MULTI-SENSOR SATELLITE SURVEY OF NATURAL OIL SLICKS IN THE SOUTHEASTERN BLACK SEA

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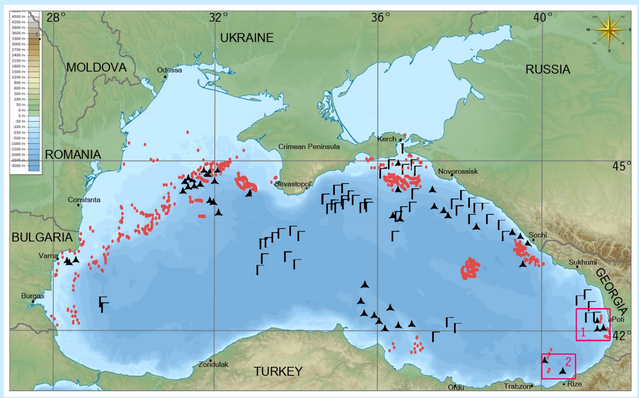
MAIN GOAL

The work is aimed to the development and enhancement of satellite remote sensing technics for monitoring of sea surface oil pollution caused by the natural seepages of hydrocarbons from the seabed.

MOTIVATION

- High levels of pollution of marine environment can result not only from anthropogenic sources but also from natural ones, such as hydrocarbon seepages at the seafloor.
- A highly probable link between seafloor hydrocarbon seeps and marine oil and gas deposits that turns the seeps into a criterion of oil and gas exploration.
- The knowledge of seep locations is necessary for ensuring safety of marine facility construction.
- Natural seafloor hydrocarbon seeps are sources of persistent pollution to be considered in marine environmental appraisals and studies of synoptic and climatic changes in the ocean.



Schematic map of the distribution of natural showings from the seafloor in the Black Sea. Red dots are documented methane seeps. The black triangles are gas seeps. Г- Mud volcanoes.

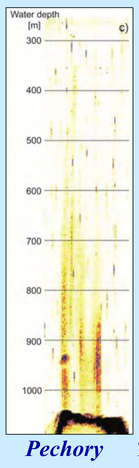
Two main areas of interest :

1. The continental slope off Georgia in the eastern part of the sea.
2. The continental slope off Turkey close to Rize town on the south-east of the sea.

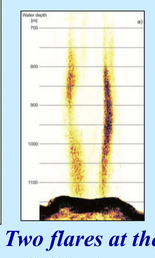
MAIN RESULTS

- The validity is shown of combined use of diverse satellite remote sensing data to identify and specify locations of seep sources at the seafloor in the south-eastern part of the Black Sea.
- A persistence analysis of satellite remote sensing data obtained in different spectral ranges – visible, infra-red, microwave – demonstrated the consistency of slick formations above the source locations.
- Spatial and temporal drift and evolution pattern of natural oil slicks at the sea surface is retrieved from remotely sensed data.
- The assessment of the variability of spatial and temporal distribution of natural oil slicks at the sea surface in the seepages area is performed. Direct and indirect impact of dynamic processes on the natural oil slicks drift and spread is revealed.
- The precise estimation of the actual seafloor source location was performed by means of satellite SAR imagery.
- A map is created of sea surface pollution by natural surface oil slicks discovered in satellite imagery taken over seepages area in the south-eastern part of the Black Sea.
- Two areas of the heaviest surface pollution of the South-Eastern Black Sea are outlined. These are areas of natural seepages off the Georgian coast near the Poti town as well as in the shelf area off the Turkey coast near Rize town.
- Satellite observations corroborate that the eastern Black Sea region over the continental slope off Georgia should be ranked as a zone of high ecological risk.

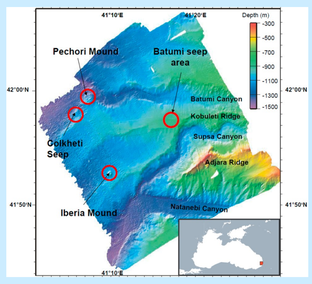
1. SEA SURFACE OIL POLLUTION DUE TO NATURAL HYDROCARBON SHOWINGS IN THE EASTERN BLACK SEA OFFSHORE GEORGIA



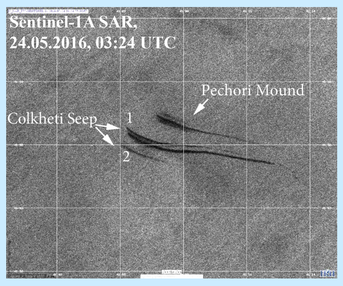
Pechory mound



Two flares at the Colkheti seep



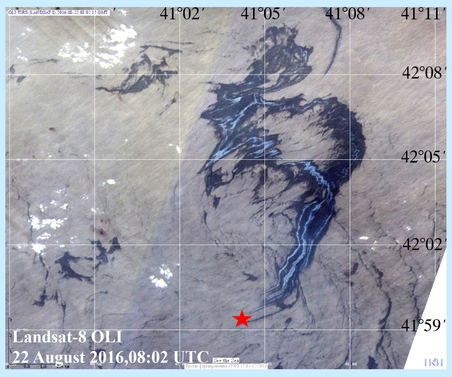
Bottom relief and location of the investigated seep sites offshore Georgia.



