Remotely Sensed Data Application for Hydrocarbon Exploration Offshore Ukraine*

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Search and Discovery Article #40712 (2011)
Posted March 18, 2011

*Adapted from oral presentation at AAPG European Region Annual Conference, Kiev, Ukraine, October 17-19, 2010

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Abstract

This study features the research program developed at CASRE to apply space-born data to oil and gas prospecting in the Black Sea Basin. The program includes processing and thematic interpretation of space-born imagery coupled with analysis of available geological, geophysical, hydrophysical, environmental and meteorological information. The applied technique is based on rather simple and clear theory, and the prognostic power of which is proved by experiments, numerical modeling and exploration practice. It is based on immanent attribute of oily material to attenuate higher harmonics of sea waves due to surface tension forces of the film at the water-air interface (Marangoni effect). That is why a microwave radar signal beamed from orbit onto a smoothed sea surface backscatters to the sensor with a low impedance that drastically, up to 20 dB, differs from surrounding wavy medium if the wind velocity ranges from 3 to 10 m/s. Oil slicks form very characteristic features and patterns on the sea surface and produce peculiar semi-lunar, dogleg, spiral, snake-like and star-like patterns.

The repetitive oil slicks in two areas, west and south of Tarkhankut Peninsula and south of Cape Opuk of Crimea (known for numerous submarine gas seeps, mud cones and pockmarks) allowed delineation of hydrocarbon emission zones and selection of first-order prospects to increase success ratio within this highly promising but still immature hydrocarbon-prone basin. A comprehensive analysis of all available data permitted to conclude (2004) that an optimal solution is to spud the first wildcat within the Subbotin prospect where rather thick Plio-Quaternary seal rocks cap the eroded crest of the Maykop Anticline.

As to the NW shelf, the data appear complicated due to significant pollution coming from the Danube and Dnieper, accidental spills along main tanker routes and ship lanes, leaks from exploration platforms and intensive algal bloom during summer months. Several slick groups of higher population density were recorded nearby Zmeiny Island on the western part of the area studied; however, they
were deselected from consideration for the moment due to an ambiguity caused by severe pollution of the sea with oil products. Nevertheless, it was possible to discriminate natural oil manifestations from spills and confidently delineate several emission zones, and one of them to mention is the Pribiyna prospect located west of Tarkhankut Peninsula, near Krymske Gas Field. The radar images of this area demonstrate a compact group of slicks (5 repetitions) shown on ERS scenes. It is worth mentioning that Pribiyna prospect is located not far from the onshore West Oktyabrske Oil Field. There is some evidence that certain phenomena like earthquakes, solid Earth tides and strong barometric fronts affect submarine seepage activity and produce higher slick population density, however, these assumptions need to be proven with proper statistic retrieval of the data.
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AAPG European Region Conference, Kiev, 18 October 2010
Dick had the forethought also to order about a dozen barrels of their cargo to be brought in front, so that when the “Pilgrim” struck, the oil escaping and floating on the waves would temporarily lull their fury, and make smoother water for the passage of the ship.

Now, my lads!” he cried to his crew, “now’s your time; out with your oil! Let it run!”

Ready for the order, the negroes poured out the oil, and the raging waters were stilled as if by magic. A few moments more and perchance they would rage more vehemently than ever. But for the instant they were lulled.

The “Pilgrim,” meanwhile, had glided onwards, and made dead for the adjacent shore.

