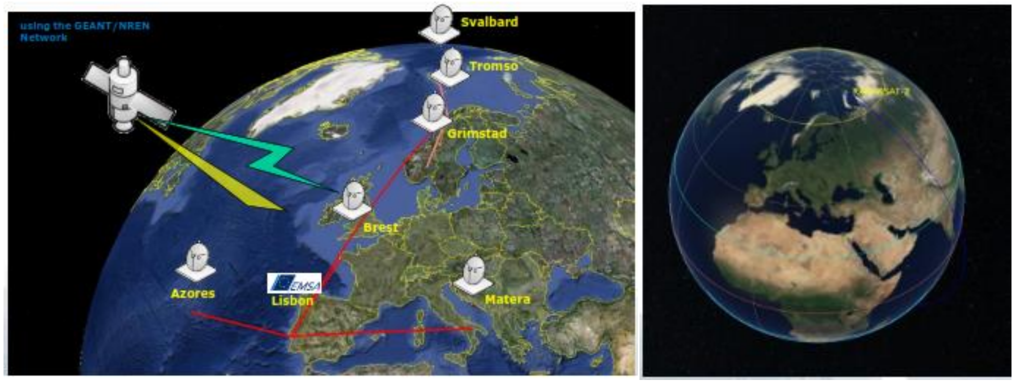


Figure 7. EMSA CleanSeaNet system - Network and Coverage Ground stations

How does work and what the measures Synthetic Aperture Radar (SAR): The radar emits electromagnetic waves in the direction of the earth's surface, after which the reflected waves are processed in the Synthetic Aperture Radar and it is possible to measure all the characteristics of the reflected wave.

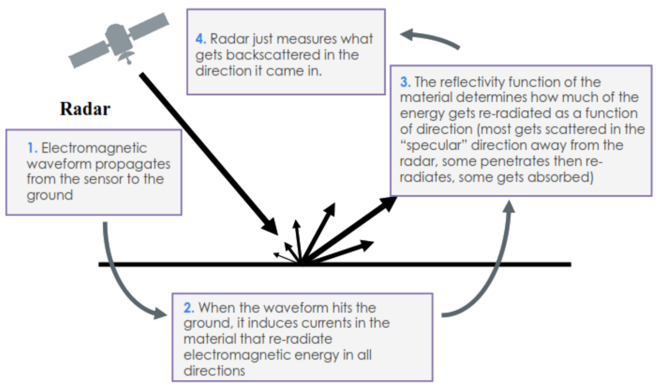


Figure 8. EMSA CleanSeaNet system - Synthetic Aperture Radar function

SAR images are highly influenced by the wind. The SAR images dependency with Wind varies within 2-3 m/s <wind<12-15 m/s. With Moderate winds: strong contrast between oil slick and surrounding waters [7].

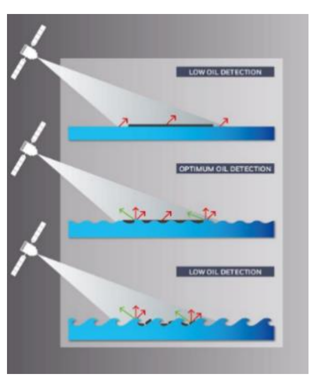


Figure 9. EMSA CleanSeaNet system - wind influence

Today 30 Maritime countries Service users. On average, more than 2000 cases are recorded per year, they are being monitored and analyzed. The probable source of the spill could be:

- Ship, sunken ship;
- Oil Pipeline;
- Natural source of oil from the seabed, or so-called, "Griffons".

