

Earth Exploration from Space

Mapping of Oil Slicks Polluting Sea Surface Based on Space Radar Data (The Caspian Sea)

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Starting 1991 space radar imaging and in particular synthesized aperture radar (SAR) has been applied extensively for oil spillage observation and monitoring in the sea. On the basis of collection, processing, and assessment of available radar images the present study offers the method of mapping slick pollution for the Caspian Sea. The method utilized ERS-1 and ERS-2 low resolution radar images, so-called quicklooks, available on the ESA (European Space Agency) server. The results of the radar data interpretation and expert review served as basis for building the map of oil slicks and petroleum products distribution in the sea area as of May 1996 integrated with other data layers in the GIS shell. On the basis of the map analysis a number of conclusions were made with regard of intensity of pollution and its connection to possible sources. Modern tendencies of the Caspian oil production development evoke the need to establish all-Caspian system of oil pollution monitoring on the basis of regularly updated maps of pollution distribution and GIS-integrated space data bases.

INTRODUCTION

Oil spills seriously damage the sea environment. Sea oil spills occur everywhere but they are especially dangerous on tanker crashes or oil platform accidents. As for the Caspian Sea the scale of its pollution has not been identified to date. The inner Caspian Sea, which area belongs to Russia, Azerbaijan, Iran, Turkmenistan and Kazakhstan has fully developed ecosystems with rich flora and fauna, including populations of the Caspian sturgeon, sprat and seal, and represents one of the important oil sources [1]. Oil exploration started in the Caspian at the end of XIX century triggered present ecological problems, which were aggravated as a result of unreasoned approach to the issues of environmental protection in the period of aggressive exploration of sea resources in the times of USSR. On the other hand, after USSR collapse the Caspian Sea became the arena of new independent states and large international oil companies fighting for utilization of oil resources for the purpose of gaining strategic resources and geopolitical advantages. Due to the above stated the scientific media responded with a number of concerns reference future prospects of oil production intensification in the Caspian Sea in connection with the environmental disaster of the regional scale [1, 2].

Output of the studies carried out in the recent decades made clear what happens to oil leaked in the sea [3-5]. Due to its physical and chemical properties oil can stay in the ocean for quite a long time in the form of film, emulsified substance or aggregates. Oil spilled on the sea surface forms films of various thickness as the oil itself and products of its refining represent complex compounds. Unlike surfactants oil never spreads to monomolecular layers and oil films are of greater thickness (from several centimeters to fractions of millimeter). Light fractions of spreading oil including toxic aromatic hydrocarbons quickly evaporate in the air while water-soluble substances bleach, therefore residual film possesses increased viscosity causing oil spreading tendency to decay. Oil adsorbed on solid particles sink to the bottom. There are two processes that affect film spreading on the sea

surface: transfer (drift) caused by wind and currents and self-induced spreading across the surface. Thus with no wind, waves and currents one cubic meter of oil spreads to form a 50 meter radius slick for 1.5 hour. With strong waves and wind the slick decays forming oil-water emulsion in wind-induced mixing layer. Oil emulsification process also slows down slick spreading. On the sea surface oil undergoes oxidation (accelerated by sea water salts and sun irradiation) and bacterial decomposition, with that these processes greatly depend on water temperature.

Oil spill monitoring in the sea with the use of traditional monitoring resources is quite difficult. Remote monitoring from space present an alternative to common methods due to large area coverage and at significantly lower cost; they allow monitoring of oil slicks translation and transformation from spacecraft and aircraft. The primary scientific and practical task assigned to the monitoring system is to detect and localize with maximum allowable accuracy the fact and location of an accident (oil spill) at offshore facilities of the oil and gas complex and along shipping lanes, on the basis of disturbances observed on the sea surface [6], using signatures that are likely to be detected remotely.

The most effective resource for oil pollution monitoring is radar sensing capturing variations of surface roughness (wave pattern). This application utilizes radars with synthesized aperture (SAR) on ERS-1/ERS-2, Radarsat and Envisat.

Possibility of remote detection of sea oil pollution and its diagnostics with the use of RSA is ensured by a number of physical causes, the most significant of which is changing of sea surface physical condition due to wave pattern changes caused by oil film (wave smoothing and formation of smoothed areas – slicks) [7]. It is illustrated in theory and through experiments that the main reason for short surface waves damping is the great dependence of wave damping decrement on the film matter concentration. Radar methods based on the analysis of the signal scattered by sea surface are classified as active, besides they could be used at any time of the day and in overcast conditions. Their attraction is explained by capability of fast acquisition of operational data for large sea areas which allow observing virtually instantaneous picture of oil pollution distribution and tracking its transformation with time [6]. Weak points of radar methods shall include difficulty in obtaining quantitative characteristics, however even in this respect significant progress has been recently achieved [10].