Jules Verne

“Un capitaine de quinze ans”
1878
## Assessment of oil pollution

### Oil pollution of the Black Sea

<table>
<thead>
<tr>
<th>Source of Pollution</th>
<th>Bulgaria (t/y)</th>
<th>Georgia (t/y)</th>
<th>Romania (t/y)</th>
<th>Russia (t/y)</th>
<th>Turkey (t/y)</th>
<th>Ukraine (t/y)</th>
<th>Total (t/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td>5,649.00</td>
<td>3,144.10</td>
<td></td>
<td>7.30</td>
<td>21,215.90</td>
<td>30,016.30</td>
<td></td>
</tr>
<tr>
<td>Industrial</td>
<td>2.72</td>
<td>78.00</td>
<td>4,052.50</td>
<td>52.78</td>
<td>752.86</td>
<td>10,441.00</td>
<td>15,379.86</td>
</tr>
<tr>
<td>Land-Based</td>
<td></td>
<td></td>
<td>4,200.00</td>
<td></td>
<td>5,169.20</td>
<td>9,369.20</td>
<td></td>
</tr>
<tr>
<td>Rivers</td>
<td>1000.00</td>
<td></td>
<td>165.70</td>
<td></td>
<td>1,473.00</td>
<td>2,638.70</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6,651.72</strong></td>
<td>78.00</td>
<td>7,196.60</td>
<td>4,418.48</td>
<td>760.16</td>
<td>38,299.10</td>
<td><strong>57,404.06</strong></td>
</tr>
</tbody>
</table>

Total from the Black Sea Coastal Countries: 57,404 t/y

Accidental Oil Spills*: 136 t/y

From the Danube River: 53,300 t/y

**TOTAL IN THE BLACK SEA**: 110,840 t/y

*Note: The value of accidental oil spill is average for the last years. There is not included any information for illegal discharges from shipping.

**Sources of the information:**

3. [http://www.grid.unep.ch/bsein/tda/files/3a18t.htm](http://www.grid.unep.ch/bsein/tda/files/3a18t.htm)

ONE OF THE CONCLUSIONS:

Annual oil pollution of 110-130 Kt/y is close to ultimate absorption capacity of the basin. However, ten years of direct observations at sea say that measured concentrations of hydrocarbons in the Black Sea waters are twice as much those predicted by numerical modeling and assessment of net oil pollution made by environmentalists. Published estimates of oil influx to the basin can be significantly underestimated.
This exploration technique employs a possibility of recognizing on radar scenes the hydrocarbon films that appear on the sea surface owing to upward migration of oil from the deposit in sedimentary traps. Liquid hydrocarbons can come to the water column from submarine sources in the form of oil itself, gas condensate, or as admixture to natural gas transported by gas seeps acting permanently, or much typically, with some periodicity, like submarine geysers.
Gaseous and liquid hydrocarbons always come to the top and can emerge even in two-phase state (water emulsions in oil) and then decay at the sea surface and amalgamate into a single continuous film or several spots of micron thickness.

www.bubbleology.com

NPA Group website
The applied technique is based on immanent ability of oily material to damp higher harmonics of sea waves (so-called capillary ones) due to surface tension forces the film produces. That is why radar signal (of 5.67 cm wavelength for ERS-1,2) beamed onto a smoothed air-water interface backscatters to the sensor with lower impedance (visible dark areas) that drastically, up to 20 dB, differs from surrounding wavy medium (visible light-gray background) if wind velocity exceeds 3 m/s.
La Goleta natural oil seep

UCSB Hydrocarbon Seeps Project
Man-made pollution

Blowout at Union Oil’s Platform A
January 14, 1969

Ballast waters...
## Oil slicks parameters

<table>
<thead>
<tr>
<th>Type of oil manifestation</th>
<th>Appearance</th>
<th>Approximate thickness</th>
<th>Approx. volume, $m^3/m^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil sheen</td>
<td>Silver and mirror-like film</td>
<td>&gt;0.0001 mm</td>
<td>0.1</td>
</tr>
<tr>
<td>Oil film</td>
<td>Iridescent film</td>
<td>&gt;0.0003 mm</td>
<td>0.3</td>
</tr>
<tr>
<td>Crude oil or fuel</td>
<td>From brown to black</td>
<td>&gt;0.1 mm</td>
<td>100</td>
</tr>
<tr>
<td>Emulsion of water in oil</td>
<td>Brown or orange</td>
<td>&gt;1 mm</td>
<td>1000</td>
</tr>
</tbody>
</table>
Experiments

- Radar image of artificial oil slicks

This image was acquired by the Spaceborne Imaging Radar-C and X-band Synthetic Aperture Radar (SIR-C/X-SAR) aboard the space shuttle Endeavour on October 6, 1994, NASA
How to find relevant data?