An example of a natural oil showing at the sea surface of the southeast Black Sea in satellite radar image. Total pollution area is 5.2 km².

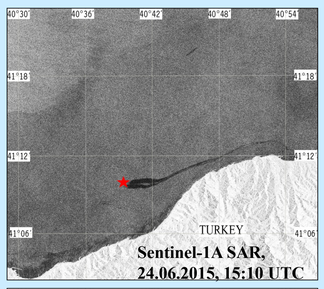
Persistent oil slicks having three source points can be regarded as a characteristic feature of satellite images available for this region.

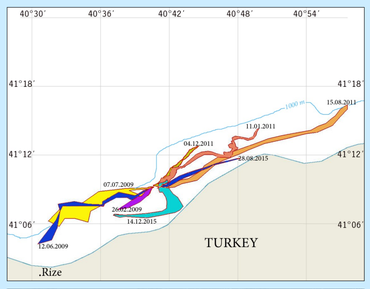
The presence of three distinct bands is explained by the fact that the oil is brought to the sea surface by oily bubbles rising from three gas plumes: one of Pechori Mound and two of Colkheti Seep.



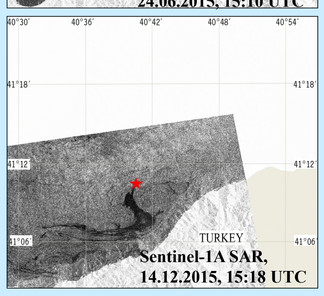
A complex multi-component structure of oil showing adds considerable complexity to its spreading, driven by wind and current, making it poorly predictable and limiting the reliability of existing oil spreading models

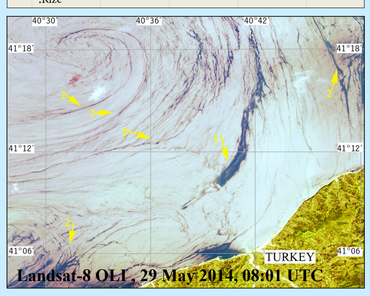
2. SEA SURFACE OIL POLLUTION DUE TO NATURAL HYDROCARBON SHOWINGS IN THE SOUTH-EASTERN BLACK SEA OFFSHORE TURKEY





- ✓ **The site of seep source was documented as the persistent location of origins of 230 oil slicks detected in satellite images taken over the region of interest in years 2010-2017.**
- ✓ **The point with coordinates 40°41′E, 41°09′E appeared a "source" of the natural oil slicks origin. This point can by recognized as a point of location of an offshore seep at the seafloor at a depth about of 1000 m.**
- ✓ **The emersion point is located close to the shore, at the distance of only 5 km from the coastal line.**
- ✓ **The high risk of oil beaching exists in this area.**





It is not always possible to outline well-shaped natural oil slick in radar images taken over this area. The detection of natural oil slick trajectory in radar image may by hindered considerably by signatures of biogenic films existing in abundance in coastal waters. The analysis of data taken by satellite sensors in VIS/NIR bands of electromagnetic spectrum in sun glint conditions proves that oily films are always present on the sea surface in the test area.
Many filamentary slicks entrained in the eddy motion are seen in a color-synthesized Landsat-8 OLI image (composition of channels 4, 2, and 1) taken in the sun glint region. The natural oil slick is seen in the image as a characteristic elongated slightly curved iridescent band with a darker halo, in accordance with the film thickness unevenness.

3. MAP OF SEA SURFACE POLLUTION BY NATURAL OIL SLICKS IN THE SOUTH-EASTERN BLACK SEA

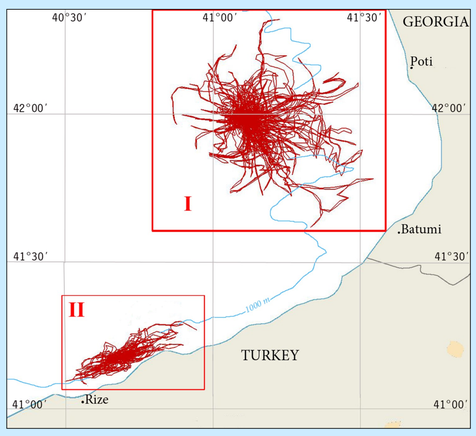
Two areas of the heaviest pollution are identified:

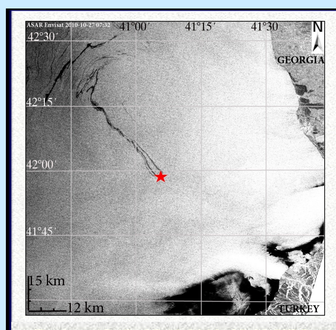
I. The areas of natural seepages off the Georgian coast near the Poti town.