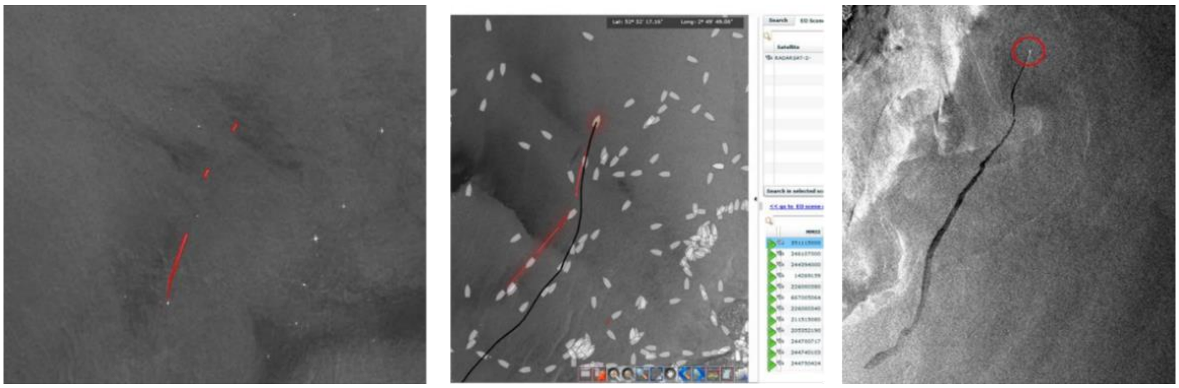


Figure 10. EMSA CleanSeaNet system - probable source of the spill

Often the probable source of the spill is false detections, in the form of lookalikes: low wind area, algae, current front, upwelling area, fish or vegetable oil cannot be discriminated in SAR from mineral oil. For validation, they are considered as true detections [7].