Go to www.odisseo.esrin.esa.it
ERS SAR, ASAR ENVISAT, and other full-resolution radar images are quite expensive data.

ERS SAR quick-looks are of lower spatial resolution and cannot be properly georeferenced, corrected, etc.

Discrimination of natural oil slicks from natural films and spillages is rather ambiguous task.

Depending on the season local sea currents within the South Kerch offshore vary from ~ 5 to few tens of cm/s.

Lack of direct slick observations at sea corresponded to the available images.

Only few compositional analyses of submarine seeps in the Black Sea are available to the date.

There are some submarine waste disposal sites offshore South Kerch Peninsula.
Tanker routes

1995: Main Tanker Movement via the Bosphorus

Seep trajectories vs. sea currents

Shnyukov Ye.F., Sozansky V.I., 2002
Romanian offshore

Lebada and other fields on ERS-SAR scenes
Geological map

Kerch Peninsula, Scale 1: 100000

Cape Opuk
Miocene limestones outcrop

Cape Opuk, southernmost point of Kerch Peninsula
Transpressional folds governs the geological structure

Dovzhok Ye.M. et al., 1996
ESA Catalogue of satellite data on the area of interest contains 1290 ERS-SAR images for 1992 – 2003. Each ERS-SAR scene covers ~ 100x100 km. On the first stage of the study it was selected 230 quick-looks that suits the task and were analysed further.
ERS – 1 scene (quick-look) of May 11, 1993
Cumulated useful signal

- Slick map, 22 selected ERS-1,2 interpreted scenes
Natural oil slicks detected within South Kerch offshore according to interpretation of ERS SAR images for 1992-2003
Sea floor relief and repetitive slicks points out on neotectonic control of seepages and deep-seated oil deposits, respectively.
Methane and higher homologues, He, $^{222}$Rn
New hydrocarbon prospect

ERS – 1 and ENVISAT images of 1991 and 2004, to the west of Tarkhankut Peninsula
New hydrocarbon prospect

Рис. 3. Карта-схема аномалий поля силы тяжести в свободном воздухе в районе Западно-Тарханкутской аномалии. 1 - изолинии в мГд, 2 - расположение галсов геофизических наблюдений: а – прямой, б – обратный ход судна, 3 - станции геологического опробования, 4 – контуры Западно-Тарханкутской аномалии.

Radar imaging is a reliable remote sensing tool for offshore oil and gas exploration using processing and thematic interpretation of space-born data coupled with analysis of available geological, geophysical, hydrophysical and meteo information.

The technique is based on rather simple but quite clear theory the prognostic power of which is proved by experiments, numerical modeling and exploration practice.

Oil slicks are not ordinary anomalies of a radar image; first of all slicks are objects because they can reflect just that matter what we are searching for.

The principle of stationarity of search features through criterion of repetition / spatial compactness of slick populations allow delineation of hydrocarbon seeps zones and improvement of prospects ranking and assessment owing to accumulation of useful signal.
Results of this reconnaissance study is accepted by SGE CHORNOMORNAFTOGAZ and resulted in discovery of Subbotin oil field.

It was found that typical slicks are much less abundant within Gulf of Odessa shelf comparing with Kerch Peninsula southern offshore that circumstantially evidences about dominant gas-prone hydrocarbon charge of the former one.

There is a lot of poorly understood features, processes and factors related to submarine seeps, oil slicks, and their images on radar scenes. Much should be done further to improve the theory and the technique.