As of today radar methods of sea oil pollution monitoring already allow solving the following tasks [11]: 1) detection of pollution on sea surface; 2) observation of slick translation/transformation; 3) age assessment of an oil spill; 3) determination of boundaries and area of an oil slick (and if additional data is available – determination of oil film thickness and its volume). In particular the SAR capabilities listed above are supported by results of experiments on ERS-1, SIR-C\X and Radarsat satellites [10, 12, 13] carried out for the purpose of developing methodologies of detecting oil in the sea as well as during the missions of domestic spacecraft Cosmos-1870 and Almaz-1 [11, 14, 15]. In 1998 – 2000 a number of campaigns were run on oil pollution detection and monitoring in various seas of the World Ocean [13, 16-18]. The studies [16, 17] first showed the prospects of using large radar array covering areas of this or that sea for mapping spatial distribution of oil slicks, while [18] discovered connection between oil pollution spatial distribution and its sources.

Regardless of the fact that space radar imagery has been extensively applied for oil spills observation and monitoring since 1991, SAR-images on the most seas have not yet been collected, processes or analyzed. For instance, the search made in Internet, on European and Canadian space agencies servers showed that starting 1991 when radar imagery became a pervasive phenomenon, ERS-1 and ERS-2 satellites have acquired over 600 radar images of the Caspian Sea while Radarsat satellite – around 150 images.

Development and application of cartographic methods to surveying sea basins using Geographic Information Systems (GIS) and GIS-methods – one of the promising directions forming on the junction of several scientific disciplines. These methods call for collection and taxonomy of data

with subsequent conversion, mathematic and statistic processing, analysis and cartographic or graphic representation. This direction becomes a priority for resolving the issue of mapping oil pollution on the entire sea area.

On of the objectives of this study besides analysis of existing archive of space radar data and mapping oil products distribution (by the example of the Caspian Sea) – is to demonstrate capabilities of the methods of mapping films of oil and oil products on the sea surface for assessing the scale of the existing problem. The approach is based on the collection, computer-assisted processing and analysis of available radar images using up-to-date GIS methods.

Quicklooks of RSA images available in the ESA EOLI ODISSEO catalog (total number of imageries shown in brackets)

Year	ERS-1	ERS-2
1991	-	-
1992	-	-
1993	7 (24)	-
1994	2 (10)	-
1995	-	-
1996	40 (50)	43 (61)
1997	5 (5)	4 (20)
1998	-	-
1999	-	8 (334)
2000	-	15 (53)
2001	-	8 (37)
2002	-	7 (107)
Total:	54 (89)	85 (612)

1. INITIAL DATA

Methodological fundamentals for Earth remote sensing data processing were reviewed in [19]. In light of the above we fixed upon the data of ESA radar satellites ERS-1 and ERS-2. We will briefly dwell upon the specifications of radar products and associated archives.

1.1. Description of available data

The standard SAR.PRI product of processing radar images acquired by ERS-1/ERS-2 satellites represents synthesized radar image with triple incoherent accumulation on azimuth, 16-bit dynamic range, 12.5 x 12.5 pixel size and 25 meter resolution. SAR.PRI product provides all opportunities for solving a number of remote sensing tasks and is supported by most software packages for remote sensing data processing. However those data are of commercial nature priced at 800 to 1200 euro for commercial users (150 euro for research projects). For Russian users there is only one way to obtain data and radar images from ESA – this is the research project program called Announcement of Opportunity providing real opportunity to receive required data with considerable discount. However ESA server such as EOLI (Earth-Net OnLine Interactive) ODISSEO (Open Distributed Information and Services for Earth Observation) has posted quicklooks for preview of radar images. These are thinned images in JPEG graphic format which have resolution of around 400 m (about 50kB of file size). However it's worth pointing out that unlike SAR.PRI product quicklooks cannot be used for measuring specific scattering cross-section and radiometric contrasts; the main objective of creating them is to evaluate quality of original (initial) image. Nevertheless as a free product

quicklooks may be used for a number of applications. Moreover, ESA have no objections to free copying and usage of quicklooks provided copyright requirements are observed. Based on the above the decision was made to use low resolution radar images i.e. quicklooks located in EOLI ODISSEO catalog as initial data. An example of radar image quicklooks and the mosaic made of them, which illustrates pollution of the Caspian Sea is shown on fig.1 and 2.

EOLI ODISSEO catalog is an interactive browser that allows working with ERS-1 and ERS-2 databases via Internet – searching, viewing, selecting and even ordering required images of ERS-1 (1991 – 2000) and ERS-2 (1995 to present). The catalog Internet address is <http://odisseo.esrin.esa.it>. Besides SAR.PRI, SWM (wave product) and (scatterometric product) radar products the browser allows searching and viewing other products of ERS-1 and ERS-2: ALT (altimetry), ATSR-1/ATSR-2 (optics/IR) and GOME (ozone).

Browsing and data searching in the EOLI catalog is based on the interface represented by in-built, interactive and dynamically scaled world map where user sets a region of interest (data search range) and where the search results are displayed. It's convenient to search catalog by imagery date or by known orbit (pass) number of pre-selected satellite for the set region of interest.