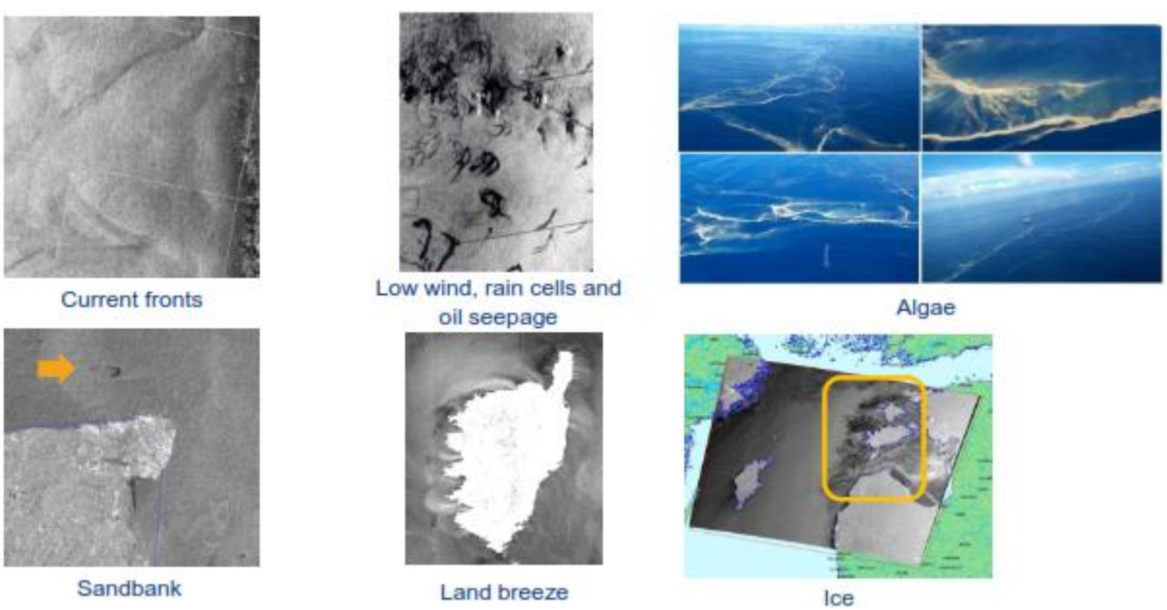


Figure 11. EMSA CleanSeaNet system - false detections

3. Practical use data of oil pollution using European Maritime Safety Agency satellite service

The satellite images are downloaded using antennae in Norway, Italy and Portugal (from 2008 onwards). The data is processed and analyzed to detect possible oil slicks. An alert report is produced for every planned image to inform the Coastal States on the results of the analysis, i.e. whether possible oil slicks are detected or not. In case slicks are detected, the affected Coastal State immediately receives an alert to enable the Coastal State to take quick actions in order to verify and quantify the slick and to identify the potential source. The complete process, from satellite overpass to the alert, takes a maximum of 30 minutes. Maritime Rescue Coordination Center (MRCC) Receives Possible Spill Information – Alert report, from the CleanSeaNet System (See Fig.12.) [2].

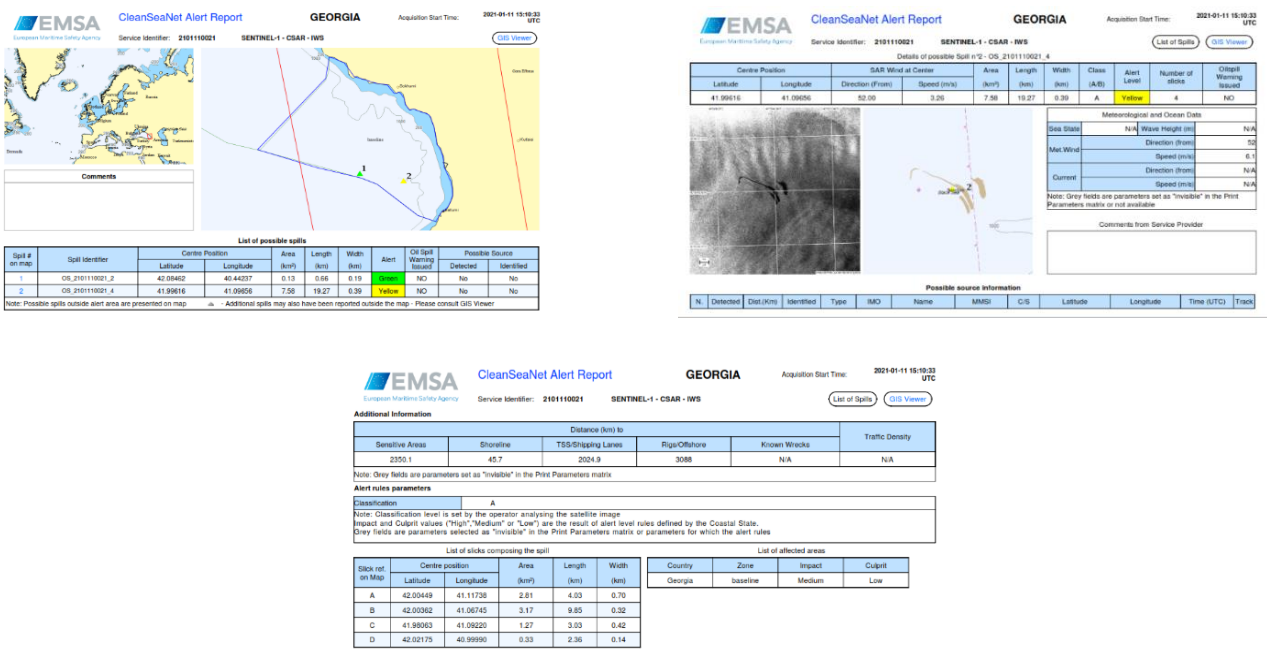


Figure 12. EMSA CleanSeaNet system - Alert report

Alert image and further e-mail ("Alert report") consists of (See Fig.12):

- Position of the possible oil pollution,
- Date and time of observation,
- Estimated size of the polluted area,
- Wind speed and direction,
- Polluter category e.g. Ship, platform, industry,

➢ If available, the name of the platform or the geographical name in the case of release from onshore sites,

➢ Probability level (low, medium or high).

