Information Technology and Management Science

doi: 10.2478/itms-2013-0004

2013 / 16

Monitoring Facilities and Information Processing of Water Pollution

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Abstract **– The topical problem of oil pollution monitoring in water areas is considered in the paper. Recently, the solution to this problem has been found by the complex use of space and land data within geoinformation systems. Thus, the data obtained from remote sensing of Earth (RSE) satellites supplement the data obtained from traditional land-based and aviation sources. Features of application of both RSE optical and radar data are discussed.**

Keywords **– Complex use, ERS data, land data, oil pollution of water areas**

I. Introduction

Monitoring of pollution of the water areas is one of the ways to monitor the condition of natural and technogenic objects (components of nature are: water area, coast, natural (native) oil showings, man-made (technogenic) objects – ships, oil rigs, ports, oil terminals).

At present, the technology using the earth remote sensing (ERS) data to monitor pollution of the sea areas has reached a commercial exploitation level and is widely applied in many countries [1]. Satellite information is integrated with the data delivered by the other observation facilities (air, sea, coastal), providing control of the vast water areas in a detailed overview and shooting modes (Fig. 1).

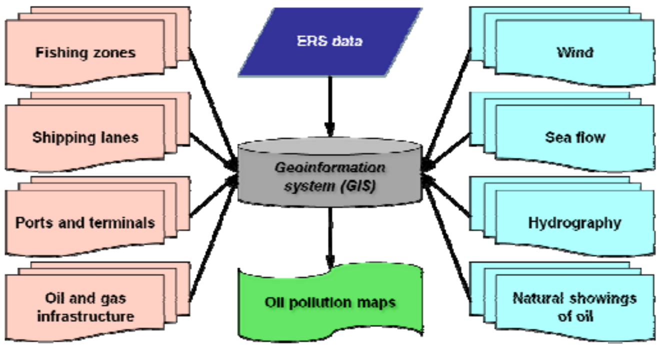


Fig. 1. Integrated ground-space technique of oil pollution monitoring in water areas

Monitoring volume for Latvia:

- coastline length: near 500 km;
- the area of the Gulf of Riga: 18 100 кm²;
- large seaports with oil terminals: Riga (6,57 million tons of oil in 10 months, 2012 – Korabel.ru), Ventspils (15 million tons of oil in 11 months, 2012 – Ventas Balss), Liepaja (0,3 million tons of oil in 2012 – Korabel.ru);
- active navigation in the Baltic Sea: 15% of world sea cargo carriage, 56000 ships in 2007 (including 17% tankers – 170 million tons of oil).

II. Main Types of the Used Data

As space data, the earth remote sensing data in both optical and radio frequency range can be used [2].

When using data of sensing in the optical range, the implementation of the following requirements is necessary:

1) favourable weather conditions: lack of overcast, illumination of the water area is desirable by the Sun under a certain corner (existence of a solar patch of light);

2) implementation of multispectral Earth remote sensing, i.e., sensing is obligatory on the sites of an electromagnetic range corresponding to natural visible colours and in the infrared range.

The example of use of ERS data in the optical range for monitoring of oil slick in the Gulf of Mexico is given in Fig. 2.

Fig. 2. Oil slick in the Gulf of Mexico: on the left – optical data from Envisat, 29/04/2010, 16:04 UTC; on the right – optical data from Terra, 29/04/2010, 16:50 UTC (in a zone of a patch of sunlight) ©ESA. NASA/GSFC

Thus, the technique of determination of oil slick thickness from colour of a slick in a visible site of a range (Table I) is developed.