II. The shelf area off the Turkey coast.

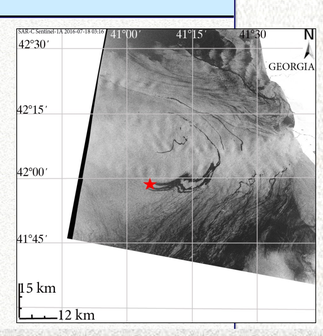
The geographical distribution of natural surface oil slicks correlates with geographical locations of natural off shore hydrocarbon seeps on the seafloor.

High risk of the sea surface oil pollution is attributed to areas of 859 km² and 360 km² respectively.





Envisat ASAR, 27.10.2010, 07:32 UTC

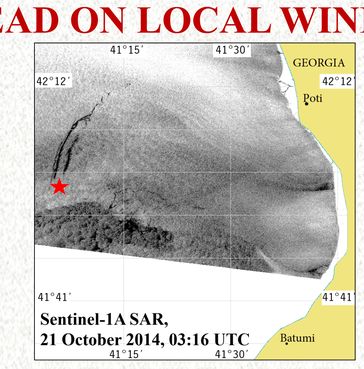


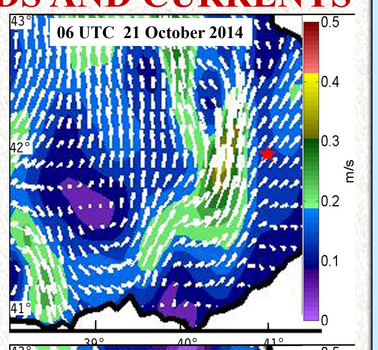
Sentinel-1A SAR, 18.07.2016, 03:16 UTC

The most important factors which influence the size, extent and spreading of oil films on the sea surface are local winds and surface currents. Our observations show that during the initial phase of oil patch evolution, the oil moves and spreads mostly under the influence of local winds. During the second phase, the oil can be entrained in a local current and travel long distances or be involved in an eddy motion.

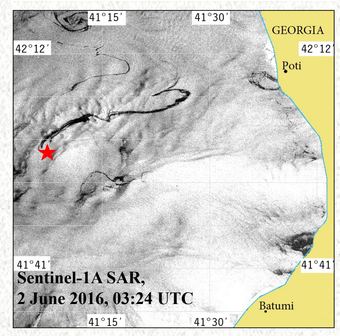
4. DEPENDENCE OF SURFACE OIL FILM SPREAD ON LOCAL WINDS AND CURRENTS

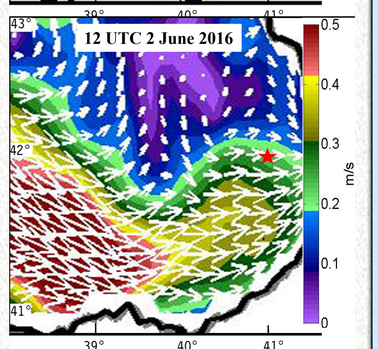
I.



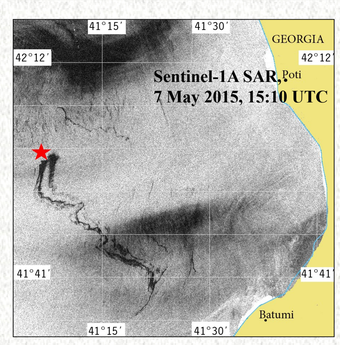


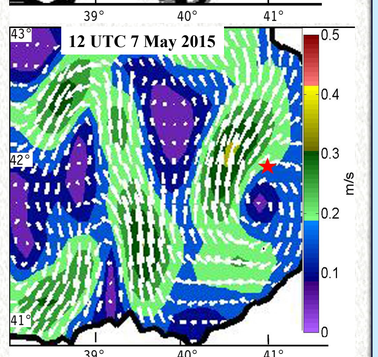
II.





III.





I. The basic circulation in the Black Sea is characterized by strong cyclonic basin-wide current along the shore which is referred to as the Rim Current. Flow velocities can be as high as 40-60 cm/s, gradually decreasing in directions both to the coast and to the open sea. This current contributes to the transport of pollutants according to the cyclonic scheme. In the natural seepages area off the Georgian coast it leads to transport in the oil films in north direction
II. The Rim Current is hydrodynamicaly highly unstable. Its intense meandering results in occurrence of mesoscale anti-cyclonic and cyclonic eddies, vortex dipoles, filaments and jets. Some meso-scale hydrodynamic structures can interrupt the Rim Current locally, resulting in substantial cross-shelf transport of pollutants.
III. The so-called Batumi quasi-stationary anti-cyclonic eddy is a quite persistent structure of this region. Natural oil films can be entrained in its vortical motion which results in mostly southward drift of oil films

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