1.3. Radar data for operations region

The table lists the statistics of the Caspian Sea coverage by ERS-1 and ERS-2 satellite imagery based on the data of Display Earth Remote Sensing Swath Coverage Windows Application (DESCW version 3.7). It ensues that the sea coverage of ERS-1 and ERS-2 imagery is extremely uneven – the analysis of the available data made the authors conclude that the most acceptable period for such analysis is 1996. In the ESA archive total of 139 ERS-1 and ERS-2 radar images were found that contained signatures of oil pollution. Each scene was accompanied by metadata file with accompanying data (imagery date and time, angular coordinates, etc). Figure 3 shows examples of the Caspian Sea coverage by SAR imagery in 1996.



Figure 1. 400 meter resolution radar image (quicklook) (Apsheron peninsula and Neftyaneye Kamni settlement). © ESA.

2. SOFTWARE

ERDAS IMAGINE (version 8.6) and ArcView 3.2 software products were provided by LLP "Data+" for conducting the present study.

1. ERDAS IMAGINE software package combines capabilities of converting and analyzing space images, digital photogrammetry, image processing in raster and vector formats. Radar images analysis and conversion utilized space imagery geometric correction tools – “Geometric Correction” module containing primary computer model for conversion, mosaics module – “Mosaic images”, image contract and brightness conversion tools as well as “Vector” module for creating digital maps in vector format and vector image analysis.
2. ArcView GIS software package was used for working with digital layers of oil products distribution in the Caspian Sea area and creating digital cartographic base for the output map. ArcView package allowed operations on both creating map elements with editing them online and finalizing the map and creating simple GIS shape.

3. RADAR IMAGE PROCESSING

The first stage of images processing was comprised of coordination and was required due to the fact that received raster images did not have a geo-location. Radar images coordination was done on the basis of the angular coordinates data and central point of each scene contained in metadata files. Transformation was carried out using “Geometric Correction” module of ERDAS IMAGINE package on the basis of integrated transformation model for Earth remote sensing data. In particular geographic coordinates data (latitude/longitude) were entered for angular pixels of each scene. In case the image central pixel could be defined with high probability the fifth base point was introduced in the transformation model; after that each radar image was transformed.

Virtually all images acquired by ERS-1 and ERS-2 satellites over the Caspian Sea consisted of more than a single scene. Average number of scenes received from the archive for each pass was 4 - 5. After each scene transformation separate scenes were mosaiced into strips. This operation was assisted by digital mosaics module “Image Mosaic”. An example of the image “mosaiced” from five scenes is shown in figure 2.

Since images were of low spatial resolution semiautomatic processing and classification of detected slicks was considered unpractical. Due to the above the only appropriate method for detecting oil pollution in the Caspian Sea became expert review performed by specialists of P. P. Shirshov Institute of Oceanology under the Russian Academy of Science.

Prior to radar image analysis brightness and contrast of halftone images were adjusted using standard tools “Breakpoint Editor” and “Look Up Table Editor” to make detection of oil and petroleum products slicks on the sea surface more precise and to delineate them on the basis of brightness and texture signatures from other similar structures (slicks).

One of the obstacles for oil slick mapping on the entire sea was non-uniform coverage of the Caspian Sea by radar images of ERS-1 and ERS-2. Therefore in most cases imagery of the northern and north-western parts of the Caspian (Russian sector) was missing (fig.3). The table well illustrates that quantity of available radar images in some years was extremely low except 1996 when extensive imagery of the Caspian Sea was carried out using two satellites - ERS-1 and ERS-2.

4. DELINEATION OF THE CASPIAN FILM POLLUTION IN SAR IMAGES

Delineation of films of oil, petroleum products and surfactants on the sea surface was performed by expert review method or visual analysis. It is commonly applied in cases when reliable additional data are not available, and is based on the complex analysis of a number of signatures visible on a radar image. Form, size, contours, texture, border sharpness, slick brightness parameters are the primary signatures used for interpretation; with that account is taken for slick dynamics in the field of surface flows, their position relative to possible pollution sources (developing production fields, ports, shipping lanes, river mouths, griffons, etc) and driving wind velocity [11-13, 16-18]. Briefly

dwelling upon the procedure we point out that at the beginning all radar images of 1996 had areas delineated that were different in texture and brightness (dark spots) from the background of the sea surface (grey tone). Later those areas were analyzed for their origin, since besides slicks of oil, petroleum products and surfactants radar images might had displayed other phenomena in the top sea layer and bottom atmospheric layer (areas of wind smoothing). It's also worth to note that interactive and automated methods of film pollution identification are presently still under development.