MRCC conducts an analysis of the CleanSeaNet Alert Report, determines where the oil slick may be at a given time, takes into account the weather (sea wave, current, wind direction, distance to the spill site, etc.) and accepts On the expediency of sending a special team to the site of the alleged spill, which should determine whether the information about the alleged spill is true, is there a polluting vessel, if we are dealing with a natural or any other type of spill [9].

The probable polluting vessel is identified as follows:

1. Vessel detected by satellite radar (bright spot);
2. According to the traces of spilled oil;
3. According to AIS information.

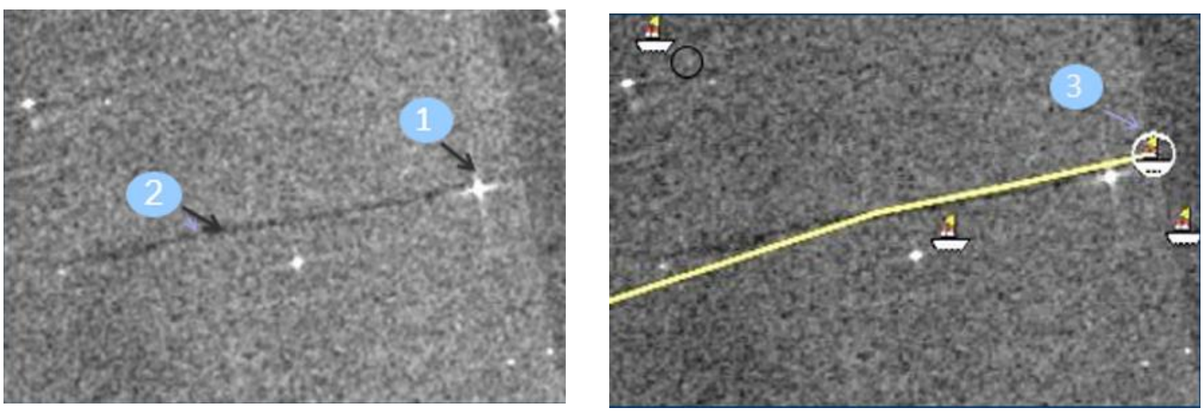


Figure 13. EMSA CleanSeaNet system - Types of identify

After receiving Alert report from CleanSeaNet when a potential source detected in satellite images MRCC promptly should identify a vessel which is potential contaminant.

Further rapid action is essential to ensure that at the time to identify sites of pollution and the vessel. Need to use all available means (AIS, VTS, RADAR) to identify and track suspected pollutant - in this case, if the potential polluter is a ship). If a potential source of the ship, which was determined by its delay in the sea to investigate, and if it fails to send a request to port State control to be checked at the next port of call. Proofs sent via e-mail at the next port of call. If the ship continues on his way, messages are transmitted MRCCs neighboring countries [9].

4. **Observation of possible spill images by using radar images acquired by Synthetic Aperture Radar sensors on polar orbiting satellites**

Observation and analysis of possible spill images obtained through polarized aperture of radar sensors of satellites in polar orbit significantly increases the likelihood of discovering natural sources of oil in the sea;

Long-term analysis of radar images obtained from satellites allows us to say:

- CleanSeaNet Alert reports from EMSA contain many natural oil sources from the last decade;
- The positions of the spots of the natural sources of oil and their shape do not differ greatly from one another, and they are all located in the south-eastern part of the Black Sea;
- Previous laboratory studies of natural sources of oil indicate their natural origin.