TABLE I

The Technique of Determination of Oil Slick Thickness from Colour of a Slick

Colour	Thickness, 10^{-3} mm	Volume, l/km^2
silver-grey	from 0.04 to 0.30	40-300
rainbow	from 0.30 to 5.0	300-5000
bluish	from 5.0 to 50	5000-50 000
brownish	from 50 to 200	50 000-200 000
from brown to the black	> 200	> 200 000

This technique, apparently, allows receiving quite a rough estimate of oil slick thickness, and, knowing the slick area according to ERS data, it is possible to calculate the approximate volume of oil in a slick [3].

a) Oil slick on COSMO-SkyMed-1, 11/05/2010, 23:57 UTC (© Agenzia Spaziale Italiana, e-GEOS, CSTARS)

b) Oil slick on Radarsat-1, 22/05/2010, 23:49 UTC, ScanSAR Narrow (© CSA/MDA, CSTARS)

c) Gulf of Mexico in 10 days after a cap of an emergency well on COSMO-SkyMed-1, 26/07/2010, 00:03 UTC (© Agenzia Spaziale Italiana, e-GEOS, CSTARS)

Fig. 3. The application of radar ERS data (using the catastrophe in the Gulf of Mexico)

Features of use of radar ERS data:

1) all-weather capability, but the need for existence of a favourable wind situation – wind speed 2…3 – 5…7 m/s;

2) existence of hindrances in the form of wind shadow, congestions of the surface-active substances (SAS) or seaweed.

Examples of application of radar ERS data to oil pollution monitoring (the Gulf of Mexico, 2010) are given in Fig. 3.

III. Technology of Oil Spill Monitoring in the Water Areas

The traditional technology of oil spill monitoring in the water areas based on the ERS data consists of the following stages [4] – [6]:

1) determining the area of monitoring;

2) receiving data regarding the territory of monitoring;

3) preliminary processing of the earth remote sensing data;

4) targeted processing of the ERS data and making the map of oil spills;

5) delivery of the results to the customer.

Determining the territory of monitoring implies the creation of the vector map containing the borders of the territory. For the water areas it is the coastline and the borders of the areas of concern. Scale of the map with the boundaries should be as good as the scale of the maps, which can be obtained based on the use of ERS data.

It is also necessary to analyse features of this territory. For example, climatic conditions essentially influence the choice of a type of data. In view of the climatic conditions of the territory in question (a small number of clear days), the use of optical ERS data may only be complementary. It is appropriate to use ERS data received from satellites equipped with Synthetic Aperture Radar, as the basic data.

Receiving of ERS data for the territory of monitoring consists in receiving the optical band and radio frequency region ERS data delivered to the technical facilities. If necessary, shooting of the territory of monitoring can be ordered from the ERS providers. When ordering, the map of the borders received at the first stage can be used.

Preliminary processing of ERS data consists of:

- reduction of the corresponding format of diverse data;
- elimination of various distortions (if necessary);
- geographical and temporary reference of the obtained ERS data.

To facilitate preliminary processing, there are various software tools.

Targeted processing of the ERS data consists in the detection of oil pollution in the images, and formation of vector outlines of such images. Here it is advisable to use the images obtained by satellites with optical and radar equipment [7], results of land measurements as complex data.

Use of land data in targeted processing has two purposes:

- land data are a source of additional informative signs;
- land data allow estimating reliability of targeted processing results.

The complex use of ERS and land data certainly favourably affects the reliability of detection of oil pollution. However, the complex use of data has also the negative consequences related to big dimension of data. To decrease in dimension the data without an essential decrease in reliability of detection, different methods can be used. For example, selection of the most essential informative signs, which can be carried out by means of a method, is a main component. Binary coding of informative signs is also one of approaches [8].

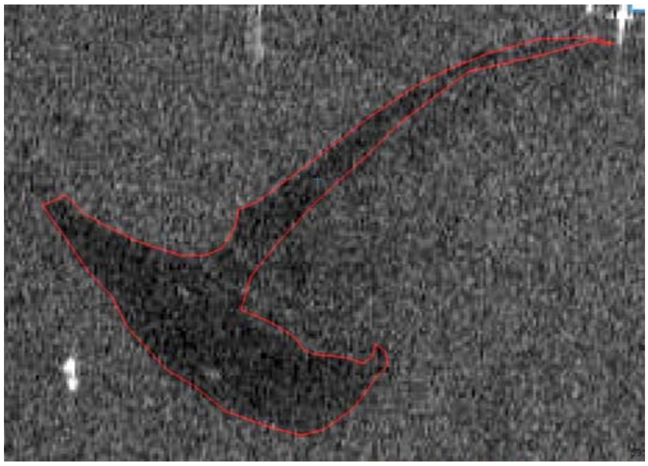
Detection of oil spills is carried out only within the limits defined during the first phase. This allows reducing the volume of processed data and, therefore, reducing the time of processing. In addition, it allows excluding some processing errors: some objects possibly detected on land and in the inland waters may have characteristics similar to oil pollution, actually not being such.