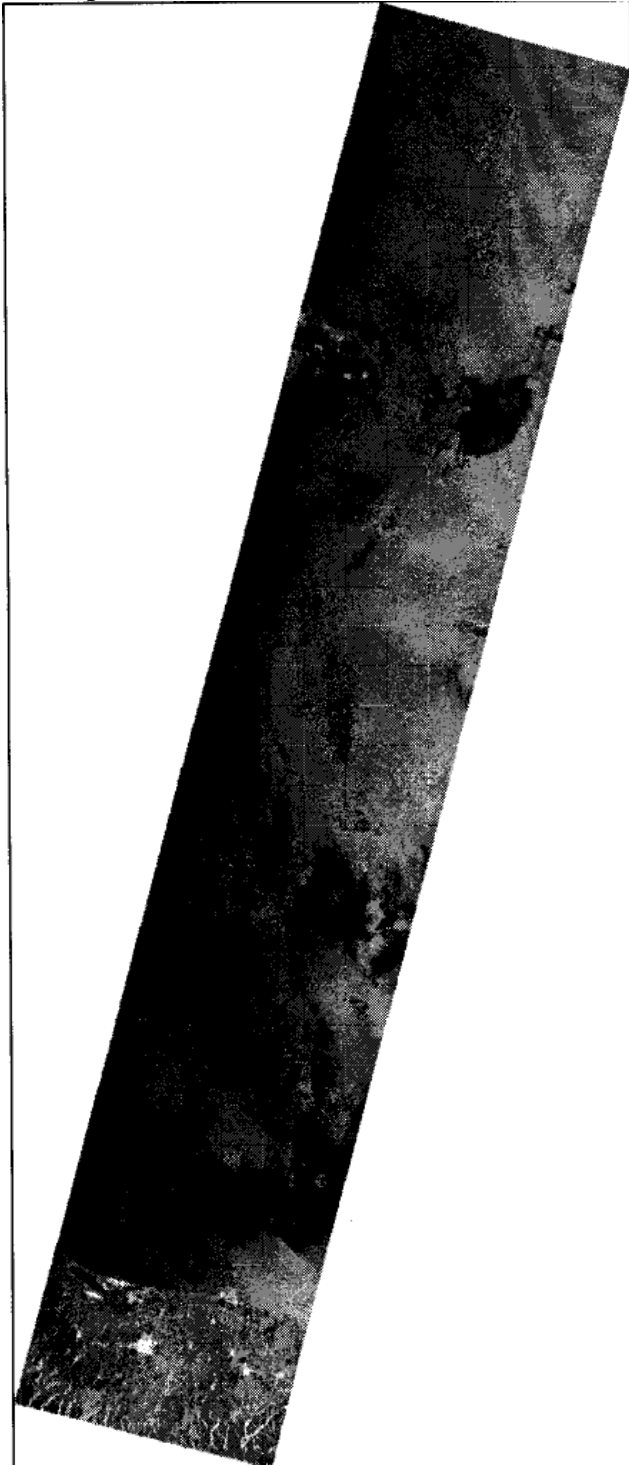


Figure 2. Example of radar image “mosaiced” from five scenes (ERS-2 satellite). © ESA.

Analysis of a set of quicklooks showed that when accounting for size and form of spots, texture and border signatures as well as other available data (including that on wind velocity) and regardless of their low resolution, slicks of film pollution could be delineated (sized from several kilometers) from other exhibits on the sea surface. An example of interactive delineation of oil film on radar image is shown in fig. 4. Using ERDAS IMAGINE package module – “Vector” vector layers were created for each strip mosaiced from several scenes.

This vector coverage in Arc/Info format was exported into ArcView software package. Vector layers obtained through it were combined into one vector layer. The resulting layer was additionally checked for correctness of contour displaying by overlaying the radar image and prepared as the primary information layer for the vector map of oil films distribution in the area of the Caspian Sea.

5. MAPPING DISTRIBUTION OF OIL AND PETROLEUM PRODUCTS FILMS

The base for the oil pollution distribution map was represented by the set of digital cartographic layers of the Caspian Ecological Program (CEP) which included the following data of the general geographic nature:

- a) coastal line of the Caspian Sea. CEP data were taken as the source. Vector polygonal coverage was created in 1997 on the basis of materials of the navigational map with the scale of 1:1,000,000 (1987) and corrected in accordance with the changes of the coastal line on the basis of Resurs satellite imagery data;
 - b) settlements. DCW was used as data source on settlements. Settlements data for the Russian sector of the Caspian Sea region were verified using the map with the scale of 1:1,000,000 (State Department of Geodesy and Cartography, 1986);
 - c) state (and administrative) borders of the Caspian region states (onshore). Data source was DCW. Besides, layers were created reflecting specific tasks of the study, in particular:
 - a) offshore and onshore locations of oil production (oil rigs/platforms, terminals, refineries, etc) in the Caspian region. The basis of the information layer was CEP data (base layer – DCW and data of CEP ecological monitoring agency). The information was supplemented with the data of the map “The Caspian Sea and Its Resources” [20];
 - b) the most important oil pipelines of the region. Data source – DCW. The data were supplemented with information provided by CEP and KazTransOil company (Kazakhstan);
 - c) integral schematics of the Caspian Sea currents (based on the study [21]);
 - d) digital model of the underwater topography (bathymetry) of the Caspian Sea. Data source – CEP.
- After preparation of the cartographic base GIS shape was created using ArcView program, which included all information layers listed above and the new information layer containing data on distribution of oil and petroleum films. Then automatic layers overlaying was performed and the map was finalized (fig. 5a).