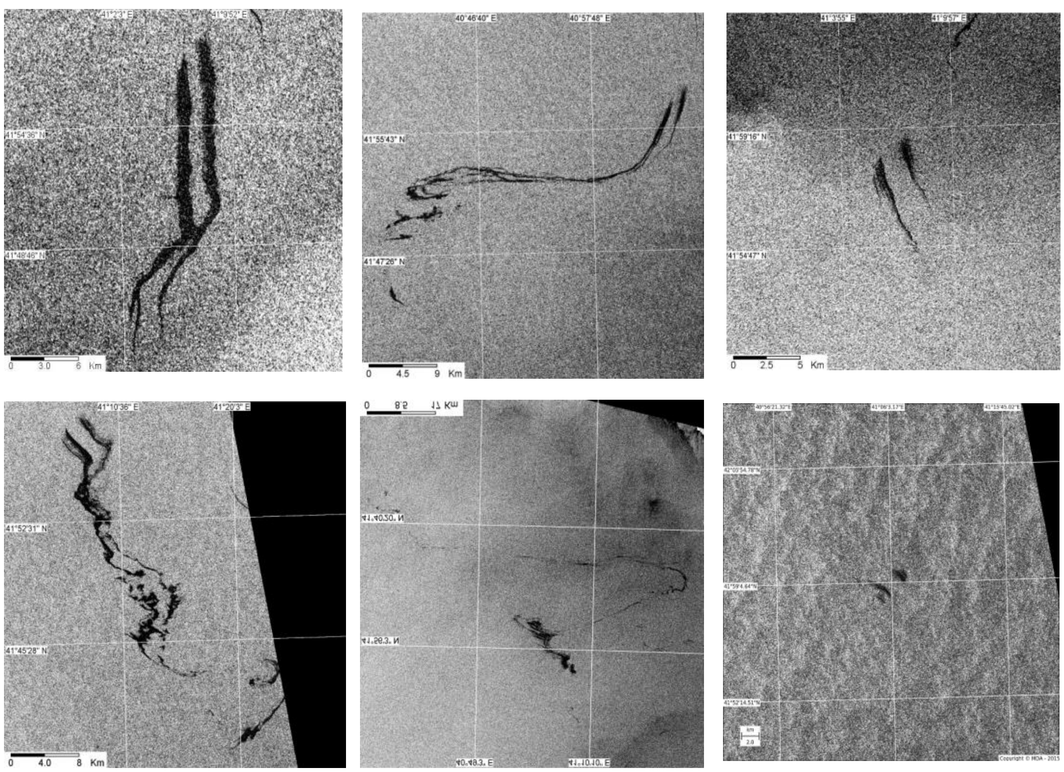


Figure 14. Types of identify Pictures of natural oil sources obtained by polarized aperture of radar sensors of satellites in polar orbit

5. Geoinformation methods used to analyze and study natural sources of oil detected using satellite radars

For the analysis and study of natural oil shows detected by radar survey, a geoinformation technique was used. This method has worked well and many natural sources of oil in different seas have been discovered with its help.

In particular, a geoinformation approach was used. With the help of the latter, natural sources of oil in the Caspian Sea have been investigated and even discovered.

Geoinformation System (GIS) is a multifunctional system designed for collecting, processing, modeling and analyzing spatial data, displaying and using them in solving problems, preparing and making decisions within an enterprise/organization, as well as for integration into various sites and public portals. The aggregate of heterogeneous layer-by-layer realized data and their precise binding to coordinates allow performing complex analysis of spatial objects.

Using space radar and GIS approach natural sources of oil in the Black Sea were investigated and even discovered [10].

The processing of radar images for these tasks is usually carried out according to a standard scheme and includes: geometric correction, geographic referencing of images to a digital map, and interactive interpretation of radar images with extraction/vectorization of dark spots (slicks) taking into account the environment and the presence of slick-forming phenomena of a different nature. In particular, the identification of detected natural oil slick spots occur by their shape, size, direction of drift, degree of clustering (repeatability in time and space), the presence of repeating signatures, etc. In addition, slicks of natural oil seepages, having a much greater thickness than biogenic slicks, exist on the sea surface in a wider range of wind speeds - up to 6-7 m/s, that is, they are also observed when biogenic slicks disappear from the sea surface (with a wind of more than 3-4 m / s) [11], [12].