Targeted processing is based on the analysis of various characteristics of the image: spatial, spectral or temporary. Spatial characteristics treat: texture, context, form and structural ratios [9]. It is necessary to understand changes of information classes in time as temporary characteristics, for example, movement and change of a form of an oil slick. In spite the spectral characteristics belong to ERS optical data, they contain essential information about the nature of the objects.

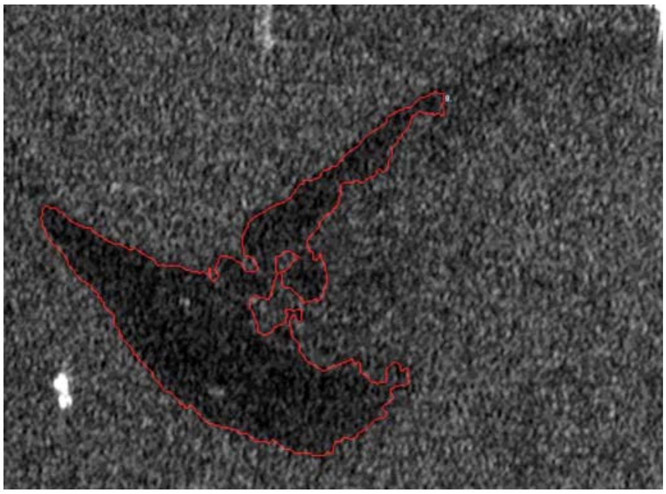
Oil spills are detected by the radar remote sensing data based on the statistical characteristics. The values of the statistical characteristics are specific to the area in question. Therefore, the method of detecting must be adapted to the characteristics of the areas of concern. Based on the reference site chosen by the expert, the maximum and minimum values of brightness corresponding to oil pollution are determined. Then, the areas in the areas of concern, with brightness levels between the above values, are detected, and contour imaging of the areas is implemented. As a result, we receive vector outlines of the areas, which may be represented by oil spills.

In this case, there was a reference result of detection of this oil spill (see Fig. 4a – the red contour line). Detection was performed with the application of the described technology, and the obtained results were compared with the reference values. The comparison showed a great degree of conjunction (see Fig. 4b).

However, among the identified sites there can be not only oil contaminated areas but also areas of wind blanketing effect, and accumulation of surface-active agents (surfactants) or algae. For a more reliable detection of oil spills, we shall use remote sensing data of optical band and the additional data received from land-based sources: information on the anthropogenic activities, which is the potential source of pollution, as well as information about the natural phenomena and processes that affect pollution. Also, the information about the natural (native) oil showings should be used. Thus, for reliable detection of oil contaminated areas, it is reasonable to integrate the terrestrial and space-based data.



a)



b)

Fig. 4. Detection of oil contaminated areas according to radar remote sensing data: a) the reference results, b) the actual result

Delivery of the results to the customer by the most expeditious method shall be the use of web services and geological portals. The geoportal http:\\ocean.kosmosnimki.ru can be considered the prototype. In this case, the obligatory information layers should be the following:

1) geospatial base – the map containing the most significant landmarks; perhaps, the base is formed only for the area of concern;

2) outlining of the oil pollution areas, ranked by the dates of detection; for each contour, the attribute information such as date, size, additional information, should be defined;

3) converted to the format suitable for use in the geoportal, the earth remote sensing data used in monitoring; remote sensing data should also be ranked according to the date of their receiving.

IV. Conclusion

Today oil spill monitoring in the water areas is topical, especially for the Baltic Sea and Latvia. The complex use of ERS and land data for oil spill monitoring in the water areas finds the increasing distribution and demands the adaptation of existing or the development of new technologies of data processing. As ERS data both optical and radio frequency range can be used. There are some factors influencing receiving and processing of data, first of all, the meteorological factor.