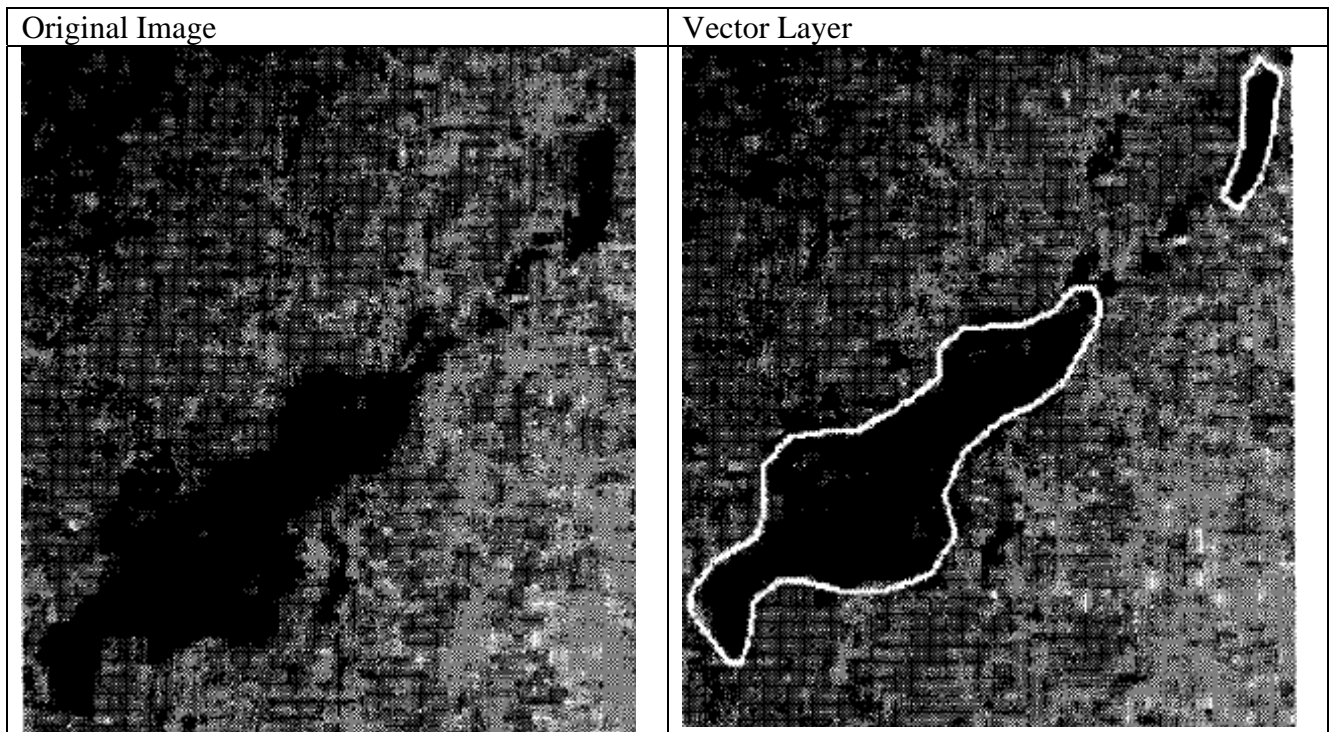


Figure 4. Example of interactive delineation of an oil slick (creation of a vector layer) on a SAR image acquired by ERS-2.

6. ANALYSIS OF OIL AND PETROLEUM PRODUCTS DISTRIBUTION MAP FOR THE CASPIAN SEA AREA

Please note that the authors did intend to classify detected film slicks on the basis of pollutant types and used the term “films of oil and petroleum products” to identify all oily and oily-tarry fractions of crude oil, petroleum products as well as surfactants getting in the sea and forming slicks (smoothed areas). Based on the data [22] the main sources of oil pollution in the Caspian Sea could be: 1) offshore and onshore oil wells/platforms in Russia, Azerbaijan, Kazakhstan and Turkmenistan; 2) navigation and oil transportation by sea; 3) flooding of former oil production facilities (secondary pollution) related to the increasing level of the Caspian Sea; 4) carry-over of oil and petroleum products along with river runoff (refinery and municipal waste water); 5) oil seeps from griffons on the sea bottom (natural pollution) registered at south-western and southern parts of the sea. The authors [23], for instance, point out that the area of the Caspian Sea periodically gets covered by oil film of hundreds of square kilometers.

Obtained map of oil, petroleum product and surfactant films distribution in the Caspian Sea area (fig. 5a) characterizes the situation as of the first half of May 1996 and allows delineating the sea regions different in pollution intensity and source type.

The big picture of distribution (and transfer) of films of oil and petroleum products generally corresponds to the global currents system of the Caspian Sea (fig. 5b), which is confirmed by satellite data (for instance, NOAA AVHRR and SeaWiFS data) and also referenced to the locations of extensive operation of offshore and onshore oil fields.