An important feature of the interaction of electromagnetic radiation of the radio frequency spectrum with the water surface is the resonant scattering mechanism, known as the Wolfe-Bragg condition, which determines the so-called resonant wavelength of the water surface – Λ,

$$\Lambda = \frac{\lambda}{2 \cdot \sin\theta},$$

where λ - is the wavelength of electromagnetic radiation of the radio frequency spectrum,

θ - is the vertical angle of incidence of the electromagnetic radiation wave.

The Wolfe-Bragg condition allowed us to use GIS as a multifunctional system for collecting, processing, modeling and analyzing spatial data.

Mathematical modeling was carried out using the theory of frequency-angular spectrum using the coefficients of surface and of bottom friction.

To describe the fields of excitement uses the concept of frequency-angular spectrum

$$E\ (\sigma, \theta, x, y, t),$$

where, σ, θ - frequency and angular coordinates;
x, y, t - horizontal coordinates and time.

Appropriate equation for the determination of E is given by the law of conservation of energy:

$$\frac{\partial}{\partial t}N + \frac{\partial}{\partial x}(c_x N) + \frac{\partial}{\partial y}\left(c_y N\right) + \frac{\partial}{\partial \omega}(c_\omega N) + \frac{\partial}{\partial \theta}(c_\theta N) = \frac{S}{\omega} \quad (1)$$

Where, N = $\frac{E}{\omega}$ - density of wave action;

Magnitudes, $c_x, c_y, c_\omega, c_\theta$ - transport velocity along the appropriate spatial and frequency-angular coordinates.

For numerical solution of equation (1) is applied a modified version of the model, in which the source (oil) function is defined as

$$S = S_{in} + S_{nl} + S_{ws} + S_{bf} + S_{dib} \qquad (2)$$

where,

S_{in} – the source of generation of waves by the wind;

S_{nl} – non-linear interactions spectral harmonics;

S_{ws} – dissipation of the energy due to the caving of the wave crests;

S_{bf} – dissipation of the energy due to of bottom friction;

S_{dib} – caving waves on the critical depths.

In the original version the source of wave generation Sin - is determined by assuming that the friction coefficient Cd only depends on the wind speed.

Solution of problem (1), (2) makes it possible to obtain estimates a number of spectral wave characteristics, in particular the significant wave height and root mean square wave height [14].

A characteristic feature of this model is allows use of geoinformation methodologies for accounting and analysis of natural sources of oil.

At the final stage of radar image processing, the vector layers of the spots and the geological and geophysical information required for analysis are combined on specialized geoportals of a web-based cartographic service that allows interactive analysis of the collected data [13].

6. Conclusions

1. Long-term observations show that the EMSA SAR sensors have the capability to detect oil slicks on the sea surface in darkness as well as daylight hours and to see through clouds;
2. The analysis CleanSeaNet Alert Report possible spills, based on the radar images, it's safe to say that we are observing a natural expression of oil on the sea surface, which is formed by the migration of oil hydrocarbons in the sedimentary complex of the southeastern part of the Black Sea;
3. Their connection with underwater sources has been established and processes of formation, migration and seepage petroleum hydrocarbons in the sedimentary complex of the Black Sea;
4. Based on the analysis of spots detected at different times of radar images obtained in 2015–2020, the position of the sources on the bottom, as well as a number of their other characteristics, were determined;
5. According to various estimates, the unloading of reservoir oils in the southeastern part of the Black Sea only from this source, taking into account the constant flow, can provide an average supply of 1 to 8 tons per day or from 400 to 3000 tons of oil per year.
6. In particular, the results of studies in the southeastern part of the Black Sea showed that at present it is not difficult to detect and study the outflows of liquid petroleum hydrocarbons using satellite and related geoinformation and geophysical methods.

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