The complex use of data has an essential impact on traditional technology of oil spill monitoring. Complex application of data allows increasing reliability of processing results. However, there is also a negative effect – increase in dimension of processed data; therefore, the review of some methods of decrease in this dimension is given. In practice, the operability of technology is shown.

Acknowledgements

The research has been supported by the Russian Federal Property Fund (grants No. 13-07-00279-a, 13-08-00702-a), project ESTLATRUS 2.1/ELRI–184/2011/14 "Integrated Intelligent Platform for Monitoring the Cross-border Natural-Technological Systems" (2012–2013).

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Valerijs Matjašs. Akvatorijas pasārņojuma monitoringa un informācijas apstrādes līdzekļi

Palielinoties ogļūdeņraža izejvielu transportēšanas apjomiem un šelfu teritorijām, arvien lielāka uzmanība tiek pievērsta ūdens akvatoriju naftas piesārņošanas monitoringam. Īpaši aktuāli tas ir Baltijas jūrai un Latvijai. Rakstā ir apskatīta aerokosmisko un virszemes datu kompleksa izmantošana akvatoriju analīzei, kuri piesārņoti ar naftu. Šīs kompleksās pieejas izmantošana kļūst populāra, kaut arī prasa esošo datu apstrādes tehnoloģiju adaptāciju vai jaunu tehnoloģiju izstrādi. Rakstā tiek izanalizēti aerokosmisko datu veidi, kurus ir lietderīgi izmantot akvatoriju piesārņojuma ar naftu analīzei. Kā piemērs ir izskatīti zemes zondēšanas tālizpētes dati elektromagnētiskā spektra optiskajā diapazonā un radio diapazonā. Ir parādīti faktori, kas ietekmē to ieguvi un apstrādi. Galvenokārt tie ir meteoroloģiskie faktori. Rakstā ir aprakstīta tehnoloģija, kas ļauj pēc optiskajiem zondēšanas datiem aprēķināt aptuvenu naftas piesārņojuma apjomu. Ir izskatīti akvatoriju naftas pasārņojuma datu apstrādes etapi, izanalizēta šo etapu specifika gadījumā, ja tiek izmantoti aerokosmiskie un virszemes dati. Kompleksā izmantošana ļauj paaugstināt datu apstrādes rezultātu ticamību. Tomēr, izmantojot datu apstrādes komplekso tehnoloģiju, eksistē arī negatīvs efekts, kas ir saistīts ar pārstrādāto datu apjomu un tā dimensijas palielināšanu. Rakstā ir parādīts piemērs par kompleksās tehnoloģijas izmantošanu, pierādot tās darbspējas.

Валерий Анатольевич Матьяш. Средства мониторинга и обработки информации о загрязнениях водных акваторий

Внимание к мониторингу нефтяных загрязнений водных акваторий возрастает по мере увеличения масштабов шельфовой добычи и морской транспортировки углеводородного сырья. Для Балтийского моря и Латвии это особенно актуально. Рассмотрены вопросы комплексного использования аэрокосмических и наземных данных для анализа нефтяных загрязнений акваторий. Такое использование данных находит все большее распространение и требует адаптации существующих или разработки новых технологий их обработки. Проанализированы виды, прежде всего, аэрокосмических данных, пригодных для анализа нефтяных загрязнений акваторий. В качестве таких данных рассмотрены данные ДЗЗ в оптическом диапазоне электромагнитного спектра и радиодиапазоне. Показаны факторы, влияющие на их получение и обработку, прежде всего метеорологические. Существует технология, которая позволяет по оптическим ДЗЗ получать приблизительную оценку объема нефти в нефтяном пятне. Рассмотрены этапы обработки данных для мониторинга нефтяных загрязнений акваторий и проанализированы особенности этих этапов при решении данной задачи с использованием аэрокосмических и наземных данных. Комплексное применение данных позволяет повысить достоверность результатов обработки. Однако есть и негативный эффект – увеличение размерности обрабатываемых данных, поэтому рассмотрены некоторые методы снижения этой размерности. Приведен пример использования описанной технологии, который показал ее работоспособность.