It is reasonable to start analysis of dynamics of oil and oil products films transfer from the western coast of the Caspian Sea (Azerbaijani sector), from the Apsheron peninsula since this region is the most extensively exploited. The map (fig. 5a) northward the Apsheron peninsula shows slicks of

petroleum products related to Apsheron Bank, Darwin Bank, Neft Dashlary and Gyuneshli oil deposits. Further south-westward big size slicks are observed in the region of extensive oil production – Neftyanye Kamni settlement. Films of oil and petroleum products are observed in the region of Baku Bay and Shakh-Deniz and Azeri oil fields. The most likely origin of pollutants is leaks during production (including drill cuttings) and transportation or chronic leaks from defective pipelines [24]. It's worth noting that part of films could be involved in the coastal stationary anticyclonic circulation, located between the Apcheron peninsula and the estuary of the Kura River. Due to the above part of the slicks could be carried over back to the locations of oil production in the region of the Apsheron peninsula. In [23] increased oil carryover with the Kura runoff is noted. In the western part of the Iranian sector of the Caspian Sea, as it was mentioned before, sea bottom griffons are widespread, which blow out crude oil to the sea surface (natural seeps). As a rule these are local point-source blow-outs, which are easily identified on a radar image by their structure (elongated narrow slicks sometimes spiral-wound with visible thickening at their exit to the sea surface).

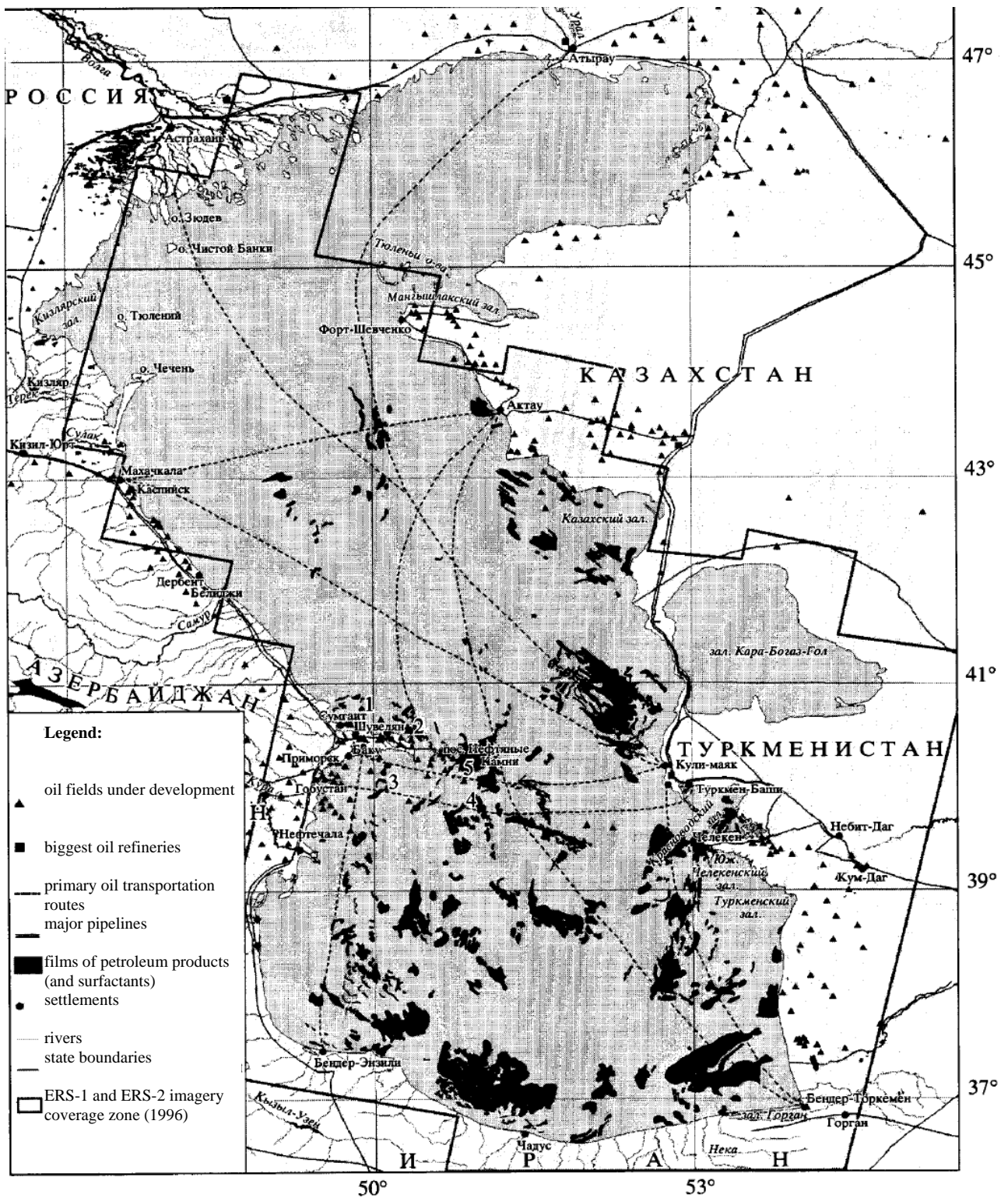


Figure 5.a – Integral map of slick formations distribution in the area of the Caspian Sea (May 1996), most likely connected to the films of oil, petroleum products and surfactants; Scale 1:1,500,000. The map shows the following oil deposits: 1 – Darwin Bank, 2 – Gyunesli, 3 – Shakh-Deniz, 4 – Azeri, 5 – Neft Dashary.

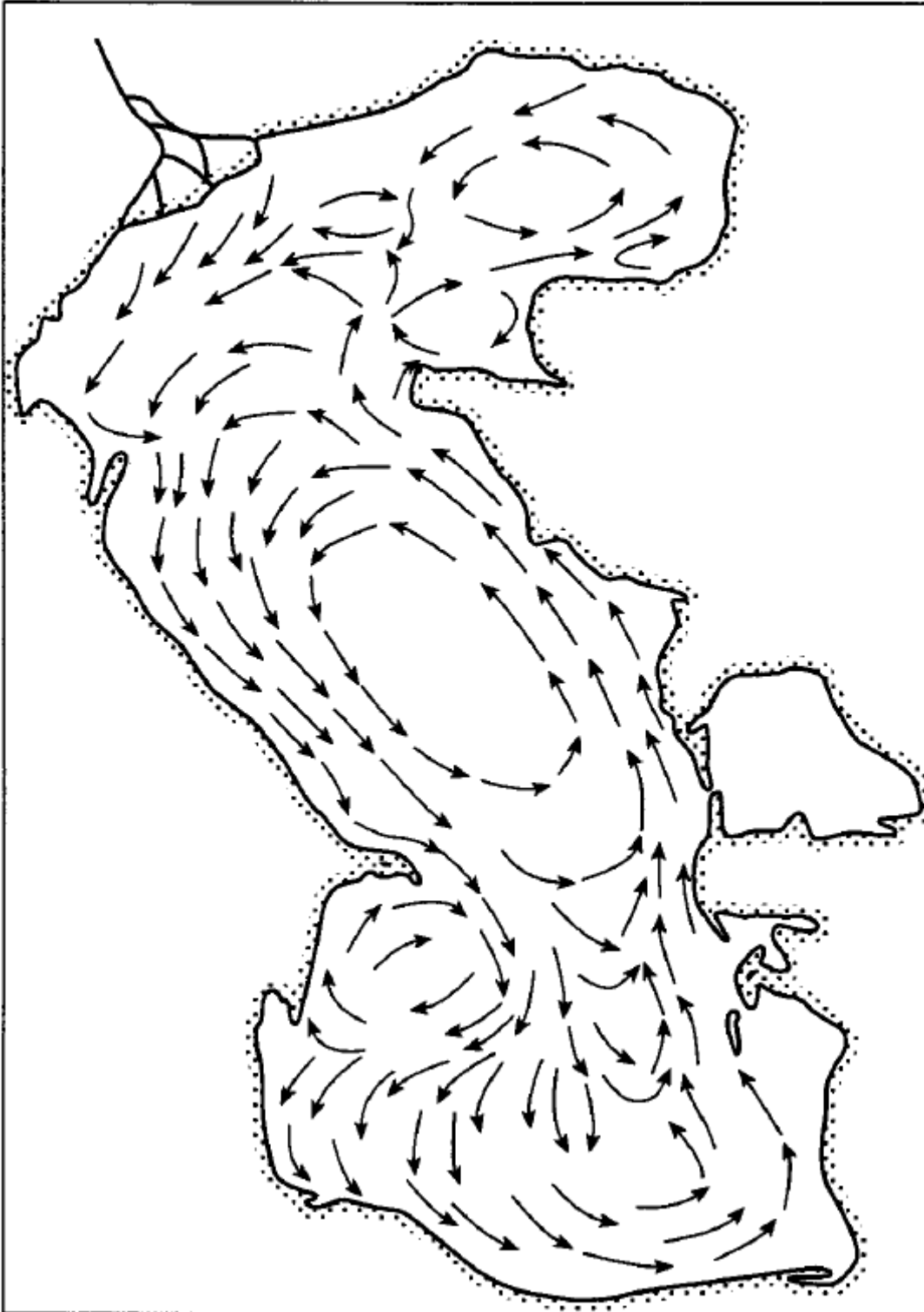


Figure 5. End: b – Schematic of the Caspian currents based on the study [21]. Single oil blowout is small in volume. However, the number of such blowouts in the Iranian sector judging by the space radar data is quite big, which periodically can significantly worsen ecological situation in the region in question.

Large films of petroleum products were also discovered in the Iranian sector and their origin is not quite clear. On the one hand it is most probable that these are slicks spread over the sea surface, which were involved in the branch of the cyclonic circulation of the southern Caspian in the region of the Apsheron peninsula. On the other hand, large film pollution was also discovered in this sector (possibly not related to oil), and extensive river runoff was observed in the central and western parts (4.4% of the total runoff [23]). Since there is no extensive oil fields development in this region, the most likely origin of them is either slicks drifting towards the branch of the southern cyclonic circulation (both oil slicks from the central Caspian Sea and the slicks related to the griffons) or carryover of the petroleum products and surfactants with the river runoff from the Iranian territory. Presence of petroleum products slicks in the Turkmen sector of the sea could be explained by the development of the region oil fields; these are blowouts and leaks during production and transportation including dumping of petroleum products from vessels. In the Krasnovodsk bay the most likely is the dumping of industrial wastewater and residual petroleum products from onshore refineries and industrial facilities. In the northern part of the sector large films of petroleum products are observed, which to all appearance are carried over from the oil production region to the region of the Cheleken peninsula and the town of Krasnovodsk (presently called Turkmenbashi) by the longshore current being the branch of the stationary circulation in the southern Caspian. Thus, based on the data [23] besides Neftyanje Kamni the Krasnovodsk and Turkmen bays are considered the most polluted sea regions.

Several slicks up to 10km long are observed in the southern part of the Kazakhstan sector. They are related to the locations of offshore oil production and they are also observed in the region of Shevchenko town (presently Aktau) and could be related to oil refining and industrial wastewater dumping in the port. Surface films were also discovered in the open sea along Aktau-Makhachkala and Aktau-Baku routes. The most probable reasons – unauthorized (or emergency) dumping from vessels during oil transportation by sea.

Possibility of oil films transfer from oil deposits in the region of the Apsheron peninsula to the northern part of the Caspian Sea are not supported by radar imagery data for the specified period. However SeaWiFS data (not specified here), reflecting distribution of suspended material/phytoplankton in the sea surface layer circumstantially indicate possibility of such transfer of film pollution.

CONCLUSION

The present study developed the methodology for mapping film pollution distribution for the Caspian Sea on the basis of collection, processing and interpretation of available radar imagery. Low resolution radar images of ERS-1 and ERS-2 satellites, so-called quicklooks were utilized for this exercise, which are available on the ESA server. Available radar images found in the ESA catalog were transformed into the joint projection and then deciphered for the purpose of delineating films of oil and petroleum products (83 images acquired in the first half of May 1996 out of 139 available ERS-1 and ERS-2 images were deciphered). Based on the results of images interpretation and through application of expert review method the map was created for oil and petroleum products films distribution in the sea area for May 1996, which was overlaid with the digital cartographic base, other CEP information layers and then integrated into the GIS shape. Obtained map was analyzed for detection of primary pollution sources and regions of the highest ecological risk; a number of preliminary conclusions were made regarding the intensity of pollution and their relation to the sources.

The resulting map (fig. 5a) shows how greatly polluted the Caspian Sea area could be with petroleum products as of May 1996. With account for modern trends of oil production development in the Caspian the conclusion was made that the scale of pollution will only keep growing if

rectifying measures are not taken. Due to the above the need is quite obvious for creating All-Caspian oil pollution monitoring system on the basis of regularly updated distribution maps and GIS-integrated databases.

Taking into account the above said the present study could be considered as the first step on the way to creating effective monitoring system for oil pollution in the Caspian Sea. Ecological monitoring systems should be taken as basis for that. Abrupt deterioration of the ecological situation due to intensified oil and gas production offshore and offshore the Caspian Sea requires creating the system of continuous monitoring and control of the sea ecosystems condition and primarily the system of monitoring intensity and dynamics of oil pollution. After USSR collapse data acquisition and analysis systems functioned in the region turned out to be non-operational and nowadays they are not covering the entire Caspian Sea. Besides, there is no unified system of monitoring and responding to oil pollution at intergovernmental/All-Caspian level.

As the practice of Earth remote sensing showed the best tool for imaging sea areas for the purpose of detecting oil spills is the synthesized aperture radar, which forms radar images of the sea surface. Space monitoring radar assets represent an alternative to both conventional monitoring methods and to other remote sensing sensors (in visible and IR ranges) due to high sensitivity to surface roughness, all-weather capability and independence from sunlight. The data of the existing radar systems are suitable to support the monitoring system i.e. ERS-2, Envisat and Radarsat.

It should be noted that at the initial stage of the monitoring system design it is required to work out the methodology of receiving and thematic processing of all available information, acquired by modern SAR. The processing methodology can be based on visual/interactive interpretation of radar images and expert review of its results. Final results may become the basis for periodically updated digital maps of petroleum products distribution. In the future when working with SAR data it will be necessary to develop and apply algorithms of automated classification of radar signatures on the basis of the library of reference values. Results obtained through the classification may be added to already created GIS-integrated database or preformed digital cartographic base in the form of new layers and then analyzed. Provided there are trained personnel, software packages for SAR data processing and state-of-the-art computers each work stage could be accomplished in real-time which will permit real-time system operation.

Besides real-time requirement the system should be assigned with the task of accumulating data on the Caspian oil pollution. The base like that could be created through acquisition and analysis of SAR data for all the period of active imaging (starting 1991) as well as supplementing it with data on oil pollution from modern sources. Important role in this data bank will be played by the radar imagery automated interpretation subsystem.

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